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Investigation of noise annoyance and audiometric results of Tehran subway workers and their relation to noise exposure

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ABSTRACT

Introduction: One of the most important sources of pollution is the noise generated by traffic and transportation, especially the urban railway system (metro), thus this study aimed to assess the noise exposure of Tehran Metro employees and its relation with noise annoyance and audiometric results of employees.

Materials and methods: Measurement was done by using a TES-1351B sound level meter recommendations for all employees which consists of the staff of the station affairs and the staff of the administrative department. A self-reporting questionnaire on workplace noise annoyance were distributed to the employees and then audiometric were used to measure the employees' hearing level.

Results: The average noise exposure in platform workers was 79.3±10 dB and in control room workers was 56.5±6.9 dB. A significant difference was found between the average noise exposure in the employees of the two groups (control room-platform) (p-value=0.001). Based on the results, noise in the work environment was significantly more annoying for people working in metro line 1 than in line 6 (p-value=0.025).

Conclusion: These results show that in general, due to the sound pressure level of 10% of the platform employees being higher than the permissible limit and the increase in the level of noise annoyance of the employees at the frequency of 8 kHz, it is necessary to plan and adopt administrative and technical-engineering measures to reduce the level of noise pollution to about it seems necessary to allow the standard.

Introduction

Noise is one of the crucial challenges of industrial facilities and a significant number of workers are exposed to it [1], to the point that, according to statistics, 7% of the world's population is exposed to hazardous noise at work [2]. In Iran, about 2

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million workers are exposed to noise above the national limit, according to the Health Center of the Ministry of Health report (85 dB) [3]. The Main source of outdoor noise around the world is public transportation, which periodically produces noise in the 94-99 dB range [4]. Hearing threshold lowering is the most important physiological effect of sound, and the hearing effects caused by sound in the ear can be divided into three groups: acoustic trauma, short-term and permanent hearing loss [5]. Other physiological problems caused by exposure to noise include increased blood pressure, increased heart rate, muscle reflexes, and sleep disturbances. The increase in adrenaline levels caused by noise exposure can worsen the blood pressure condition by increasing stress hormones [6]. The psychological effects of NOISE are expressed in the form of anxiety tension, anger, concentration, and perception disorders [7]. In 2016, Zamanian et al concluded that noise is one of the factors that can affect work stress [8].Noise interferes with daily activities and leads to a similar sense of helplessness in depressed patients, particularly in complex mental activities, and repeated failures in performing tasks subsequently increase. the consequences of noise pollution also lead to disturbances, which manifest themselves in the form of aggressiveness and social isolation. Robert Koch's predictions from the end of the 19th century that "noise will become a menace to human health that we must fight against", like cholera or the plague, have come true. Noise levels can be measured and evaluated subjectively or objectively [9]. Noise annoyance, as one of the negative effects of exposure to noise and its most common mental response, has attracted the attention of many researchers, policymakers, and the general public. Noise annoyance as a measurable psychological reaction is considered one of the most important negative side effects of noise and can even be seen as an indicator of other harmful effects of noise [10-12]. Annoyance refers to unspecified conditions that are associated with such things as discomfort, anxiety, resentment, sadness, despair, and unpleasant feelings. Noise annoyance is considered a feeling, a result of the disorder, attitude, knowledge, result of logical decisions, and as psychological stress. The World Health Organization has defined annoyance as an individual or group feeling of discomfort related to the harmful effects of substances or conditions. In general, noise annoyance is a feeling of discomfort caused by unwanted sound and its conditions [10].Studies related to noise annoyance show that there is a direct relationship between the feeling of annoyance and noise level, however, the role of other noise characteristics such as frequency is also important in this relationship. Based on reports, the relationship between noise level and annoyance has been evaluated as a dose-response relationship [12]. Due to the increase in the world population and the demand for transportation in big cities, modern and low-cost technologies have received considerable attention. In the meantime, subway systems have gained high acceptance as a means of transporting people, considering factors such as saving time, cost, and avoiding traffic. Although this technology has many advantages, it also has negative points. This device may have many risks such as physical risks (noise, vibration, electromagnetic radiation, electrical sources, and high temperature), biological risks (transmission of infectious diseases from person to person), and chemical risks (exposure to toxic chemicals or allergens) [13]. In most subway systems, especially older ones, noisy environments can be observed. This is not only due to noise from rail transport systems but also as a result of sound reflection in an indoor environment, Therefore, workers exposed to noise levels over standards are at greater risk. Thus, the assessment of the problem and the applicable practical plans to

