Original Article

Occupational Noise Exposure and Hearing Loss in Truck Drivers: A Cross-sectional Analytical Study in Iran

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Abstract

Aim: Drivers have a significant role in transporting and moving goods using heavy vehicles. These drivers are exposed to various complications including hearing loss, due to long journeys and constant exposure to road noise. Considering the importance of preventing hearing loss, this study was conducted to determine the occupational exposure of truck drivers to noise and its effect on noise-induced hearing loss. **Methods:** This cross-sectional-analytical study was conducted on 692 truck drivers of 16 types of heavy vehicles in Iran. The hearing status of the truck drivers was measured in the right and left ears using a Welton 1300 clinical audiometer in a soundproof room based on the guidelines provided by the American Speech–Language–Hearing Association. The equivalent sound pressure level (LAeq) in the truck driver's cabin was measured by a sound meter with a CEL-440 analyzer model and according to the standard (ISO 9612 1997) in A-frequency weighting. Finally, using SPSS V-26, the prevalence of hearing loss, the amount of hearing loss in different frequencies, and its relationship with exposure to noise in different frequencies were investigated. **Results:** The mean ± standard deviation LAeq in the examined truck was determined as 75.89 ± 5.98. The highest average LAeq was related to the frequency of 500 Hz with 62.76 dBA. The average LAeq was generally higher at lower frequencies (250, 500, and 1000). The prevalence of hearing loss in the right and left ears was estimated at 59.98% and 64.74%, respectively. The highest average hearing loss in the right and left ears was related to 6000 and 8000 Hz frequencies. There was a statistically significant difference between the LAeq inside the truck's cabin with hearing loss compared to people without hearing loss in the right and left ears ($P < 0.001$). A statistically significant relationship between LAeq at different frequencies in different truck brands with hearing loss at different frequencies in the right and left ears was observed in the majority of trucks in reverse ($P < 0.05$). A significant relationship was observed between age and work experience with hearing loss in the right and left ears ($P < 0.001$). **Conclusion:** Truck drivers suffer from a high level of hearing loss which is very similar to any industrial worker with high frequencies such as 4000 and 6000 Hz. Despite the lack of frequency relation between noise and hearing loss, increasing age, work experience, and noise exposure, regardless of frequency, can lead to increased hearing loss in these truck drivers, especially in the left ear. The appropriate cabin design, regular maintenance of vehicles, use of personal protective equipment, reduction of driving hours, and periodic annual examinations of drivers are suggested to prevent further progress of hearing loss in them.

Keywords: Hearing loss, noise, occupational exposure, truck drivers

Introduction

Workers in different fields are always exposed to a wide range of health-impacting factors in their environment, known as harmful occupational factors, which threaten various aspects of their well-being.[1,2] Some of these occupational harmful factors are physical factors.[3,4] The most important detrimental physical factors that annoy employees in most jobs are noise and vibration. Noise is an irregular and usually unwanted part of sound waves that have the potential for physiological damage or disturbance.[5]

According to the World Health Organization (WHO) report, exposure to noise can directly and indirectly impact the mental health, productivity, and physiological performance of exposed

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workers. The most important and discussed effect of noise exposure is its effect on the auditory system which can lead to permanent and temporary hearing loss.[6] After presbycusis, noise-induced hearing loss is the second most common cause of hearing loss in adults.[7] In addition to auditory effects, there are many nonauditory neurophysiological effects of sound, most of which have been proven.[8-11] According to the statistics of the Occupational and Environmental Health Center in 2015, out of a total of 22,604,718 people working in Iran, nearly 11 million people are in the service and administrative sectors with low sound levels (<75 dBA) and more than 2 million workers are in direct contact with the levels moderate and high sound levels (above 75 dBA) are exposed.[12] According to the statistics provided by the Health Department of the WHO in 2017, Iran ranks third in hearing loss in the world.[13,14]

