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Occupational Noise Exposure and Hearing Loss of Workers in Two Plants in Eastern Saudi Arabia

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Objective: To determine the prevalence of hearing loss associated with occupational noise exposure and other risk factors.

Design: A cross-sectional study involving 269 exposed and 99 non-exposed subjects (non-industrial noise exposed subjects) randomly selected. Current noise exposure was estimated using both sound level meter and noise-dosimeter. Past noise exposure was estimated by interview questionnaire. Otoscopic examination and conventional frequency (0.25–8 kHz) audiometry were used to assess the hearing loss in each subject.

Results: 75% (202 subjects) from the exposed group were exposed to a daily Leq above the permissible level of 85 dB(A) and most (61%) of these did not and had never used any form of hearing protecion. Hearing loss was found to be bilateral and symmetrical in both groups. Bivariate analysis showed a significant hearing loss in the exposed vs non-exposed subjects with a characteristic dip at 4 kHz. Thirty eight percent of exposed subjects had hearing impairment, which was an 8-fold higher rate than that found for non-exposed subjects. Multivariate analysis indicated exposure to noise was the primary, and age the secondary predictor of hearing loss. Odds of hearing impairment were lower for a small sub-group of exposed workers using hearing protection (*N*=19) in which logistic regression analysis showed the probability of workers adopting hearing protective devices increased with noise exposure, education, and awareness of noise control. Hearing loss was also greater amongst those who used headphones to listen to recorded cassettes.

Conclusion: Gross occupational exposure to noise has been demonstrated to cause hearing loss and the authors believe that occupational hearing loss in Saudi Arabia is a widespread problem. Strategies of noise assessment and control are introduced which may help improve the work environment. © 2001 British Occupational Hygiene Society. Published by Elsevier Science Ltd. All rights reserved

Keywords: noise; hearing loss; Saudi Arabia; hearing protectors; impact noise

INTRODUCTION

General

Occupational exposure to excessive noise is commonly encountered in a great variety of industrial processes. The resulting injury of occupational hearing loss is a well-recognized and global problem, and affects many subjects both civilians and military (Fletcher and Chandler 1983; Hessel and Sluis 1987; Alleyne *et al.*, 1989; Army Environmental Hygiene Agency 1990). Occupational hearing loss continues to be among the 10 leading occupational diseases in both Canada (Alleyne *et al.*, 1989) and the United States (Anon, 1986). In the US about 11 million workers are exposed to potentially hazardous noise levels in the work place (NIOSH, 1988). In Sweden, about 9% of the total work force are exposed continu-

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ously to a hazardous noise level (Ivarsson *et al.*, 1992). Noise induced hearing loss (NIHL) is very costly. Approximately 100 million dollars are paid annually for compensation in Sweden (Ivarsson *et al.*, 1992). The Canadian compensation board estimated the average cost per hearing loss claim to be C$14 000 (Alleyne *et al.*, 1989). In the United States, compensation for hearing is estimated as US$200 million for the calendar year 1990 (Army Environmental Hygiene Agency, 1990).

Occupational hearing loss resulting from exposure to high noise level depends not only on exposure time but also on the frequency, intensity, and the type of noise (continuous or impact). During the last few decades, greater understanding of the effects of noise on hearing have led to minimum standards for noise exposure being adopted and legislation passed to limit noise exposure has been enacted in many countries. However, difficulties have arisen where there was no pre-employment audiometry and unknown previous occupational noise exposure as in developed countries.

In Saudi Arabia, many industries have been established since the 1970s. Many within the work force of these industries were and are exposed to occupational hazards and consequently are at high risk of work-related diseases. Though work-related diseases are amenable to prevention through the recognition, evaluation, and control of the hazards in an ideal world, effective practice of occupational health and hygiene has yet to be fully accepted and developed in Saudi Arabia as in the other developed countries. To date few studies have been conducted in Saudi Arabia to investigate the occupational hazards, such as noise, and its health effects on the working population. Against this background, the investigators designed and progressed an epidemiological study of noise exposure and hearing loss among workers in two plants in the Eastern Province of Saudi Arabia.

Objectives

The specific objectives of the study were: to estimate levels of current and past occupational noise exposure, to determine the extent and pattern of hearing loss among the study population, to assess the risk factors that influence hearing loss at each of the conventional frequencies tested, and finally to evaluate the knowledge and practice of workers to noise hazards.

