The Assessment of Exposure to Occupational Noise and Hearing Loss for Stoneworkers in Taiwan

Feng-Jung Huang1, Chia-Jung Hsieh1, Chi H. Young2, Shun-Hui Chung2, Chun-Chieh Tseng1, Lih-Ming Yin1

1Department of Public Health, Tzu Chi University, Hualien City, 2Institute of Labor, Occupational Safety and Health, Ministry of Labor, New Taipei City, Taiwan

Abstract

Introduction: Stoneworkers in Taiwan are exposed to occupational noise and suffer hearing impairment. A complete assessment of exposure and health effects is needed for a better understanding. Materials and Methods: We accessed nine stone factories, monitored the environmental and personal doses of noise, analyzed the frequency spectra of noise from various machines, and recruited 55 stoneworkers and 25 administrative staff as controls for pure tone audiometry testing. Results: The means (standard deviations) of 8-h time-weighted averages for environmental and personal monitoring were 85.0 (6.2) and 87.0 (5.5) dB(A), respectively, with seven of nine personal measurements being higher than the respective environmental results. The monitoring data suggest that occupational noise in the stonework environments should be a matter of great concern. Nearly all frequency spectra indicated peak values occurring between 2 and 4 kHz, which were within the bands for early noise-induced hearing loss (NIHL). The mean hearing threshold levels of the study participants were elevated in low and high frequencies (29.2 and 41.2 dB) compared to that of controls (∼25 dB for both bands). Linear regression analysis indicated no significance in the low frequencies (P = 0.207) but statistical significance in the high frequencies (P = 0.002) after adjustment for covariates, suggesting NIHL among the stoneworkers. Conclusion: Stoneworkers apparently display early signs of NIHL. Noises in the stonework factories with peaks in the high frequencies are harmful to hearing ability. Employers and workers have to comply with the regulation strictly to prevent further hearing damage.

Keywords: Frequency spectrum, noise-induced hearing loss, occupational noise, pure tone audiometry, stonework

INTRODUCTION

Noise-induced hearing loss (NIHL) causes irreversible damage and occurs among workers who are frequently exposed to occupational noise at high decibel (dB) levels.[1] In 2000, it was estimated that 16% of hearing loss in adults worldwide was attributed to occupational noise, with larger effects in developing countries or regions.[2] To prevent and control occupational noise, the International Labor Organization (ILO) recommended a warning at 85 dB and set the dangerous limit of noise levels at 90 dB measured on the A scale (A) for time-weighted average (TWA) over an 8-h work shift.[3] These recommendations were adopted in the regulations for occupational noise control by many countries, including Taiwan. An NIHL surveillance established in Taiwan in 1995 demonstrated that approximately 34% of noise-exposed workers (>85 dB[A]) had hearing thresholds higher than 40 dB in either one or both ears, suggesting that the hazard of occupational noise might be prevalent among Taiwan’s industries.[4]

Stonework, one of Taiwan’s industries that is known for occupational noise generation, has a series of steps in the work process: primary and secondary cutting, crushing, sculpturing, and gemstone processing. These tasks are processed by various machines, such as gang saw, polisher, bridge saw, jaw crusher, vibrating or rotary screen machine, and grinder, which generate significant noises when in operation. A previous study conducted in Ghana indicated that the prevalence rate of NIHL among stone crushing workers was around 17%.[5] An earlier study on Taiwanese stoneworkers found that the noise levels were usually above 85 dB(A) and,

Address for correspondence: Dr. Lih-Ming Yin, Department of Public Health, Tzu Chi University, 701 Sec. 3 Zhongyang Road, Hualien City 97004, Taiwan. E-mail: lmyin@mail.tcu.edu.tw

This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.

For reprints contact: reprints@medknow.com

How to cite this article: Huang F-Jung, Hsieh C-Jung, Young CH, Chung S-Hui, Tseng C-Chieh, Yin L-Ming. The assessment of exposure to occupational noise and hearing loss for stoneworkers in taiwan. Noise Health 2018;20:146-51.
as a result, 21–42% stoneworkers had hearing impairment, especially in the middle and high frequencies. Although the Taiwanese study showed a significant effect of occupational noise exposure on the hearing ability of stoneworkers, the assessment of noise exposure was limited to personal monitoring, and specific questions (e.g., personal vs. environmental noise and the frequency spectrum of noise) were yet to be answered.