In creating sounds, various factors play a significant role, which the sound pressure level is known as the main factor affecting these aftermaths. Other influencing factors include the type of noise, sound frequency, duration of exposure, and sensitivity to noise.[15-20] In today's society, transportation, moving passengers, or goods are considered a basic service. In line with the progress in other fields, significant progress has been made in the field of transportation, but the drivers are still responsible for driving heavy vehicles. Therefore, drivers have an important role in transporting and transferring loads using trucks. Various studies have been conducted by epidemiologists, sociologists, engineers, doctors, and psychiatrists to investigate the health status of drivers as a stressful job.[21] The results show that truck drivers have suffered irreversible sensory-neural hearing loss due to long journeys and constant exposure to road noises.[22] Furthermore, truck drivers face a lot of noise while working on old and defective vehicles and transporting them on bumpy roads.[23] Heavy vehicles, such as trucks, produce more noise than light ones due to their wheel weight. Similarly, traffic congestion and honking increase the level of noise exposure.[24]

Despite the significance of exposure to noise and its effect on hearing loss in drivers, a comprehensive study on the prevalence of hearing loss and its relationship with sound at different frequencies, ages, and work experience in truck drivers in Iran and especially in Isfahan has not been done. In addition, the noise level of truck drivers used on the roads in Iran is not considerately known. While prevention of hearing loss is part of the healthcare programs in most countries, especially Iran, and receives considerable attention. One of the intended jobs for annual hearing examinations is a driver.

As a result, to improve understanding of the prevalence of hearing loss in these drivers and the level of exposure to noise on roads, the present study was conducted with the following objectives: (1) determining the occupational exposure of truck drivers to noise at different frequencies, (2) determining the level of noise-induced hearing loss in truck drivers, and (3) determining the relationship between noise exposure and hearing loss in truck drivers.

Materials and Methods

Study design

This analytical cross-sectional study was conducted among the 692 truck drivers in Iran. All subjects completed and signed the consent form to participate in the study. Furthermore, the present study was approved by the Ethical Committee of Isfahan University of Medical Sciences (Ethical Code: IR.MUI.RESEARCH.REC.1400.379). According to the results of the study by Pourabdian *et al*.,[24] and the report of the prevalence of hearing loss in drivers (P = 14.6%), with a confidence level of 95% (α =0.05) and a margin of error of 0.02 (d = 0.02), the sample size was determined by equation 1:

$$n = \frac{z_{1-\frac{\alpha}{2}} P(1-P)}{d^2} \qquad (1)$$

Considering the possibility of a 10% dropout of the sample, 671 people were determined as the sample size, and finally, 692 people were examined in the present study.

Participants

The studied population consisted of truck drivers in Isfahan province in the center of Iran. To reduce errors and eliminate some confounding and hidden variables in the study, the study subjects were selected among 3000 drivers based on some entry criteria using a simple random sampling method. The inclusion criteria were the absence of conductive hearing loss and any sensory-neural hearing loss except tinnitus and noise-induced hearing loss as diagnosed by an occupational medicine specialist, not having a second job that adversely affects hearing, containing at least 5 years of working experience with a specific vehicle, having at least more than 8 h of work per day and 5 days of work per week (total of 40 h of work per week), and not taking long-term steroid anti-inflammatory drugs that affect the auditory nerve (such as aspirin and ibuprofen) and aminoglycosides (gentamicin and streptomycin). The people who had traffic accidents affecting the hearing system, had diseases affecting the hearing system, or had to intake anti-inflammatory steroids and aminoglycosides due to any disease were excluded from the study.

