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Original article

ANTHROPOMETRY AND ACOUSTIC PHARYNGOMETRY OF THE ORAL CAVITY IN SLEEP-DISORDERED BREATHING

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ABSTRACT

Purpose: This study aimed at applying the method of acoustic pharyngometry in sleep-disordered breathing within a preventive otorhinolaryngological programme in the city of Varna for the first time in Bulgaria.

Material/Methods: During the period between January 1, 2016, and December 31, 2019, 100 subjects, 62 males at a mean age of 48.82±11.45 years and 38 females at a mean age of 52.42±16.54 years, underwent screening examinations for sleep-disordered breathing in the Division of Otorhinolaryngology, St. Anna Hospital of Varna. Clinical inspections, pharyngoscopy, indirect laryngoscopy, and acoustic pharyngometry by means of Eccovision® acoustic pharyngometer were used. Data were statistically processed by using the *t*-test for independent variables and the correlation analysis.

Results: Low soft palate and uvula elongation belonged to the most common oral cavity alterations identified by acoustic pharyngometry. There are statistically significant changes of the anthropometric (body mass index, neck circumference and adjusted neck circumference) and pharyngometric (cross-sectional area, minimal cross-sectional area, minimal distance, oral cavity length and volume) parameters between males and females. There were statistically significant positive and negative correlations between the values of these parameters.

Conclusion: A more comprehensive research on the specific acoustic pharyngometric and anthropometric parameters could elaborate a cost-effective otorhinolaryngological algorithm for Screening and early diagnosis of OSA and snoring.

Keywords: acoustic pharyngometry, obstructive sleep apnea, oral cavity dimensions, uvula elongation, low soft palate,

INTRODUCTION

Sleep-disordered breathing represents a medico-social problem of rising importance worldwide. During recent decades, there have been substantial advances in the diagnosis of snoring as well as obstructive sleep apnea (OSA), obstructive sleep apnea-hypopnea (OSAH), OSA syndrome (OSAS), and OSAH syndrome (OSAHS), and central sleep apnea as well.

Moderate-to-severe OSA is diagnosed in up to 50% of men and 25% of women in the middle-aged population and results in a fourfold increase of all the causes of mortality [1]. OSA prevalence is underestimated, partly due to the absence of symptoms and lack of knowledge amongst the population at large as well as sectors of the medical profession. Identification and treatment of severe OSA can improve health-related quality of life [2].

The OSA leads to worsening of patients' personal relationships, decreasing work productivity, and increasing the risk of occupational and motor vehicle accidents [3]. Untreated OSA is associated with long-term health consequences, including arterial hypertension, heart disease, diabetes mellitus, depression, metabolic disorders, stroke, cognitive dysfunction, impaired workplace productivity and vigilance, daytime somnolence, performance deficits, morning headaches, mood disturbances, neurobehavioural impairments, general malaise, etc. The costs of undiagnosed and untreated OSA to healthcare organizations are high.

Twenty-two out of a total of 148 patients at a median age of 68 years (14.86% of the cases) are morbidly obese (with body mass index ≥40 kg/m²) [4]. Seventy-four patients (50% of the cases) are at high risk for OSA, yet only 28 of them (37.84% of the cases) are previously diagnosed with OSA.

Polysomnography is considered the 'golden standard' in the diagnosis of OSA and snoring, although it is an expensive and time-consuming hospital-based laboratory procedure. For screening purposes, however, computed tomography, magnetic resonance imaging, polygraphy, ApneaGraph, home sleep apnea testing with portable devices, acoustic rhinometry and acoustic pharyngometry are more and more widely used.

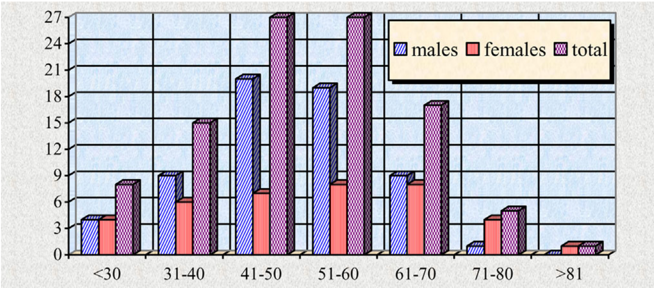
The purpose of the present study was to apply the method of acoustic pharyngometry in subjects with sleep-disordered breathing who had undergone otorhinolaryngological Screening within a recent preventive programme in the city of Varna.

