ORIGINAL ARTICLE

# Assessment of Noise Related Disorders among Health Care Personnel: A Cross-Sectional Study in Shiraz Hospitals

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## Abstract

**Background:** Noise pollution has a particular importance in quiet environments such as hospitals. The main objective of this study was to evaluate the effects of noise exposure on the auditory system, blood pressure and precision, concentration and other psycho-neural components.

**Methods:** This cross-sectional study was carried out in three large hospitals of Shiraz, during the period of 2012 to 2013. The study population consisted of 81 health care personnel (the exposed group) and 79 non-exposed individuals (the referent group). Day and night time sound levels were measured at different wards of the hospitals by a sound level meter (B&K 7110). Hearing status was assessed by pure tone audiometry of subjects by an Inter-acoustic AD27 audiometer. Blood pressure was measured with a mercury sphygmomanometer at resting time and psycho-neural components including sleep disturbances, headache, irritability and … were evaluated by a questionnaire devised and validated for this purpose. Data were analyzed by SPSS 16 software.

**Results:** Average sound pressure level for the exposed group (65.32±5.23 dB) was significantly higher than that of the referent group (53.26±2.46 dB) ($P<0.05$). Similarly, the mean values of permanent threshold shift (dB) as well as systolic and diastolic blood pressure were significantly higher in the exposed group than in their counterpart individuals ($P<0.05$). Likewise, symptoms such as headache and irritability were significantly more common among the exposed subjects.

**Conclusion:** The findings suggest that exposure to sub-TLV levels of noise (recommended by ACGIH) in hospital environments is also associated with decreased hearing threshold, increased blood pressure, and prevalence of psycho-neural disorders.

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**Keywords:** Noise, Pollution, Hospital, Personal Health Services, Hearing Loss

## Introduction

Noise is an unwanted and unacceptable musical quality voice[1] and one of the fundamental problems in today's industrial world. Furthermore, a large number of people (at work and in life environment) are affected by adverse effects of noise.[2] According to the National Institute for Occupational Safety and Health (NIOSH), approximately 30 million people in US are occupationally exposed to unsafe noise levels and/or ototoxic drugs.[2,3]

In addition to temporary and permanent hearing loss,[4-6] noise induces other disorders such as sleep

disturbance, dizziness, confusion, fatigue, high blood pressure, digestive problems, cardiac arrhythmia and psychoneural disorders. Moreover, noise is known as the most common cause of discomfort, stress and communication disruption.[2,7-10]

The issue of noise pollution in quiet environments such as hospitals has not been thoroughly investigated. Patients and staff in hospital setting are exposed to noise from different sources. Noise pollution in hospitals is often the result of a series of traffic noise from motor vehicles, medical equipment, hospital facilities, transportation of patients, staff and visitors, telephone, etc.[11-17] According to the World Health Organization (WHO) guidelines, the permissible sound level ($L_{eq}$) for hospitals is 30 dB and the maximum level of noise at night should not exceed 40 dB.[13,16] Maximum allowable noise level in hospital wards is 45 dB during the day and 35 dB at night according to US environmental protection agency (US-EPA).[17,18]

Hospital noise pollution and its effects on patients and medical personnel have been studied in a limited number of international studies.[12-15,19-22] McLaren and Armstrong showed that noise pollution in surgery ward is higher than the recommended standard.[13] Buelou showed that noise levels in emergency departments exceeded the standard levels and as a result employees complained about mental and physical fatigue.[14] In another study, noise was reported to exceed the standard value at clinics, patients' rooms, offices, waiting rooms and corridors.[15] Tijunelis reported that the noise level was higher in the intensive care unit, which imposed stress on individuals.[12] Juang and colleagues showed that exorbitance noise exposure in the hospital environment directly and indirectly affects patients and medical personnel and also impairs communication and neuropsychological function.[18] Furthermore, results of some studies at Johns Hopkins hospital in Baltimore, Maryland state, has shown that the noise level was higher than the WHO recommended noise limit in all parts of the hospital. Probably, this is a scenario and a picture observable throughout all world hospitals.[21,22]

In general, the problem of hospitals' noise pollution is a global issue and because of its negative health impacts, it requires and deserves further attention. Despite the importance of this issue, to the best of the authors' knowledge, hospital noise pollution has not been studied in Iran. Therefore, this study was conducted to obtain the necessary information as to the noise levels to which health care personnel are exposed, asses the auditory effects of this exposure, find out if there is any association between exposure to hospital noise levels and hypertension and also if exposure to hospital noise levels is associated with neuropsychological disorders.