To understand thoroughly the resultant health effect for stoneworkers on exposure to occupational noise, we conducted a complete exposure assessment of occupational noise, including environmental and personal monitoring and the analysis of frequency spectrum for various machines. Thereafter, pure tone audiometry was performed on the participating stoneworkers with administrative staff as controls. The results of this study provide a convincing and better explanation about the nature of noise and the reasons for NIHL occurrence among stoneworkers, which could be valuable for occupational noise control and prevention.

MATERIALS AND METHODS

This study was conducted at the stone industries in Hualien, where more than 80% of Taiwan’s stone factories were located. With Taiwan Marble Association’s referrals, we successfully got access to nine stone factories representing various types of stonework. We recruited 55 workers as study participants. Meanwhile, we obtained the willingness of 25 administrative staff, who were not exposed to occupational noise during their work, to participate as controls. All study participants and controls took part in the study based on their own interest, and the factories agreed to cooperate with the study procedures. Although the participants were not recruited in a fully random manner, the sampling should have included representativeness without significant deviation. Environmental and personal noise measurements were conducted for at least 6 h to calculate the 8-h TWA of sound pressure levels using a noise dosimeter (TES-1354/1355, TES Electric Electronic Corp., Taipei, Taiwan) with the threshold level and exchange rate set at 80 dB and 5 dB, respectively. Slow time weighting was selected to record sound levels at 1-s intervals. For environmental monitoring, the dosimeter was placed 1.2 m high from the ground in an accessible location adjacent to a stationary source of the most significant noise (3–5 m). Personal measurement was performed on individual workers who carried the dosimeter with the microphone set onto their collar during the 8-h work shift. The frequency spectra of noise were measured from locations near specific machines that generated significant noises using a 01 dB Blue Solo sound level meter (01dB-Metravib, Limonest, France), which recorded the 1/3 octave band spectra and the equivalent continuous sound level (A weighted) at 1-s intervals. Data were downloaded to a computer and processed using the dBTrait version 5.2 software (01dB-Metravib, Limonest, France). The stone processing machines and their respective tasks are listed in Table 1.

Basic information (e.g., age, gender, education, years in current job, habits such as smoking and alcohol consumption, etc.) was collected from each participant by filling out a concise questionnaire. For the feasibility of study implementation, we performed pure tone audiometry on site before a work shift using a portable audiometer (Oscilla SM910-B, Denmark) with a PeltorTM headset fitted with TDH-39 earphones. To ensure the quality of measurement, the test was made in a quiet environment (e.g., meeting room or closed office), where the background noise was kept below 50 dB(A). Testing on each participant started with 1 kHz at 40 dB for the right ear using increments of 5 dB and decrements of 10 dB to determine the threshold level. The other frequencies of 2, 3, 4, 6, and 8 kHz were subsequently performed in the same manner, followed by 1, 0.5, and 0.25 kHz. Should the difference of the two measurements at 1 kHz be larger than or equal to 10 dB, the ear needed reevaluation. The same process was repeated for the left ear, and the ear with the higher threshold level (dB) was considered the weaker ear. Hearing threshold levels in the low (HTL-L) and high (HTL-H) frequencies were calculated by taking an average of the weaker ears’ threshold levels at 0.5, 1, and 2 kHz, and that at 3, 4, and 6 kHz, respectively.

All the procedures including obtaining informed consent, questionnaire, and study protocols were in compliance with relevant laws and institutional guidelines, and approved by the Research Ethics Committee of Tzu Chi Hospital/University (IRB105-06-B).

Descriptive statistics was conducted on the basis of participants’ basic information. Independent t-test and chi-square test were used to compare continuous and categorical variables between study and control groups, respectively. Linear regression analysis was applied to determine whether HTL-L or HTL-H was significantly different between the two groups with or without adjustment for covariates (e.g., gender, education, years in current job, and smoking). All analyses were performed using SAS version 9.4 software.

