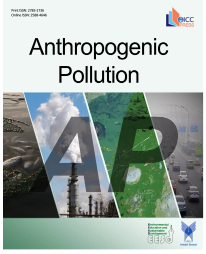

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Assessment of noise pollution in sports halls in Lahijan, Iran

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Original Research

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Abstract:

The aim of this study was to assess the noise pollution of sports facilities in multi-purpose halls in Lahijan city, Iran. This research was of applied type. Through networking, 16 halls were randomly selected in four zones of the city and data were collected in the field. The sound level in the clubs was measured at level A and as an equivalent level by a portable device and Decibel X 2019 and compared with the sound standard (OSHA-90 dBA). The measurements were performed in triplicate and repeated three times. The calculated parameters included sound pressure level (SPL), average sound level ((LP)), continuous sound equivalent level (Leq) and individual daily dose LAEp, d. The results showed that the lowest sound pressure level was 73.9 dB in the northern zone and in the first turn. The highest sound pressure level in the western zone was 97.7 dB. As the time changed from early morning to night, the average sound pressure level increased, highlighting the direct relationship between the sound pressure level and the measurement time. The average sound level in the western zone was higher than in other zones, and the average sound level in the southern zone was lower than in other zones. In both zones, the gyms were of the shed type, which could not establish a relationship between the structural form and the sound level. All the studied halls had levels higher than the standards for recreation centers and parks, as well as the standards of the United States Environmental Protection Agency (EPA). However, all of the gyms met other standards such as ACGIH, NIOSH and OSHA standards related to occupational health. Finally, there was a relationship between the urban location of sports halls and the sound level, such that halls located in the northern and western zones (the more affluent part of the city) had higher sound levels; in contrast, those located in the southern and eastern zones (poorer areas of the city) had lower sound levels.

Keywords: Noise pollution; Sound level; Networking; Multi-purpose sports halls; Lahijan city

1. Introduction

Noise pollution is defined as the emission of any sound and vibration exceeding the permissible limits in open (non-covered) spaces and is one of the examples of environmental damage Vogiatzis (2012), so that it has clear and specific consequences on human health and ecosystems (WHO, 2018). Although sound waves are considered an essential factor in human life, in some cases hearing these sound waves is not very pleasant and excessive exposure to sound causes annoyance and hearing loss in humans (Agrawal et al., 2010). In addition to having a bad effect on the auditory system, noise also affects the circulatory system and causes nervousness, anxiety and mental problems (Bazaras, 2006). Exposure to noise can affect a person's performance, especially in intellectual tasks (Hahad et al., 2019; Babisch et al., 2013). Exposure to noise occurs not only in the workplace, but also includes non-occupational activities such as leisure, transportation and shopping (Clark et al., 2013). Noise pollution plays a significant role in dissatisfaction with space (Bouzir et al., 2022). Nowadays, people are