control the harmful effects of noise in the vicinity of large cities have become an important issue and a matter of urgent concern for those responsible [14]. It seems necessary to assess the noise exposure of the employees of the Tehran Metro, as well as the psychological effects of noise on them, and, if necessary, to reduce exposure. The necessity of carrying out this research is more evident due to the special position of the subway transportation system in the country and the high volume of manpower working in this underground city, and of course, considering the destructive physical and psychological effects of noise exposure.This study was carried out on Lines 1 and 6 of Tehran Metro to evaluate noise exposure and determine the degree of annoyance and hearing problems caused by it among the employees of two administrative departments (control room) and employees who are on the platforms in direct contact with the noise.

Materials and methods

This descriptive-analytical study was conducted on Lines 1 and 6 of the Tehran Metro in the summer of 2022. The reasons for choosing these two lines include: a) the difference in the age of the two lines, Line 1 is the oldest line of the Tehran Metro, while Line 6 is newly established and new. b) The difference in the amount of passenger traffic in the two lines (Line 1 is the most frequented line of Tehran Metro, while Line 6 is one of the least frequented lines of Tehran Metro). It consisted of the station staff located on the platforms (in direct contact with the noise of the trains) and the staff of the administration department (control room).

Data collection steps include:

A) Sound pressure level measurement: noise measurement according to ISO 9612 standard in Tehran metro lines 1 and 6 using sound level meter model TES-1351B manufactured by TES Company with the selection of weighted network A and slow response speed. The sound level was measured at least three times at each point and finally, the logarithmic average was reported at the selected station. Measurements were carried out during the work shift of the employees in the time interval of 6:00-14:00 at each station and in the places with frequent stops of both groups of employees. According to the ISO 9612 standard, the height of the microphone at the position of people's heads and the noise level was measured on the platforms at a distance of one meter from the ground and half a meter from the edge and in the office rooms at the location of the employees as a measurement station [15-16]. To measure the annoyance caused by noise, all the employees present in the morning shift were evaluated.

B) Noise annoyance determination: in the second phase of the research and after determining the level of exposure of people to noise, demographic information questionnaires and self-reporting questionnaires for workplace noise annoyance were distributed among both groups of employees on the platforms and office workers and in-person. The validity and reliability of the self-report questionnaire on workplace noise annoyance were evaluated by Farhang and his colleagues in 2013, and its Cronbach's alpha coefficient was determined (0.81) [17]. This questionnaire consists of three sub-tests: scoring the intensity of the noise in the workplace, scoring the annoying level of the noise in the workplace, and determining the states that people experience during the day (such as feeling tired, laziness, reduced concentration power, etc.). In the first sub-test, which examined the intensity of the received noise, the 2 studied groups were asked to assign a score from 0 to 10 to the noise intensity of their surroundings (Based on Fig. 1).

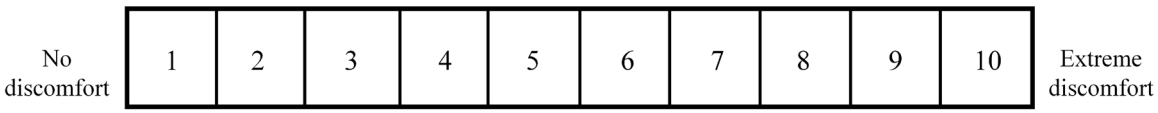

Fig. 1. Noise intensity scoring scale [18, 19]

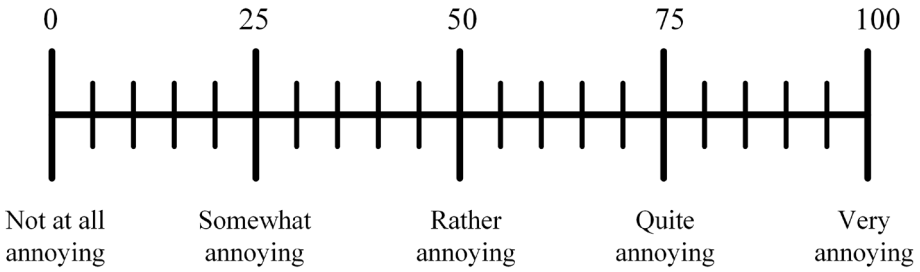

Fig. 2. Noise annoyance scale [20]

Which of the following feelings do you experience daily in the work environment:

I feel sad
Yes □ No □

I feel vibration in my body
Yes □ No □

I feel pressure and heaviness in my head
Yes □ No □

I feel pressure and fullness in my ears
Yes □ No □

I have other feelings besides the above
Yes □ No □

I have no feelings
Yes □ No □

To what extent are you involved with the following in your work environment on a daily basis?

