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Influence of smoking on voice quality

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Summary

Introduction. During smoking, specific morphological changes occur within the larynx, which results in changes in voice quality. Given that voice is related to quality of life, it is necessary to identify the impact of smoking on voice quality.

Methods. A group of 85 respondents, aged 22 to 70 years (AS = 35.61; SD = 11.36), both sexes, categorized into two groups, smokers and non-smokers, were selected for this study. A recording of extended vocal A phonation was analyzed in the program for acoustic voice analysis - PRAAT. The research was realized at the Faculty of Medicine in Foca, during 2021.

Results. A statistically significant difference was found in four out of the five examined voice parameters. Namely, a statistically significant difference was observed in the mean value of the fundamental frequency (Fo) ($p = 0.042$), jitter ($p = 0.007$), shimmer ($p = 0.026$) and in the noise-to-harmonic ratio ($p = 0.018$) between smokers and non-smokers. Also, a statistically significant difference was found between two subgroups of subjects (those who smoked less than 10 years and those who smoked longer than 10 years) in the fundamental voice frequency Fo ($p = 0.011$), standard deviation of the fundamental frequency STD ($p = 0.047$) and amplitude perturbation expressed through shimmer in percentage (Shim) ($p = 0.017$). For other examined voice parameters, no statistically significant difference was noticed between these two subgroups of respondents.

Conclusion. Smoking affects most of the acoustic parameters of the voice, resulting in poorer voice quality. Also, the quality of the voice decreases as the smoking experience increases.

Key words: smoking, smoking experience, voice quality

Introduction

Despite the global anti-smoking campaign, most of the world's population still consumes nicotine. A study that aimed to investigate the prevalence of smokers in 12 European countries, find data that 42.4% of respondents had at least some experience with nicotine, in the way that 25.9% of respondents consume cigarettes, while 16.5% of them was with previous smoking experience [1].

The harmful effects of smoking on human health are well known. During smoking and prolonged exposure to the direct influence of nicotine, specific morphological changes occur within the larynx. Also influence of cigarette consumption on the physiology of the vocal tract is well documented [2] and includes pharyngeal diseases and disorders caused by prolonged

exposure to various harmful chemicals that are concentrated in cigarette smoke. Exposure to cigarette smoke can affect laryngeal tissue, causing inflammation of the vocal cords [3], as well as degradation of lung function resulting in reduced airflow through the vocal cords [4].

In addition to studies that have addressed structural and histological changes in the vocal cords, there are several studies that have examined changes in the acoustic parameters of the voice caused by cigarette smoking [5–8]. The results of these studies indicate a significant decrease in the fundamental frequency of the voice (Fo) in smokers as well as a significant increase in shimmer and jitter. All these parameters determine the quality of the voice [5]. The fundamental frequency of the voice (Fo) is an important acoustic characteristic of the speech signal. Fo is the lowest, and usually the strongest frequency produced by complex vocal cords, and it is expressed in hertz (Hz). Jitter as an acoustic parameter refers to the fundamental frequency perturbation, while the shimmer refers to the amplitude perturbation.

Smokers feel more tired when using their voice and are more likely to lose their voice, compared to non-smokers [9,10]. Voice can significantly affect social interaction [11] and quality of life in vocal professionals (people who use voice as one of the basic tools for work). Given that voice is related to quality of life in general, it is necessary to identify the impact of smoking on voice quality. Therefore, our study had two aims: 1) to examine the impact of smoking on selected acoustic voice parameters and 2) to examine the existence of differences in the quality of smokers' voices in relation to smoking experience.

Methods

A group of 85 healthy respondents, aged 22 to 70 years (M= 35.61; SD = 11.36), both sexes, were selected by the method of intentional sampling for this study. We divided the subjects into two groups, smokers (A) and non-smokers (B). The criterion for inclusion of the subjects in the first group was the consumption of cigarettes for a period of at least one year. This criterion was met by 42 respondents, 23 female and 19 male respondents. In the group of smokers, the respondents were aged 22 to 67 years, with an average age of M = 35.83 SD = 10.94. We further divided these respondents into two subgroups in relation to the smoking experience. Thus, the first subgroup consisted of respondents with a smoking experience of one to ten years, and the second subgroup consisted of those whose smoking experience was longer than 10 years. The control group consisted of 43 respondents, non-smokers, of whom 24 were female and 19 male. In the group of non-smokers, the respondents were aged 22 to 70 years, where the average age in this group was M = 35.39, SD = 11.89. Subjects of the A and B groups were matched by sex and age.