SUBJECTS AND METHODS

Workers from two factories in the Eastern Province of Saudi Arabia were selected for this cross-sectional study. One factory manufactured steel pipes and the other manufactured air conditioning units. The study was conducted between 1996 and 1999. 269 exposed subjects were randomly selected from a total workforce of 600 from the two factories. Similarly 99 non-exposed subjects (non-industrial noise exposed subjects) were randomly selected from the administrative staff of the two factories and other neighbouring industries. All subjects were males, as females do not work in industry in Saudi Arabia.

Estimates of noise levels along with concurrent octave band analysis were determined throughout all work areas in both two factories using a precision integrating sound level meter (Bruel and Kjaer 2230 and 1/3-1/1 octave filter set 1625). Personal noise exposure from each subject was obtained using noise dosimeters (type B and K 4436 and type MARK MK1). Past occupational noise exposure was estimated by interviewer-administered questionnaire. In addition the Noise Immission Level (NIL) as defined by Burns and Robinson (1970) was calculated for each subject (exposed and non-exposed) as follows:

i. Current Noise Immission Level (CNIL) = Leq + $10\text{Log}_{10}(T)$; where Leq is the current equivalent continuous sound level in dB(A) and T=duration of current exposure in yr.
ii. Past Noise Immission Level (PNIL) = Leq + $10\text{Log}_{10}(T)$; where Leq is the past estimated equivalent continuous sound level in dB(A) and T=duration of past exposure in yr.
iii. Total Noise Immission Level (TNIL)=CNIL+PNIL using the summation law for the sound pressure level which written as:

$$\text{Total sound pressure level} = 10\text{Log}_{10}\frac{P_1^2 + P_2^2}{P_{\text{ref}}^2}$$

where, P=sound pressure level and P_{ref}=reference sound pressure.

It follows that the TNIL = $10\text{Log}_{10}(10^{\text{CNIL}/10} + 10^{\text{PNIL}/10})$

Information collected from the questionnaire included personal data; present and past occupational history, including subjective estimates of noise exposure; present and past medical history of hearing problems; hereditary ear diseases; use of ototoxic and other drugs; and hobbies. Questions were also included which were designed to evaluate the subjects knowledge and practice relating to occupational exposure and protection to noise prior to audiometric testing; all subjects were examined otoscopically in addition to Rinne's and Weber's tests. Pure-tone air conduction audiometric test was conducted to determine the hearing thresholds in the conventional frequencies 0.25, 0.5, 1, 2, 4 and 8 kHz for both ears of each subject, using a Grason-Stadler GSI 16 audiometer, with TDH-50P ear phones. The audiometer met ANSIS3.26-1981 standard, and was calibrated in dBHL.

All audiometric tests were conducted by two experienced audiologists in a testing facility fulfilling ISO 8253-1(1989) criteria. Measurements were taken using 5 dB increments. Audiometric tests were only made at least 18 h after the last exposure to noise to allow recovery from any temporary hearing threshold shifts. The criterion used for hearing impairment was the average hearing threshold of 25 dB or more at frequencies 0.5, 1, 2, and 4 kHz. Ears with conductive hearing or impacted by wax or perforated were excluded from the statistical analysis. Subjects with a history of firing guns and non-exposed subjects with previous occupational exposure to noise estimated to be greater than or equal to 85 dB(A) were excluded from the bivariate statistical analysis.

Reliability of the data collected within the study was determined using a variety of techniques. As a measure of reliability of the answers of the subjects to the questionnaire, the statistic Kappa was calculated for pre and post answer for each question. The Kappa coefficient varied between 0.71 and 1.00 which indicates reliable responses. The Pearson correlation coefficient calculated between the two audiologists for each frequency ranged between 0.7 and 0.99, indicating that audiograms obtained through the two audiologists had good agreement. Finally, to determine the comparability between the two noise dosimeters used, the mean of the difference and correlation coefficient between 30 paired readings from of the noise-dosimeter type B&K and that of type Mark 1 (taken simultaneously) were calculated and found to be 0.2 and 0.9958 respectively, indicating results from the two dosimeters were virtually identical.

STATISTICAL ANALYSIS

Data were analyzed using SPSS (version 6.0). Normality of the audiometric data was first tested by computing the skewness and kurtosis. Descriptive statistics, means, medians, standard deviations were calculated to describe central tendencies in each of the groups. *T*-test for independent samples, and median test were used to evaluate the differences between mean and median of the groups, and between right and left ears in each group respectively. Two-way analysis of variance was performed to study the effect of noise and age on hearing loss and the interaction between them. Multiple linear regression analysis and multiple logistic regression analysis were used to determine the most important factors (predictors) that influence the measured hearing threshold values, the hearing impairment and the use of hearing protection devices respectively.

