Introduction

The hearing system is considered one of the main components of communication in industrial and professional societies (1,2). Damage to the auditory system is one of the concerns of occupational medicine and occupational health experts, and according to reports, the amount of damage to the auditory system has doubled (3). Biologically, the sound causes hearing loss by damaging the hair cells of the cochlea and also causing metabolic changes due to hypoxia caused by vascular contraction (4). Hearing loss can be the result of diseases such as middle ear infection, damage to the eardrum, injury to the ear, and formation of a hole in the eardrum. In addition, several physiological-chemical damages with no clear physiological explanation have also been reported. Hearing loss caused by exposure to noise is confirmed by several researchers (3-5).

Although noise-induced hearing impairment is irreversible, permanent, and common, it can be prevented. Hearing impairment affects speech perception, which can affect workers’ performance. Although hearing loss caused by sound is affected by various factors such as gender, age, racial characteristics, sound frequency range, and lesions of the middle ear transmission system (6), studies have shown that other factors are independently associated with hearing loss. They suggest that one of these factors is smoking (5, 7). Some studies showed that smoking can affect the blood supply to the cochlea by changing the peripheral vascular function, increasing blood viscosity, and decreasing the amount of available oxygen (8). As a result, smoking and noise have a common process for hearing loss. This effect becomes more intense as the intensity of smoking and age increase. The important point is that there are industries that are noisy and the risk of hearing loss in smokers can cause more accidents in industries in addition to imposing an economic burden on society, as well as isolation, social problems, and a reduction in people’s quality of life. Therefore, more emphasis should be placed on the implementation of smoking cessation training plans, especially for workers who work in noisy environments.

Keywords: Tobacco, Deafness, Smoking
Several factors such as exposure to noise, meningitis, encephalitis, head trauma, otosclerosis, ototoxicity, diabetes, and so on can cause hearing loss. Researchers have shown that smoking can affect hearing due to the lack of oxygen in blood, vessel blockages, and changes in blood viscosity. However, there is still disagreement about the effect of smoking on the auditory system because no comprehensive study has been conducted in this regard (13). Various studies have shown the relationship between tobacco use and hearing loss. However, these studies have shown the need for further studies in this regard. More details are still needed about the types of changes that tobacco can cause and the site of damage to the auditory system (10,13). One of the important consequences of hearing loss is disruption in social communication, which causes social isolation and mental disorders. In this study, the effect of smoking on hearing loss was investigated based on some common and important factors.

Is Smoking Related to Hearing Loss?
One of the most common causes of sensorineural hearing loss at high frequencies is presbycusis (age-related hearing loss), which often starts at the age of 40 years. Smoking can affect the cochlear blood supply due to peripheral vascular changes such as increased blood viscosity (14). Ototoxicity is caused by CO in cigarettes. CO reduces the level of oxygen in the auditory cochlea located in the inner ear. As a result, it causes vasoconstriction, increases blood flow, reduces oxygen transfer, and disrupts the breakdown of oxyhemoglobin (15). All these changes can affect the cochlear blood supply and cause damage to the hair cells of the organ of Corti and hearing problems (16).

Although different studies have reported a positive relationship between smoking and hearing loss (1, 17, 18), the joint effects of smoking and noise have rarely been evaluated (19,20). In some studies, the combined effects of smoking and exposure to noise on hearing were reported (19). In contrast, according to tests, smoking has been reported to have a possible protective effect on hearing (20). There are few studies on the effects of noise exposure and smoking on hearing loss. While in some studies, after audiometric evaluation, no relationship was found between hearing status and smoking or the number of cigarettes smoked (20,21). In other studies, smoking has been described as a factor contributing to hearing loss even in the absence of exposure to noise (22,23).

Although a study found a protective effect against noise-induced hearing loss (NIHL) for smoking (20,22), other studies found a simple synergistic or incremental effect of smoking and noise (22,24). In a study, the researchers reported that current smokers were 1.69 times more likely to have hearing loss than non-smokers after adjusting for other risk factors (25).

The results of a systematic review of studies published during 2009-2016 showed that the hearing threshold of smokers is more damaged compared to non-smokers (26). In a cross-sectional study conducted in the United States, even after adjusting for other variables, smokers had hearing loss of 25 dB, which was 1.7 times higher compared to non-smokers (27). In a survey on non-smokers, a slight increase in hearing loss (odds ratio (OR) = 1.3) was observed with exposure to environmental tobacco smoke (25).