The voice recording was performed in an adequate room. The respondents were given the task of phonating vocal A for a long time, with optimal volume and pitch, for at least ten seconds. The recordings were recorded using the Voice Memos app. The recording was repeated three times, and the highest quality voice recording was used for acoustic analysis. The recorded material was converted to WAW format, so that it could be analyzed in the PRAAT program (Paul Boersma and David Weenink, Phonetic Sciences, University of Amsterdam) [12]. The voice quality was analyzed through the following five acoustic parameters: mean values of the fundamental frequency (Fo in Hz); standard deviation of the fundamental frequency (STD in Hz); jitter (Jitt in %); shimmer (Shimm in %) and noise-to-harmonic ratio (NHR in dB). Data were analyzed using the SPSS 20.0 statistical package.

Results

Table 1 shows the differences between smokers and non-smokers in terms of acoustic parameters of vocal A. We can observe that there is a statistically significant difference in four out of the five examined voice parameters. Namely, a statistically significant difference was observed in the mean value of the fundamental frequency (Fo) ($p = 0.042$), jitter ($p = 0.007$), shimmer ($p = 0.026$) and in the noise-to-harmonic ratio ($p = 0.018$).

By observing Table 2, we can see the acoustic structure of the voice in relation to the smoking experience. Namely, in the category of smokers, we categorized the two subgroups, smokers whose smoking experience is from one to ten years (smokers 1) and those whose smoking experience is more than 10 years (smokers 2). By testing the differences using the Mann-Whitney U test, a statistically significant difference was found in the fundamental frequency of the voice Fo ($p = 0.011$), in the standard deviation of the fundamental frequency STD ($p = 0.047$) and the amplitude perturbation expressed through shimmer in percentage (Shim) ($p = 0.017$). For other examined voice parameters, no statistically significant difference was noticed between these two subgroups of respondents.

Table 1. Differences between acoustic parameters of smokers and non-smokers

Vocal parameters	Group	N	Mdn	Min	Max	Mann-Whitney U	Z	P
Fo	smokers	42	142.54	92.60	221.44	672.000	-2.030	**0.042**
	non-smokers	43	142.54	95.23	230.68			
STD	smokers	42	2.02	1.06	63.08	740.500	-1.428	0.153
	non-smokers	43	1.76	0.73	50.85			
Jitt	smokers	42	0.40	0.15	0.96	597.500	-2.686	**0.007**
	non-smokers	43	0.31	0.13	0.92			
Shim	smokers	42	6.24	2.69	15.38	650.500	-2.219	**0.026**
	non-smokers	43	4.76	2.90	13.24			
NHR	smokers	42	16.37	7.21	24.00	634.000	-2.365	**0.018**
	non-smokers	43	14.17	5.26	22.64			

Fo - mean value of the fundamental frequency; STD - standard deviation of the fundamental frequency; Jitt - jitter; Shim - shimmer; NHR - noise-to-harmonic ratio in dB

Table 2. Acoustic parameters of voice in relation to the smoking experience

Vocal parameters	Group	N	Mdn	Min	Max	Mann-Whitney U	Z	P
Fo	smokers1	17	172.09	100.31	216.25	113.000	-2.550	**0.011**
	smokers2	25	132.59	92.60	221.44			
STD	smokers1	17	2.49	1.25	63.08	135.000	-1.986	**0.047**
	smokers2	25	1.95	1.06	42.22			
Jitt	smokers1	17	0.39	0.15	0.83	158.500	-1.385	0.166
	smokers2	25	0.44	0.20	0.96			
Shim	smokers1	17	7.25	3.60	14.13	119.000	-2.396	**0.017**
	smokers2	25	4.81	2.69	15.38			
NHR	smokers1	17	11.63	7.61	19.37	146.500	-1.691	0.091
	smokers2	25	15.40	5.26	22.64			

