Emina Aldžić[1]

Leila Begić[2]

[1]**Center for Hearing and Speech rehabilitation Sarajevo**

[2]**University of Tuzla, Faculty of Education and Rehabilitation**

e-mail: emina_aldzic1@hotmail.com

The Impact of Smoking on Olfactory Function and Muscle Compensation Movements in the Oral Phase of Swallowing

Utjecaj pušenja na olfaktornu funkciju i kompenzacije mišićnih pokreta u oralnoj fazi gutanja

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ABSTRACT

Smoking is a serious public health problem, as smoking and passive exposure to tobacco smoke are important risk factors for global morbidity and mortality. It also negatively affects the structure and functionality of the sensory-motor-oral system, disrupting key functions such as breathing, phonation, chewing and swallowing. Therefore, the aim of this research is to investigate the influence of cigarette consumption on olfactory function and compensatory muscle movements during the oral phase of swallowing. 80 respondents participated in the research (40 smokers and 40 respondents who did not consume tobacco products). The research procedure included examination and analysis of the subject's olfactory ability in the form of recognition of presented smells. The compensatory movements of the lip muscles - *musculus mentalis* and *musculus orbicularis oris* - were evaluated. The research results showed that smokers have a weak ability of olfactory perception compared to non-smokers, which implies the occurrence of muscle compensation during swallowing.

Key words: olfactory function, compensatory muscle movements, smoking

SAŽETAK

Pušenje je ozbiljan javnozdravstveni problem, jer su pušenje i pasivna izloženost duhanskom dimu važni faktori rizika za globalni morbiditet i smrtnost. Također, negativno utječe na strukturu i funkcionalnost senzorno-motorno-oralnog sistema, remeteći ključne funkcije - poput disanja, fonacije, žvakanja i gutanja. Stoga je cilj ovog istraživanja istražiti utjecaj konzumacije cigareta na olfaktornu funkciju i kompenzacijske pokrete mišića u oralnoj fazi gutanja. U istraživanju je sudjelovalo 80 ispitanika (40 pušača i 40 ispitanika koji nisu konzumirali duhanske proizvode). Postupak istraživanja obuhvatio je ispitivanje i analizu olfaktorne sposobnosti ispitanika u obliku prepoznavanja prezentiranih mirisa. Procijenjeni su kompenzacijski pokreti mišića usana - *musculus mentalis* i *musculus orbicularis oris*. Rezultati istraživanja pokazuju da pušači imaju slabu sposobnost olfaktorne percepcije u odnosu na nepušače, što implicira pojavu mišićne kompenzacije tijekom gutanja.

Ključne riječi: olfaktorna funkcija, kompenzacijski pokreti mišića, pušenje

INTRODUCTION

Several factors can alter the ability to perceive taste and smell, such as changes in the structure or function of the nose and mouth, trauma, neurological conditions, and even pregnancy, which can temporarily affect an individual's perception. Another factor that can significantly influence the sensitivity of olfactory and gustatory receptors is smoking (Neto et al., 2011). Exposure to toxic substances that affect the olfactory system can result in the loss of the sense of smell lasting from several days to several years and may be either reversible or permanent. The degree of lesion is associated with the duration of exposure, as well as the concentration and toxicity of the agent, which is often linked to tobacco (Deems et al., 1991).

Swallowing, or deglutition, is one of the essential functions necessary for sustaining human life. This activity plays a significant role in maintaining health and contributes to the overall quality of life and well-being. Deglutition ensures safe transfer of food from the oral cavity to the stomach, helps maintain nutritional status, and protects the airways (Chaves et al., 2011). In other words, swallowing encompasses two primary physiological aspects: transporting food from the oral cavity to the stomach and preventing food or liquid from entering the airways to avoid contamination of the trachea, bronchi, and lungs (Matsuo & Palmer, 2009). It is considered a complex activity involving both voluntary and involuntary actions, requiring coordination of many muscles and brain regions (Yamamura et al., 2010).