looking for places with high environmental quality and free from environmental pollution (Lou and Morsal, 2021).
Sports facilities always host a large number of users (professional and amateur), which seem to have high noise levels due to the variety of activities, devices and equipment available, which increases the possibility of injury. The purpose of this research was to measure the sound level in sports venues, especially multi-purpose halls. To this end, the city of Lahijan (Gilan Province, Iran) was chosen as a research pilot. The development of urban communities has caused changes in urban life, one of the manifestations of which is the emergence of abnormalities in urban areas. Among these, we can mention various types of environmental pollution that reduce the quality of urban life (Malekshahi et al., 2020).
Quality of life reflects social, economic and environmental characteristics and can be used as a powerful tool to monitor social development planning (Mousavi and Kashkoli, 2014; Pourqorban, 2018). The quality of life is determined by various subjective and objective indicators. One of the environmental indicators in the quality of life is the level of environmental tensions and stresses. Accordingly, noise pollution plays a very important role in expressing citizens' satisfaction or dissatisfaction with work and living environments (Peris, 2020). In general, it can be said that sudden and loud noises that cause anxiety and fear increase blood pressure, reduce salivation, and cause dry mouth. According to studies, physiological complications related to noise pollution appear in humans at a level of 30-60 decibels (dB). Severe physiological effects and resulting diseases occur at higher levels, in the range of 85-120 dB (Babisch and Van Kamp, 2009; Luzzi et al., 2016).
Exposure to sound pressure of 80 dB can cause aggressive behavior in people. Noise pollution at high sound pressure levels (more than 85 dB) has direct effects on the auditory organ, including Temporary Threshold Shift (TTS), and in case of prolonged exposure, Permanent Threshold Shift (PTS). Long-term exposure to noise can cause hearing damage that people may not even notice (Chandana et al., 2017; Evans and Hygge, 2007; Muhr et al., 2007). In recent years, noise pollution and its consequences have become an important topic in scientific research. several studies have been conducted globally to reduce the problem of noise pollution in cities and different human settlements (WHO, 2018; Babisch et al., 2009; Abbaspoor, 2016). While the increase in various activities in urban services has caused noise pollution to emerge as a social problem, unfortunately, the importance and position of noise pollution in Iran, like most pollutions, is not very clear and defined.
Lee et al. (2024) measured noise exposure in the pickleball courts and assessed the risk of noise-induced hearing loss (NIHL) based on the guidelines provided by the National Institute of Occupational Safety and Health (NIOSH). Their results showed that the average sound levels recorded in the waiting areas adjacent to the courts, measured by LAeq, LASmax, and LCpeak, were 69.1 dBA, 92.0 dBA, and 112.1 dBC, respectively, while courtside measurements were 69.7 dBA, 92.2 dBA, and 115.6 dBC, respectively. These measurements were in accordance with the recommendations of National Institute for Occupational Safety and Health (NIOSH) and Occupational Safety and Health Administration (OSHA). Mascolo et al. (2023) investigated the noise pollution level on the mountain climbing route in Tehran (Iran) and it was found that most of the studied area had a level above the standard and about 20-25 percent of the mountain climbers. They are affected by noise levels above the permissible limit. Ling-Hsiang et al. (2021) measured the sound level of sports clubs and concluded that the sound level exceeded the standard in half of the sites studied. The relationship between the two categories of sports and the city is reciprocal and complementary, which includes the effects of sports on urbanization on the one hand and the impact of city development on sports on the other (Lou and Morsal, 2021).
Based on the literature review, assessments of noise pollution in sports are very diverse; although they mainly include open spaces, indoor spaces are more important because they accommodate a large number of users in a small space that has not been studied so far. Today, sports are referred to as a means to achieve sustainable development. The issue of sports and the environment is being pursued seriously in scientific circles, as environmental pollution affects the health and performance of athletes (Mishkar and Morsal, 2021). The goal of sustainable urban development is to create a healthy city according to the needs of its users. Reducing environmental pollution, improving the environment, increasing energy efficiency, and improving per capita services, education, health, etc. are among these (OEL, 2017).
Previous studies have generally been limited to measuring sound levels on highways and streets, as well as some specific industrial applications and outdoor sports spaces. To the best of our knowledge, no comprehensive and detailed study has been conducted on the sound levels of indoor sports venues such as multi-purpose halls. Given the potential negative effects of noise pollution on the health of users, the present study was conducted to better manage sports venues by assessing the noise pollution of multi-purpose halls. The research questions were: What is the sound level in the studied indoor sports spaces? Does the time of use have an effect on the sound level? Does it comply with the standards or not? Is the urban location (prosperous and poor) related to the sound level? On the other hand, is the geometric shape related to the propagation and reflection of sound or not?