Hearing loss measurement

To check the hearing status of the drivers, pure air and bone tone conduction audiometric parameters were used. The drivers' hearing was measured using a Welton 1300 clinical audiometer equipped with AD-19 supra aural headphones in a soundproof room based on the guidelines provided by the American Speech–Language–Hearing Association.[25] Pure tone and bone thresholds were measured for each ear at frequencies of 0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz by a skilled audiologist. The ambient noise level in the test room was so low that it did not allow the hearing loss test even to 0 dB of air connection to the tester. The audiometer and all related equipment were calibrated before the start of the research and every 3 months. Hearing loss was calculated based on the average hearing loss in each ear at frequencies of 0.5, 1, 2, and

4 kHz. Finally, using the guidelines of the WHO, people with a hearing loss of <25 dB were grouped as normal people, and people with a hearing loss of more than 25 dB were grouped as people with hearing loss.[26]

Sound pressure level measurement

The equivalent sound pressure level (LAeq) in the driver's cabin was measured by a sound meter with a Cel-440 analyzer model and according to the standard (ISO 9612 1997) in A-frequency weighting.[27] For measurement, the sound level meter was placed in the driver's hearing height. Before each measurement, the device was calibrated by Cel-282 model calibrator in 1-kHz frequency. During the entire route, from the time the driver started at the beginning of the route until the driver stopped at the end of the route, the device was on and LAeq was measured. Then, the necessary information, including the total LAeq and the amount of sound at each frequency, is extracted from the device. Sound frequency analysis was measured and recorded in the range of one-octave band. To create consistent conditions for all drivers, sound measurements were conducted on a specific asphalt road (polymer, NC-type asphalt with 4.7% bitumen) near the city. The road was picked out and arranged with the transportation department and contained a specific schedule with low traffic for the measurement to be carried out. After the vehicle started moving, the drivers were asked to reach and maintain their speed at 80 km/h. Then, the sound measurement began. To measure the sound, one number was selected from each truck model under the same conditions and the measurement was repeated three times in each truck. Before recording the sound inside the cabin, to eliminate any disturbing noise, all audio devices such as radios and cell phones were turned off; in addition, the cabin windows were rolled up.[28,29]

Statistical analysis

To analyze the data, Statistical Package for Social Sciences (SPSS) for Windows software, version 24.0 was used (SPSS Inc., Chicago, IL, USA). Mean values and standard deviation (SD) were used to describe quantitative variables (age, work experience, hearing loss, and LAeq). An independent *t*-test was used to compare the average LAeq, age, and work experience of the people present in two groups of hearing loss and no hearing loss. Kendall's tau-b test was used to investigate the relationship between different levels of age and work experience with the grouping of drivers with and without hearing loss. Spearman's correlation test was used to investigate the relationship between exposures to sound at different frequencies and hearing loss at different frequencies. All mean comparison tests and correlation tests were performed at a significance level of 95% (α =0.05).

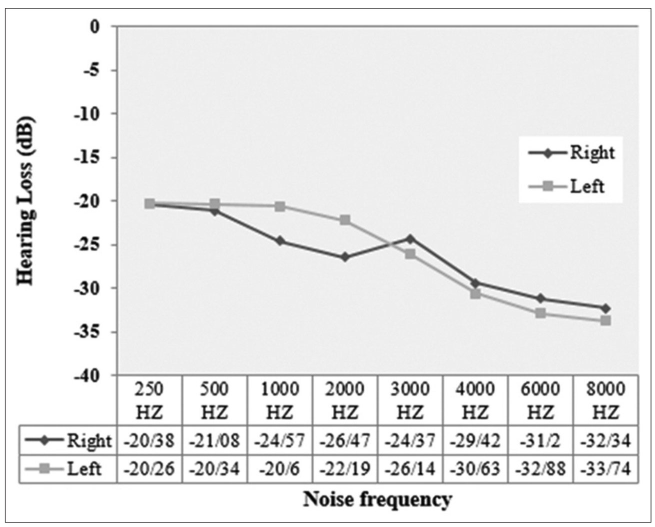
Results

The demographic characteristics of drivers and LAeq inside the cabin are presented in Table 1, separated by the examined types of truck brands. A total of 692 drivers of 16 types of trucks were examined in this study. The largest number of drivers belonged to Volvo, Scania, and Jac trucks. The mean ± SD of the age and work experience of the investigated drivers was recorded as 54.13 ± 8.27 and 26.09 ± 9.59, respectively.