Normal swallowing physiology begins with the oral preparatory phase, which represents the voluntary component of the swallowing process. Its duration depends on several factors, including the taste of the food, environment, hunger level, motivation, and the individual's awareness (Ertekin & Aydogdu, 2003, as cited in Begić, Duranović & Jovanović-Simić, 2018). Although it is a conscious activity, the oral phase of swallowing also involves reflex mechanisms that depend on the readiness of anatomical structures to receive the bolus and on central commands for executing movements. Reflex activation requires stimulation of efferent nerves involved in this process. Swallowing, in turn, is initiated by mechanical stimuli through contact with food, and by mechanical stimuli, through olfaction and gustation (Yamamura et al., 2010). The oral preparatory phase is preceded by mouth opening, involving the lowering of the mandible and separation of the lips for food or liquid intake, followed by lip closure via elevation of the mandible. The preparatory part of the oral phase begins with food fragmentation through chewing, during which the extrinsic tongue muscles move the food toward the occlusal surfaces of the teeth while simultaneously mixing it with saliva. Thanks to coordinated tongue movements, mainly enabled by the intrinsic tongue muscles, a swallowable bolus is formed (Šimić, 2015). Once the oral preparatory phase is complete, the oral transport phase follows, during which the bolus is transferred along the palate to the pharynx. Frye et al. (1990) state that the effect of smoking on olfactory function is an important issue, noting that smoking causes long-term but reversible detrimental effects on the sense of smell. Cigarette smoke has harmful effects on the respiratory system, with some of its components directly damaging the sensory systems, while others exert toxic effects on the airways, leading to cell injury or death. Exposure of the olfactory epithelium to harmful substances reduces the regenerative capacity of sensory cells, resulting in decreased sensitivity and impaired odor recognition (Da Ré et al., 2018). Smokers exhibit inferior sensory recognition ability compared to non-smokers, as well as greater muscle compensation during the swallowing process. The amount of nicotine consumed is associated with muscle tone and, consequently, with sensations of tension and

relaxation (Fagerström & Götestam, 1977). Smoking leads to early functional aging of facial structures and is associated with increased facial muscle tonicity. Changes in muscle tone may trigger atypical motor patterns during swallowing. This could reflect a delayed motor response in smokers and/or an acute effect of nicotine due to peripheral neuromuscular actions, as nicotine has been shown to alter muscle tension (Da Ré et al., 2018).

RESEARCH GOAL

The aims of this research are to examine whether cigarette consumption significantly affects olfactory perception compared to individuals who have never been exposed to nicotine, and to investigate differences in patterns of compensatory muscle movements during the oral phase of swallowing between smokers and non-smokers.

Based on these objectives, the following hypotheses were formulated:

Cigarette consumption alters olfactory perception compared to individuals who have never used nicotine.

There are differences in compensatory movements during the oral phase of swallowing between individuals who consume and those who do not consume cigarettes.

METHOD

Participants

The study included 80 participants, of whom 40 constituted the group of smokers and 40 participants who did not use tobacco products and did not live with smokers, and therefore were not considered passive smokers. The smokers formed the experimental group, while the non-smokers represented the control group. The group of smokers consisted of volunteers who agreed to participate in this study and completed a survey on cigarette consumption. The non-smokers were healthy individuals without diagnoses of neurodegenerative, systemic, salivary, or orofacial anatomical disorders, nor abnormalities in the upper respiratory tract. At the time of assessment, exclusion criteria included current medication use, ongoing speech-language therapy, and pregnancy in female participants. All participants provided written informed consent after receiving detailed information about the study's objectives and procedures.

Material

To assess olfactory perception, the Olfaction Test: Smell Diskettes as a Screening Test of Olfaction (Briner & Simmen, 1999) was used. The test serves as a tool for evaluating the functional capacity of the sense of smell and is designed to determine whether olfactory function is preserved or compromised. It consists of eight multiple-choice odor diskettes and an accompanying questionnaire constructed in a multiple-choice format with three response options. The maximum score is eight, with each correct answer earning one point. According to the evaluation criteria, a result of 7 to 8 points indicates preserved olfactory function, while a result of 0 to 6 points indicates hyposmia, anosmia, or insufficient cooperation from the participant during testing. During the assessment, participants were presented with olfactory stimuli by opening a container with a characteristic odor, simultaneously displaying three visual symbols on the test protocol. The participants' task was to identify which of the symbols offered corresponded to the recognized smell. This included eight different stimuli with short pauses between them. The assessment of compensatory muscle movements during swallowing involved the analysis of contractions of the *musculus orbicularis oris* (orbicularis oris muscle) and *musculus mentalis* (mentalis muscle) during the swallowing of solid food and liquids. A pastry was used as the solid food item, while water served as the liquid, presented in a glass. The activity of each of