MATERIALS & METHODS

During the period between January 1, 2016, and December 31, 2019, a total of 100 subjects from the city of Varna underwent screening examinations for sleep-disordered breathing in the Division of Otorhinolaryngology

St. Anna Hospital of Varna. There were 62 males at a mean age of 48.82±11.45 years (range, 20 to 74 years) and 38 females at a mean age of 52.42±16.54 years (range, 21 to 85 years). Participants' distribution according to gender and 10-year age groups was illustrated in Fig. 1.

Fig. 1. Participants' distribution according to gender and age



The following diagnostic methods were used: clinical inspection, pharyngoscopy, indirect laryngoscopy, and acoustic pharyngometry in a sitting position. The acoustic pharyngometric investigations were performed using the Eccovision® acoustic pharyngometer (HOOD Laboratories, Boston, MA, USA) (Fig. 2) in order to assess the whole area and volume of the mouth for the first time in Bulgaria.

Fig. 2. Eccovision® acoustic pharyngometer

The anthropological measurements included neck circumference, height and weight. Individual body mass index and adjusted neck circumference were calculated. Statistical data processing was accomplished by using the *t*-test for independent variables and the correlation analysis by Pearson and Spearman coefficients.

RESULTS

Low soft palate (LSP) and uvula elongation were the common pathological findings in males and females. Both LSP and uvula elongation could be objectively assessed by means of pharyngoscopy and acoustic pharyngometry only.

The values of the anthropometric parameters of the males and females from the *t*-test for independent variables were demonstrated in Table 1.

Table 1. Values of the anthropometric parameters in males and females

Parameter	minimal	maximal	mean	SD	SE
males (n=62)					
neck circumference	36	62	42,91	4,39	0,56
adjusted neck circumference	40	65	49,95	5,49	0,7
body mass index	22,7	46,2	31,11	5,41	0,69
females (n=38)					
neck circumference	29	46	35,39	3,32	0,54
adjusted neck circumference	31,5	48,5	40,1	4	0,65
body mass index	19,1	39	26,79	5,41	0,88

The values of five pharyngometric parameters of the oral cavity in males and females from the *t*-test for independent variables were presented in Table 2.

Table 2. Values of five pharyngometric parameters in males and females

Parameter	minimal	maximal	mean	SD	SE
males (n=62)					
oral cavity length	2,02	11,5	8,09	1,74	0,22
oral cavity volume	3,93	68,38	27,91	9,86	1,25
cross-sectional area	0,22	2,23	0,91	0,49	0,06
minimal cross-sectional area	0,21	2,57	0,76	0,51	0,06
minimal distance	2,44	14,88	9,7	2,38	0,3
females (n=38)					
oral cavity length	5	11,4	8,77	1,26	0,2
oral cavity volume	12,43	76,75	34,51	15,74	2,55
cross-sectional area	0,25	3,41	1,11	0,69	0,11
minimal cross-sectional area	0,25	2,62	0,88	0,63	0,1
minimal distance	7,59	14,45	10,29	1,69	0,27

The results from the *t*-test for independent variables concerning three anthropometric parameters between males and females were presented in Table 3.

Table 3. Values of five pharyngometric parameters of the participants aged below and over 40 years

Parameter	< 40 years (n=23)			≥ 40 years (n=77)		
	mean	SD	SE	mean	SD	SE
oral cavity length	8.730	1.316	0.274	8.235	1.673	0.191
oral cavity volume	32.865	14.226	2.966	29.691	12.300	1.402
cross-sectional area	1.089	0.573	0.119	0.957	0.584	0.067
minimal cross-sectional area	0.851	0.544	0.113	0.792	0.562	0.064
minimal distance	10.499	1.630	0.340	9.750	2.271	0.259

The results from the *t*-test for independent variables concerning five pharyngometric parameters between males and females were indicated in Table 4.

Table 4. Values of independent variables concerning three anthropometric parameters between males and females

Levene's test for equality of variables							
neck circumference							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
1.253	0.266	9.075	0.0001	7.516	0.828	5.873	9.160
adjusted neck circumference							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
2.626	0.108	8.626	0.0001	8.846	1.025	6.811	10.881
body mass index							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
0.007	0.935	3.881	0.0001	4.326	1.115	2.114	6.538

The results from the *t*-test for independent variables concerning five pharyngometric parameters of the participants aged below and over 40 years were compared in Table 5.

Table 5. Values of independent variables concerning five pharyngometric parameters between males and females

Levene's test for equality of variables							
oral cavity length							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
2.293	0.133	-2.111	0.037	-0.687	0.325	-1.332	-0.041
oral cavity volume							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
9,35	0.003	-2.316	0.024	-6.589	2.845	-12.290	-0.888
cross-sectional area							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
3.925	0.050	-1.718	0.089	-0.204	0.119	-0.439	0.032
minimal cross-sectional area							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
2.296	0.133	-1.030	0.305	-0.118	0.114	-0.345	0.109
minimal distance							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
3.862	0.052	-1.334	0.188	-0.586	0.442	-1.464	0.292

The results from the *t*-test for independent variables concerning five pharyngometric parameters between the participants of these two age groups were demonstrated in Table 6.