RESULTS

Demographic characteristics of the study population

The majority, 66% (244 subjects), of the study population were less than 35 yr of age. Of these, 170 (70%) were exposed. The mean of age of the total exposed subjects was 32.9 (SE=0.5) yr compared with 30.2 (SE=0.7) for the non-exposed subjects (P=0.003). Of the total exposed subjects, 182 (67.7%) had a current duration of exposure of less than 5 yr, with a mean of 4.5 (SE=0.3) yr for the total exposed subjects. However the majority of the exposed subjects (56.5%) worked for 5 yr or more before joining their current factories, and only 8.6% of them never worked in the past. The exposed subjects belong to three major ethnic groups: Indians (57.6%), Filipinos (23.4%), Saudis (13%), and others (5.9%). The corresponding figures for the non-exposed subjects were 59.6%, 20.2%, 13.1% and 7.1% respectively. Both factories adopt the two shift system (12 h each), and most of workers worked on average a 72 h week (12 h per day, 6 days a week). However, official daily working hours per day were 8, and the extra hours were considered as overtime earning additional income.

Noise levels

Workers were exposed to predominantly impact noise with continuous background of wide or mid-band type in the steel factory, while in the air conditioners factory workers were exposed to noise of wide-band type and predominantly continuous, except for some machines where it was impact with continuous background.

The overall noise levels in the two factories ranged between 72 and 102 dB(A). It exceeded the 85 dB(A) criterion adopted in Saudi Arabia in eight out of the ten departments in the two factories (Table 1). Three quarters (202 subjects) of the exposed workers were exposed to a daily Leq above the permissible level of exposure, currently 85 dB(A). Nearly half (93 subjects) of them were exposed to a daily Leq above 90 dB(A) (Table 2). While non-exposed subjects (non-industrial noise exposed subjects) were exposed to a daily Leq less than 80.3 dB(A). The arithmetic mean Total Noise Immission Level (NIL) for exposed workers (N=269) was 95.4 dB (A). While that for non-exposed subjects (N=99) was 84.8 dB(A) (Table 2). Sixty-one percent of workers who were exposed to a daily Leq greater than 85 dB(A) never used hearing protection devices.

Hearing threshold levels

It was found that the distribution of the data (hearing levels) of all subjects was positively skewed. Ln-transformation was applied to help normalise the distribution. Consequently, parametric tests of significance were applied to ln-transformed data, after the exclusion of those reported firing guns. No statistically significant difference was found (P>0.05) between right and left ears in both exposed and non-exposed groups (Fig. 1). Thus results of both ears are presented and discussed rather than left and right ears separately.

The type of the noise was found to be different between the two factories, one being continuous (air conditioners manufacturing) the other continuous and impact (steel plant) and this may have a confounding

Table 1. The overall sound pressure level in the two factories by department

Factory	Department	Sound level range in dB(A)	No.of workers(%)
Steel	Steel fabrication	88–102	70 (26)
	Tower	87–100	18 (6.7)
	Shipping	80–84	9 (3.3)
Air conditioners	Fabrication shop	85–100	30 (11.2)
	Coil shop	85–96	19 (7.1)
	Tubing shop	85–92	15 (5.6)
	Furnace	86–100	12 (4.5)
	Spot-welding shop	85–95	19 (7.1)
	Duct shop	85–90	20 (7.4)
	Assembling and packaging	72–80	57 (21.2)
Total (%)	All departments	72–102	269 (100)

Table 2. Distribution of the total subjects by equivalent continuous noise level pershift (Leq/shift) as assessed by personal noise dosimeter, together with the mean Leq/shift and mean of the Total Noise Immission Level(TNIL)

Leq/shift in dB(A)	Exposed			Non-exposed (*N*=99) (%)
	Steel factory (*N*=97) (%)	AC factory (*N*=172) (%)	Both (*N*=269) (%)	
<80	1 (1)	8 (4.7)	9 (3.3)	98 (99)
80–85	5 (5.2)	53 (30.8)	58 (21.6)	1 (1)
85.1–90	23 (23.7)	86 (50)	109 (40.5)	–
90.1–95	37 (38.1)	20 (11.6)	57 (21.2)	–
95.1–100	18 (18.6)	4 (2.3)	22 (8.2)	–
>100	13 (13.4)	1 (0.6)	14 (5.2)	
Mean[a] Leq/shift	92.8	86.4	88.7	71.8
Mean[a] TNIL	111.6	93.3	95.4	84.8

[a]Arithmetic mean.

effect in interpretation of occupational hearing loss. However, accoding to Atherly and Martin (1971), continuous and impact noise are considered to have an equal effect on hearing provided that the noise level is below 125 dB. As this was the case in this study, hearing loss vs exposure in workers from the two factories were combined prior to analysis.

