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Morpho-spiro-voice-acoustic differences between smokers and non-smokers

Diferencias morfo-espirométricas y acústico-vocal entre fumadores y no fumadores

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SUMMARY

The organs most impacted by tobacco smoke are primarily those of the respiratory system, along with the vocal cords. This study aims to determine the significant differences in morpho-spirometric and voice-acoustic variables between non-smokers and smokers, emphasising the substantial effects of smoking on health and vocal quality.

Two morphometric variables, eight spirometric variables, and thirteen voice-acoustic variables were measured in 117 male Albanian subjects from Kosovo (78 non-smokers and 39 smokers). Statistical analysis was performed using SPSS version 20. The data were examined using descriptive statistics (arithmetic means, minimum and maximum values, and standard deviation), independent samples t-test, and discriminant canonical analysis.

Discriminant statistical parameters indicate that the group of non-smokers significantly ($p < 0.00$-0.05) differs from the group of smokers, showing lower body weight (within normal limits), higher spirometric parameters (within normal limits), and greater voice amplitude. No significant differences were observed between the groups in variables such as stature, PIF (peak inspiratory flow), jitter variables (voice period variability), and the fundamental frequency of the voice sample.

Based on the Wilks' Lambda value, it can be concluded that spirometric variables (Wilks' Lambda = 0.56) provide better discrimination between smokers and non-smokers compared to voice-acoustic variables (Wilks' Lambda = 0.66).

Keywords: Tobacco, spirometry, acoustic-voice parameters, smokers, non-smokers.

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1. Introduction

Smoking remains one of the leading preventable causes of global health burden, demanding urgent public health responses [1]. Tobacco smoke inhaled by smokers, results from the combustion of dried leaves of the tobacco plant (*Nicotiana tabacum*). Tobacco smoke contains over 4,000 substances harmful to human health, around 100 of which are known to be carcinogenic [2, 3, 4, 5]. Among these, the most harmful components include tar, carbon monoxide, oxidizing chemicals, heavy metals (arsenic, beryllium, cadmium, chromium, cobalt, lead, and nickel), and radioactive compounds. These toxic substances affect the entire organism, particularly targeting the respiratory system especially the terminal bronchioles and alveoli.

Voice production involves multiple systems and anatomical structures, including the respiratory system, cardiovascular system, nervous system, articulatory organs (tongue, jaw, lips, and larynx), as well as endogenous/genetic factors, growth and developmental processes, age, and diseases affecting the aforementioned organs. The health of articulatory organs, environmental influences, spoken language, vocal fold training, and cultural factors also play a critical role [6, 7]. Scientific studies have demonstrated the significant influence of breathing on voice-acoustic parameters. Since air movement from the lungs is the foundation of phonation, a healthy voice relies on healthy respiration [8]. Iwarsson [9] identified a correlation between phonation at high lung volumes and increased subglottal pressure compared to phonation at low lung volumes. As a result, researchers frequently use spirometric and voice-acoustic parameters to evaluate the impact of respiratory function on speech production. Although Cox & Selent [10] found no substantial interaction between Maximum Phonation Time and Vital Capacity, nor between these variables and age, Dejonckere [11] emphasized the importance of spirometric and aerodynamic analyses in diagnosing voice disorders related to airflow obstruction. Emerging machine learning approaches using vocal biomarkers show promising potential for identifying health risks associated with lifestyle factors, including smoking [12]. There is no doubt that tobacco smoke irritates the vocal folds, resulting in their irreversible thickening and a consequent lowering of vocal pitch [13]. Numerous studies have identified smoking as a major risk factor for cancers of the respiratory tract (particularly the larynx), deterioration of vocal health, and increased risk of laryngeal diseases later in life [13, 14]. Van der Vaart *et al.* [15] investigated the effects of cigarette smoke on oxidative stress and inflammation, finding that acute exposure may lead to tissue damage by increasing lipid peroxidation and the degradation of extracellular matrix proteins. Gonzales & Carpi [16] observed that even less than a decade of smoking can negatively affect vocal parameters, likely due to the neurotoxic effects of nicotine or other tobacco smoke constituents. However, findings on this topic are not entirely consistent. Roy *et al.* [17], in a cross-sectional study of the general U.S. population, found no independent relationship between smoking and voice disorders. In contrast, Byeon [18] identified a direct association between smoking and organic voice disorders in the Korean population.