The authors of another review study concluded that tobacco use can cause brainstem involvement because in both ears of smokers, the latencies of waves I and V and latencies of interphase III-V were increased. Therefore, it can be concluded that tobacco may interfere with the neural transmission of auditory information (26). Various studies in this field have shown that smoking affects hearing, indicating that the hearing threshold is higher in smokers. It should be noted that through the analysis of the articles, it is evident that the use of tobacco mainly affects the hair cells of the auditory cochlea because high frequencies are highly damaging (1,11,14).

Given the emerging evidence of a relationship between early tobacco smoking and hearing loss, it is reasonable to assume that there is a similar relationship between second-hand smoke (SHS) and hearing loss. However, the results of few studies on exposure to SHS are inconsistent and associated with only a small reduction or no increase in the risk of hearing loss (7,28). In an article, statistical data from 1999 to 2004 were collected from 11 405 housewives exposed to SHS. In this article, a serum cotinine (primary metabolite of nicotine) level higher than 0.050 ng/mL was classified as SHS-exposed. The results showed that among former smokers, the prevalence of low/mid-frequency and high frequency hearing loss was 14% and 46.6%, respectively (11).

Is Smoking Related to Occupational Hearing Loss?
Hearing loss due to exposure to industrial noise in the workplace is an important health problem with economic consequences. NIHL is an occupational disease that, according to The Norwegian Labor Inspection Authority, accounts for 60% of all reported work-related diseases in an active population of 2.7 million people (29).

Noise is considered as one of the most common occupational hazards around the world. It is estimated that approximately 600 million workers are exposed to occupational noise. Long-term exposure to noise is one of the causes of hearing loss, a debilitating and irreversible disease. Although NIHL is a potentially preventable disease, it is still an important public health problem. The biological basis of NIHL is a combination of mechanical and metabolic factors (22): excessive exposure to noise damages the hair cells of the cochlea and causes metabolic changes resulting from hypoxia caused by capillary vasoconstriction (30). One of the most common hazardous substances is tobacco, which
is used by about 1.3 billion people in the world. Tobacco may also affect cochlear blood flow by causing peripheral vascular changes such as increased blood viscosity and reduced oxygen availability. These effects were identified in the etiology of cochlear lesions in laboratory animals and humans (22).

Few results have been reported about the synergistic effect of smoking and exposure to occupational noise on hearing loss. Several studies on animals have demonstrated that exposure to CO potentiates NIHL. However, a simple incremental effect of smoking and noise on human hearing has been observed (19). In addition, smoking is negatively associated with temporal threshold changes in humans, indicating a possible protective effect of smoking on NIHL, which is biologically inconsistent (25).

Some studies have shown that noise and smoking cause hearing loss through a common pathway, that is, the reduction in cochlear blood supply (22). According to the results of a study by Mizoue et al, factory workers are at a higher risk of hearing loss compared to office workers due to the high rate of smoking and exposure to noise (19).

In another study conducted in Japan on white-collar workers, hearing loss was higher in smokers than in non-smokers, and a dose-response relationship was observed between smoking and hearing loss, which was more obvious at higher frequencies than low frequencies (6, 12). In the study conducted by Etemadinezhad et al, smoking was significantly associated with the risk of hearing loss at higher frequencies and no correlation was found at lower frequencies (31). In a large epidemiological study conducted on 34912 male industrial workers in Japan to investigate the effect of duration of smoking cessation on the risk of hearing loss, it was found that hearing loss has occurred at the frequency of 4 kHz threshold of hearing up to more than 40 dB at least in one of the ears, which was lower among former smokers than current smokers (32).

In a study conducted in 2010 on 478 male employees of an automobile factory in Tehran, it was found that the prevalence of hearing loss in smokers was significantly higher (P<0.001) compared to non-smokers (33). In another study that was conducted on 439 men working in one of the home appliance industries around Tehran, it was found that the prevalence of hearing loss in smoking workers who were exposed to noise higher than 85 dB was 10.29 times higher compared to non-smokers who were exposed to the same noise (12).