## Materials and Methods

*Subjects*

This cross-sectional study was carried out in three large hospitals of Shiraz during 2012-2013. The study population consisted of 160 individuals (81 health care personnel as the exposed group and 79 subjects from an educational center as the referent group). Those with a history of conditions such as tinnitus, thyroid disorders, vertigo, exposure to noise and ototoxic medications such as gentamycin, neomycin, tetracycline and streptomycin were excluded. The study subjects were selected through stratified random sampling as recommended by one of the authors of this study who is an expert in the field of clinical epidemiology.

*Data Gathering*

The study data were collected using a designed and validated questionnaire. This questionnaire contained questions on demographic and individual characteristics (age, sex, weight, height, etc.), job experience, education, job satisfaction, performance, headache, dizziness, irritability, ease and ability to communicate with colleagues, concentration, history of some diseases (such as renal failure, thyroid disorder, autoimmune disease, meniere's syndrome, meningitis, encephalitis, syphilis, scarlet fever, diphtheria, rubella, diabetes and high blood pressure), present and past history of using ototoxic drugs (such as aspirin, streptomycin, vancomycin, quinine and its derivatives), and a history of exposure to known ototoxic chemical agents (such as carbon monoxide) and solvents (such as toluene, carbon disulfide, methanol, styrene, xylene, trichloroethylene, benzene and n-heptanes).

To eliminate or minimize the effects of confounding variables, the employees with a history of exposure to non-occupational high noise levels as well as individuals with a family or personal history of hypertension or current use of ototoxic drugs were excluded.

*The Questionnaire Validation*

The study data were collected by a questionnaire, devised and validated by the authors. This questionnaire contained questions on demographic and individual characteristics (age, sex, weight, height, etc.), job experience, education, Job satisfaction, performance, headache, dizziness, irritability, ease and ability to communicate with colleagues, and the ability to concentrate. Furthermore, some questions including the history of some diseases (such as renal failure, thyroid disorder, autoimmune disease, meniere's syndrome, meningitis, encephalitis, syphilis, scarlet fever, diphtheria, rubella, diabetes and high blood pressure), as well as present and past history of

using ototoxic drugs (such as aspirin, streptomycin, vancomycin, quinine and its derivatives) and history of exposure to known ototoxic chemical agents (such as carbon monoxide) and solvents (such as toluene, carbon disulfide, methanol, styrene, xylene, trichloroethylene, benzene and n-heptanes) were adopted from Neghab et al.'s study.[2] It should be noted that the initial validity of the questionnaire was poor (Cronbach's coefficient of 0.6). An expert clinical epidemiologist (one of the coauthors) revised and amended the questionnaire. A second measurement showed that Cronbach's coefficient reached an acceptable value of 0.8.

*Blood Pressure Measurement*

The employee′s blood pressure was taken at normal resting position. Using WHO criteria, we defined hypertension as a diastolic blood pressure (DBP) of 90 mmHg or greater and/or a systolic blood pressure (SBP) of 140 mmHg or greater.[23]

*Workplace Noise Measurement*

Measurement and assessment of noise levels were conducted using a modular precision sound level meter (B&K/ Integrating SLM module/ BZ 7110), an octave band analyzer (B&K / Type 1625 /Octave filter set). It should be noted that the levels of noise exposure were measured in different hospital wards, during day and night time, and at the work station of each of the subjects.

*Audiometry Test*

All subjects underwent an audiometry test, using an audiometer device (Inter Acoustic/Model AD 27). To effectively minimize the effects of noise-induced temporary threshold shift (NITTS), audiometric testing was performed about forty-eight hours after the last noise exposure.[24] Hearing threshold was calculated based on the recommendations of ACGIH by the addition of hearing threshold at frequencies of 500, 1000, 2000 and 4000 Hz divided by 4.[27]

*Statistical Analysis*

The experimental results are presented as arithmetic mean±SD (standard deviation). Analysis of the study data was performed using SPSS software (version 16). P value of less than 0.05 was considered as the significance level. Independent sample t-test was used to compare the quantitative variables such as age, job experience, BMI index, noise level, and blood pressure and hearing threshold. Qualitative variables such as smoking status, gender and education were analyzed using Chi-square test. To adjust the effects of confounders, multiple linear regression analysis was performed.

