Int. j. adv. multidisc. res. stud. 2026; 6(2):637-641

Received: 03-02-2026
Accepted: 13-03-2026

International Journal of Advanced Multidisciplinary Research and Studies

ISSN: 2583-049X

Effects of Smoking on Eustachian Tube Functions

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DOI: https://doi.org/10.62225/2583049X.2026.6.2.6018

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Abstract

Background: Functions of Eustachian tube are essential for middle ear health, with impact on its equalization, ventilation, and protection. Smoking has been linked to altered Eustachian tube functions, thus, affecting its activities.

Objectives: To evaluate the effect of tobacco smoking on the Eustachian tube functions.

Patients and Methods: Cross-sectional study was conducted on 100 adults' participants, whom divided into: group A: 50 smokers, and group B: 50 non-smokers, the Eustachian tube function was assessed via tympanometry, stapedial reflexes test (SRT), 9-steps Eustachian tube (ET) function test; inflation/deflation tympanometry test, as well as, linear regression analysis, a statical evaluation were studied, and compared.

Results: Middle ear Pressure: in group A; -1.93± 15.54 SD * dapa, and in group B; 2.86±11.72 SD * dapa, compliance (ml): in group A; 3.94±0.63, in group B; 1.02±0.58, ear canal volume: in group A; 0.12±0.36, and in group B; 2.97±3.84, mean tympanometry peak pressure: in group A; basal -13.59± 8.47, Valsalva -9.48±32, Toynbee -7.46±9.83, and in group B; basal -29.81±5.37, Valsalva-27.49±6.75, Toynbee-59.32±1.14, type C tympanometry curve in group A; (96%), and type A curve in group B; (94%), nine-step inflation/deflation tympanometry test: in group A; (94%), and in group B; (6%), stapedial reflex absent: in group A; (94%), in group B; (4%), the linear regression analysis: in group A; (R^2 =0.867), with 1.62 [95% confidence interval, CI: 1.34-2.12], and in group B; (R^2 = 0.0124). with 4.73 [95% confidence interval, CI 7.96-5.23].

Conclusions: A statically significant impairment in Eustachian tube functions among smokers' group.

Keywords: Eustachian Tube Functions, Tympanometry, Smoking

Introduction

The Eustachian tube (ET) is a functional tubular structure connecting the middle ear to the nasopharynx, its known functions are to equalize the pressure of the middle ear, drain secretions from the middle ear, and protect the middle ear from sounds and pathogens from the nasopharynx. Eustachian tube dysfunction (ETD) can be divided into three subtypes: dilatory (obstructive), baro-challenge-induced (baro-ETD), and patulous ETD [1].

The prevalence of obstructive Eustachian tube dysfunction (OETD) in adults is estimated to be 5%, its symptoms; such as otalgia, a feeling of pressure, and hearing impairment decrease patients' quality of life [2].

Several tests evaluate ET function, but there is no consensus on the best protocol to diagnose ETD, as otomicroscopy and tympanometry can objectively provide information on middle ear pressure conditions, but fail to measure ET function directly, as well as, Valsalva maneuver can give information on ET patency, however, it is non-physiological, and many healthy individuals also fail this test, also Toynbee maneuver is more physiological, but almost half of the healthy individuals fail this test, and the repeatability of the test is inferior to the Valsalva maneuver, Trans-nasal video endoscopy allows direct evaluation of the ET's orifice and can be used to detect pathologies of the orifice and evaluate the muscle activity, yet, the entire opening of the ET cannot be evaluated with endoscopy, now adays, Sonotubometry, along with tubomanometry (TMM), is considered the most reliable test for ET patency [3].

Smoking any form of tobacco, including cigarettes, cigar, pipe, and narghile (Water-pipe) was estimated about 25.7% in men and 1.9% in women in the Iraq, also, the World Health Organization (WHO) classifies cigarette smoking based on the level of dependence and the impact on health. The classification focuses on the degree of addiction and the risk factors associated with

smoking. Here is a general breakdown of the classifications: Smoker Categories: Current Smoker: A person who is actively smoking cigarettes. Ex-Smoker: A person who has quit smoking, but was previously a smoker. Non-Smoker: A person who has never smoked or has smoked very little in their lifetime. Smoking Intensity (based on the number of cigarettes smoked): Light Smoker: Typically refers to someone who smokes fewer than 10 cigarettes a day. Moderate Smoker: A person who smokes 10–20 cigarettes a day. Heavy Smoker: Someone who smokes more than 20 cigarettes a day. Health Impact: The WHO highlights that any level of smoking has detrimental effects on health, including increased risks of lung cancer, heart disease, stroke, and respiratory diseases, the risks rise with the number of cigarettes smoked and the duration of smoking [4].