Spirometry is a rapid and straightforward diagnostic test commonly used to assess pulmonary function and monitor respiratory pathologies by measuring airway obstruction or inflammation. Spirometric values can be affected by a wide range of internal and external factors, both pathological and non-pathological—such as sex, height and weight, age, smoking (tobacco or drugs), altitude, physical activity, malnutrition, and comorbidities involving the respiratory, cardiovascular, and musculoskeletal systems [2, 5, 19]. Boran *et al.* [20], for example, found no significant impact of anthropometric parameters on spirometric values in children with average or slightly elevated body weight.

Most studies confirm the significantly harmful effects of smoking on nearly all spirometric parameters [20, 21, 22]. Sill [23] reported that although smoking was associated with increased residual volume, it did not significantly affect total lung capacity or functional residual capacity. According to Chatterjee *et al.* [24], several spirometric parameters (FVC, FEV1, FEV1 %, FEF 200-1200, FEF 25-75 %, FEF 75-85 %, MVV, and PEFR) were significantly lower in smokers than in non-smokers. Additionally, studies emphasize that smoking in youth can lead to early deterioration in respiratory health, underscoring the importance of prevention and early cessation campaigns [14, 25].

Nonetheless, spirometric and acoustic assessments alone are insufficient for a definitive diagnosis and should be complemented with additional clinical evaluations, depending on patient complaints. As the human organism functions as an integrated system of interrelated subsystems, a more holistic approach is increasingly adopted in contemporary health assessment.

The aim of this study is to determine the differences between non-smokers and smokers in selected morpho-spirometric and voice-acoustic parameters.

The research hypotheses are defined as follows:

- The null hypothesis (H_0) posits that there are no significant differences between non-smokers and smokers in selected morpho-spirometric and voice-acoustic variables.
- The first alternative hypothesis (H_1) posits that there are systematic and significant differences in morpho-spirometric variables between the two groups.
- The second alternative hypothesis (H_2) posits that there are systematic and significant differences in voice-acoustic variables between the two groups.

2. Methods

Research Design

The present study is part of the project "The Relationship Between Anthropometric and Voice-Acoustic Variables" [19], conducted within the framework of the Institute of Sports Anthropology (INASP) in Prishtina, Kosovo. By its nature, this research may be classified as an observational, cross-sectional, descriptive study.

Study Site and Sampling

This study adopted a transdisciplinary approach, integrating morphometric, functional (physiological and pathological), and acoustic perspectives. Two morphometric variables, eight spirometric variables, and thirteen voice-acoustic parameters were measured in 117 Albanian male participants from Kosovo. Among them, 78 participants (mean age = 21.7 years; range: 16-58) were non-smokers, and 39 participants (mean age = 36.2 years; range: 22-56) were smokers.

Participant Selection and Recruitment

Participants were randomly selected, with the condition that their psychophysical health was normal and free from diagnosed diseases. Prior to data collection, all participants underwent preliminary screening to exclude those with any known voice, morphological, or functional pathological conditions. Individuals exposed to harmful environmental factors were excluded. For the smoker group, an additional inclusion criterion was set: a smoking history of at least one year, with an average consumption of approximately 20 cigarettes per day (min = 10, max = 60).

Measuring Tools and Data Collection

Morphometric variables:

- Stature (cm): measured with a classical anthropometer.
- Body Weight (kg): measured using a digital scale.