The results of the sound measurement in the cabin of the examined trucks along with the frequency analysis are presented in Table 2. The average LAeq in the investigated trucks was determined to be 75.89 ± 5.98. The value of LAeq in four types of trucks including White, Scania, Benz, and Mack was determined higher than 80 dBA. Among the 16 investigated brands, only the LAeq of WHITE-type trucks with LAeq of 88.3 dBA was higher than the permissible limit recommended in the Iranian standard (85 dBA). The results of frequency analysis showed that the highest average LAeq corresponds to the frequency of 500 Hz with 62.76 dBa. Overall, the average LAeq in lower frequencies (250, 500, and 1000) was higher than in high frequencies (2000, 4000, and 8000).

The prevalence of hearing loss in the studied drivers and its relationship with the total LAeq inside the truck cabin of the studied drivers, separately for the right and left ears, are presented in Table 3. The results showed that the prevalence of hearing loss in the right and left ears is 59.98% and 64.74%, respectively. There is a statistically significant difference between LAeq in the truck cabin of people with hearing loss compared to people without hearing loss in the right ear ($P < 0.001$). There is a statistically significant difference between LAeq in the truck's cabin of people with hearing loss compared to people without hearing loss in the left ear ($P < 0.001$).

The condition of hearing loss in different frequencies is also presented in Figure 1. The highest average of hearing loss in the right and left ears was related to the frequencies of 6000 and 8000 Hz. In general, the average hearing loss in lower frequencies (250, 500, 1000, and 2000) was lower than the average hearing loss in higher frequencies (3000, 4000, 6000, and 8000).



	250 HZ	500 HZ	1000 HZ	2000 HZ	3000 HZ	4000 HZ	6000 HZ	8000 HZ
Right	-20/38	-21/08	-24/57	-26/47	-24/37	-29/42	-31/2	-32/34
Left	-20/26	-20/34	-20/6	-22/19	-26/14	-30/63	-32/88	-33/74

Figure 1: The graph of the average hearing loss in different frequencies for the right and left ears

The relationship between noise exposure at different frequencies and hearing loss at different frequencies according to the examined machines in the right and left ears is presented in Table 4 and Figure 2. The relationship between LAeq at different frequencies in different trucks with hearing loss at different frequencies in the right and left ears can be seen inversely in the majority of trucks. However, this inverse relationship is statistically significant ($P < 0.05$). As can be seen in Figure 2, even though the highest average LAeq is related to low frequencies, the greatest hearing loss occurs in higher frequencies.

The comparison of the average age and work experience of drivers with and without hearing loss is presented in Table 5. The results of the independent *t*-test indicate that the average age and work experience were significantly higher in the group with hearing loss than those without hearing loss ($P < 0.001$). The relationship between different levels of age and work experience with drivers with and without a hearing loss was also investigated using Kendall's tau-b test and the results showed a significant relationship between age and hearing loss in the right ear ($r^2 = 0.339$, $P < 0.001$) and there is work experience and hearing loss in the right ear ($r^2 = 0.179$, $P < 0.001$). Furthermore, a significant relationship was observed between age and hearing loss in the right ear ($r^2 = 0.353$, $P < 0.001$) and work experience and hearing loss in the left ear ($r^2 = 0.206$, $P < 0.001$).

Table 1: Demographic and occupational characteristics of the investigated drivers, separated by the names of the vehicles

Type of truck	Number of drivers, *n* (%)	Age (years), mean±SD	Work experience (year), mean±SD
Dongfeng	32 (4.6)	58.47±6.95	29.66±10.43
Volvo	51 (7.4)	52.10±8.80	25.25±9.66
Benz	50 (7.2)	54.98±6.83	26.66±9.99
Iveco	50 (7.2)	53.00±9.10	24.90±8.79
Mack	30 (4.4)	56.00±6.85	26.37±9.94
Scania	51 (7.4)	54.43±7.21	26.33±8.56
Faw	26 (3.7)	61.35±6.04	32.88±8.66
Howo	28 (4)	59.86±6.61	30.29±9.46
Renault	49 (7.1)	52.98±9.18	24.59±10.56
White	27 (3.9)	58.19±5.71	28.07±10.38
Jac	51 (7.4)	52.20±8.32	23.98±8.94
Saipa diesel	48 (6.9)	51.75±8.49	22.96±7.95
Man	49 (7.1)	52.35±8.75	25.10±10.28
Actros	50 (7.2)	52.80±7.80	26.34±8.78
Hyundai	50 (7.2)	53.26±7.76	25.92±9.61
Axor	50 (7.2)	53.32±8.39	25.44±9.43
Total	692 (100)	54.13±8.27	26.09±9.59