the aforementioned muscles was evaluated based on the degree of contraction, classified into four categories: absent, mild, moderate, and pronounced, as used in the study by Santos et al. (2014). Contraction of the *musculus orbicularis oris* was defined as absent when the muscle did not move at all during swallowing; as mild when only the corners of the lips narrowed; as medium when the narrowing of the corners of the lips was followed by a slight narrowing of the lips; and as accentuated when the narrowing of the corners was followed by an intense narrowing of the lips. Contraction of the *musculus mentalis* was defined as absent when the muscle did not move during swallowing; as mild when the muscle only lifted; as medium when the contraction was slight; and as accentuated when the contraction was intense.

Data Analysis

The statistical analysis of data was performed using the SPSS 21.0 statistical software. The normality of data distribution was tested using the Kolmogorov-Smirnov test. The data analysis included the application of both parametric and non-parametric statistical methods. A significance level of $p<0.05$ was used as the criterion for statistical significance in all analyses.

RESULTS

Olfactory Perception in the Experimental and Control Groups of Participants

Figure 1. presents the distribution of participants based on the number of points achieved on the olfactory function test, comparing the experimental group and the control group. In the experimental group (N=40), the majority of participants (N=31) scored between 2 and 6, which indicates the presence of hyposmia or anosmia. The remaining nine participants scored 7 or 8 points, which is considered an indicator of preserved olfactory function. In contrast, in the control group (N=40), most participants (N=25) scored 7 or 8 points, indicating normal olfactory function, while 15 participants scored between 5 and 6 points, which may suggest mild olfactory dysfunction or insufficient cooperation during testing.

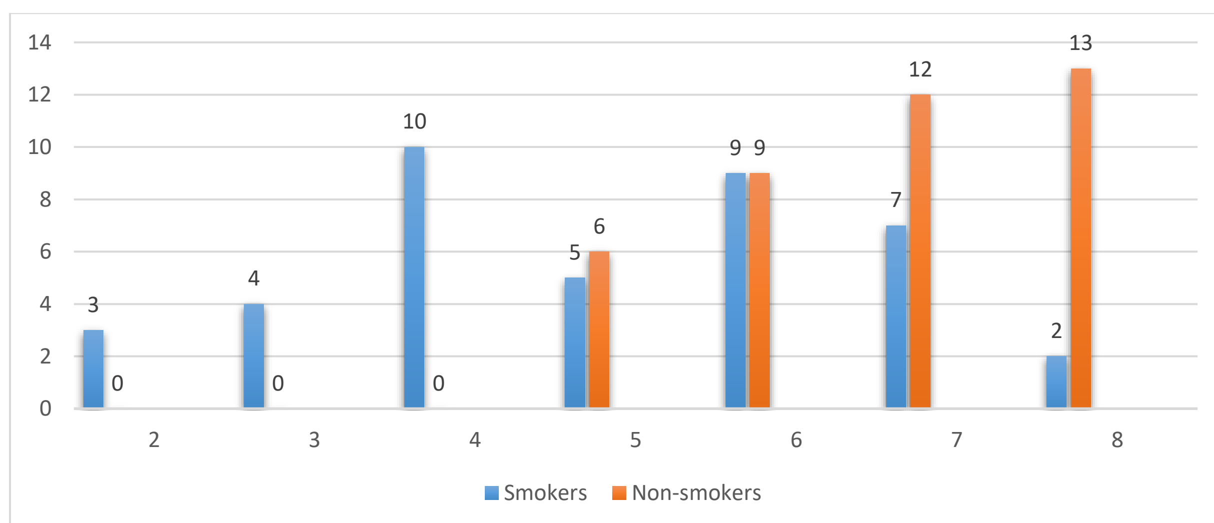

***Figure 1**. Distribution of participants based on olfactory stimulus scores*

Table 1. shows the results of the olfactory perception test for participants who smoke and those who do not. The results of the chi-square test (χ^2 = 28.74; df = 6; p =0.001) indicate that there is a statistically significant difference between the observed groups at the p<0.05 level.