The reason for the increase in hearing loss at higher frequencies compared to lower frequencies is that the basal cells of the inner ear that are responsible for high frequency hearing are located at the end of the arteries and might be easily damaged through ischemic mechanisms (19). Since the impairment of the auditory system due to smoking affects speech perception, the important and significant issue is that the performance of workers is strongly affected by this parameter, which can cause numerous events.

**Does the Number of Cigarettes a Person Smokes Affect Hearing Test Results?**

In a survey conducted in the United States, men who smoked two or more packs per day reported more hearing impairment (24). Four articles studied this subject (34-37). For hearing threshold, the authors of two studies reported worsening of the thresholds by increasing the number of cigarettes smoked (35, 36). However, other authors disagree with this finding (34, 37) and one of these articles showed that worsening of hearing threshold was associated with the number of cigarettes smoked only at the frequency of 12 kHz (37). It is found that by increasing the time of exposure to the toxic substances of smoking, an increase in the rate of health damage can be observed. Therefore, it is expected that the effects will worsen as the number of cigarettes and the smoking time increases. This probably applies not only to the auditory system but also to the body.

A prospective cohort study was conducted in this field, the results of which were published in 2020. This study was conducted on 81505 female nurses aged 25-42 years. In this study, smoking (those who never smoked, used to smoke, and currently smoke), hearing, and smoking per year (never, 1-9, 10-19, and more than 20 packs per year) were investigated during 1991-2013. The results showed that the risk of hearing loss was higher among women who smoked more, indicating that lifetime exposure to smoking may increase the risk of hearing loss among former smokers as well as current smokers (28).

In a study conducted on 439 men working in the home appliances industry in 2010, it was found that hearing loss in smokers who smoked more than 5 packs per year was 2.41 times higher compared to workers who smoked less (3). A study conducted on 443 reindeer herders with a mean age of 42 years who frequently used noisy tools and equipment, especially electric saws, showed a dose-dependent relationship between smoking and hearing loss. In this study, hearing loss was found in smokers who were exposed to noise for a long time (38).

**Is There a Relationship Between Smoking, Exposure to Noise, Hearing Loss, Gender, and Age?**

Given the increasing elderly population, age becomes a major risk factor for hearing loss. Age-related degenerative changes may affect nerve fibers, stria vascularis (in the auditory cochlea), and inner and outer hair cells and cause progressive hearing impairment (28). Therefore, smoking, noise, and aging may act in common causal pathways for hearing loss, through the reduction of cochlear blood flow, supporting the hypothesis that these factors interact under an additive model (22).

In a study, the incremental effect of smoking and age on hearing loss was reported, but no statistically
significant result was presented (28,36). Another study found a positive relationship between smoking, NIHL, and age, but the combined effects were not investigated (29). In several studies, a dose-response gradient has been observed between the number of cigarettes and hearing impairment among noise-exposed workers, indicating the synergistic effects of smoking, noise, and age on hearing loss and estimating the direction and magnitude of each joint effect (22,31).

This synergistic effect of smoking, noise, and age can be attributed to the presence of a high concentration of CO in the mainstream of cigarette smoke, contraction of capillary vessels, reduction in the blood oxygen level of the cochlea, decrease in oxygen absorption, disruption in the breakdown of oxyhemoglobin, and increase in blood viscosity. Exposure to noise also induces hypoxia in the cochlea (39). Chronic hypoxia may result in cochlear lesions, especially in the basal high-frequency region, the most vulnerable part of the cochlea. Besides, age-related degenerative changes may affect nerve fibers and sensitive parts of the auditory cochlea, including vascular structures, which have the greatest effect at high frequencies (40). Despite the low concentration of ototoxic substances in mainstream cigarette smoke, these substances may potentially interfere with noise and/or age and cause hearing impairment. Analyzing complex compounds is difficult because their effects are intertwined and sometimes changed in unexpected directions (41).

Experimental studies have shown direct ototoxic effects of nicotine on hair cell function through nicotine-like receptors on hair cells (19,42). Ototoxic agents present in cigarette smoke (toluene, lead, mercury, and CO), even at low concentrations, can interfere with noise or aging and aggravate hearing loss (22,43). CO in cigarette smoke can enhance the ototoxic effects of chemicals by increasing the access of these agents to the cochlear area due to increased blood supply and vascular permeability (31,40).