SD: Standard deviation

Discussion

Examining the health of hearing truck drivers has received increasing attention in recent decades because the problems found are not only limited to hearing loss. Exposure to noise in drivers can cause a wide range of auditory and nonauditory effects in these people. In the present study, the prevalence of hearing loss in truck drivers and its relationship with the level of noise exposure, age, and work experience were investigated. The results of the study showed that the average exposure of drivers to noise is lower than the occupational exposure limit and the highest sound pressure can be seen at lower frequencies. The prevalence of hearing loss in truck drivers was determined to be higher than 50%. Moreover, a significant inverse relationship was observed between LAeq at different

Table 2: Noise measurement results in general and frequency analysis

Truck type	250 HZ	500 HZ	1000 HZ	2000 HZ	4000 HZ	8000 HZ	SPL
Dongfeng	65.8	65.7	62.2	55.6	47.1	37.4	77
Volvo	65.4	59	53.4	47.7	37.7	31.8	74.4
Benz	71	70.2	72.2	68.4	57.9	45.8	83.7
Iveco	62.9	66	58.6	50.9	41.7	31.4	73.3
Mack	66.2	72.5	70.5	70.7	66.6	55.2	83.5
Scania	67	69	73.4	63.1	59.2	47.3	84.9
Faw	62.1	59.7	61.2	51.1	46.5	33.2	73
Howo	63.7	61.7	62.3	55.3	51.6	47.5	76.3
Renault	60.6	59.2	55.5	50.1	47.2	39.3	72.1
White	60.2	69.2	72.1	68.5	62.8	49.4	88.3
Jac	60.8	61.7	59.1	54.4	46.6	35.9	75.5
Saipa diesel	63.1	59.5	57	49.2	41.2	34.2	71.6
Man	56.8	60	58.5	52	45.5	37.9	69.9
Actros	49.4	54.3	56.6	49.7	39.7	29.3	70.4
Hyundai	56.3	58.2	57.8	52	41.2	32.9	69.6
Axor	56.2	58.3	55.7	52.1	45.8	37.6	70.8
Statistics	**250 HZ**	**500 HZ**	**1000 HZ**	**2000 HZ**	**4000 HZ**	**8000 HZ**	**SPL**
Mean±SD	61.71±5.24	62.76±5.28	61.63±6.66	55.67±7.59	48.64±8.63	39.13±7.61	75.89±5.98

SD: Standard deviation

Table 3: Prevalence of hearing loss and its relationship with equivalent sound pressure level in the cabin of the examined driver's trucks, separately for right and left ears

	SNHL frequency (%)	Mean±SD (dB)*	Mean difference	*t*	*P*
Right					
Normal group	277 (40.02)	74.20±4.73	2.01 (−2.85–−1.17)	−4.71	<0.001
SNHL group	415 (59.98)	76.21±5.97			
Left					
Normal group	244 (35.26)	74.30±4.84	1.71 (−2.57–−0.84)	−3.88	<0.001
SNHL group	448 (64.74)	76.01±5.88			

*LAeq. SNHL: Sensorial hearing loss, SD: Standard deviation, LAeq: Equivalent sound pressure level

Table 4: Correlation between noise exposure and hearing loss in different frequencies according to different trucks in the right and left ears