Feeling exhausted
Never □ Rarely □ Sometimes □ Mostly □ Always □

Lethargy and sleepiness
Never □ Rarely □ Sometimes □ Mostly □ Always □

Dizziness
Never □ Rarely □ Sometimes □ Mostly □ Always □

Reduced concentration power
Never □ Rarely □ Sometimes □ Mostly □ Always □

Headache
Never □ Rarely □ Sometimes □ Mostly □ Always □

Sadness
Never □ Rarely □ Sometimes □ Mostly □ Always □

Other such problems
Never □ Rarely □ Sometimes □ Mostly □ Always □

No problems or complaints
Never □ Rarely □ Sometimes □ Mostly □ Always □

Fig. 3. Emotions associated with noise exposure [20]

In the second sub-test, people were asked to give a score from 0 to 100 to the degree of annoying noise in their work environment (Based on Fig. 2).

In the third sub-test, it was asked about the situations that people experience in their work environment and are involved in it as shown below (Based on Fig. 3).

C) Examining the results of the hearing test: The results of the hearing test of the employees of Tehran metro lines 1 and 6 (aerial audiometry test) were extracted from the occupational examination

files of the employees in the last year at different frequencies. It should be noted that male employees were included in the study who had at least one year of previous work in the metro.

The results were analyzed using SPSS version 26 software and descriptive tests, correlation, ANOVA, T-TEST, etc.

Results and discussion

Considering the inclusion criteria, 54 male employees (25.9% unmarried and 74.1% married), separated by 25 people working on line 6 and 29 people working on line 1 of Tehran Metro (including 8 stations and all employees present on two lines at the time) were evaluated) with the average age and work experience equal to 7.4 ± 37.6 and 5.3 ± 9.9 years, respectively, and with the level of education, 43% had a diploma, 37% had a bachelor's degree, and 20% had an under-diploma education.

The results of measuring the daily noise exposure (8 h) of employees are summarized in Table 1. Based on the results of the daily balance, the exposure of all the control room employees was assessed to be less than the permissible limits(85 dB), while only 10% of the employees stationed at the platforms had a daily exposure above the permissible limit.

The average hearing threshold of the two studied groups at different frequencies of the audiometric test is presented in Figure 4. Although all the studied subjects had normal hearing status, the hearing thresholds at frequencies of 3, 4, 6, and 8 kHz showed a significant difference between the two studied groups ($p<0.05$).

Daily noise exposure	Mean ± SD	Exposure>85 dB (%)	P-value
Station staff	79.3 ± 10	10.3	<0.001
Control room staff	56.5 ± 6.9	0	