Table 6. Values of independent variables concerning five pharyngometric parameters between the participants aged below and over 40 years

Levene's test for equality of variables							
oral cavity length							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
1.142	0.288	1.308	0.194	0.497	0.380	-0.257	1.252
oral cavity volume							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
0.064	0.802	1,47	0.298	3.173	3.032	-2.843	9.189

cross-sectional are							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
0.025	0.875	0.952	0.344	0.132	0.138	-0.143	0.406
minimal cross-sectional area							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
0.012	0.914	0.445	0.657	0.059	0.133	-0.204	0.322
minimal distance							
F	significance	*t*	p	mean difference	mean error of the difference	95% confidence interval for mean	
						lower bound	upper bound
2.029	0.157	1.470	0.145	0.749	0.509	-0.262	1.759

We analyzed the correlation dependences between age and three anthropometric parameters, on the one hand, and five pharyngometric parameters, on the other hand, by using Pearson and Spearman correlation coefficients.

We established the following statistically significant positive and negative Pearson correlations: between patient's age and minimal cross-sectional area (r=-0.200; p=0.046); between body mass index, on the one hand, and oral cavity length (r=-0.229; p=0.022) and oral cavity volume (r=-0.222; p=0.027), on the other hand; between oral cavity length, on the one hand, and oral cavity volume (r=0.625; p=0.0001), minimal cross-sectional area (r=0.245; p=0.014) and minimal distance (r=0.667; p=0.0001), on the other hand; between oral cavity volume, on the one hand, and cross-sectional area (r=0.259; p=0.009), minimal cross-sectional area (r=0.415; p=0.001) and minimal distance (r=0.223; p=0.026), on the other hand as well as between cross-sectional area, on the one hand, and minimal-cross sectional area (r=0.788; p=0.0001) and minimal distance (r=0.198; p=0.048), on the other hand.

We found out the following statistically significant positive and negative Spearman correlations: between neck circumference, on the one hand, and adjusted neck circumference (r=0.885; p=0.0001), body mass index (r=0.638; p=0.0001) and oral cavity length (r=-0.279; p=0.005), on the other hand; between adjusted neck circumference, on the one hand, and body mass index (r=0.661; p=0.0001), oral cavity length (r=-0.332; p=0.001) and oral cavity volume (r=0.199; p=0.047), on the other hand; between body mass index, on the one hand, and oral cavity length (r=-0.285; p=0.004) and minimal distance (r=-0.212; p=0.034), on the other hand; between oral cavity length, on the one hand, and oral cavity volume (r=0.666; p=0.0001), minimal cross-sectional area (r=0.313; p=0.002) and minimal distance (r=0.619; p=0.0001), on the other hand; between oral cavity volume, on the one hand, and minimal cross-sectional area (r=0.485; p=0.002) and minimal distance (r=0.229; p=0.022), on the other hand as well as between cross-sectional area, on the other hand, and minimal cross-sectional area (r=0.779; p=0.0001) and minimal distance (r=0.315; p=0.001), on the other hand.

DISCUSSION

Our initial data are similar to recently published results abroad.

The standard preset output of acoustic pharyngometry (minimal cross-sectional area) is reliable, and by conducting post-processing measures on specific breathing tasks, oral length, oral volume, pharyngeal length, and pharyngeal volume data can be established, too [5].

There are statistically significant differences between 20 middle-aged nonobese men and 18 middle-aged, nonsmoking, morbidly obese men with documented OSAS concerning the mean body mass index (24.9±2.8 versus 55.8±9.9 kg/m^2, respectively; p<0.001) and neck circumference (39.3±2.4 versus 51.1±3.7 cm, respectively; p<0.001) [6].

The minimum cross-sectional area in 57 male patients with snoring and 11 of them with severe OSAHS as assessed by acoustic pharyngometry is negatively associated with both apnea-hypopnea index and the percentage of time with oxygen saturation below 90% (p<0.01) [7]. In a supine position, the correlation coefficients of the minimum cross-sectional area with apnea-hypopnea index and time with oxygen saturation below 90% are r=-0.569 and r=-0.478, respectively. The minimum cross-sectional area negatively correlates with body mass index (r=-0.265; p=0.033) and with neck circumference (r=-0.309; p=0.012).