2. Materials and methods

2.1 Study area

The studied area was Lahijan city located in Gilan province, Iran. Figure 1 shows the location of Lahijan city.
The statistical population of the research was the multi-purpose sports halls in the city of Lahijan, which were first divided into four zones and then four sports halls were randomly selected from each zone. Thus, the northern and western zones were located in the affluent context, and the eastern and southern zones represented the weak economic sector of the studied city. Data were extracted through field sampling. The sound level emitted at each of the measurement stations was measured at a distance of one meter, at

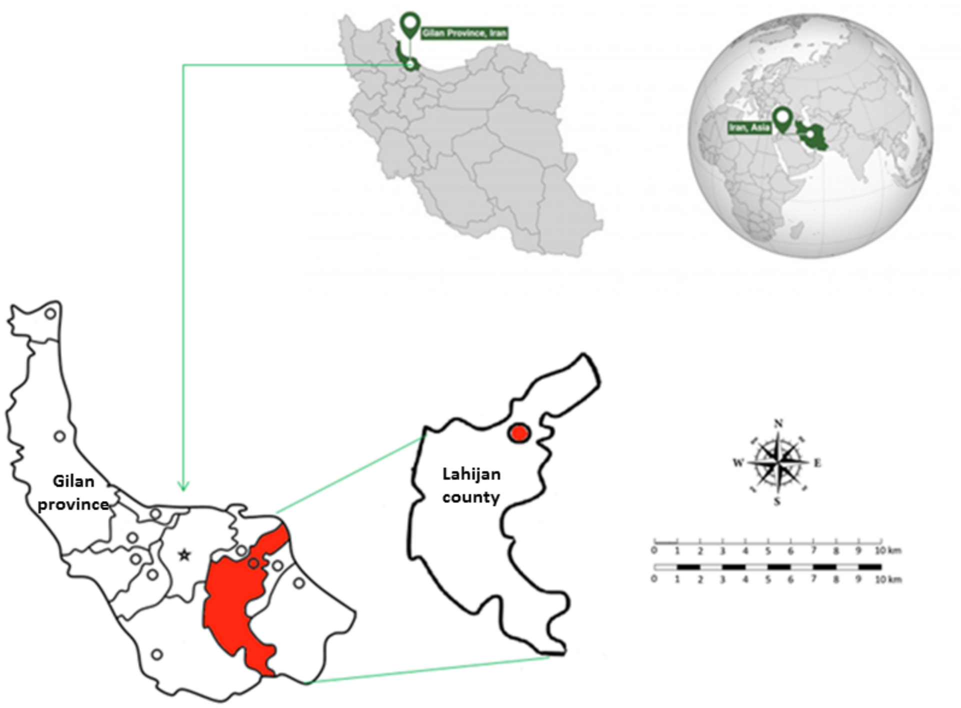

Figure 1. Location of the study area.

level A and its equivalent, by a portable device and Decibel X version 2023 software, and compared with the sound standard (OSHA -90 dBA). When evaluating sound, the sound meter microphone should be at least 3 meters from the walls and 1.5 meters from the ground, and an error of up to 6 dB was negligible during the assessment (Ling-Hsiang et al., 2021; Mishkar and Morsal, 2021). The measurement duration at each station was 15 minutes and each was performed in triplicate and repeated three times. In this study, the measured parameters were sound pressure level (SPL or LP), continuous sound equivalent level (Leq) and individual daily dose LAEp,d. Thus, at each station, the SPL (dBA) was measured by the Decibel X application based on equation 1 and recorded in the relevant table (South, 2016).

$$SPL(dB) = LP = \log(\frac{P^2}{P_0^2}) = 20\log(\frac{P}{P_0}) \quad (1)$$
$$SPL = 20\log P + 94$$

Since athletes are exposed to different levels of sound pressure during sports activities, the L_{eq} (dBA) was used for accurate assessment, which was calculated according to equation 2 (Golmohammadi, 2023).

$$L_{eq}(dB) = 10\log[\frac{1}{T}\sum_{i=1}^{N} t_i 10^{\frac{LP_i}{10}}] \quad (2)$$

Also; Individual daily dose LAep, d of an athlete was calculated in the study site from equation 3 (South, 2016):

$$LAEp.d = L_{eq} + 10\log\frac{t}{m} \quad (3)$$

where, L_{eq} is the equivalent level of sound exposure, t is the duration of the athlete's presence in the hall, and m is the maximum duration of exposure to noise pollution in the International Labor Organization standard, equal to eight hours. According to the study, the average time spent in the gym in a day was about two hours. The maximum time allowed for exposure to noise for athletes in multi-purpose halls was calculated using the standard table published by the British Health and Safety Organization in the field of noise reduction in workplaces (OEL, 2017). Figure 2 shows the network of the study area.