Table 1: Tasks involved in stonework and respective equipment used during the process

| Task and equipment | Function |
|--------------------|----------|
| Primary cutting    | Slicing rock cubes to pieces of boards |
| Gang saw           | Board surface finishing |
| Polishera*         | Cutting boards to desired shapes or sizes |
| Secondary cutting  | Smoothing and finishing |
| Bridge saw/waterjet cutter | |
| Handheld grinder   | |
| Crushing           | Breaking rocks to small ones |
| Jaw crusher        | |
| Vibrating/rotary screen machine | |
| Sculpturing and gemstone processing | |
| Handheld cutter*   | Cutting rocks to desired shapes or sizes |
| Handheld grinder*  | Finishing |

*No analysis of frequency spectrum.
RESULT

The 8-h TWA for the environmental and personal measurements of noise were conducted in nine stone factories [Table 2]. More than half of the measurements for either environmental or personal monitoring were higher than 85 dB(A), and some even exceeded 90 dB(A), indicating that occupational noise exposure in the stonework sector was a serious issue. Gang saw 1, an old model for years, resulted in a much higher TWA value (94 dB[A]) than that measured from a recently new model, gang saw 2 (77.4 dB[A]), suggesting that replacement could be one of the strategies that could help minimize exposure. It was surprising to see that personal exposure in most cases (i.e., seven of nine) was higher than the respective environmental exposure, which was presumably considered the major source of noise hazard in the factories. A reasonable answer to this finding is that stoneworkers might have repeatedly approached places closer to the machines than the requisite 3–5 m apart, which was how the environmental exposure was measured.

The frequency spectra for the seven machines are given in Figure 1. Because of the variability of sampling locations, it may not have been appropriate to compare the magnitudes of noises among the seven measurements. However, frequencies within each spectrum were readily comparable. Gang saw, the major component for primary cutting, had sound pressure levels peaked around 1 kHz, whereas bridge saw, one of the tools for secondary cutting, resulted in equivalently high sound pressure levels from 0.5 through 5 kHz. All other machines reached the highest levels between 2 and 4 kHz, which overlapped most of the bands for HTL-H testing.

Basic information regarding the participating stoneworkers and administrative staff showed differences in various aspects [Table 3]. Above 90% of the stoneworkers were males, compared to 28% of controls; it was common that men perform laboring jobs, rather than administrative jobs. Other than gender, education and exposure to smoke were also significantly different between the two groups ($P < 0.001$). These significant variables might have had confounding effects on the HTL results and were adjusted in the linear regression analysis.

Data of HTL-L and HTL-H, categorized into several levels, are listed by group in Table 4. Stoneworkers in the study group apparently had higher hearing thresholds in both the low and high frequencies ($29.2 ± 7.0$ dB, $41.2 ± 17.4$ dB) than did the control group ($24.3 ± 9.8$ dB, $25.1 ± 14.9$ dB). Those who were considered having normal hearing ability (<25 dB) were merely about 25% or less among the stoneworkers compared to 60% for controls. A big difference in hearing loss was observed from the HTL-H results, which showed 51 and 8% of study participants and controls, respectively, with thresholds exceeding 40 dB. Checking the weaker ears’ threshold levels by frequency, we saw large gaps between the two groups occurring at the high frequency end [Figure 2], which is a sign of NIHL among the stoneworkers.

To further examine the differences between stoneworkers and controls in HTL-L or HTL-H, we conducted linear regression analysis with adjustment for possible confounding factors [Table 5]. For HTL-L, the model without adjustment showed significance ($P = 0.012$), same as that in Table 4, but became

---

Table 2: Eight-h TWA of noise measurements (dB[A]) for environmental and personal monitoring at nine stone factories

| Type of stonework  | Machine for environmental measurement | Environmental measurement | Personal measurement |
|--------------------|--------------------------------------|---------------------------|---------------------|
| Crushing           | Jaw crusher 1                         | 87.6                      | 73.3                |
|                    | Jaw crusher 2                         | 86.0                      | 91.4                |
|                    | Rotary screen machine                 | 82.3                      | 84.4                |
|                    | Vibrating screen machine              | 91.1                      | 84.9                |
| Primary cutting    | Gang saw 1                            | 94.0                      | 95.7                |
|                    | Gang saw 2                            | 76.8                      | 91.4                |
|                    | Polisher 1                            | 77.4                      | 83.6                |
|                    | Polisher 2                            | 82.4                      | 87.0                |
|                    | Polisher 3                            | 87.4                      | 91.0                |
| Mean ± SD          | 85.0 ± 6.2                            | 87.0 ± 5.5                |                     |

---

Figure 1: Frequency spectra of machines for primary cutting (a) and crushing (b)
insignificant \((P = 0.207)\) with adjustment for confounding factors. It was suggested that stoneworkers’ hearing ability in the low frequencies should display no significant difference from that of the administrative staff. For HTL-H, even with adjustment, the model showed significance \((P = 0.002)\) between the two groups, indicating that stoneworkers who were exposed to occupational noises during work shifts suffered considerable hearing loss in the high frequencies.