	Dongfeng	Volvo	Benz	Iveco	Mack	Scania	Faw	Howo
Right								
R^2	−0.782	−0.891	−0.829	−0.0943	−0.0371	−0.771	−0.943	−0.943
P	0.004	0.003	0.042	0.005	0.468	0.072	0.005	0.005
Left								
R^2	−0.829	−0.978	−0.829	−0.943	−0.371	−0.771	−0.943	−0.943
P	0.001	0.001	0.042	0.005	0.468	0.072	0.005	0.005
	Renault	**White**	**Jac**	**Saipa**	**Man**	**Actros**	**Hyundai**	**Axor**
Right								
R^2	−0.952	−0.371	−0.943	−0.924	−0.829	−0.600	−0.829	−0.943
P	0.001	0.468	0.005	0.002	0.042	0.208	0.042	0.005
Left								
R^2	−0.972	−0.371	−0.943	−0.981	−0.829	−0.600	−0.829	−0.943
P	0.001	0.468	0.005	0.004	0.042	0.208	0.042	0.005

Table 5: Relationship between hearing loss with age and work experience of truck drivers by the right and left ears

Variable	Grouping	Mean±SD	Mean difference	*t*	*P*
Right					
Age	Normal group	50.04±7.76	−6.83 (−7.99–−5.68)	−11.63	<0.001
	SNHL group	56.88±7.43			
Work experience	Normal group	23.60±9.11	−4.17 (−5.61–−2.74)	−5.73	<0.001
	SNHL group	27.77±9.55			
Left					
Age	Normal group	49.22±7.64	−7.59 (−8.76–−6.43)	−12.82	<0.001
	SNHL group	56.82±7.32			
Work experience	Normal group	22.89±8.87	−4.95 (−6.41–−3.50)	−6.68	<0.001
	SNHL group	27.85±9.53			

SNHL: Sensorial hearing loss, SD: Standard deviation

frequencies with hearing loss. In addition, a significant direct relationship was observed between work experience and the age of drivers with hearing loss.

One of the goals of this study was to investigate the exposure of truck drivers to total LAeq and LAeq at different frequencies. Sound measurements inside the cabins showed that in the majority of vehicles, the average sound level was around the auditory comfort level (<75 dB) and the action level (<82 dB), and the average LAeq was also lower than the standard occupational exposure limit in Iran (85 dB). These results are consistent with studies conducted on bus drivers. In their study of bus drivers, Bruno *et al.* determined the exposure level of bus drivers to be higher than the comfort level and lower than the permissible level of occupational exposure in Brazil.[28] In another study, van den Heever and Roets showed that the average exposure of truck drivers in Canada is lower than the occupational exposure limit.[29] The results of accepted studies in Iran are also in line with the results of this study.[30,31] In some studies, it has been reported that truck drivers are exposed to noise higher than the permissible occupational levels, and it is different from the sound levels in the present study. In a

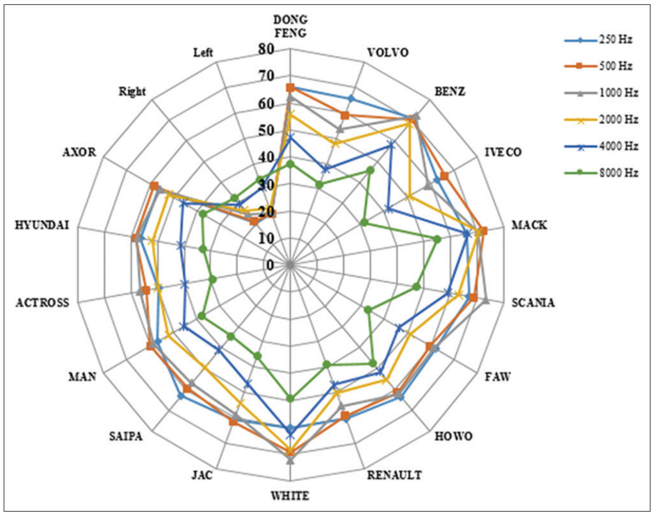


Figure 2: Status of equivalent sound pressure level and hearing loss in different frequencies