The effect of smoking on eustachian tube dysfunction is well established in anecdotal clinical practice; however, the quantitative relationship between smoking and eustachian tube dysfunction has never been established, the eustachian tube dysfunction is the failure of the eustachian tube to properly ventilate, and balance pressure between the middle ear and nasopharynx, lead to "obstructive eustachian tube dysfunction" (OETD), the most common subtype, is thought to occur due to the inability of the structure to effectively dilate, so, OETD is diagnosed by a combination of symptoms, physical examination findings, and tympanometry, so, it diagnosed when type C tympanogram or a peak pressure of less than −100 deca pascals (daPa) [5, 6].

Cigarette smoking may affect hearing, through its effects on antioxidative mechanisms or on vasculature supplying the auditory system, tobacco smoke disturbs the normal clearing mechanism of ear canal, facilitating infections organism entry into the body resulting middle ear infection can be very painful, as pressure and fluid buildup in the ear, so continued exposure to tobacco may result in persistent middle ear infections and eventually, hearing loss, moreover, tobacco-specific nitrosamines, a group of carcinogens produced by nicotine and tobacco-derived alkaloids, in fact, can determine squamous metaplasia of the tubal mucosa and depletion of its hair cells, delegated to the mucociliary function of the eustachian tube [7].

Various tests to measure ET function have been developed, including tympanometry, pneumatic otoscopy, sonotubometry, nine-step test and tubomanometry. However, none has been found to be completely reliable and in clinical practice usually the diagnosis of ETD relies on patient's history and clinical examination combined with tympanometry, as the main problem in exploring eustachian tube is that test available explores its opening under artificial circumstances as a surrogate marker for ET function, in reality, this complex organ has a dynamic functioning and does not necessarily open with each swallowing, moreover, it has also been hypothesized that, similarly to nasal mucosa, fluctuations in mucosal congestion can cause significant changes in tube patency [8].

Tobacco-specific nitrosamines, a group of carcinogens produced by nicotine and tobacco-derived alkaloids, in fact, can determine squamous metaplasia of the tubal mucosa and depletion of its hair cells, delegated to the mucociliary function of the eustachian tube. The loss of mucociliary clearance mechanisms, allergic response of the mucosa to substances contained in the tobacco smoke, chemical irritation and overall immunosuppressive effects secondary to tobacco smoke exposure could lead to greater susceptibility to bacterial infections of the middle ear [9].

Since, data on the effects of tobacco in the pathogenesis of diseases of the middle ear in the adult population are scarce, to date, and there exist no studies in the literature aimed at the analysis of its effect on the tubal function in its entirety, so the current study aims to evaluate the effect of tobacco, on the Eustachian tube functions.

Patients and Methods

The cross-sectional study sample was composed of 100 adults' participants, consecutively from Otolaryngology clinic, and were divided into groups; group A; consist of 50 smoker, whom smoked at least10 cigarettes per day over a year, and group B; consist of 50 non-smokers, whom were had no smoking history or quit for over 12 months "control group", those healthy volunteers were recruited from the institutional staff and their relatives, a statical evaluation of both groups were studied, and compared.

The study protocol was approved by the institutional ethical committee, it`s number 187 at 03-01-2024, and their verbal consents were obtained, also, it performed in accordance with the Declaration of Helsinki.

Inclusion criteria: Adults, no acute or chronic otologic diseases, nasal or sinus infections, or structural anomalies of the nose and middle ear.

Exclusion criteria: Children, as their age < 18 years, noise exposure, ototoxicity, tinnitus, acute or chronic rhinosinusitis, systemic diseases, chronic middle ear pathologies, and present or previous ear and head trauma.

All participants were submitted to complete medical history, and precise (Ear, Nose, and Throat) ENT examination, then they were submitted to an audiological evaluations including; pure tone audiometry as, basal tympanogram, stapedial reflexes analysis, and nine-steps Eustachian tube function test through inflation/deflation tympanometry test (Valsalva and Toynbee), as well as, linear regression analysis.