3. Results

The Lp (dBA) was measured and recorded in each of the selected sports halls and zones at different times. The average sound level at each site and each turn was also calculated (Table 1).

As can be seen, the lowest sound pressure level measured in the study area was in sports hall number 2, in the north zone and in the first turn, equal to 73.9 dB. The highest measured sound pressure level also belonged to the western zone and sports hall number 10, equal to 97.7 dB. On the other hand, the results showed that the average sound pressure level increased with the change in time from early morning (10 am) to evening (8 pm). In other words, there was a direct relationship between the sound pressure level and the measurement time (figure 3). Moreover, the average sound pressure level was higher in the western zone than that in other zones and also was lower in the southern zone

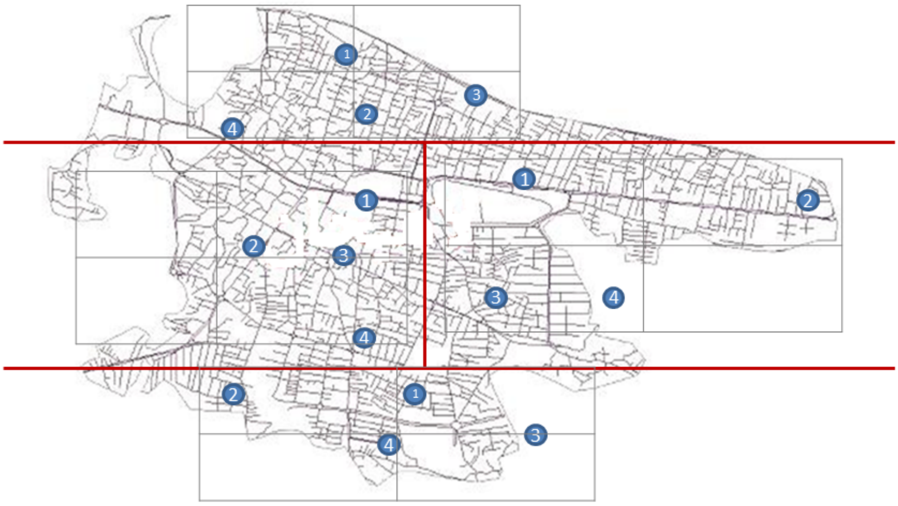

Figure 2. Networking of the study area and the location of the measurement sites.

Table 1. Average 15-minute network-weighted sound pressure level (dB) in two time periods in selected halls.

Location	**Site**	**The level is equivalent to the measured sound**			**Average sound pressure level in each station**
		First turn 10-12	**Second turn 16-18**	**Third turn 18-20**	
Northern zone	1	78.7	74.7	81.4	78.3
	2	73.9	84.7	83.2	80.6
	3	76.5	84.3	84.5	81.7
	4	80.2	92.7	88.5	87.1
Eastern zone	1	79.6	78.2	81.7	79.8
	2	82.7	80.3	84.9	82.6
	3	83.3	88.8	90.5	87.5
	4	78.7	85.7	84.7	83
Western zone	1	86.8	88.9	92.5	89.4
	2	90.3	90.5	97.7	92.8
	3	82.2	76.5	88	82.2
	4	80.3	80.2	77.8	79.4
Southern zone	1	75.5	83.2	79.1	79.2
	2	76.5	84.5	75.1	78.7
	3	80.2	88.5	82.2	83.6
	4	79.6	77.5	80.3	79.1
	16	80.32	83.7	84.5	82.8