In ten obese OSAH patients at a mean age of 55±9 years, with a mean body mass index of 35.1±6.1 kg/m^2, a mean apnea-hypopnea index of 58.8±27.1 events/hour and a mean Epworth Sleepiness Scale score of 12.3±3.6 points, the oropharyngeal junction area is 0.74±0.28 cm^2 initially, 0.90±0.24 cm^2 after one week and 1.05±0.31 cm^2 after six months (one week and six months versus basal conditions;

p<0.05) [8].

In 96 consecutive patients of both sexes with or without OSAS, body mass index, free oropharynx, uvula breadth, cardiovascular medication use and arterial hypertension are significantly related to apnea-hypopnea index, while tonsil size shows borderline significance [9]. The OSAS index using the parameters of body mass index and free oropharynx has a positive predictive value of 82% and a negative predictive value of 77%.

There is a statistically significant negative correlation of r=-0.2 between the mean apnea-hypopnea index of 29.07±16.65 events/hour in 31 OSA patients and the mean cross-sectional area prospectively investigated by acoustic pharyngometry in the supine position during expiration [10]. The mean cross-sectional areas and airway volumes in any segments assessed by acoustic pharyngometry in 15 OSA patients are statistically significantly smaller in OSA patients than in 15 healthy controls (p<0.05) [11].

Children with increased pharyngeal compliance measured during wakefulness using acoustic pharyngometry exhibit decreased sympathetic tone associated with increased apnea-hypopnea index in non-rapid eye movement sleep [12]. A multivariate analysis with apnea-hypopnea index as the dependent variable and body mass index z-score, neck circumference, mean pharyngeal area in supine position, and estimated pharyngeal compliance as independent variables examined by means of acoustic pharyngometry demonstrate that only body mass index z-score and estimated pharyngeal compliance remained independent predictors of obstructive sleep apnea in children (r^2=0.25; p<0.0001) [13].

The acoustic pharyngometric examinations indicate that 52 subjects, 35 men and 17 women, with OSA, have a higher degree of tonsil enlargement and tongue hypertrophy, while their minimal cross-sectional area and pharyngeal volume are smaller than those of 16 control subjects, 12 men and four women, in China [14]. The pharyngeal volume and minimal cross-sectional area are two helpful indicators for OSA screening.

In 203 children aged 8-11 years, the coefficients of variation of the minimal and mean cross-sectional areas examined by acoustic pharyngometry are similar to those in adults (8.0% and 11.1%, respectively) [15]. Only the minimal cross-sectional area is statistically significantly reduced in preterm children, habitual snorers, and children with sleep-disordered breathing relative to unaffected children.

Overall and subgroup analyses in 138 OSAHS patients reveal that the minimal cross-sectional area of the oropharyngeal lumen statistically significantly decreases (p<0.05), whereas that of the velopharyngeal lumen does not significantly change with mouth opening (p>0.05) [16]. A wider mouth opening combined with larger tonsils leads to a narrower oropharyngeal airway. The relative position of the tongue to the soft palate is the main factor influencing velopharyngeal lumen changes with mouth opening.

The morphological and functional correlations of the tongue with jaw bones, dental rows and oropharynx which surround it are assessed [17].

Among 188 consecutive patients with nonvalvular atrial fibrillation, acoustic pharyngometry identifies OSA in 86% of the cases, as 49% of them present with moderate or severe OSA [18].

Modern imaging methods undoubtedly contribute to the precise identification of the structural alterations in the upper airway, which cause sleep-related breathing disorders.

In a prospective study, 31 mild to moderate OSA patients at a mean age of 43,5±9,7 years and 13 control subjects at a mean age of 48.5±16.2 years undergo NewTom5G cone-beam computed tomography [19]. The airway resistance during expiration is statistically significantly higher in OSA patients than in control subjects (p=0.04). In OSA patients, there is a statistically significant negative correlation between this resistance, on the one hand, and the minimum cross-sectional area (r=-0.41; p=0.02) and the volume of the oropharynx (r=-0.48; p=0.01), on the other hand.

The measurements of the volume and the cross-sectional area of the oropharynx are accomplished by two multi-detector row computed tomography scanners and by three cone-beam computed tomography ones [20]. The intra- and inter-observer reliability of the oropharynx segmentation is fair to excellent. The most accurate volume and cross-sectional area measurements are acquired using the Siemens multi-detector row computed tomography scanners.

CONCLUSION

Our present study paves the road to more comprehensive research on the specific acoustic pharyngometric parameters juxtaposed to the anthropometric ones in order to elaborate a cost-effective otorhinolaryngological algorithm for Screening and early diagnosis of OSA and snoring in adults and children in our country.

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