Smoking history, in the current study, the smoker participants included, were smoking at least 10 cigarettes daily over year, (1 pack=20 cigarettes) was defined as pack-year and calculated, thus, "Total pack-years smoked" was calculated, as the number of cigarettes smoked per day multiplied by the number of years of smoking.

A conventional tympanometry testing, uses a probe tone at a frequency of 220 Hz, for evaluation of Eustachian tube function, with Intra acoustics AZ 26 (A/S, Assens, Denmark), in sound-proof chamber. Standard tympanometry was carried out to collect middle ear pressure data, so the primary outcome of Eustachian tube obstruction was defined; as a peak mean middle ear pressure < –100 daPa.

The nine-steps inflation/deflation tympanometry test according to the following steps: it begins with a baseline tympanogram to establish a reference value, then the ear canal pressure was increased to +200 mm/H2O, so that, the tympanic membrane moves toward middle ear, (at this point patients were asked to swallow 3 times to equilibrate middle ear overpressure, via the Eustachian tube), If the equilibration was successful, the second tympanogram documented the established middle ear under pressure (peak at a negative pressure) was done, after that, to normalizes the middle ear pressure again, by asking the participant again to swallow 3 times, then, to measure middle pressure after re-equilibration, the tympanogram was repeated (the peak returns toward 0 daPa), the same procedure was

performed with -200 mm/H2O ear canal pressure, so, in this case the expected pressure changes were towards positive values.

Failure to alter middle ear pressure at least 10 mm/H2O with swallowing was considered, as Eustachian tube dysfunction, whereas if the equilibration was successful, then the Eustachian tube function was considered normal.

So, Valsalva maneuver was usually done by closing mouth and nose, in order to forceful attempt of opening the Eustachian tube, while the Toynbee maneuver was done via swallowing motion with the nose closed, that`s leads to pressure changes in the middle ear.

This study assessment was done, to investigate qualitative variables (number of participants with tubal dysfunction) to compare them between the 2 studied groups, whereas, binary logistic linear regression analysis test, was performed to assess the Eustachian tube dysfunction, with cigarette consumption, taking tympanometry as dependent variable, and smoking habit as independent variables.

Statistical Analysis

Data were analyzed using SPSS software (Inc., La Jolla, California, USA). Descriptive statistics (mean ± standard deviation) were computed for all variables. Independent t-test, and relative risks (RRs) were used to compare the Eustachian tube function between smokers and non-smokers. A p-value of <0.05 was considered statistically significant.

Results

Among 100 participants involved in this study, which were divided into 2 groups (group A= 50 smoker, and group B= 50 non-smoker).

Demographic characteristics: Age group was between 18-50 years, there were 74 males (74%), and 26 females (26%), were being in group A; 36 males (72%), and 14 females (28%), and in group B; were 38 males (76%), and 12 females (24%).

The mean age (37.26± 1.48 SD years), as being; in smoker group A; (39.28± 1.64 SD years), and in non-smokers group B; (38.26± 1.98 SD).

About the residency: From urban area: in group A; were 38 participants (76%), and in group B; 36 participants (72%), and from rural area: in group A; were 12 participants (24%), and in group B; 14 participants (28%).

Regarding the age, gender, and the residency, there were no significant differences were detected between both groups, as the P values were > 0.05.

Regarding, the ears sites (right or left) were also studied, and this study found no significant differences in comparing them in both groups, and also, in each group, as the P values were > 0.05.

The number of pack-years of smoking ranged from 10-40, with an average 27.63± 1.58 SD pack-year, a significant result was detected of the effect of smoking with increased consumption of cigarettes smoking, associated with high level of risks, with P <0,005, as shown in table 1.

Table 1: Relative Risk of smoking history with Attributable Risk

Smoker	Relative risk [95% CI]	Attributable risk (%)
10 pack/year	24.29 [3.64, 1.83]	5.76
20 pack/year	29.43 [3.91, 1.84]	5.92
30 pack/year	31.41 [2.57, 2.42]	6.63
40 pack/year	34.98 [4.86, 3.27]	6.98

There was a significant result, with descriptive statistics (mean ± standard deviation), for middle ear pressure, middle ear compliance, and ear canal volume, for both ears in smokers and non-smokers groups, with P values were < 0.005, as seen in table 2.