Table 1. *Olfactory perception test results for smoking and non-smoking participants*

Olfactory perception test									χ^2	p
Participants		2	3	4	5	6	7	8	**28.74**	**0.001**
Smokers	N	3	4	10	5	10	7	1		
	%	7.5	10.0	25.0	12.5	25.0	17.5	2.5		
Non-smokers	N	0	0	0	6	9	12	13		
	%	0.0	0.0	0.0	15.0	22.5	30.0	32.5		
Total	N	3	4	10	11	19	19	14		
	%	3.8	5.0	12.5	13.8	23.8	23.8	17.5		

Differences in Compensatory Movements During the Oral Phase of Swallowing Between the Experimental and Control Groups of Participants

Among smokers (N=40), various compensatory patterns during swallowing were observed. During the swallowing of solid substances, contraction of the *orbicularis oris* muscle was absent in 8 participants, mild in 14, medium in 10, and accentuated in 8 participants. During the swallowing of liquids, contraction was absent in 15 participants, while the remaining participants exhibited mild (11), medium (14), and accentuated (8) compensatory responses. Activity of the *mentalis* muscle during the swallowing of solid substances was absent in 2 participants, mild in 10, medium in 13, and accentuated in 15. During the swallowing of liquids, contraction was absent in 5 participants, while the remaining participants exhibited mild (9), medium (12), and accentuated (14) compensations.

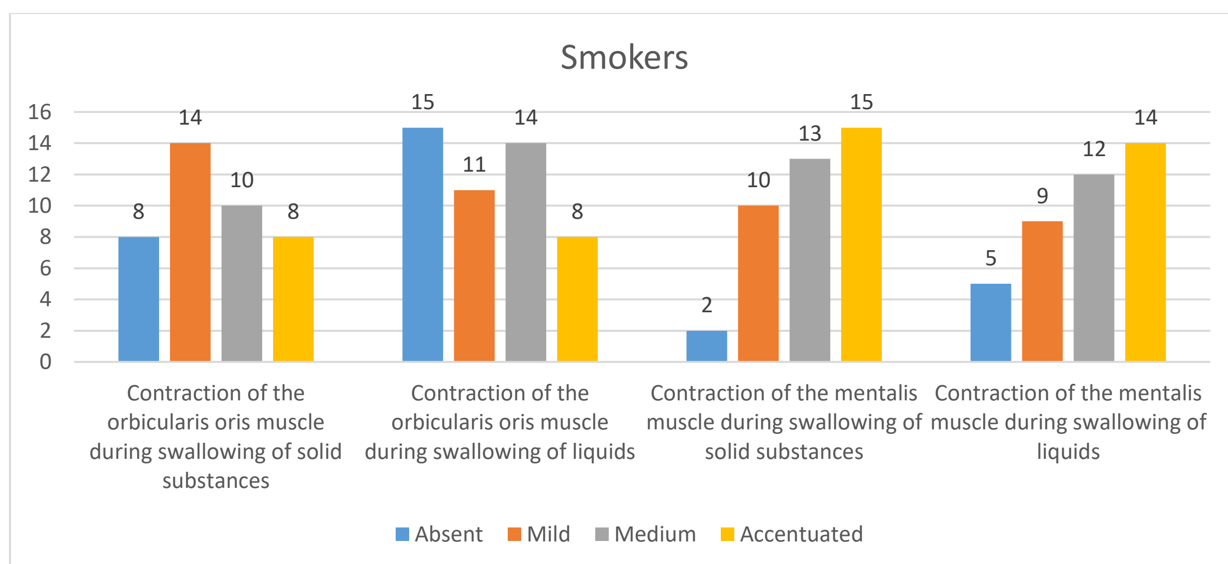

Figure 2. *Compensatory muscle activity observed in the experimental group*

Among non-smokers (N=40), minimal muscular compensation during swallowing was recorded. Contraction of the *orbicularis oris* muscle during the swallowing of solid substances was absent in 33 participants, mild in 4, and medium in 3. A similar pattern was observed during the swallowing of liquids, with contraction absent in 33 participants, mild in 6, and medium in 1. Regarding the *mentalis* muscle, contraction during the swallowing of solid substances was absent in 31 participants, mild in 5, and medium in 4, with the same distribution recorded during the swallowing of liquids.