Smoking, noise, and age have no protective effect on hearing, each of which can impair hearing independently (22,28). Moreover, in some studies, joint effect of smoking, exposure to noise, and age on hearing loss has been observed (22,44). Smoking does not exacerbate the effect of noise on hearing but acts independently (19). The prevalence of hearing disorders and tinnitus increases not only by increasing time of exposure to noise, even after adjusting for age, but also by increasing age (24). Age-related degenerative changes usually affect high-frequency hearing (22,44). Smoking, noise, and age have a synergistic effect on the incidence of hearing disorders due to the common pathogenic pathway (22). It should be noted that studies examining contemporary exposure, especially cross-sectional ones, have limitations in causality (19,22,33).

In a study that was conducted in China on 4685 people with a mean age of 20-80 years during 2016-2018, a significant relationship was found between smoking and hearing loss at speech and high frequencies in men, but no significant relationship was found in women (P > 0.05). In this study, no significant difference (P > 0.05) was found between smoking in the youth group (20-39 years) and hearing loss at speech and low frequencies. The hearing loss of the middle-aged (40-59 years) smokers at both frequencies was significant (P < 0.05). In the same middle-aged group, heavy smokers had a higher risk of hearing loss with a ratio of OR = 2.32 compared to the group that consumed fewer cigarettes (OR = 1.89) (44). Besides, a significant relationship was reported between SHS and hearing loss (11).

Many studies have shown that genetic predisposition is very important for hearing loss. Most studies have shown that between half and two-thirds of the changes in hearing with age can be attributed to individual differences in genetic susceptibility (10,25,26). However, many studies have a small or medium sample size, which is a bit complicated to comment on (11,32,42). In recent years, a number of molecular genetic studies have also been conducted on the relationship between genetics and hearing impairment. However, to date, there is no genetic test that can distinguish between individuals who are susceptible or resistant to NIHL (45).

Effects of Exposure to Chemicals, Smoking, and Noise
It is possible that exposure to acceptable concentrations of toxic substances, especially in the presence of noise, may cause hearing impairment when they come into contact with other toxic substances. The smoke of cigarettes contains ototoxic agents such as toluene, styrene, and xylene, as well as lead, mercury, and CO (33). These substances have been described as independent factors and/or potential factors interacting with noise exposure in hearing loss (34-36). The combined effects of noise and toxic substances were also observed (37). They differ in terms of their ototoxic properties and can affect sensory or neural auditory structures (28, 35-37). The mechanism of the interaction of noise and chemicals in hearing loss includes changes such as increasing the vulnerability of the cochlea to noise and intensifying damage to the cochlea due to the joint effect of noise and chemicals that are ototoxic (28). Smoking may also enhance these ototoxic effects by increasing their access to cochlear sites, where CO is present at high concentrations, leading to increased blood flow and vascular permeability as response (14).

Discussion
There are relatively few studies on the auditory system of smokers alone. In fact, samples that are exclusively smokers are very rare; therefore, their hearing can barely be evaluated without the influence of other parameters. For example, smokers are usually exposed to ethyl due to
the substances in cigarettes, which can distort the results of the joint effect of smoking with other parameters to some extent.

All of the studies reviewed in the present article provide data showing an increased risk of hearing loss in smokers. Several types of hearing evaluation were used in these subjects. It can be concluded that smoking negatively affects hearing, as the hearing threshold is worse in smokers. It should be noted that through literature review, it is evident that tobacco use mainly affects the basal hair cells of the cochlea. The relationship between smoking and hearing loss at high frequencies is stronger compared to low frequencies. This is most likely because smoking has a direct toxic effect on the function of the outer hair cells. Additionally, an increase in carboxyhemoglobin and a reduction in blood flow to the cochlea can damage the hearing system, which has a greater negative impact on hearing loss at high frequencies.

**Conclusion**

The study results showed that the prevalence of hearing loss among smokers is higher compared to non-smokers. According to the results, it was concluded that workers should be encouraged to quit smoking in the workplace, especially in the noisy workplace. Additionally, regular audiometric tests should be performed, especially in smokers. Not only noise but also all factors contributing to hearing loss in the workplace should be considered.

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**Competing Interests**

In this study, the authors have no conflict of interests.

**Ethical Approval**

Not applicable.

**References**


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