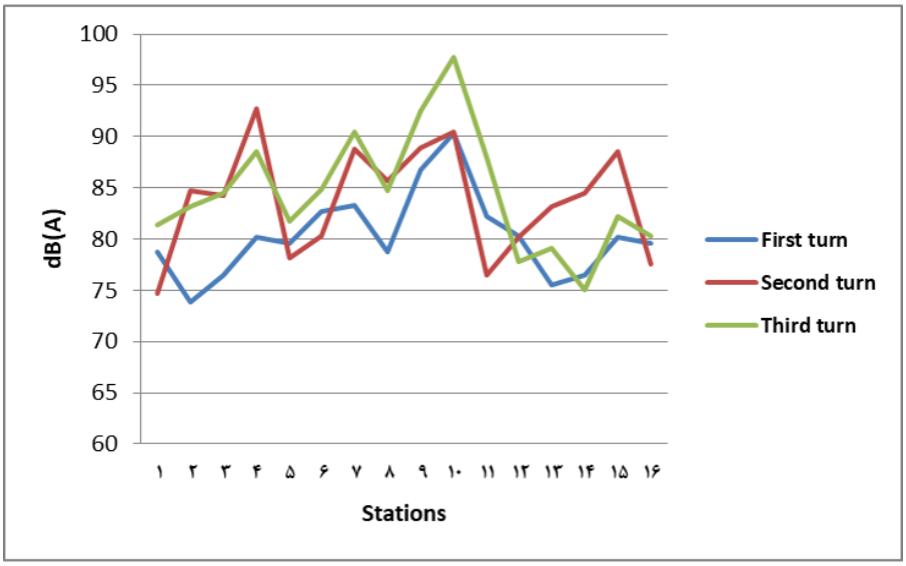

Figure 3. Comparative chart of measured sound pressure level (15-min Leq, dB(A)) in multi-purpose sports halls on separate occasions.

than that in other zones. Overall, the lowest and highest average sound pressure levels were related to sports hall number 1 in the northern zone (78.3 dB) and sports hall number 2 in the western zone (92.8 dB) (figure 4).
Next, equation 2 was used to estimate the equivalent level of sound exposure (dBA) Leq. As presented earlier, based on interviews with athletes, the average time spent on a sports day in the studied halls was about 2 hours. Accordingly, the equivalent level was estimated for each hall separately. Then, equation 3 was used to calculate the individual daily dose LAEp,d of an athlete in the gym (Table 2).
It was found that the gyms located in the western zone had a higher average daily dose (82.94) and the gyms located in the southern zone had a lower average daily dose (77.14).
As shown in Table 2, sports halls with a geometric shape of space frame had lower sound levels than sheds, indicating that the structural form was effective in sound reflection.

4. Discussion

The purpose of this research was to measure the sound level in multi-purpose sports halls. Various sports such as futsal, basketball, volleyball, handball, goalball, etc. are held in these halls. All of these disciplines are performed with the presence of a large number of users (more than 15 people). The results of the current research showed that the lowest sound pressure level measured in the study area in sports hall number 2, in the northern area and in the first turn, 73.9 dB. The highest measured sound pressure level also belonged to the western zone and sports hall number 10, equal to 97.7 dB. On the other hand, the measured sound pressure level showed that the average sound pressure level increased as the time changed from early morning (10 am) to evening (8 pm). In other words, there was a direct relationship between the sound pressure level and the measurement time. One reason was probably the presence of more users, and