Table 1. Daily noise exposure (mean±SD) of 54 employees

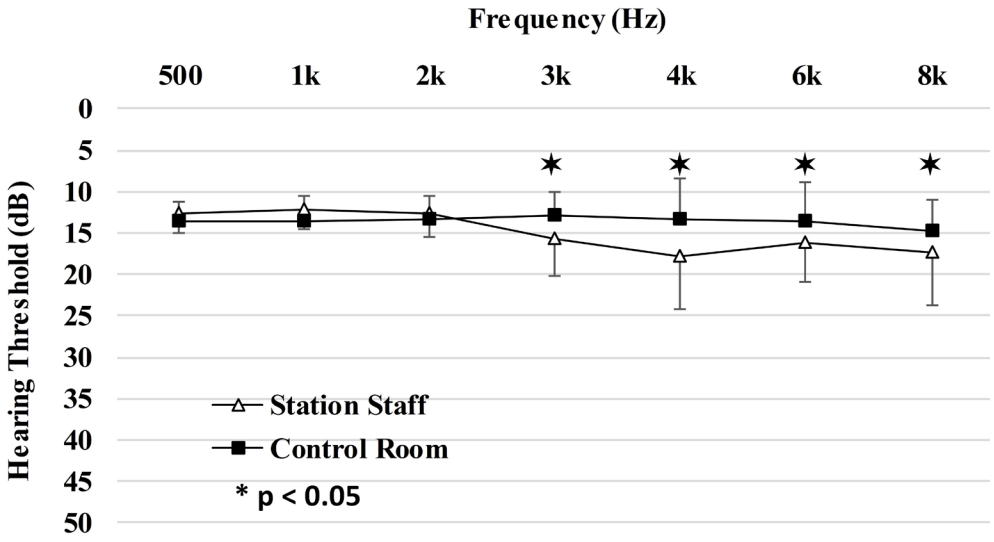

Fig. 4. Hearing thresholds (mean±SD) of 54 participants

Table 2. The results of noise annoyance (mean ± SD) and its relationship with two studied groups and the metro line where they work

Noise annoyance		Mean ± SD	P-value
Station Staff		36.2 ± 34.5	0.320
Control Room Staff		24 ± 16.9	
Line of Metro	Line 1	37.9 ± 27.2	0.025
	Line 6	22 ± 27.3	

Table 3. The intensity of the noise of the work environment and its relationship with the variables of the work position and the line of activity

Noise annoyance		Mean ± SD	P-value
Station Staff		5.62±3.18	0.22
Control Room Staff		4.44±2.81	
Line of Metro	Line 1	4.69±3.62	0.003
	Line 6	5.52±2.20	

Based on the results, there was no significant difference between the noise annoyance score of the platform employees and the control room employees (p value=0.320), while the average noise annoyance score of the employees working in the metro line one compared to line six was evaluated significantly more (p-value=0.025). A statistically significant difference was not reported between noise annoyance and marital variable (p-value=0.497) and different workstations (8 workstations) (p=0.155). Also, based on the results, a significant correlation between voice annoyance and age (P-value=0.041, r=0.766) was reported, while no significant correlation was reported between voice annoyance and work experience.

Based on the results, there was no significant difference between the noise intensity score of the platform employees and the control room employees (p value=0.22), while the average noise intensity of the employees working in the sixth metro line is significantly higher than that of the first line was evaluated more (p-value=0.003).

Examining the relationship between the level of noise annoyance and the average hearing thresholds showed that this relationship is positive and significant only at the frequency of 8 kHz (P-value=0.013, r=0.338).

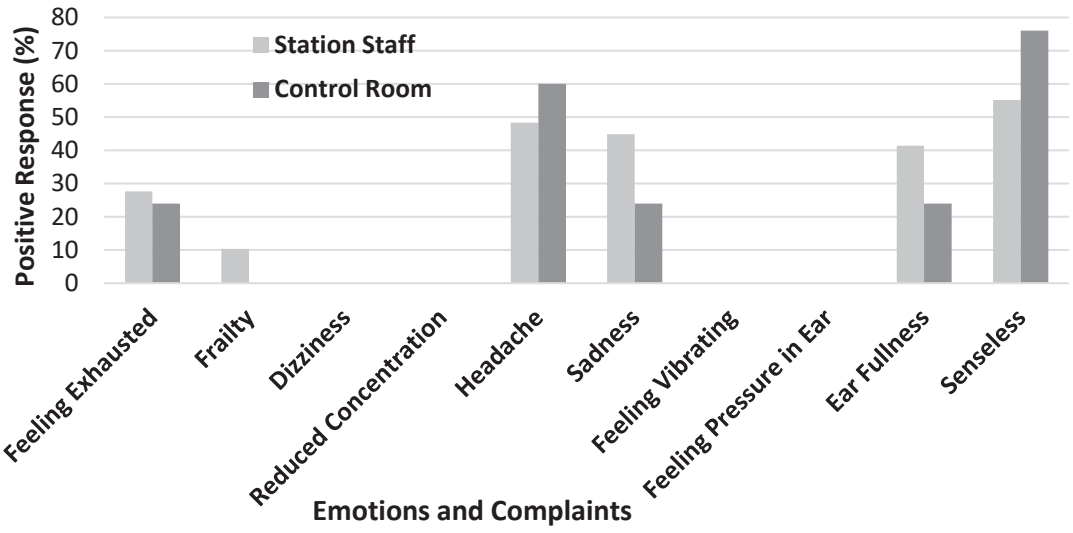

Fig. 5. Emotions and complaints positive response distribution to noise exposure among participants

The percentage distribution of people's feelings/complaints based on the self-report questionnaire (noise annoyance) of the situations they experience during the day from the sound of their work environment is presented in Figure 5. Based on the results, the percentage distribution of positive responses to feelings and noise complaints between the two study groups did not have a statistically significant difference (p-value>0.05). Also, the percentage distribution of reports of feelings/complaints by people working in metro line 1 and line 6 did not have a statistically significant difference (p-value>0.05), the feeling of ear fullness and no feeling, a statistically significant relationship was reported (p-value <0.05). No significant relationship was reported in other frequencies.