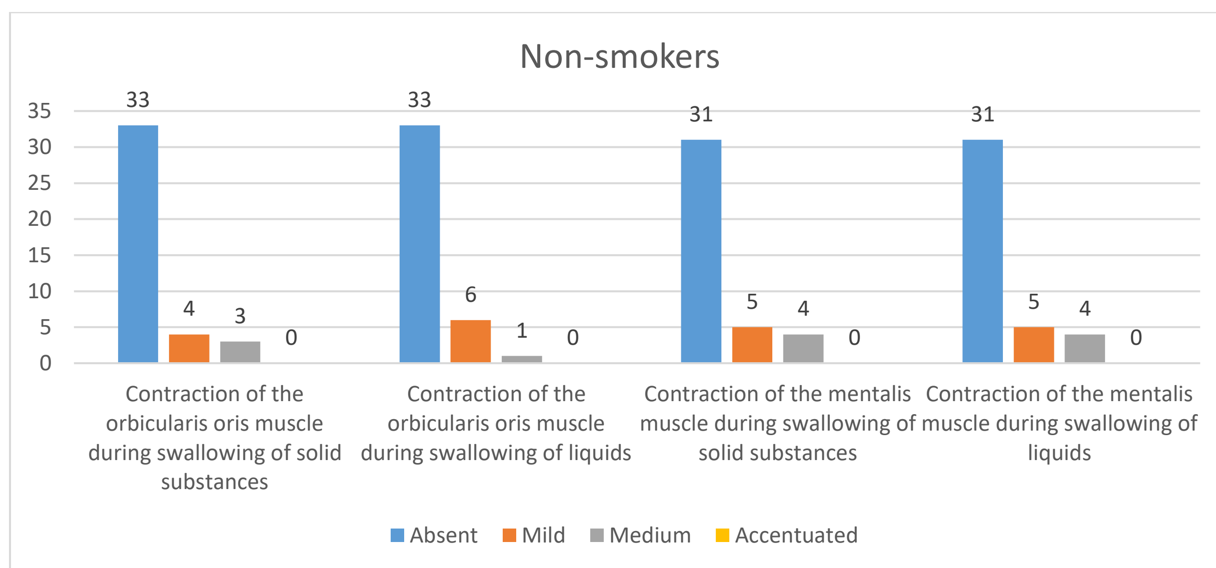

Figure 3. *Compensatory muscle activity in the control group*

Table 2. presents the distribution of participants in relation to the degree of muscle compensation (*orbicularis oris* and *mentalis*) during the swallowing of solid food and liquids. The results of the t-test indicate statistically significant differences between smokers and non-smokers across all analyzed variables. For the contraction of the *orbicularis oris* muscle during solid food swallowing, statistically significant differences were found at the p<0.05 level (SD=0.18; t=6.36; p=0.001). The mean for smokers was 2.45±1.03, while for non-smokers it was 1.25±.58. Statistically significant differences were also observed during the swallowing of liquids (SD=0.18; t=5.86; p=0.001), with a mean score of 2.27±1.06 for smokers and 1.20±.46 for non-smokers. For *mentalis* muscle contraction during the swallowing of solid food, statistically significant differences were found at the p≤0.05 level (SD =0.17; t=9.52; p=0.001). The mean for smokers was 3.02±.91, and for non-smokers 1.32±.65. During the swallowing of liquids, statistically significant differences were again observed (SD=0-19; t=7.96; p=0.001), with a mean of 2.87±1.04 for smokers and 1.21±.65 for non-smokers.