Spirometric variables: Spirometric measurements were obtained using a computer-based pulmonary function analyzer (QUARK PFT), with hardware and software conforming to ATS/ERS standards:

- FVC: Forced Vital Capacity, the volume exhaled during a maximal forced expiration following full inspiration.
- FEV1: Forced Expiratory Volume in one second.
- PEF: Peak Expiratory Flow (L/min).
- PIF: Peak Inspiratory Flow (L/min).
- FEF25-75: Forced Expiratory Flow between 25 % and 75 % of FVC.
- MEF25, MEF50, MEF75: Maximum Expiratory Flow at 25 %, 50 %, and 75 % of FVC.

Voice-acoustic variables:

a) Fundamental frequency variables:

- MPitch (Hz): Mean fundamental frequency of the voice sample.
- MinP (Hz): Minimum fundamental frequency.
- MaxP (Hz): Maximum fundamental frequency.

b) Perturbation measures (Jitter):

- Jitter (%): Measures variability in pitch period.
- Jloc: Average absolute difference between consecutive periods, divided by the average period (%).
- Jrap: Relative Average Perturbation (%).
- Jppq5: Five-point Period Perturbation Quotient (%).
- Jddp: Average absolute difference between consecutive period differences (%).

c) Perturbation measures (Shimmer):

- Shimmer (dB): Variability in peak-to-peak amplitude.
- Shloc: Average absolute difference in consecutive amplitudes.
- ShdB: Logarithmic amplitude difference (base-10) multiplied by 20.
- Shapq3/5/11: Three-, five-, and eleven-point Amplitude Perturbation Quotients.
- Shdda (Shddp): Average absolute difference between consecutive amplitude changes.

Voice Recording Environment

Due to the lack of a dedicated sound laboratory, recordings were conducted in a quiet room. A personal computer and an AKG D5 Supercardioid Unidirectional Dynamic Vocal Microphone were used. The microphone was positioned approximately 5 cm from the participant's mouth, aligned parallel to the ground and perpendicular to the mouth. Cool Edit 96 software was used for audio capture, and the PrAAT4324_winsit program was used to analyze the recordings. Recordings were made at a sampling frequency of 44.1 kHz. Each participant, after a resting period of about one hour, was instructed to speak naturally and maintain typical loudness and speech rate. Recordings began with a brief self-introduction, followed by sustained articulation of vowels A, E, I, O, and U for five seconds each. Each test was repeated twice, and the best sample was used for analysis.

Data Analysis

Statistical analysis was conducted using IBM SPSS Statistics, version 20. Data were processed using descriptive statistics (arithmetic mean, minimum, maximum, and standard deviation), independent samples t-tests, and discriminant canonical analysis. A significance level of $p \leq 0.05$ was considered statistically significant.

Ethical Considerations

This study fully complied with the principles outlined in the Declaration of Helsinki (JAMA, 1997; 277: 925-926) and received approval from the Ethics Committee of the Institute of Sports Anthropology.

3. Results

Descriptive statistics and t-test results for the measured variables in each treated group are presented in **table I**. The analysis shows systematic differences between the two groups. According to the t-test values, significant differences were found in all variables except for body height, peak inspiratory flow (PIF), fundamental frequency (Pitch), and Jitter, where no statistically significant differences were observed. Regarding body weight, non-smokers had values within the normal range, while smokers were overweight. This can likely be attributed to higher levels of physical activity among non-smokers compared to the predominantly sedentary lifestyle of smokers.

Table I.
Descriptive statistics and t-test results for morpho-spirometric and voice-acoustic variables between smokers and non-smokers

	Non-Smokers				Smokers				t-test	
	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	t	Sig.
Stature	167.70	197.40	178.13	6.03	163.00	197.00	178.34	8.14	0.15	0.88
BW	55.00	104.80	73.23	10.14	60.00	123.50	85.76	15.09	5.32	0.00
FVC	4.24	8.14	5.53	0.74	2.95	6.49	4.80	0.81	-4.89	0.00
FEV1	3.46	6.91	4.79	0.64	2.66	5.85	4.03	0.77	-5.62	0.00
PEF	6.94	14.89	10.27	1.65	5.14	13.38	8.89	2.28	-3.76	0.00
PIF	3.21	11.93	7.26	1.73	1.66	12.00	6.70	2.49	-1.45	0.15
FEF25e75	2.86	8.32	5.24	1.20	0.93	7.80	4.41	1.47	-3.29	0.00
MEF25	5.30	13.96	8.63	1.57	4.08	12.18	7.84	2.15	-2.26	0.03
MEF50	3.43	9.00	5.85	1.33	2.32	8.52	5.24	1.62	-2.18	0.03
MEF75	1.11	6.01	2.96	1.04	0.17	3.72	2.11	0.81	-4.51	0.00
MPitch	85.39	177.63	119.61	16.70	81.54	151.98	115.87	18.65	-1.10	0.28
MinP	83.17	173.53	117.09	16.62	77.77	148.52	110.90	18.86	-1.82	0.07