Discussion

While hearing damage is the main concern regarding noise exposure, other physical and psychological effects should not be neglected [21]. Noise pollution is one of the dangerous factors in the human environment that can seriously endanger the mental, psychological, and physical health of humans. Although rail transportation is generally known as environmentally friendly transportation, it is not without pollution, and noise pollution caused by traffic and urban transportation, especially the urban railway system (metro), is the second main source of environmental noise pollution [22]. In this study, the exposure of Tehran metro employees to noise (as people who constantly face the noise caused by the movement of trains every day during their work shift) and its relationship with noise annoyance and the results of measuring the hearing of metro employees in Lines one and six have been addressed. Line 1 of Tehran Metro is an inner-city line of 37.5 kilometers with 29 stations that starts with Tajrish Station and ends with Kehrizak Station and has 11 intersection stations with other metro lines, and Line 6 of Tehran Metro is a line It is a 38 km long inner city (27 active km) with 17 active stations, which starts with Dowlat Abad station and ends with Shahid Sattari station and has 9 intersection stations with other lines [23]. The results of this research showed that the daily level of exposure to noise in all control room employees with an average of 56.5 ± 6.9 dB is lower than the permissible limit of 85 dB, and only 10% of the

platform employees with an average of 79.3±10 dB have a higher daily exposure level. are above the permissible limit, and this sound equivalent level, both in the platform staff and in the control room staff, is an average of different modes of train movement (station without a train, during the movement of one train, during the movement of both trains, during the stop of a train) train while stopping both trains). These results show that all the control room staff and 90% of the platform staff are in good condition in terms of noise pollution. However, 10% of platform workers face noise pollution exceeding the permissible limit of 85 decibels, which can cause serious damage to the hearing system and other physiological systems of the body [24]. And it causes proven psychological reactions including anger, pressure, irritability, and physical reactions such as increased blood pressure or increased magnesium excretion, which may lead to long-term disorders of the body's balance mechanisms caused by exposure to sound pressure levels even less than 85 decibels [21]. In the study of Saade et al. [25], the sound equivalent level in the train carriages was between 61.24-81.87 dB, which was higher in some stations and lower than the permissible limit in some stations, and between 61.26-70.26 dB in the operator's cabin. Which is less than the standard, this study is close to the result of the present study. In the study of Sarkhil et al. [24], 90% of the measurement data on the platforms of the first line (passenger exposure to noise) was reported as exceeding the permissible limit, and it does not agree with the results of the present study, The increase in sound in that study can be due to factors such as 1. The hours of noise measurement (measurements were made until 20:00) and 2. The noise measurement season (which was done in the spring season with high passenger density). However, in the current study, the noise measurement shift was the morning shift, which has less passenger density than the evening shift, and the measurement season is summer, which is less due to the closure of schools and universities, and as a result, the amount of noise is reduced. In Stephany's study [26], the equivalent noise level in the Hong Kong subway sometimes reaches 100.9 dB during peak hours (peak hour), which is 5 dB higher than non-peak hours (non-busy hours) with an average of 74.174 decibels. Bell, which shows the effect of the clock factor and the measurement shift on the increase and decrease of noise pollution. Among other factors that can affect the difference in the results related to the level of sound equivalent in different studies, is the difference in transportation trains, which include: the passing frequency of trains and type of passing trains at the time of environmental noise evaluation [27]. And one of the other important factors in creating noise in metro stations is the high speed of trains, as the train becomes more modern and complex, the problem of noise and noise caused by its movement has increased [28].

The results of the evaluation of the questionnaires related to the evaluation of the noise intensity of the work environment and its annoyance level in the two groups of control and platform workers are also in line with the results of the environmental evaluation of the sound pressure level on the platform and the control room, so that out of 54 participating workers In this study, only 3.84% (1 person) evaluated the noise level of their work environment as very high (code 10), however, 20.37 percent (11 people) chose the evaluation code [8], which means that the noise level of the work environment is almost high. They know that the increase in the sound pressure level from the standard limit of 85 dB in more than 10% of the measurement points confirms this result. And on the other hand, in terms of sound annoyance, 33.3% (18 people) of the employees participating in the study also expressed the sound of the work environment without any discomfort (code 0).