Exposed subjects with Leq/shift greater than 85 dB (A) had significantly higher mean (worse hearing) ($P<0.02$) and median ($P<0.03$) than the non-exposed subjects at every frequency tested (Table 3). The exposed subjects with Leq/shift≤85 dB (A) ($N=118$ ears) had significantly greater mean and median ($P<0.03$) than the non-exposed subjects at all frequencies tested (Table 3). Although both exposed and non-exposed subjects were currently exposed to Leq/shift≤85 dB(A), the significant difference between them might be due to the past NIL and current NIL (i.e. total NIL) of exposed group. The difference between the mean of the measured hearing threshold values of the exposed subjects with Leq/shift> 85 dB(A) and that of the non-exposed subjects increased as the frequency increased beyond the frequency 1 kHz. This difference reached its maximum at frequency 4 kHz, before it decreased again at a frequency of 8 kHz (Table 3).

After controlling the age effect through stratification (Fig. 2), the *t*-test showed that the mean threshold of the exposed subjects was still significantly worse ($P<0.05$) than that of the non-exposed subjects at all frequencies tested for the exposed subjects aged ≥20 and <40 yr, while for the older group (40–49 yr), it was worse at the frequencies 2,4 and 8 kHz ($P<0.05$). However, for the younger subjects (18–19 yr), although the sample size was small, there was no significant difference between the two groups (Fig. 2). It was found that, 119 (24.5%) ears and 56 (11.5%) ears of the exposed subjects had observed dip(>20 HLdB) localized at frequencies 4 and 8 kHz, respectively, compared to 9 (5.8%) and 8 (5.2%) ears of the non-exposed subjects. The difference between the two groups was significantly different ($P<0.03$) in this respect.

Two way analysis of variance (Hierarchical Model) showed there was no interaction between the noise exposure and the age effect at any of the six frequencies tested ($P>0.1$), indicating that the effect of the two factors is additive. The effect of noise on hearing was statistically significant ($P<0.001$). This means that at every frequency tested the exposed subjects had worse measured hearing threshold values than the non-exposed subjects regardless of age.The effect of the age was also statistically significant ($P<0.03$) for all frequencies. This indicates that as

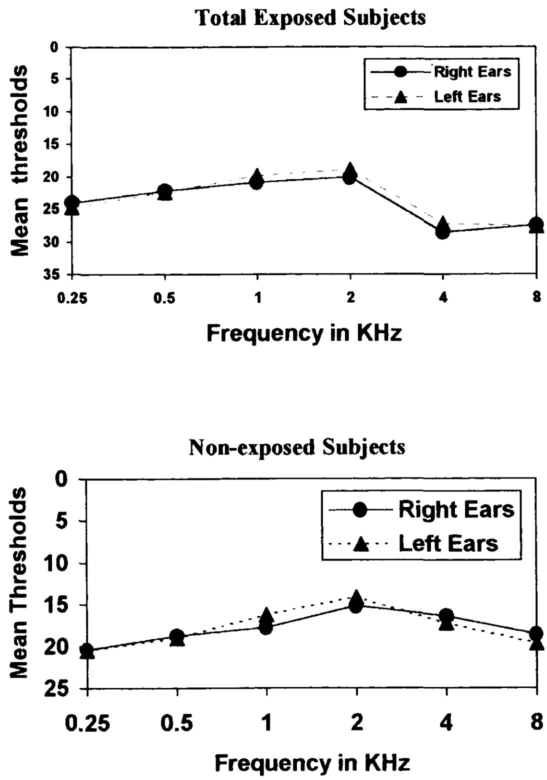

Fig. 1. Comparison between right and left ears of total exposed (upper) and of non-exposed subjects (lower).

age group increased, the mean of the measured hearing threshold values increased too, whether the subjects were exposed to noise or not.