	Non-Smokers				Smokers				t-test	
	Min	Max	Mean	Std. Dev	Min	Max	Mean	Std. Dev	t	Sig.
MaxP	87.21	180.93	122.43	17.11	83.00	174.50	119.54	21.72	-0.79	0.43
Jloc	0.17	7.11	0.53	0.78	0.17	3.25	0.57	0.60	0.31	0.76
Jrap	0.09	4.74	0.29	0.52	0.06	1.07	0.27	0.24	-0.29	0.77
Jppq5	0.09	2.84	0.29	0.31	0.09	1.45	0.30	0.27	0.16	0.87
Jddp	0.26	14.22	0.88	1.57	0.19	3.22	0.81	0.72	-0.28	0.78
Shloc	0.68	13.55	2.31	1.70	0.97	12.68	3.45	2.51	2.90	0.00
ShdB	0.06	1.17	0.20	0.15	0.08	1.18	0.31	0.23	2.99	0.00
Shapq3	0.28	9.04	1.20	1.11	0.32	4.70	1.64	1.03	2.07	0.04
Shapq5	0.10	5.50	1.39	0.83	0.50	7.16	1.95	1.36	2.75	0.01
Shapq11	0.61	7.13	2.00	0.99	0.11	17.71	3.19	2.99	3.20	0.00
Shdda	0.82	27.11	3.59	3.35	0.96	14.11	4.92	3.09	2.08	0.04

Source: Original data collected by the authors as part of the research project "The Relationship Between Anthropometric and Voice-Acoustic Variables".

The canonical discriminant analysis was used to verify multidimensional differences between the two groups and to identify the variables that best differentiate them. Separate analyses were conducted for spirometric and voice-acoustic spaces, each including morphometric variables (Stature and Body Weight) to account for body composition influences. In the morpho-spirometric space, a significant discriminant function was extracted (Sig = .000), with an eigenvalue of λ = 0.787 (Table II). The canonical correlation was Rc = 0.664, and the discriminative strength was indicated by Wilks' λ = 0.56 and Bartlett's Chi-square X^2 = 63.871.

Table II.

Canonical discriminant function summary for morpho-spirometric variables

Function	λ	Rc	Wilks' Lambda	Chi-square	df	Sig.
1	0.787	0.664	0.560	63.871	10	0.000

Source: Original data collected by the authors.

Table III.

Group centroids based on morpho-spirometric variables

Group	Function
Smokers	-1.244
Non-smokers	0.622

Table IV.

Structure matrix of morpho-spirometric variables contributing to group discrimination

Variables	Function
FEV1	0.591
BW	-0.559
FVC	0.514
MEF75	0.474
PEF	0.395
FEF25e75	0.346
MEF25	0.238
MEF50	0.229
PIF	0.153
Stature	-0.016

Source: Original data collected by the authors.

Similarly, with the results of the morpho-spirometric space, through the discriminative canonic analysis of the measured morpho-voice acoustic variables was extracted a significant discriminant function (Sig = 0.00), with the eigenvalue of the discriminant equation $\lambda = 0.515$, and the canonical correlation Rc = 0.583. The discriminative power criterion of the measured morpho-voice acoustic variables was Wilks'$\lambda = 0.66$, while the statistical significance of the discriminative equation (Bartlet Chi-square-test) was X2 = 45.287 (**table V**).