## Results

Individual and demographic characteristics and information about population exposure are shown in table 1. The average age and job experience for the

**Table 1:** Demographic characteristics and exposure information of the study subjects (n=160)

| Demographic characteristics and exposure information | Exposed Group (n=81) | Referent Group (n=79) | P value |
|---|---|---|---|
| Age (yr) (mean±SD) | 33.31±7.71 | 31.89±6.58 | 0.212† |
| Length of exposure or employment (yr) (mean±SD) | 10.15±6.62 | 8.62±5.51 | 0.116† |
| BMI (kg/m$^2$) (mean±SD) | 24.35±3.63 | 23.66±3.21 | 0.205† |
| Gender | | | |
| Female | 56 (69.1%) | 55 (69.6%) | 0.947‡ |
| Male | 25 (30.9) | 24 (30.4%) | |
| Education | | | |
| Diploma & sub-diploma | 29 (36.2%) | 14 (17.7%) | 0.009‡ |
| Academic education | 51 (63.8%) | 65 (82.3%) | |
| Smoking | | | |
| Yes | 3 (3.7%) | 4 (5.1%) | 0.674‡ |
| No | 78 (96.3%) | 75 (94.9%) | |
| Hyperlipidemia | | | |
| Yes | 9 (11.1%) | 8 (10.1%) | 0.840‡ |
| No | 72 (88.9%) | 71 (89.9%) | |
| Diabetes | | | |
| Yes | 3 (3.7%) | 3 (3.8%) | 0.975‡ |
| No | 78 (96.3%) | 76 (96.2%) | |
| Hypertension | | | |
| Yes | 5 (6.2%) | 6 (7.6%) | 0.722‡ |
| No | 76 (93.8%) | 73 (92.4%) | |

†Independent sample t-test; ‡Chi square test

exposed group were 33.31±7.71 and 10.15±6.62 years, respectively and the corresponding values for the referent group were 31.89±6.58 and 8.62±5.51 years, respectively; the differences were not significant. The results showed that the mean body mass index (BMI) in both referent and exposed groups was 23.66±3.21 and 24.35±3.63 kg/m$^2$, respectively and the difference was not significant. Sex distribution and smoking status of both groups were not different.

Results of sound pressure level measurement at the three studied hospitals are presented in table 2. According to the results, the average noise in each of the hospitals during the day-time is higher than night-time.

Additionally, mean values of sound levels were significantly different in the studied hospitals.

The results of noise levels, blood pressure and hearing threshold are presented in table 3. The mean noise levels for the exposed and the referent group were 65.32±5.23 and 53.26±2.46 dB, respectively and the difference was statistically significant (P=0.001). Mean values for diastolic (DBP) and systolic blood pressure (SBP) in the exposed group were 79.91±8.22 and 120.95±12.81 mmHg, respectively. The corresponding values for referent subjects were 71.74±9.85 and 115.99±6.88 mmHg, respectively; the differences were statistically significant (P<0.05).

Hearing threshold of the right ear in the exposed and referent groups was 14.25±10.59 dB and 10.60±6.18 dB, respectively. Similarly, hearing threshold of the left ear in the exposed and referent groups was 14.21±8.09 dB and 9.85±6.43 dB, respectively. Hearing threshold of both ears for the exposed and referent subjects were 12.65±7.51 dB and 8.81±4.92 dB, respectively and the differences were statistically significant.

Results of noise induced neuropsychological effects in the exposed and referent groups are presented in table 4. As shown, the incidence of all neuropsychological disorders in the exposed group was significantly higher than those of the referent group (P<0.05).