study in Bangalore, India, truck drivers' exposure level was higher than 85 dB.[32] Furthermore, in a study in America, sound levels were reported to be higher than 90 dBA in many cases.[33] The reason for the difference in the obtained results can have several factors. The amount of sound exposure in drivers can usually change under several parameters. One of the most effective factors in intensifying the noise inside the cabins of trucks is opening the window while driving to create a favorable air temperature for the drivers. Opening the window due to the increase in air flow turbulence and sudden changes in airflow when other vehicles pass by can lead to pressure changes inside the cabin and can lead to a significant increase in the amount of sound received by the drivers.[34] Furthermore, using the radio while driving with different sound levels, having a conversation with other people and the place of driving and the noise caused by traffic of other vehicles can lead to changes in the level of noise exposure of drivers.[33,34] In addition, the life of the vehicle and the location of the engine and its distance relative to the driver's location can have a significant effect on the changes in the amount of exposure of drivers to noise.[30] One of the main reasons for the lower exposure to sound compared to the occupational exposure limit was the sound measurements conducted in controlled conditions (closed windows, radio off, and standard asphalt road). The results of frequency analysis in the present study generally indicate that LAeq is higher at lower frequency levels than at higher ones. These results are consistent with the study of Chen *et al*., who reported higher LAeq in the cabin of trucks at low frequencies.[35] Furthermore, Gardziejczyk, in a study aimed at comparing the noise of trucks on dry and wet roads, recorded more vehicle noises in low frequencies (500–1500 Hz) than in higher frequencies.[36] The results of other studies also confirm the results of the present study.[37-40]

The prevalence of hearing loss in the examined drivers was higher than 50% in both ears. The results of examining the amount of hearing loss in different frequencies also show more loss in higher frequencies (3000, 4000, 6000, and 8000) in both ears. These results indicate a high prevalence of hearing loss in truck drivers, and to reduce it, special attention should be paid to these workers. Based on the findings of the present study and the results of other studies,[13,24,34,41-43] it was found that hearing loss in the left ear of drivers is more common than in their right ear. This observation may be due to the position of the driver in the cabin, which in Iran is on the left side of all vehicles, and as a result, the left ear is closer to the car window, road, wind, noise, driving speed, and any other outside noises. Hearing loss in drivers of vehicles such as buses and trucks has been investigated in several studies. In other studies, the prevalence of hearing loss in drivers has been widely reported, and in many cases, the prevalence rate is higher than 50%.[13,32,44] However, Ansari *et al*. observed that the greatest hearing loss in drivers occurred at a frequency of 250 Hz. This difference may be due to a history of hearing problems or work in other environments.[45]

In the present study, it was found that with increasing age and work experience, the risk of hearing loss in drivers increased. This relation can be for various reasons. Naturally, with increasing age, the performance and capacity of the hearing system decrease, which in many cases is referred to as senile hearing. Either way, in drivers, the increase in age and work experience indicates an increase in the exposure of these people for many years to different levels of sound and other factors that affect hearing loss, and it leads to an increase in hearing loss in them compared to people with younger age and less work experience.[46] The results of the present study are in line with the results of studies conducted in India,[47] Belgium,[48] Brazil,[42] and Iran,[13,41,43,45] which show a significant direct relationship between age and work experience and have reported hearing loss.