Multi-linear regression analysis was applied to determine the most important factors (predictors) which influence measured pure-tone hearing threshold values at each frequency. The variables used are presented in Table 4 and the results of multiple linear regression analysis are presented in Table 5. The results (Table 5) demonstrate that TNIL was the most important factor influencing the measured hearing threshold values and they were directly related for each of the frequencies tested. The TNIL alone accounted for between 80 and 100% of the variation of the measured threshold at all frequencies tested (Table 5). Age did not influence the hearing thresholds at the frequencies 0.25 and 0.5 kHz. However, at all other frequencies, age was positively related to hearing thresholds. The contribution of the age alone to the total variation of the measured hearing threshold values ranged between 10 and 15% (Table 5) and ranked as the second important factor. Wearing hearing protection devices (WHPD) was among the important factors that influence the measured hearing threshold values at low frequencies. It was inversely (−ve sign, Table 5) related to the hearing thresholds. In other words, subjects who did wear hearing protection devices had lower (i.e. better) measured hearing threshold values than subjects who did not wear hearing protection. The contribution of the WHPD to the total variation of the hearing threshold values was 10%. The inclusion of the WHPD in the models for the frequencies 0.5 and 1 kHz only, indicates that this practice was mostly related to the hearing loss in the speech frequencies range. None of the remaining variables was included in any model, indicating that none influenced measured hearing threshold values at any frequency tested.

Table 3. Comparison of mean, and median of hearing thresholds in (HLdB) between non-exposed and exposed subjects, after exclusion of subjects with a history of firing guns, for the conventional frequencies tested (*t*-test applied to Ln-transformed data)

Frequency (kHz)	Statistic parmeter	Non-exposed (155 ears)	Both factories	
			Leq<85 (118 ears)	Leq>85 (368 ears)
0.25	Mean (SE)	20.5 (0.45)	23.6 (0.56)	24.6 (0.37)
	Median	20	25	25
P-value	Mean (Median)	–	0.01 (0.01)	0.01 (0.02)
0.5	Mean (SE)	18.8 (0.44)	21.6 (0.48)	22.6 (0.33)
	Median	20	20	25
P-value	Mean (Median)	–	0.01 (0.01)	0.01 (0.01)
1	Mean (SE)	17 (0.39)	20.1 (0.43)	20.5 (0.34)
	Median	15	20	20
P-value	Mean (Median)	–	0.01 (0.01)	0.01 (0.01)
2	Mean (SE)	14.6 (0.4)	18.1 (0.58)	20 (0.47)
	Median	15	20	20
P-value	Mean (Median)	–	0.01 (0.01)	0.01 (0.01)
4	Mean (SE)	16.8 (0.53)	23.3 (1.2)	29.4 (0.79)
	Median	15	20	25
P-value	Mean (Median)	–	0.01 (0.01)	0.01 (0.01)
8	Mean (SE)	19.1 (0.72)	24.9 (1.3)	28.4 (0.84)
	Median	15	20	25
P-value	Mean (Median)	–	0.01 (0.01)	0.01 (0.01)

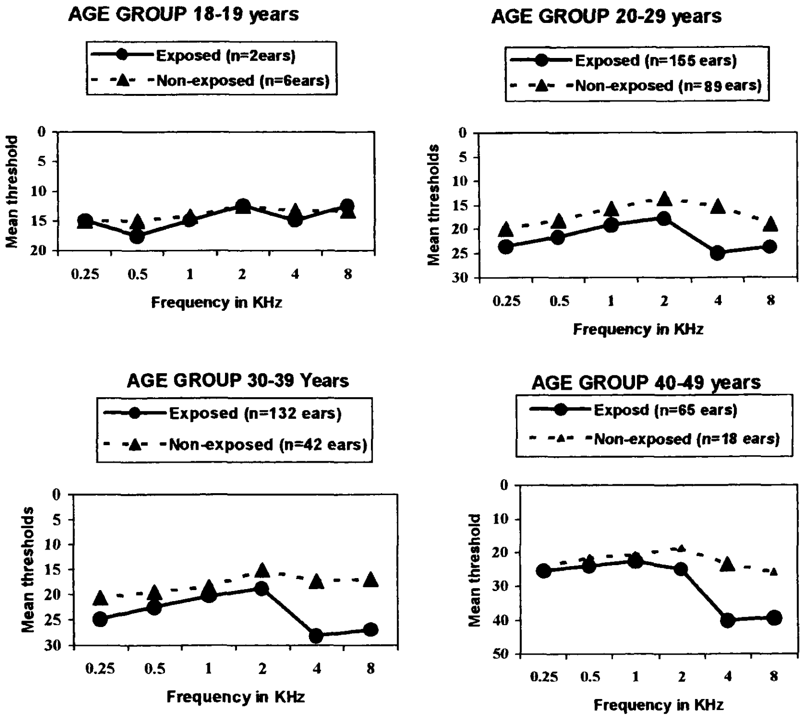

Fig. 2. Hearing thresholds of exposed subjects from both factories versus non-exposed subjects in different age groups.