Table 5 presents the results of multiple linear regression analysis. Noise exposure entered the model as an independent variable and the variables of age, work experience, BMI, smoking and education as confounders. The results of modeling showed a

**Table 2:** Comparison of mean noise levels in the studied hospitals at day and night times

| Hospital | Total (n=27) | Hospital A (n=9) | Hospital B (n=9) | Hospital C (n=8) | P value‡ |
|---|---|---|---|---|---|
| Noise level (dB) at day-time | 64.60±7.90 | 58.27±4.56 | 66.53±7.71 | 69.31±7.05 | A vs. B P<0.05<br>A vs. C P<0.01<br>B vs. C P>0.05 |
| Noise level (dB) at night-time | 60.21±6.36 | 55.52±3.83 | 63.07±6.56 | 61.91±5.94 | A vs. B P<0.05<br>A vs. C P>0.05<br>B vs. C P>0.05 |
| P value† | 0.029 | 0.186 | 0.294 | 0.040 | |

‡One-way ANOVA; †Independent sample t-test

**Table 3:** Assessment of workplace noise level, blood pressure and hearing threshold in the study population (n=160)

| Variable (mean±SD) | Exposed Group (n=81) | Referent Group (n=79) | P value† |
|---|---|---|---|
| Noise level (dB) | 65.32±5.23 | 53.26±2.46 | 0.001 |
| DBP (mmHg) | 79.91±8.22 | 71.74±9.85 | 0.001 |
| SBP (mmHg) | 120.95±12.81 | 115.99±6.88 | 0.003 |
| Hearing loss in right ear (dB) | 14.25±10.95 | 10.60±6.18 | 0.001 |
| Hearing loss in left ear (dB) | 14.21±8.09 | 9.85±6.43 | 0.001 |
| NIHL (dB) | 12.65±7.51 | 8.81±4.92 | 0.001 |

†Independent sample t-test

**Table 4:** Comparison of neuropsychological disorders in study subjects (n=160)

| Neuropsychological Disorders | Exposed Group (n=81) | Reference Group (n=79) | P value‡ |
|---|---|---|---|
| Sleep disturbanes | 24 (29.6%) | 2 (2.5%) | 0.001 |
| Headache | 67 (82.7%) | 47 (62.7%) | 0.006 |
| Irritability | 68 (84.0%) | 25 (32.9%) | 0.001 |
| Inability to concentrate | 60 (74.1%) | 19 (24.1%) | 0.001 |
| Job-related errors | 56 (69.1%) | 22 (27.8%) | 0.001 |
| Reduced accuracy | 38 (46.9%) | 20 (25.6%) | 0.008 |
| Impaired verbal communications | 38 (46.9%) | 8 (10.1%) | 0.001 |
| Job dissatisfaction | 33 (40.7%) | 59 (74.7%) | 0.001 |

‡Chi square test between exposed and reference groups

**Table 5:** Association of noise exposure and hearing threshold

| Independent Variable | Coefficient of B | Standard Error | †P value |
|---|---|---|---|
| Noise Exposure‡ | 3.217 | 0.977 | 0.001 |

†Multiple Linear Regression; ‡Data of the referent group are used as the baseline.

significant linear relationship (P<0.05) between noise exposure and hearing threshold. This finding indicates that an increase of one-dB in noise exposure is associated with a decreased hearing threshold of 3.217 dB.

## Discussion

In addition to temporary and permanent hearing loss,[4-6] exposure to excessive noise is associated with sleep disturbance, and symptoms such as dizziness, confusion, fatigue, high blood pressure, digestive problems, heart arrhythmias and neuropsychological disturbances. Moreover, noise is considered as the most common cause of discomfort, imposes stress and disrupts communication.[2,7-10] According to our data, the two examined groups were similar as far as social, economic and most demographic characteristics, such as mean age, work experience, body mass index (BMI), and smoking habits were concerned.

Due to differences in geographical distribution of the hospitals, type and size, traffic load, etc., mean values of sound levels were significantly different in the studied hospitals. Furthermore, comparing these values with WHO and EPA standards indicated that noise levels in the studied hospitals, both, during day and night, exceeded the existing standards.[13,16-18] This finding is also consistent with studies carried out at Johns Hopkins Hospital in Baltimore, Maryland.[21-22]

The mean levels of noise to which health care workers and referent subjects were exposed were 65.32±5.23 and 53.26±2.46 dB, respectively and the difference was statistically significant. According to WHO guidelines, the permissible level of noise in hospital environments is 30 dB for overall day time and under no circumstances this value should exceed 40 dB overnight.[13,16] Similarly, according to EPA standards, the permissible level of noise in the hospitals is 45 dB during the day and 35 dB at night time.[17,18] Given the above, health care workers were exposed to noise levels much higher than those internationally adopted. This finding is in full agreement with other studies undertaken in this field.[12-15,19-22]