Fo - mean value of the fundamental frequency; STD - standard deviation of the fundamental frequency; Jitt - jitter; Shim - shimmer; NHR - noise-to-harmonic ratio in dB; smokers1 - smokers who smoke for less than 10 years; smokers2 - smokers who smoke for more than 10 years

Table 3 shows a regression analysis, where we examined predictive influence of sex and smoking experience. The model originally included age, sex, and smoking history, but by examining the preconditions for applying multiple regressions, we found that there was a collinearity between the variables of smoking experience and age ($r \geq 9$), so only sex and smoking were included in the regression model. Multiple standard linear regression showed that within the group of smokers, sex and smoking experience were statistically significant ($p < 0.001$) predictors of two out of the four examined voice parameters (Fo, Jitt). These predictors together as a model explain about 50% for Fo, i.e. 25% of the variance of Jitt values, and the most significant individual contribution in the model is given by sex (Fo = $\beta = 0.689$; $p < 0.001$; Jitt = $\beta = 0.448$; $p < 0.001$), which means that sex in relation to smoking experience best predicts the values of acoustic voice parameters.

Table 3. Predictors of acoustic voice parameters

	Model 1	β	t	p	F	p	Adjusted R^2
Fo	Sex	0.689	6.010	0.000	21.63	**0.000**	0.502
	Smoking experience	-0.106	-0.926	0.360			
Jitt	Sex	0.448	3.198	0.003	8.04	**0.001**	0.256
	Smoking experience	-0.203	1.450	0.155			
Shimm	Sex	0.251	1.629	0.111	3.32	0.046	0.102
	Smoking experience	-0.227	-1.477	0.148			
NHR	Sex	0.124	0.768	0.447	1.21	0.308	0.010
	Smoking experience	1.77	1.093	0.281			

Fo - mean value of the fundamental frequency; Jitt - jitter; Shim - shimmer; NHR - noise-to-harmonic ratio

Discussion

The fact is that the larynx is only part of the system of organs involved in the formation of voice and speech, however, as the larynx is responsible for phonation, we examined only how smoking affects the phonation of vocal A, or how it affects acoustic parameters (Fo, STD, Jitt, Shimm, NHR).

Fundamental frequency values obtained in speech signals are usually less than 300 Hz for children and greater than 100 Hz for adults, or 120 Hz for men and 210 Hz for women [13–15]. The results of our study showed that the fundamental frequency of voice (Fo) is significantly lower than the frequency of voice in non-smokers, which is an indicator of poorer voice quality. The obtained results are consistent with the results of other studies that found that smoking reduces the values of the fundamental frequency of the voice [16, 17].

Both parameters have elevated values in smokers compared to non-smokers and this difference is statistically significant (jittter ($p = 0.007$); shimmer ($p = 0.026$)). Increased jitter value is an indicator of poorer voice quality, while at the same time higher shimmer values in the spoken voice are perceived as hoarseness [18]. NHR as an acoustic parameter estimates the presence of noise in the analyzed speech signal, and higher NHR indicates the presence of more noise in the signal and poorer voice quality. In our study, smokers had higher NHR values compared to non-smokers,

and the difference between the groups was statistically significant (p= 0.018). Research examining the isolated and multifactorial effect of smoking on voice quality has yielded similar results, that smoking affects the presence or occurrence of noise in the fundamental voice [16]. The literature shows that cigarette smoking changes the quality of the voice, causing a reduced amount of harmonics and an increased presence of noise in the voice [19].