**DISCUSSION**

A previous study conducted by Yang et al.,\(^6\) including more than 300 participants from the same population of stoneworkers as ours, provided valuable results for comparisons with this work. They reported 87.7 dB(A) as the mean sound pressure level, which was close to the personal exposure result of ours (87.0 dB[A]), indicating that stonework was a stable and steady noise-laden business over the years. In accordance with the recommendation by ILO or Taiwan’s Occupational Safety and Health Act, employers should take action to provide hearing protection, including environmental monitoring and exposure assessment, protection gears provision, educational training, and health examination and management. Unfortunately, these stone factories did not seem to comply with the regulation well, according to our on-site

### Table 3: Basic information of study participants and controls

| Item                        | Study          | Control        | \(P\) value |
|-----------------------------|----------------|----------------|-------------|
| \(N\) (%) Mean ± SD        | \(N\) (%) Mean ± SD |
| Total                       | 55             | 25             | <0.001*     |
| Gender\(^a\)                | Male 50 (90.9) | 7 (28.0)       |             |
|                             | Female 5 (9.1) | 18 (72.0)      |             |
| Age (year)                  | 40.5 ± 12.2    | 40.5 ± 12.0    | 0.60        |
| Education\(^a\)             | Up to high school 38 (74.5) | 7 (28.0) | <0.001*     |
|                             | College or above 13 (25.5) | 18 (72.0) |             |
| Years in current job        | 7.5 ± 7.1      | 11.3 ± 8.8     | 0.044*      |
| Smoking\(^a\)               | No 27 (49.1)   | 22 (88.0)      | 0.001*      |
|                             | Yes 28 (50.9)  | 3 (12.0)       |             |
| Exposure to second-hand smoke\(^a\) | No 17 (33.3) | 8 (32.0) | 0.013*      |
|                             | Sometimes 18 (35.3) | 16 (64.0) |             |
|                             | Often 16 (31.4) | 1 (4.0)       |             |
| Drinking\(^a\)              | Never 14 (25.5) | 9 (36.0) | 0.630       |
|                             | Sometimes 33 (60.0) | 13 (52.0) |             |
|                             | Often 8 (14.5)  | 3 (12.0)       |             |
| Betel nut chewing\(^a\)     | No 41 (74.5)   | 22 (88.0)      | 0.242       |
|                             | Yes 14 (25.5)  | 3 (12.0)       |             |

\(^a\) Chi-square test. *\(P < 0.05\).

### Table 4: Statistics of hearing threshold levels (dB) of the weaker ears in the low (HTL-L) and high (HTL-H) frequencies

| Item                        | Study          | Control        | \(P\) value |
|-----------------------------|----------------|----------------|-------------|
| \(N\) (%) Mean ± SD        | \(N\) (%) Mean ± SD |
| HTL-L                       | 55             | 25             | 0.012       |
| \(<25 \text{ dB}\)         | 10 (18.2)      | 15 (60.0)      |             |
| \(25–40 \text{ dB}\)       | 40 (72.7)      | 8 (32.0)       |             |
| \(40–70 \text{ dB}\)       | 5 (9.1)        | 2 (8.0)        |             |
| HTL-H                       | 55             | 25             | <0.001      |
| \(<25 \text{ dB}\)         | 14 (25.5)      | 15 (60.0)      |             |
| \(25–40 \text{ dB}\)       | 13 (23.6)      | 8 (32.0)       |             |
| \(40–70 \text{ dB}\)       | 24 (43.6)      | 1 (4.0)        |             |
| \(\geq70 \text{ dB}\)      | 4 (7.3)        | 1 (4.0)        |             |