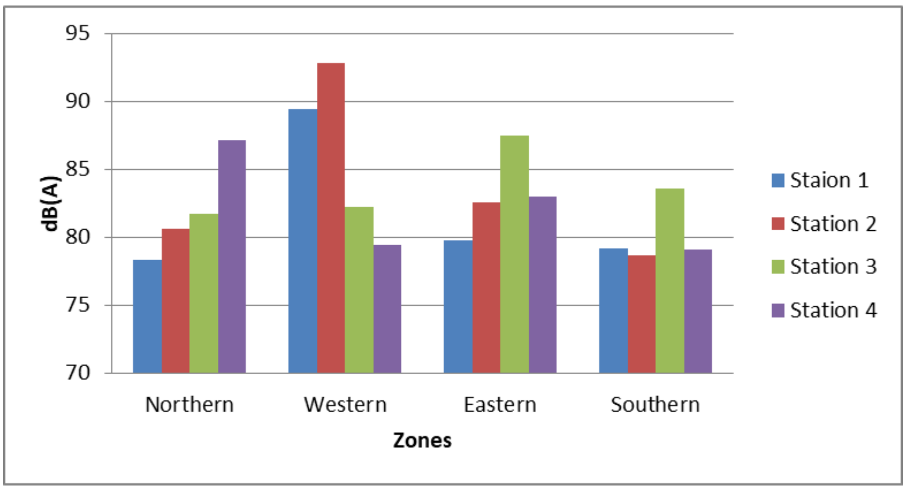

Figure 4. Comparative chart of measured sound pressure level (15-min Leq, dB(A)) in multi-purpose sports halls in four zones and related stations.

Table 2. Equivalent exposure level of sound pressure level for sports halls under study in Lahijan city.

Location	Sites	Leq (dBA)	LAEp, d	Average level	Structural form
Northern zone	1	81.31	75.29	78.91	Shed
	2	83.61	77.59		Shed
	3	84.71	78.69		Space frame
	4	90.11	84.09		Shed
Eastern zone	1	82.81	76.79	80.21	Shed
	2	85.61	79.59		Shed
	3	90.51	84.49		Shed
	4	86.01	79.99		Shed
Western zone	1	92.41	86.39	82.94	Shed
	2	95.81	89.79		Shed
	3	85.21	79.19		Shed
	4	82.41	76.39		Shed
Southern zone	1	82.21	76.19	77.14	Space frame
	2	81.71	75.69		Space frame
	3	86.61	80.59		Shed
	4	82.11	76.09		Shed

another reason was the increasing age of users, which led to a greater ability to produce higher sounds (adults compared to children). The average sound level in the western zone was higher than in other zones and the average sound level in the southern zone was lower than in other zones. In this case, it should be noted that in both zones, the gyms were of the shed type, so it was impossible to establish a connection between the structural form and the sound level.

Overall, the lowest average sound level belonged to the sports hall number 1 in the northern zone (78.3 dB) and the highest average sound level belonged to the sports hall number 2 in the western zone (92.8 dB). On the other hand, comparing the current situation and international standards revealed that all the studied halls had a level higher than the standard of recreation centers and parks, as well as the standard of the United States Environmental Protection Agency (EPA, 2014). However, all the halls met other standards such as ACGIH, NIOSH and OSHA related to occupational health.

Finally, it was found that the gyms located in the western zone had a higher average daily dose (82.94) and the gyms located in the southern zone had a lower average daily dose (77.14).

Figure 5 illustrates a graph of the average sound level in the studied halls compared to international standards.

In response to the research questions, it could be said that all the studied halls had a level higher than the standard of recreation centers and parks, as well as the standard of the United States Environmental Protection Agency (EPA). However, all the halls had met other standards such as ACGIH and