When it comes to differences in voice quality in relation to the smoking experience, statistically significant differences were shown on the following acoustic parameters: Fo (p = 0.011), STD (p = 0.047) and shimmer (0.017). Namely, the smoking experience has had the effect of reducing the fundamental frequency of voice in people who smoke for more than 10 years, compared to those who consume cigarettes for a shorter period of time. Our results showed that the values of Fo decrease more, if the smoking experience of the respondents is longer, which is again a clear indication that the smoking duration negatively affects the values of Fo. Regarding the frequency perturbation expressed through jitter, we did not find a statistically significant difference between the group of smokers1 and smokers2, however, respondents from the subgroup smokers2 had higher minimum and maximum values for this acoustic parameter. Shimmer was significantly higher in subjects from the subgroup smokers2 compared to subjects from the subgroup smokers1, and this difference was statistically significant (p = 0.017). Results similar to ours, which suggest that this type of acoustic change is associated with long-term smoking, are found in a study by Vincent and Gilbert [19]. When it comes to the acoustic parameter related to the presence of noise in the analyzed signal - NHR, no statistically significant difference was found. The absence of a significant difference between the groups is somewhat unexpected, since NHR reflects the presence of noise in the signal acoustics, and among other components, it includes frequency and amplitude perturbations. From the above results, we can conclude that some other factors besides smoking affect the presence of noise in the signal. It is also possible that acoustic parameters whose values remain unchanged when viewed in relation to the smoking experience, may be less sensitive to prolonged and continuous nicotine intake.

To further analyze the predictive influence of certain variables, we performed regression analysis, where sex and smoking experience were included into the model as predictors, while the dependent variables were acoustic voice parameters. This model explained 50% of the variance for Fo and about 25% for Jitt, while this model did not show a significant effect for other parameters ($p \geq 0.01$).

Conclusion

The acoustic analysis of the voice in smokers showed a statistically significant deviation on four out of the five examined parameters: Fo, shimmer, jitter and NHR. Decreased Fo and NHR values, as well as increased jitter and shimmer values, indicate poorer voice quality in smokers compared to non-smokers. Also, certain parameters, Fo, STD and Shimmer are significantly worse in smokers whose smoking experience is longer than 10 years compared to those who have shorter experience, which means that the quality of the voice is worse, if the smoking experience is longer.

The limitation of this research is that we did not use the number of cigarettes smoked per day, which would also contribute to a more detailed insight into the effects of nicotine on the voice of smokers. Also, comparing the objective assessment and clinical findings with the VHI index, we would get data on whether smokers subjectively feel worsening of the voice and how long after consuming cigarettes.

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Ethical approval. The Ethics Committee of the Faculty of Medicine Foca approved the study and informed consent was obtained from all individual respondents. The research was conducted according to the Declaration of Helsinki.

Conflicts of interest. The authors declare no conflict of interest.

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Uticaj pušenja na kvalitet glasa

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Uvod. Prilikom pušenja javljaju se specifične morfološke promjene unutar grkljana, što za posljedicu ima promjene u kvalitetu glasa. Imajući u vidu da je glas povezan sa kvalitetom života, neophodno je identifikovati uticaj pušenja na kvalitet glasa.

Metode. Za ovu studiju odabrano je 85 ispitanika, starosti od 22 do 70 godina (AS = 35,61; SD = 11,36), oba pola, kategorisanih u dvije grupe, pušači i nepušači. Analiziran je snimak produženog foniranja vokala A u programu za akustičku analizu glasa PRAAT. Istraživanje je realizovano na Medicinskom fakultetu u Foči, tokom 2021. godine.

Rezultati. Nađena je statistički značajna razlika na četiri od pet ispitivanih parametara glasa. Naime, statistički značajna razlika uočena je kod srednje vrijednosti osnovne frekvencije (Fo) (p = 0,042), jittera (p = 0,007), shimmera (p = 0,026) i u odnosu šuma i harmonika (p = 0,018) između pušača i nepušača. Takođe, utvrđena je statistički značajna razlika između dvije podgrupe ispitanika (oni koji puše manje od 10 godina i oni koji puše duže od toga) u osnovnoj frekvenciji glasa Fo (p = 0,011), standardnoj devijaciji osnovne frekvencije STD (p = 0,047) i perturbaciji amplitude koja je izražena kroz shimmer u procentima Shim (p = 0,017). Za druge ispitivane parametre glasa nije evidentirana statistički značajna razlika između ove dvije podgrupe ispitanika.

Zaključak. Pušenje utiče na većinu akustičkih parametara glasa, rezultirajući lošijim kvalitetom glasa. Takođe, kvalitet glasa opada kako se pušački staž povećava.

Ključne riječi: pušenje, pušački staž, kvalitet glasa