By examining the hearing threshold in the

file of medical examinations of employees (control room on the platform) in the last five years, both groups of people under study have a normal hearing condition, and by examining the personnel's answers to questions related to the situations they experience during the day in the work environment. 75% of the control room staff and 55% of the platform staff gave the highest positive vote for the question "I don't feel uncomfortable", which confirms the standard of the noise situation in metro lines 1 and 6 in most places. In a study [29], noise in the Guangzhou subway is at a relatively low level, and the level of noise annoyance in people who are constantly exposed to this level of noise is also reported at a low level, which is consistent with the results of the present study.

Based on the results, the amount of annoying noise in the work environment was significantly higher among people working in metro line 1 than in line 6. Factors such as 1. High train traffic 2. High passenger density 3. And the fact that Line 1 is older than Line 6 (the passage of time has caused wear and tear of the materials in the structure of the stations and thus reduces the amount of sound absorption), can be an effective factor in increasing noise annoyance among the employees of Line 1.

Based on the results of this study, there was a significant relationship between the average hearing threshold at the frequency of 8 kHz and the emotions/complaints that people experience during the day. 60% of the control room workers, nearly 50% of the platform workers had headache symptoms, and 40% of the platform workers, 25% of the control room workers had a feeling of fullness in the ears. However, a case that we encountered while filling out self-report questionnaires (situations that people experience during the day about sound) and it was also mentioned in previous studies [30], is that some employees got used to the noise caused by the movement of trains in subway stations, which will cause the participants to pay less attention to their mental and physical health, and lower their quality of life. In many places, the sound pressure level was less than 85 decibels, but it will still have its effects on the mind and body of people over time.

Conclusion

In jobs such as subway workers, which have high work sensitivity and there is a need to perform work accurately to protect the lives of passengers, whether the employees who are in the control room have to control the movement of trains and many sensitive parts of each station. And what about the platform staff who should help the passengers as a guide and keep the unsafe behavior of the passengers under control for the train to move on time. Balance and maintaining the focus of employees is a vital issue. Annoyance caused by noise, followed by the experience of feelings such as fatigue and reduced concentration, increases the possibility of human errors and sometimes irreparable occupational accidents, which increases the importance of the level of noise exposure from the point of view of health and safety as well as environmental safety. It makes the work clear and clear. According to the results of this study, the sound pressure level in most of the measurement points was lower than the permissible limit (85 dB), however, due to the high level of sound pressure in 10% of the platform employees. The permissible limit and the increase in the amount of noise annoyance of the employees at the frequency of 8 kHz, the need to plan and adopt management and technical-engineering measures to reduce the amount of noise pollution to the standard permissible limits seems necessary.

Suggestions

Considering the current noise level, only a

few minor and substantial reductions can bring the average points that were above the permissible limit to the occupational exposure standard.

1. It is possible to suggest noise analysis in the spectrum of one-third of the octave band due to the significant difference in hearing threshold results between the two studied groups at frequencies of 3, 4, 6, and 8 kHz.

2. Reducing the speed of the train to 68 km/h.

3. Use of noise-absorbing materials in the important sections of the tunnel line 1 and 6 (ideally 50% of the line length)

4. Educating employees about ear protection (for example, when working on the platform or in the control room, avoid increasing the volume of headphones, or especially vulnerable people should use noise-canceling headphones to protect their ears).

6. Replacement of old trains with new models and timely maintenance of trains.

7. Considering wide platforms for certain stations (reducing the density of passengers and thus reducing the sound level).

8. Proper repair and maintenance of escalators and elevators (reducing the density of passengers and thus reducing the noise level).

9. Not using excessive speakers and announcement systems in stations.

10. Non - establishment of peddlers in platforms.

11. Installation of appropriate signs for the correct selection of stations by citizens.

12. Proper nutrition, the creation of sports facilities, and proper rest by the metro managers.

13. Carrying out more research projects regarding the investigation of other psychological effects of sound in work environments with an emphasis on subway workers.

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Competing interests

The authors declare that there is no conflict of interest.

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Ethical considerations

“Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/ or falsification, double publication and/ or submission, redundancy, etc) have been completely ob-served by the authors.”

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