Table 2: Descriptive statistics and P-values for comparisons of studied groups

Parameter	Mean ± SD	Mean ± SD	P - value
Tympanometry	Smokers Group A	Non-smokers Group B	
Compliance (ml)	3.94±0.63	1.02±0.58	0.0025 [s]
Middle ear Pressure (dapa)	-1.93± 15.54* dapa	3.86±11.72* dapa	0.0012 [s]
Ear Canal volume (ml)	0.12±0.36	2.97±3.84	0.0015 [s]
[s] Significant, SD= Standard Deviation * Range of the middle ear pressure (dapa)			

The mean tympanometry peak pressures between studied groups, revealed impaired tubal function in smokers group A, compared to non-smokers group B, as shown in table 3. Type C tympanometry curve in smokers group A; was seen in 48 participants (96%), and type A curve was seen in 2 participants (4%), while in non-smokers group B; type A tympanometry curve was found in 47 participants, (94%), and type curve was found in (6%), with statistically significant, as P=0.0013.

Table 3: Evaluation of mean tympanometry peak pressures between studied groups

	Smokers Group A			Non-smokers Group B		
	Basal	Valsalva	Toynbee	Basal	Valsalva	Toynbee
	-13.59± 8.47	-9.48±32	-7.46±9.83	-29.81±5.37	-27.49±6.75	-59.32±1.14
P value	0.001	0.002	0.012	0.003	0.003	0.004

The nine-step inflation/deflation tympanometry test was presented in smokers group A; found in 47 participants (94%), which stated as an impaired tubal function, while 3 participants (6%) in the group of non-smokers "group B', with difference was statistically significant, as P=0.00015.

Incidence of Stapedial Reflex in both smokers and non-smokers groups was statistically significant, as P=0.0025, as shown in table 4.

Table 4: Incidence of Stapedial Reflex in both smokers and non-smokers groups

Stapedial Reflex	Smokers Group A	Non smokers Group B	P-Value
Absent	47 (94%)	2 (4%)	P=0.0025
Present	3 (6%)	48 (96%)	

Eustachian tube function test analysis through Valsalva and Toynbee tympanometry test, with statistically significant results, as P values were <0.05, as revealed in Table 5.

Table 5: Evaluation of mean tympanometry peak pressures between studied groups

	Smokers Group A			Non-smokers Group B		
	Basal	Valsalva	Toynbee	Basal	Valsalva	Toynbee
P value	-13.59± 8.47	- 9.48±32	- 7.46±9.83	- 29.81±5.37	- 27.49±6.75	- 59.32±1.14
	0.001	0.002	0.012	0.003	0.003	0.004

Linear regression analysis, showed a significant positive correlation between Eustachian tube functions and tobacco smoking, with a slope of the regression higher in smokers group A; where it was (R^2 =0.867), with 1.62 [95% confidence interval, CI: 1.34-2.12], than in non-smokers group B; as it was (R^2 = 0.0124), with 4.73 [95% confidence interval, CI 7.96-5.23].

Discussion

There are several clinical and laboratory studies, showing the influence of smoking on middle ear, so months of exposure to cigarette smoke has been shown to cause squamous metaplasia, goblet cell aplasia, and silica loss in the eustachian tube and middle ear mucosa, causes severe inflammation in the middle ear mucosa, with its both toxic and irritant actions, has been shown to have effects that increase negative pressure such as ear fluid accumulation and mucosal hypertrophy in the middle ear [10].

The findings in the current study, goes in line with the results of other studies, that smoking causes significant impact on Eustachian tube functions [7, 9, 10].

In this study, regarding; the age, gender, ear`s site, and the residency, there were no significant differences between the both studied groups, while, there was a significant result detected of the effect of smoking with increased consumption of cigarettes smoking, these detections were agreed with other studies [8, 10, 11].

Demir E, *et al* [11], in their study stated that, the wideband tympanometry measurements are more popular in the diagnosis, and follow-up of middle disease; therefore, cigarette smoking should be questioned during evaluation of results because overlooking smoking may lead to ignoring the consequences of smoking and misinterpretation of the data.