Table V.

Canonical discriminant function summary for morpho–voice-acoustic variables

Function	λ	Rc	Wilks' Lambda	Chi-square	df	Sig.
1	0.515	0.583	0.660	45.287	12	0.000

Source: Original data collected by the authors.

Table VI.

Group centroids based on morpho–voice-acoustic variables

Group	Function
Smokers	1.006
Non-smokers	-0.503

Source: Original data collected by the authors.

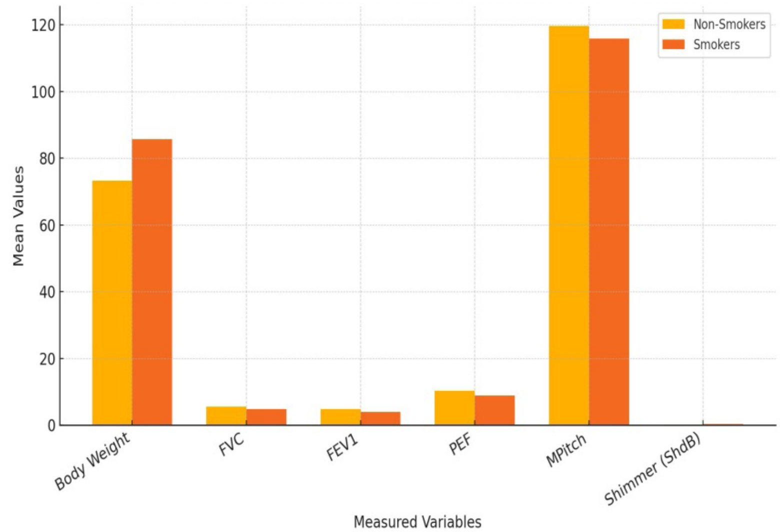
Table VII.

Structure matrix of morpho–voice-acoustic variables contributing to group discrimination

Variables	Function
BW	0.692
Shapq11	0.416
ShdB[a]	0.385
Shloc	0.377
Shapq5	0.357
Shapq3	0.269
Shdda[a]	0.267
MinP	-0.236
MPitch	-0.143
MaxP	-0.102
Jloc	0.041
Jrap	-0.038
Jddp[a]	-0.037
Jppq5	0.021
Stature	0.020

The projections shown in **tables IV** and **VII** help define the nature of the discriminant functions, while the group centroids (**tables III and VI**) facilitate interpretation of the group separation. In summary, non-smokers differed from smokers by having lower body weight, higher spirometric values, and stronger voice amplitude. No significant differences were found in Stature, PIF, Jitter, and fundamental frequency.

Figure 1.
Comparison of selected morpho-spirometric and voice-acoustic variables between smokers and non-smokers.



Source: Original data collected by the authors as part of the research project "The Relationship Between Anthropometric and Voice-Acoustic Variables" (Rexhepi & Brestovci, 2016).

The graph illustrates the most discriminating variables between the two groups, including body weight, key respiratory parameters (FVC, FEV1, PEF), voice pitch (MPitch), and shimmer (ShdB). Non-smokers consistently demonstrated more favorable values across respiratory and voice-stability indicators, while smokers presented higher body weight and shimmer, indicating vocal instability.

4. Discussion

The results of this study confirm significant differences between smokers and non-smokers across a wide range of morphometric, spirometric, and voice-acoustic variables. In particular, non-smokers exhibited lower body weight, better respiratory function, and more stable voice-amplitude parameters. These findings align with previous studies that have linked smoking to increased respiratory resistance, reduced lung volumes, and degradation of vocal fold tissue [13, 14, 25].

Interestingly, while body height and pitch-related variables (such as MPitch and Jitter) did not show significant differences, shimmer-related parameters (Shloc, ShdB, Shapq) were notably higher in smokers, indicating more unstable voice amplitude—a common outcome of chronic exposure to smoke toxins. Acoustic analysis using Praat has revealed significantly higher shimmer and jitter levels in smokers, consistent with prior findings [26].