HTL-L = \([\text{HTL}(0.5\text{k}) + \text{HTL}(1\text{k}) + \text{HTL}(2\text{k})]/3\). HTL-H = \([\text{HTL}(3\text{k}) + \text{HTL}(4\text{k}) + \text{HTL}(6\text{k})]/3\).
There was a difference in the NIHL prevalence between what Yang et al.\[6\] reported (31.7\%) and our audiometric results (more than 70\% > 25 dB in Table 4), which were not measured in a qualified audiometric test room for the feasibility of study implementation. This is one of the limitations of the study, and thus, we only used the data for the group comparison of hearing thresholds. Both the study and control groups displayed audiometric notches at 6 kHz, rather than 4 kHz that was commonly considered an early NIHL marker [Figure 2]. It is not unusual to see the audiometric notch occurring at 6 kHz;\[7-9\] as described in the ACOEM Guidance Statement on NIHL,\[10\] “its first sign is a ‘notching’ of the audiogram at the high frequencies of 3000, 4000, or 6000 Hz with recovery at 8000 Hz.” An audiometric notch found in the high frequencies, however, was not necessarily considered a sign of NIHL, as suggested by Osei-Lah and Yeoh,\[9\] who indicated that high-frequency notch without noise exposure was commonly observed, as seen for the controls in Figure 2. By comparing the hearing thresholds of both groups, we found a significant difference between the notches at 6 kHz, which sufficed to serve as an early NIHL sign among the stoneworkers. Although it is said that our equipment, TDH-39 earphones, is subject to a high variability of hearing threshold measurements at 6 and 8 kHz,\[11,12\] which may have somewhat contributed to the notches, the significant difference between both notches should be a clear result showing a sign of NIHL among the stoneworkers.

Another difference from our results was that Yang et al.\[6\] showed a downsloping pattern without recovery at 8 kHz, which was considered a sign of presbycusis or age-related hearing loss, according to the guidance.\[10\] Checking the ages of participants in both studies, we found that the stoneworkers in this study were approximately 10 years younger than those in Yang et al., which reasonably explains the difference at 8 kHz. This difference in notching between both studies could be due to a selection bias of participants for our study, which recruited relatively young participants. Owing to this, we were able to see young stoneworkers have an early sign of NIHL (i.e., notchings at 3, 4, and 6 kHz with recovery at 8 kHz), whereas Yang et al., having many veteran workers, observed a sign of presbycusis. It is expected that further damage to hearing (i.e., 8 kHz) will occur should the exposure go on.

The analysis of frequency spectra of noise [Figure 1] was in support of the work of Ottoni et al.,\[13\] which found noise during stonework peaking at 4 kHz. Because one of the NIHL characteristics was audiometric notching in the high frequencies (3, 4, and 6 kHz), noises with peaks in these bands, such as those generated from stonework, are dangerously harmful to hearing ability. Ottoni et al. also detected peak values for other industries and found 2 kHz for woodwork and 8 kHz for metallurgical work. Interestingly, having compared the two types of work, they found that woodwork with higher doses of noise resulted in lower concern with audiometric notch than did metallurgical work. It is suggested that noise with high intensities in the high frequencies could be more harmful to hearing ability than that in the low frequencies.\[14\] Data of our spectral analysis and audiology showed frequency peaking near 4 kHz and audiometric notching at 6 kHz, respectively, suggesting a exposure–response relationship. Nonetheless, the notch occurrence did not perfectly match with the frequency peak at 4 kHz. Osei-Lah and Yeoh\[9\] may have provided an explanation: “most cochlea outer hair cell loss occurs at approximately half octave above the centre frequency of the acoustic stimulus.” Therefore, our results along with the previous study of Ottoni et al.\[13\] recommend that

![Figure 2: Hearing threshold levels for study and control groups by frequency (bars denote 95% confidence intervals)](image)

### Table 5: Linear regression analysis of hearing threshold levels in the low and high frequencies for study participants and controls

|          | HTL-L | HTL-H |
|----------|-------|-------|
|          | Unadjusted model | Adjusted model\(^a\) | Unadjusted model | Adjusted model\(^a\) |
| Study    | \(\beta \pm SE\) | \(P\)-value | \(\beta \pm SE\) | \(P\)-value |
| Control  | Referent | 4.95 ± 1.93 | 0.012 | 3.79 ± 2.97 | 0.207 |
|          | \(\beta \pm SE\) | \(P\)-value | \(\beta \pm SE\) | \(P\)-value |
| Study    | Referent | 16.17 ± 1.90 | <0.001 | 17.41 ± 5.25 | 0.002 |
| Control  | Referent | Referent | Referent | Referent |

Hearing loss was calculated based on hearing threshold levels (HTLs) in the weaker ear between the left and right ears. \(^a\)Model adjusted for years in current job, gender, education, and smoking.
stoneworkers who are exposed to harmful occupational noises have to pay attention to protection from NIHL.