The correlation between LAeq at different frequencies in different trucks with hearing loss at different frequencies in the right and left ears was observed in an inverse and significant manner in the majority of vehicles. In other words, even though the highest average LAeq is related to low frequencies, the greatest hearing loss occurred in higher frequencies. Scientifically, an increase in LAeq at a certain frequency will also result in an increase in ear damage at the same frequency.[49] However, such results were not observed in the present study. As discussed above, although the results of LAeq and hearing loss at different frequencies were coherent with the results of other studies conducted on truck drivers, surprisingly, the relationship between LAeq at different frequencies in different vehicles with hearing loss at different frequencies in the right and left ears was reversed. As LAeq decreases in a certain frequency, hearing loss increases in that frequency and vice versa. These results should be interpreted with caution. As stated in the present study, the relation of total LAeq, regardless of frequency analysis, had a significant direct relationship with hearing loss, and in people with hearing loss, there was a higher LAeq exposure. These results confirm that there is a direct relation between noise exposure and hearing loss. The reason for the presence of inverse relations during frequency analysis can indicate that hearing loss can be caused by the influence of several parameters in drivers. Drivers may be exposed to sounds with different frequency distributions (different from the sounds inside the cabin during driving) while performing other activities such as car repairs, tire changing, etc. This can lead to hearing loss at different frequencies. In addition, due to the traffic of drivers on a wide variety of roads with different traffic, asphalt, and speed, as well as under various conditions inside the cabin (conversations, radio, open or closed windows, age of the vehicle, air conditioning, various amounts of vehicle wreckages, etc.), LAeq can be widely changed in different frequencies by changing these conditions.[33,34] As a result, this frequency difference between hearing loss and LAeq should be analyzed with caution, and without considering the conditions above, the results will vary. As in the study of Boger *et al*.,[49] similar results were obtained. In their study, no correlation was observed between the frequency bands carrying extreme sound levels and the frequency of hearing loss.

This study had several limitations that should be noted. First, due to the time limit, the sound measurement inside the cabin of trucks was done in a limited number. Hence, one item was selected from each type of vehicle and sound measurement was done under standard conditions. Although this measurement method is considered a standard condition, it may not represent the actual sound level inside the cabin. Since drivers generally drive in various conditions and according to the conditions, they experience different LAeq in reality. Sound measurement using the dosimetry method in drivers on various routes for long periods and in a large number of trucks can determine the actual conditions of drivers' exposure to noise, which should be considered in future studies. In the current study, we examined a large number of drivers, which is a strong point, and the results of this study can be used with higher confidence. Furthermore, researching hearing loss along with sound measurement and considering the variables of age and work experience of drivers can be evaluated as a strong point of the study. Considering the importance of the hearing system in the safety and quality of the driver's life, it is suggested to install suitable ventilation systems on old trucks by innovating in worn-out vehicles to prevent the windows from opening and to isolate the openings and vents, to reduce people's exposure to sound. Appropriate design of truck cabin, good truck maintenance, use of hearing protection equipment during driving and repairs, reducing driving time, and periodic health checks of drivers are recommended for early detection of hearing impairment and reducing damage to drivers' auditory systems. It is suggested to conduct prospective longitudinal studies by examining drivers' exposure to noise and following up on their hearing loss throughout 5–10 years.

Conclusion

The present study showed that truck drivers experience a high level of hearing loss, and their hearing loss is similar to other workers in industries at high frequencies such as 4000 and 6000 Hertz. Increased sound exposure, age, and work experience can lead to increased hearing loss, especially in the left ear. Considering the importance of the hearing system in the safety and quality of the drivers' life, it is suggested to install suitable ventilation systems on old trucks to prevent the windows from opening and to isolate the openings and valves, by innovating in worn-out trucks, to reduce people's exposure to noise. Appropriate design of the truck's cabin, periodic maintenance of trucks, use of personal protective equipment, reduction of driving hours, and periodic health checks of drivers are advised to prevent further progress of hearing loss.

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Ethical considerations Code

This study was part of a thesis approved by the Ethics Committee of the Isfahan University of Medical Sciences (IR.MUI.RESEARCH.REC.1400.379). All participants were over 18 years of age, and the informed consent form for participating in the research was read and signed.

Conflicting Interest

There is no conflict of interest among the authors.

Authors' Contributions

Siamak Pourabdian: Conceived and designed the experiments, edited the paper; Negar Ghotbi: Analyzed and interpreted the data; wrote the paper and performed the experiments; Farhad Forouharmajd: Conceived and designed the experiments; edited the paper; Yunes Jahani: Analyzed and interpreted the data, and edited the paper.

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