Table 2. *Distribution of participants in relation on the degree of muscle compensation*

Variable	Participants	N	M	SD	SE	t	p
COS	Smokers	40	2.45	1.03			
	Non-smokers	40	1.25	0.58	0.18	6.36	0.001
COL	Smokers	40	2.27	1.06			
	Non-smokers	40	1.20	0.46	0.18	5.86	0.001
CMS	Smokers	40	3.02	.91			
	Non-smokers	40	1.32	0.65	0.17	9.52	0.001
CML	Smokers	40	2.87	1.04			
	Non-smokers	40	1.21	0.65	0.19	7.96	0.001

Legend: *COS – contraction of the orbicularis oris muscle when swallowing solids, COL – contraction of the orbicularis oris muscle when swallowing liquids, CMS – contraction of the mentalis muscle when swallowing solids, CML – contraction of the mentalis muscle when swallowing of liquid*

DISCUSSION

Numerous authors have demonstrated that smoking is a risk factor for the development of sensory disorders, as well as compensatory muscle movements during swallowing, which is also evidenced by the findings of this study. Most studies confirm that smoking is one of the leading risk factors for the development of chronic diseases, particularly malignancies. However, less attention has been devoted to examining the impact of smoking on other areas of health, such as sensory and oropharyngeal aspects, which can also have significant implications for the overall health of tobacco users. One of the key negative effects of smoking is the reduction in pulmonary function, which may lead to chronic obstructive pulmonary disease and other conditions that secondarily affect functions such as swallowing. It is well established that smoking negatively impacts the process of eating, primarily through damage to the senses of smell and taste. These changes result from prolonged exposure to tobacco smoke, which can lead to both structural and functional alterations of sensory receptors, reducing their capacity to perceive stimuli. The results of this study indicate statistically significant differences in olfactory function between smokers and non-smokers. In a study conducted by Santos et al. (2018), differences in sensory function were also recorded on the olfactory perception test. The average number of correct answers was significantly higher in the non-smoker group, indicating a negative impact of smoking on the ability to recognize smells. Similar findings were reported by Pavlidis et al. (2009), whose results indicate that changes in olfactory function are a consequence of structural damage to the neuroepithelium, leading to functional impairment. Vennemann et al. (2008) showed that olfactory function is impaired in a significant portion of the population. In a clinical study of smokers, Kayalı-Dinç et al. (2019) reported a high prevalence of hyposmia - as many as 79.4% of participants exhibited reduced olfactory function, further confirming the severity of sensory impairment caused by smoking.

In addition to the significant differences in olfactory changes observed between smokers and non-smokers, differences were also found between the groups regarding the degree of muscle compensation during swallowing. Given that smoking causes numerous metabolic damages in the human body, muscle contractions also occur in the form of tightening, shortening, or deepening of the muscles due to frequent actions resulting from repeated movements while inhaling cigarette smoke - such as adjusting the lips to draw in and hold smoke in the mouth. Changes that occur in the area around the lips and chin arise from the use of specific muscles that cause dynamic transformations.

The results of this study show that differences exist in compensatory movements during the oral phase of swallowing between individuals who consume and those who do not consume cigarettes.

Santos et al. (2018) found that *mentalis* muscle contraction was less frequently observed in non-smokers, while smokers exhibited an average degree of statistically significant change compared to non-smokers. That is, *mentalis* contraction resulted in a lower degree of change among non-smokers during the swallowing of both consistencies evaluated. The significant findings of their study relate to the greater number of individuals in the smoker group who demonstrated a moderate degree of compensatory change. In contrast, no significant differences were found in the contraction of the *orbicularis oris* muscle.

CONCLUSION

The results of this study confirm the negative impact of smoking on the olfactory system and the occurrence of compensatory muscle activity during the oral phase of swallowing. A significant decline in sensory smell recognition ability was demonstrated in individuals who smoke, compared to non-smokers. The findings suggest that chronic exposure to cigarette smoke leads to damage to olfactory receptors, changes in the olfactory epithelium, and an increased rate of apoptosis in olfactory sensory neurons. Although the olfactory neuroepithelium is a type of neural tissue capable of regeneration, constant exposure to smoke reduces its natural ability to generate new sensory cells and increases the rate of apoptosis in that tissue, resulting in a loss of smell recognition. In addition to sensory changes, smoking also leads to functional and structural adaptations of the muscles involved in swallowing. Changes in compensatory patterns of the *mentalis* and *orbicularis oris* muscles were demonstrated, indicating adaptive mechanisms in the oral region associated with the chronic repetition of movements characteristic of the act of smoking. The specific inhalation patterns during smoking condition increased muscle tone and modified muscular activity, altering both their behavior and structure due to the repetitive nature of this action.

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