There are several limitations in the study, among which, unable to conduct pure tone audiometry in a standard room is the most crucial. Stonework factories were willing to let their employees participate in the study upon no interruption in their routine work. Under such a condition, we had to bring a portable audiometer for testing in a quiet room on site. Even though the background noise affected hearing thresholds more in the low frequencies than in the high frequencies, the interference with hearing threshold measurements in the notching bands may have occurred to make comparisons with results from other studies unsuitable. Despite the limitation, the audiometric results for the study participants and controls were comparable. The limited sample size is a matter of concern; however, our results of personal monitoring were much similar to that of the previous study, suggesting representativeness of the data. Due to the fewer number of participants, we assessed the exposure as a whole without further examination by job types. This should not be a problem, because the noise exposure for stonework did not appear to be largely different among workers who usually covered multiple jobs in the workplaces. Yang et al. showed a difference in hearing impairment between stoneworkers with and without additional exposure to epoxy adhesives. This study did not have to consider this factor that usually existed in factories involved with secondary cutting, because the majority of participating workers came from primary cutting and stone crushing factories with little exposure to epoxy adhesives.

**Conclusion**

Stoneworkers who are exposed to high doses of noise have significantly higher hearing threshold levels in the high frequencies, a sign of NIHL, than controls. The spectral analysis for major equipment showed noise frequencies peaking between 2 and 4 kHz, which were more harmful to hearing ability than that in the low frequencies. Regulation compliance needs improving to better protect the hearing ability of stoneworkers.

**Financial support and sponsorship**

This study is supported by Institute of Labor, Occupational Safety and Health, Department of Labor, Taiwan (Grant No. ILOSH-A311), and partly supported by Tzu Chi University Supplement Grant (610400184-08).

**Conflicts of interest**

There are no conflicts of interest.

**References**

1. Azizi MH. Occupational noise-induced hearing loss. Int J Occup Environ Med 2010;1:116-23.
2. Nelson DI, Nelson RY, Concha-Barrientos M, Fingerhut M. The global burden of occupational noise-induced hearing loss. Am J Ind Med 2005;48:446-58.
3. Concha-Barrientos M, Campbell-Lendrum D, Steenland K. Occupational Noise: Assessing the Burden of Disease From Work-Related Hearing Impairment at National and Local Levels. Geneva: World Health Organization2004. [WHOEnvironmental Burden of Disease Series, No.9].
4. Wu T-N, Liou S-H, Shen C-Y, Hsu C-C, Chang S-L, Wang J-H, et al. Surveillance of noise-induced hearing loss in Taiwan, ROC: A report of the PRESS -NIHL results. Prev Med 1998;27:65-9.
5. Kitcher ED, Ocansey G, Tumpi DA. Early occupational hearing loss of workers in a stone crushing industry: Our experience in a developing country. Noise Health 2012;14:68-71.
6. Yang HY, Shie RH, Chen PC. Hearing loss in workers exposed to epoxy adhesives and noise: A cross-sectional study. BMJ Open 2016;6:e010533.
7. Chen J-D, Tsai J-Y. Hearing loss among workers at an oil refinery in Taiwan. Arch Environ Health 2003;58:55-8.
8. McBride D, Williams S. Audiometric notch as a sign of noise induced hearing loss. Occup Environ Med 2001;58:46-51.
9. Osei-Lah D, Williams S. Audiometric notch: An outpatient clinic survey. Int J Audiol 2010;49:95-8.
10. Kirchner DB, Eversen E, Dobie RA, Rabinowitz J, Kopke R, et al. Occupational noise-induced hearing loss: ACOEM task force on occupational hearing loss. J Occup Environ Med 2012;54:106-8.
11. Lutman ME, Qasem HY. A source of notches at 6 kHz. In: Prasher D, Luxon L, editors. Advances in Noise Research: Biological Effects of Noise. New Jersey: John Wiley & Sons, Inc; 1998. p. 170-6.
12. Coles RR, Lutman ME, Buffin JT. Guidelines on the diagnosis of noise-induced hearing loss for medicolegal purposes. Clin Otolaryngol 2000;25:264-73.
13. Ottini AO, Barbosa-Branco A, Boger ME, Gravelli SL. Study of the noise spectrum on high frequency thresholds in workers exposed to noise. Braz J Otorhinolaryngol 2012;78:108-14.
14. Somma G, Pietroiusti A, Magrini A, Coppeta L, Ancona C, Gardi S, et al. Extended high-frequency audiometry and noise induced hearing loss in cement workers. Am J Ind Med 2008;51:452-62.