This supports the assertion by Byeon & Lee [14] that smoking leads to increased incidence of laryngeal dysfunction and voice fatigue. Additionally, large population-based studies have confirmed a strong association between smoking status, duration, and the prevalence of voice disorders [27, 28].

The canonical discriminant analysis further highlighted these differences by extracting significant functions that effectively separated the two groups. The spirometric space produced a stronger discriminative function (Wilks' $\lambda = 0.56$) than the voice-acoustic space (Wilks' $\lambda = 0.66$), suggesting that respiratory parameters are more robust indicators for differentiating between smokers and non-smokers. These findings correspond with Dejonckere [11], who emphasized the primacy of respiratory measurements in evaluating voice-related pathologies.

Despite the consistent trends observed, it is important to acknowledge limitations. The age difference between the two groups (non-smokers being notably younger) may have influenced respiratory capacity and voice dynamics. Furthermore, reliance on self-reported smoking behavior and lack of biochemical verification may introduce reporting bias.

In summary, the study reinforces the detrimental impact of smoking on both respiratory and vocal function. These findings underline the necessity for continued preventive efforts, especially among younger populations, to reduce smoking prevalence and mitigate long-term health consequences [1].

5. Conclusions

This study confirmed that smoking has a significant negative impact on both respiratory and vocal functions. Non-smokers exhibited more favorable values across spirometric and voice-acoustic variables, while smokers showed indications of reduced lung function and less stable voice amplitude. These results are consistent with recent studies which demonstrate that smoking negatively affects fundamental frequency, shimmer, jitter, and noise-to-harmonic ratios, all of which reflect reduced voice quality and respiratory efficiency [27, 28].

The findings support the rejection of the null hypothesis (H_0) and confirm the two alternative hypotheses (H_1 and H_2), demonstrating systematic differences between smokers and non-smokers in both morpho-spirometric and voice-acoustic parameters.

Future studies are encouraged to involve larger and more diverse samples and to apply advanced statistical techniques—such as correlation, regression, and factor analysis—to gain deeper insight into the interrelationships among respiratory, acoustic, and anthropometric variables. Recent developments in digital vocal biomarkers also open up new directions for objectively assessing the impact of smoking on voice health [28]. Additionally, age-matched cohorts and biochemical verification of smoking status are recommended to strengthen the validity of findings.

Conflict of interest

None

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RESUMEN

Los órganos más afectados por el humo del tabaco son principalmente los del sistema respiratorio, junto con las cuerdas vocales. Este estudio tiene como objetivo determinar las diferencias significativas en las variables morfo-espirométricas y acústico-vocales entre no fumadores y fumadores, enfatizando los efectos sustanciales del tabaquismo en la salud y la calidad vocal. Se midieron dos variables morfométricas, ocho espirométricas y trece acústico-vocales en 117 sujetos varones albaneses de Kosovo (78 no fumadores y 39 fumadores). El análisis estadístico se realizó utilizando SPSS versión 20. Los datos fueron examinados mediante estadísticas descriptivas (medias aritméticas, valores mínimos y máximos y desviación estándar), prueba t para muestras independientes y análisis discriminante canónico. Los parámetros estadísticos discriminantes indican que el grupo de no fumadores difiere significativamente ($p < 0{,}00\text{-}0{,}05$) del grupo de fumadores, mostrando menor peso corporal (dentro de los límites normales), parámetros espirométricos más altos (dentro de los límites normales) y mayor amplitud vocal. No se observaron diferencias significativas entre los grupos en variables como la estatura, el PIF (flujo inspiratorio máximo), las variables de jitter (variabilidad del periodo vocal) y la frecuencia fundamental de la muestra vocal. Con base en el valor de Lambda de Wilks, se puede concluir que las variables espirométricas (Lambda de Wilks = 0,56) permiten una mejor discriminación entre fumadores y no fumadores en comparación con las variables acústico-vocales (Lambda de Wilks = 0,66).

Palabras clave: tabaco; espirometría; parámetros acústico-vocales; fumadores; no fumadores.