Table 4. Description of the independent variables (predictors) used in both the multiple linear and multiple logistic regression analysis

Variable	Type	Coding	Total subjects (N=368) Mean	SD
Age	Continuous	–	32.09	7.70
Total noise immission level (TNIL)	Continuous	–	92.44	7.06
Singing	Binary	Yes=1, No=0	0.02	0.15
Motor-cycling	Binary	Yes=1, No=0	0.01	0.10
Wearing hearing protection device	Binary	Yes=1 No=0	0.05	0.22
Firing guns	Binary	Yes=1, No=0	1.00	0.30
Use of headphones	Binary	Yes=1, No=0	0.23	0.42

Prevalence of hearing impairment

The prevalence of hearing impairment among the exposed subjects with Leq/shift of >85 dB(A) was 38.3% (141 out 368 ears), compared to 4.5% (7 out of 155 ears) for the non-exposed subjects (P<0.0005). Thus the odds of hearing impairment of the ears was 13 times higher in the exposed subjects [Leq/shift>85 dB(A)] than in the non-exposed group. Multiple logistic regression analysis was applied to assess the hearing impairment (dependent) and the associated risk factors (predictors). The variables used are presented in Table 4. The results of logistic regression are presented in Table 6. The impairment of hearing was positively related to two of the seven variables (predictors): the Total Noise Immission Level and Age. In other words, the odds of hearing impairment increased with the increase of each of them. The variable use of headphones (to listen to cassettes) was included in the equation and was positively related to the impairment of hearing indicating that the probability of getting hearing impairment was higher among those who used headphones than those who did not.

Knowledge and practice

The hearing protection devices available to workers throughout both factories were ear plugs. Twelve (12.4%) from the steel factory and 7 (4.1%) subjects from the air conditioners factory reported using hearing protection all the time. 73 (27%) and 177 (66%) of the 269 exposed subjects reported to use them 'sometimes' and 'never used' respectively. By observation, 17 (89.5%) out of the 19 subjects who reported using the devices all the time were found to be wearing hearing protection (Kappa=0.9) on surprise spot checks on the factory floor.

Table 5. Results of the multiple regression analysis for the Ln of measured pure tone hearing threshold values at both ears of the total subjects, at the six conventional frequencies tested, showing variables included in the equation, and the ratio of the stepwise increase of R^2 (ΔR^2) to the the total R^2 (TR^2) for each variable

Frequency variable	Regression coefficient (B)	SE of (B)	Beta	*P*-value	95% C.I (B)	$\Delta R^2/TR^{2b}$
Frequency of 0.25 kHz						
Total NIL[a]	0.012	0.002	0.28	0.0001	0.01–0.02	1.00
Constant	1.989	0.142	–	0.0001	1.71–2.27	–
Frequency of 0.50 kHz						
Total NIL[a]	0.013	0.001	0.32	0.0001	0.01–0.02	0.90
Wearing HPD[b,c]	−0.118	0.047	−0.09	0.0124	−0.21–−0.03	0.10
Constant	1.824	0.137	–	0.0001	1.56–2.09	–
Frequency 1 kHz						
Total NIL[a]	0.012	0.002	0.25	0.0001	0.01–0.02	0.80
Age	0.005	0.002	0.11	0.007	0.001–0.008	0.10
Wearing HPD[b]	−0.131	0.053	−0.09	0.0141	−0.24–−0.03	0.10
Constant	1.694	0.158	–	0.0001	1.38–2.00	–
Frequency 2 kHz						
Total NIL[a]	0.017	0.002	0.26	0.0001	0.01–0.02	0.85
Age	0.009	0.002	0.16	0.0001	0.005–0.014	0.15
Constant	0.977	0.204	–	0.0001	0.58–1.38	–
Frequency 4 kHz						
Total NIL[a]	0.030	0.003	0.37	0.0001	0.02–0.04	0.85
Age	0.017	0.003	0.22	0.0001	0.01–0.02	0.15
Constant	−0.239	0.241	–	0.3216	−0.71–0.23	–
Frequency 8 kHz						
Total NIL[a]	0.021	0.003	0.27	0.0001	0.02–0.03	0.82
Age	0.015	0.003	0.22	0.0001	0.01–0.02	0.18
Constant	0.661	0.245	–	0.0071	0.18–1.14	–

[a]Total NIL=summation of current and past noise immersion level.
[b]Total multiple R^2.
[c]HPD=hearing protection devices.