Interestingly, while the mean values of systolic and diastolic blood pressure for the exposed group were in the normal range (normotensive category) and did not exceed the criterion set by the WHO,[23] they were significantly higher than those of the referent group. This finding is also in the same line with those of Neghab and his colleagues, where long term exposure to noise was shown to significantly increase both systolic and diastolic blood pressure of the exposed individuals as compared to a referent group.[2]

Increased hearing threshold and noise-induced hearing loss (NIHL) are the specific and measurable consequences of exposure to noise.[3-6] The results showed that health care workers significantly had a higher hearing threshold as compared to their unexposed counterparts.

Neuropsychological disorders are the other side effects of exposure to noise.[2,7-10] Several studies have shown that exposure to noise is associated with sleep disorders and symptoms such as dizziness, confusion, fatigue and other neuropsychological symptoms. The present study showed that the prevalence of symptoms such as insomnia, headache, irritability, lack of concentration, loss of precision, job- related errors, impaired verbal communications and decreased job satisfaction was significantly more common among health care workers. In line with these observations, the findings of some other studies have also shown that excessive noise exposure in the hospital environments directly and indirectly affects the health of patients and staff and causes stress, impairs communication, and is associated with neuropsychological disorders.[12,18]

Association between exposure to noise and changes in hearing threshold is shown in table 5. Multiple Linear Regression Analysis, including independent variables of age, sex, weight, height, length of smoking and length and intensity of exposure to noise in the model, showed that after adjusting for confounders, there was a statistically significant association between noise intensity and hearing threshold, in that there was a general tendency for it to become larger as exposure intensity increased. This finding indicates that an increase of one-dB in noise exposure is associated with a decreased hearing threshold of 3.217 dB. This finding is also in the same line with that of a number of other studies.[3,25-27]

According to ACGIH, hearing impairment (HI) is a mean loss of 25 dB at frequencies of 500, 1000, 2000 and 3000 Hz.[27] Given this value, the study population with a mean hearing threshold of 12.65 dB is yet to suffer from hearing impairment. This finding may well be explained by the fact that the subjects had the history of a relatively, short period of exposure to low noise levels, were a relatively young population and lacked any history of exposure to ototoxic chemicals. However, the mean hearing threshold in the exposed group was significantly higher than that of the referent group.

One important finding of this study is the

observation of a permanent threshold shift (PTS) (audiometry was performed 48 hours after cessation of exposure to noise), because it occurred at $L_{eq}$=65.32 dB, while 75-dB has been estimated as a very conservative exposure limit.[28] Due to the inherent limitations of cross-sectional studies such as this, cause and effect relationships could not be established. Therefore, one might argue that changes in hearing threshold in this study could not necessarily be attributed to occupational noise exposure. While true, several lines of evidence indicate that PTS is very likely to be the consequence of exposure to noise and is not due to other factors such as age, presbycusis, diabetes, hyperlipidemia, high blood pressure, smoking, etc.[2]

First, no significant differences were revealed between both groups as far as variables such as age, length of employment, smoking habits and the risk factors of hypertension, diabetes, hyperlipidemia, etc. were concerned.

Second, the subjects did not have any history of past or present exposure to known ototoxic chemicals or use of ototoxic drugs or exposure to excessive noise from non-occupational sources.

Third, mean value of noise to which health care workers were exposed was significantly higher than that of the referent group.

Fourth, the regression model showed that after adjusting for confounders, a significant association exists between hearing threshold and noise intensity.

## Conclusion

The findings suggest that exposure to sub-TLV levels of noise (recommended by ACGIH) in hospital environments is also associated with decreased hearing threshold, increased blood pressure, and prevalence of psycho-neural disorders.

Finally, hospital is a setting which is very sensitive to noise. That is why the maximum allowable noise level is set much lower than the standards of industrial environments. Therefore, exposure to noise should be eliminated or reduced with appropriate control measures. Constructing new hospitals in downtown areas with heavy traffic should be prevented. Application of sound barriers and acoustic materials is recommended. Prediction of a green belt around newly built hospitals and if possible near the existing hospitals is recommended. Implementing management strategies such as education, and raising awareness and culture in the care and prevention programs of noise pollution is mandatory.

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