In addition, Hussain TA [7] reported that, there were a number of ways in which smoking could affect Eustachian tube function, and tympanometry findings including a direct effect of irritants in tobacco smoke on the mucosa of the middle ear and Eustachian tube, and increased respiratory tract infection, one study was demonstrated impaired ear ciliary function due to tobacco smoke exposure, while, others found that the Valsalva induced tympanometry peak pressure shifts of young smokers were less than those measured among non-smokers, thus the aim of his study, was to analyze the association between active smoking and the tympanometry findings in healthy men aged 20-to-50 years, the results show a statistically significant difference between smokers and non-smokers with middle ear pressure in both ears (P< 0.001).

Also, a study done by Pezzoli M, *et al* [8] in their 64 patients, they found that smokers were significantly more likely to experience obstructed Eustachian tube dysfunction, which noted, as inability to alter middle ear pressure by 10 mm/H2O during swallowing.

Moreover, Smith ME, *et al* [12], detected in their study, that, the main problem in exploring eustachian tube is that test available explores its opening under artificial circumstances as a surrogate marker for ET function, in reality, this complex organ has a dynamic functioning, and does not necessarily open with each swallowing moreover, it has also been hypothesized that, similarly to nasal mucosa, fluctuations, in mucosal congestion can cause significant changes in tube patency in as little as 1 hour, this is the reason in general Eustachian tube tests shows poor repeatability, and it may be influenced by short-term fluctuations even in normal ears, no test is reported to detect opening of the ET in 100%.

Smith ME, *et al* [12], and Uzun C, *et al* [13], studies, revealed; in order to carry out an analytical evaluation of the tubal function, they used the nine-step inflation/deflation test, which had the advantage that can be performed with a tympanometry, an instrument that can be found in every institution, and does not need adjunctive and expensive equipment, it was considered a reliable test, as detects ET opening in 81% of normal subjects, and easy method for evaluating eustachian tube function; it is normally used to evaluate divers' middle ear equalization problems since it is considered a valuable tool to predict middle ear barotrauma.

While a study performed by Schröder S, *et al* [14], reported that, the nine-step inflation and deflation test to evaluate eustachian tube function, even if this test has shown to be more reliable than the simple tympanometry, it shows a poor repeatability, and therefore other test such as tubomanometry or a subjective questionnaire, such as Eustachian tube score, should have been added to the diagnostic protocol.

Gaur found in a retrospective study that middle ear diseases were significantly more common in smokers [15].

Pucci BPC, *et al* [16] study stated, that, although the effect of smoking on the middle ear was evaluated at microscopic level in laboratory studies, and in relation to otitis media in clinical studies, the anatomical and functional changes of the middle ear were not evaluated with any test previously. Wideband absorbance provides important information about the functional and anatomical structure of the middle ear.

The study done by Effat KG [17] on the adult men smoking Narghile (water-pipe), reported that tympanometry changes were not significant between smokers and non-smokers.

Pezzoli M, *et al* [8], stated that, since this test must be applied with a normal tympanogram, but they were excluded them from their study sample, therefore, they lack data about the prevalence of otitis media in smokers in their sample, and more than half of smokers showed an infra-clinical tubal dysfunction without otitis media, a value significantly higher than in the nonsmoker population, suggesting that the toxic effects of smoking could be present in the tubal mucosa, this suggests that smokers could be more prone to recurrent otitis media and barotrauma due to difficulties in pressure equalization, the latter point is particularly significant for those who carry out professional or recreational diving, however, more investigations were needed to confirm that this tubal dysfunction, could be considered a risk factor for middle ear pathologies.

In this study, the correlation between exposure to cigarette smoking, and the good function of the eustachian tube, was thoroughly analyzed, and found the presence of a high number of smokers suffering from tubal dysfunction, this had important clinical relevance, because it might lead to increases the incidence of middle ear diseases.

Limitations

Small sample size, and single study center, so, a longitudinal study with improved assessment of smoking, time exposure, body mass index (BMI), and blood levels of nicotine, also the severity levels of auditory damage with its symptoms, should be assessed to overcome methodological limitations of this study.

Conclusions

A statically significant impairment in Eustachian tube functions, based upon classical tympanometry, stapedial reflexes test, 9-steps Eustachian tube function test (inflation/deflation tympanometry test) results, (more negative middle ear pressure) in smokers' group, than those in non-smokers group.

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