Table 6. Results of the multiple logistic regression analysis for hearing impairment showing variables included in the equation

Variable	Coefficient (Beta)	SE of (Beta)	*P*-value	Partial correlation (*R*)	Odds ratio (OR)	95% Confidence interval
Total NIL	0.14	0.02	0.0001	0.26	1.15	1.11–1.20
Age	0.06	0.01	0.0001	0.15	1.06	1.04–1.58
Use of headphones	0.54	0.22	0.0140	0.006	1.71	1.11–2.64
Constant	−16.24	1.61	0.0001	–	–	–

All the subjects who reported using the devices all the time were exposed to high levels of noise [>85 dB(A)]. Approximately 45% (122 subjects) who were exposed to a noise level of more than 85 dB(A) claimed never to use hearing protection. Twelve (16.4%) subjects of the 73 who reported using the devices sometimes were exposed to low noise level of 85 dB(A) or less. The use of hearing protection devices was positively related to the noise levels (P=0.0001). There was no statistically significant dependency (P>0.05) between the age of the subjects and the use of hearing protection devices. When the current and past duration of service were summed, the use of hearing protection devices was directly related to this summation. Workers with summation greater than 5 and less than 10 yr used the devices more often than those with low or high summation. The education level of the workers was positively related to the use of the ear protection (P=0.03). Both knowledge of the workers about the hazards of and protection against noise were positively related to the use of hearing protection devices (P<0.05). However the educational level was not related (P>0.05) to any of knowledge of the workers about the hazards of and protection against the noise. On the other hand and as expected, the knowledge of workers about the protection measures was highly related to their knowledge about the hazards of the noise (P=0.0001).

All 19 subjects who reported using hearing protection all the time mentioned the protection of oneself from noise as the reason for using the devices. However, 11 (57.9%) of them claimed that the devices were either not comfortable or interfered with communication. All workers who reported using the devices sometimes said that they do so, when they felt it was noisy. Again, 36 (49.3%) of them reported feelings of discomfort, and interference with communication. Of the 177 subjects who never used the devices, 159 (89.8%) reported that the noise was not high enough to warrant use of the protection devices, and only 18 (10.2%) claimed feeling of discomfort, interference with job performance or with the communication as reasons for never using the devices. Only 104 (38.7%) out of all 269 exposed subjects knew the hazards associated with their jobs, and the adverse health effects of these hazards. Forty (14.9%) subjects reported that they were informed about the hazards associated with their jobs.

Multiple logistic regression analysis was used to determine the factors (predictors) that influence the hearing protection devices usage. The independent variables (predictors) used were noise level dB(A), age (yr), education (yr), duration of current and past service (yr), summation of current and past service (yr), knowledge about hazards of noise (yes/no) and knowledge about protection measures against noise (yes/no). The results of the logistic regression are presented in Table 7. Out of the eight variables investigated the use of hearing protection devices was related to and influenced by the following

1. Noise level: as noise increased the probability of using the devices increased (P=0.0001, OR=1.3 and 95% C.I=1.2–1.5).
2. Education: as the years of education increased, the probability of wearing the devices increased (P=0.0072,OR=1.4, and 95% C.I=1.1–1.7).
3. Knowledge about the noise protection measures, the probability of using the devices was higher among workers who knew the protection measures compared with those who did not know (P=0.0037, OR=7.5, and 95% C.I=1.9–29.7).

Inspection of the partial correlation (R) indicated that noise level had a greater weight in influencing usage of hearing protection devices than the other factors (R=0.40).

DISCUSSION

No significant difference was found between right and left ears of the exposed subjects after exclusion of those who reported firing guns. This finding indicates that the adverse noise effect is generally bilateral and symmetrical, as defined by Alberti (1988). The occurrence of hearing loss as a result of prolonged exposure to a noise level greater than 85 dB(A) without ear protection is well documented in the literature (Berger *et al.*, 1978; Dobbie, 1985; WHO, 1986). The present study also found that subjects exposed to daily Leq greater than 85 dB(A) had significantly higher mean thresholds than the non-exposed across frequencies tested. The difference between the two groups was attributed to occupational noise exposure as this was the sole hearing risk factor in which the exposed group differed from the non-exposed group after controlling for age, and excluding those with a history of firing guns.