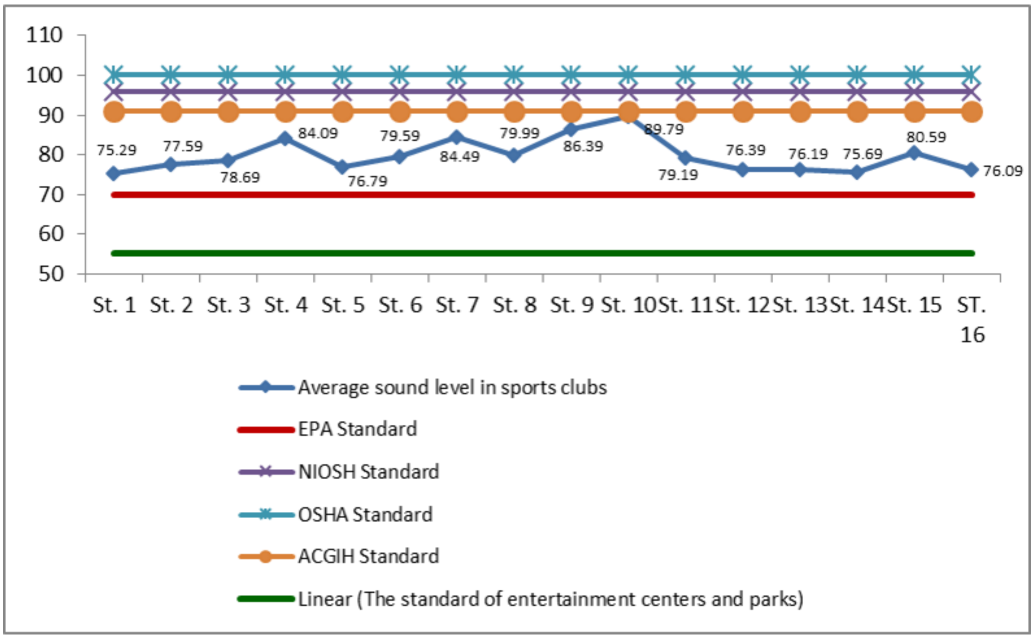

Figure 5. Comparative chart of average sound level dB(A) measured in sports halls with international standards.

NIOSH and OSHA related to occupational health. In addition, there was a relationship between the time of using sports halls and the sound level. Therefore, in the early hours of the day, when there were fewer athletes, noise pollution was also lower. Finally, there was a relationship between the urban location of sports halls and the sound level, such that halls located in the northern and western zones (the more affluent part of the city) had higher sound levels; in contrast, those located in the southern and eastern zones (poorer areas of the city) had lower sound levels.
In terms of the structural form, it was impossible to give a definite opinion. Because most of the structures are of the shed type, and due to the fact that different levels have been obtained for the sheds, it was impossible to establish a relationship between the structural form and the sound level. Gyms that had lower sound levels appeared to have one of the following:

- No music playing during sports activities;
- Having a large space and a ceiling height of more than five meters;
- Having flexible wall coverings against ball impact.

In terms of methodology, this research was similar to the research done by (Hosseinabadi et al., 2019). However, their results are not generalized and comparable, because the studied environment was of open type in their research and was of closed space type in this study. Our results were in line with the findings of (Bahmanpour et al., 2016) and (Ling-Hsiang et al., 2021). According to the World Health Organization standards, if an athlete is exposed to noise above 80 dB, the aggressive behavior is normal, and as a result, this can be observed in the studied clubs. On the other hand, hearing loss (temporary and even permanent) is also one of its consequences. According to the IOC guidelines (2000), sustainable management in sports is responsible for establishing standard conditions for athletes, spectators and all sports stakeholders and must be committed to providing the necessary conditions.

5. Conclusion

The innovation of this research was to measure the sound levels in indoor sports spaces and assess their relationship with the geometry of the hall. No previous study has examined the relationship between architecture and noise pollution.
The results showed that the structural form was effective in sound reflection. Therefore, it is recommended to pay attention to the structural form as well as the materials used in the design of sports halls. In addition, it is also very important to consider acoustic aspects.
In the end, the following are presented as solutions to reduce the sound level received in sports environments such as multi-purpose halls:

- Athletes should not be in the gym for more than two hours;
- Preferably use early hours (morning) for exercise;
- It is suggested that athletes choose gyms that have a large space and a high ceiling, and the walls are made of foam or soundproofing materials.
- Set the music playback volume to a moderate level (70 dB).
- Athletes should refrain from yelling, shouting and talking loudly.
- The sports hall should be furnished with flexible and resistant flooring.
- A quorum should be set for sports halls to avoid excessive presence of users and crowding.
- Standard ventilation devices should be used in sports halls and these devices should be serviced regularly so that they do not produce non-standard noise.
- Avoid the interference of sports fields with each other in a small and shared space.

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Project Administration: Ali Fahimi Nezhad
Resources: Ali Fahimi Nezhad
Supervision: Ali Fahimi Nezhad
Validation: Ali Fahimi Nezhad
Visualization: Ali Fahimi Nezhad
Writing - original draft: Bagher Morsal
Writing - review & editing: Bagher Morsal

Availability of Data and Materials
All data generated or analysed during this study are available from the corresponding author upon reasonable request.

Conflict of Interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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