The results of this study are in agreement with previous studies that showed noise induced hearing loss predominantly affects frequencies between 4 to 6 KHz (Nixon and Glorig, 1961; Burns, 1973; Kenney and Aayer, 1975; Shida and Yoshida, 1990; Bauer *et al.*, 1991; Celik *et al.*, 1998). The present study found, on a group basis (mean thresholds), a maximum hearing loss (dip) localized at 4 kHz, followed by a recovery at 8 kHz. However, on an individual basis (percentage of individuals) a dip was found on 4 kHz for some individuals and on 8 kHz for others. Without the inclusion of frequencies 5, and 6 kHz, it is difficult to conclude that noise-induced hearing loss can be maximal for some individuals at 8 kHz. However this finding may suggest that for some individuals the maximum hearing loss is not always at 4 kHz. The investigators believe that if the frequency where the maximum hearing loss localized is determined on individual basis and if the audiometry is extended beyond 8 kHz, the pattern of the audiogram will be different.

The results of this study in this aspect is in agreement with the conclusion of Irwin (1994) that the location of maximum hearing loss on the audiogram may depend on factors other than a single measure

Table 7. Results of the multiple logistic regression analysis for the use of hearing protection devices in both factories combined showing variables included in the equation

Variable	Coefficient (Beta)	SE of (Beta)	P-value	Partial correlation (R)	Odds ratio (OR)	95% Confidence interval
Noise level	0.28	0.06	0.0001	0.40	1.33	1.18–1.49
Education	0.32	0.12	0.0072	0.19	1.37	1.09–1.74
Knowledge about the noise protection measures	2.02	0.70	0.0037	0.21	7.54	1.91–29.73
Constant	−33.49	6.02	0.0001	–	–	–

of dB(A) intensity, including the type of the noise, the physical characteristic of the noise, duration of exposure, and individual variation.

The finding of this study that no interaction between noise exposure and age and the effects of them are additive is in agreement with findings of the previous studies of Macrae (1971) and Chen *et al.* (1992); but in contrast to the finding of Novotny (1975) that no additivity occurs between the two variables.

This study reported a positive relation between TNIL and the hearing loss, which is consistent with the energy equivalent principle developed by Burns and Robinson (1970). In this study, Noise Immission Level was found to be the most important factor in predicting hearing thresholds at all the frequencies tested with age ranking second. This finding is not in agreement with Bauer *et al.* (1991) who found the age to be the most important predictor for hearing thresholds at all of the frequencies tested. Also Neuberger *et al.* (1992) reported age, sex, and noise immission level as the most important factors in predicting hearing loss at frequency 4 kHz in order. This difference between these studies in ranking the factor age might be due to the difference in the age of the subjects included. In this study the subjects were on average younger (median age=30 yr) than those in previous studies (median age=36 yr).

Though there are differences between this study compared to other studies in the criteria used for defining hearing impairment, the prevalence rate of hearing impairment reported in this study is comparable to that reported by the other researchers who reported prevalence rate ranging between 19 and 56% (Ambasankaran *et al.*, 1981; WHO, 1986; Yassi *et al.*, 1991; Marvel *et al.*, 1991; Ostri and Parving, 1991; Celik *et al.*, 1998).

In this study, only 10% of the total exposed subjects claimed to have tinnitus, compared to none within the non-exposed. Higher rates ranging between 23.3 and 58% have been reported by other investigators (Alberti, 1987; McShane *et al.*, 1988; Phoon *et al.*, 1993; Ylikoski and Ylikoski, 1994).

The combined rate for 'all time' and 'sometimes' users of ear protection devices was approximately 34%. This figure was similar to those from other reports (Vihma and Nurminen, 1983; Dijk *et al.*, 1987; Melamed *et al.*, 1994). It seems that noise exposed employees tend not to use hearing protection devices regularly in high noise levels. The rates of full use hearing protection user when the noise level was more than 85 dB(A) were only 9%, and 'sometimes' use was only slightly higher at 30%. Such compliance figures are comparable to those reported in the literature (Bauer *et al.*, 1991; Melamed *et al.*, 1994). The high rates of noise exposure, coupled with such reluctant use of appropriate hearing protection devices leaves the majority of the exposed employees investigated within this study at high risk of developing NIHL. At lower noise levels the rate of 'sometime' user was more than 16% which was in close agreement with that reported by Melamed *et al.* (1994). These authors ascribed this relatively high rate of users for noise annoyance. However, annoyance was not one of the objectives of the present study but it may probably be an explanation for this phenomenon.

The protection of oneself from noise and the claim that the devices were not comfortable reported by noise-exposed workers in this study as reasons for the use (or non use) of protection devices were similar as that reported by Hager *et al.* (1982) and Hempstock and Hill (1990). This study further confirms the well-documented conclusion that 'all time' use of hearing protection devices protects the hearing, and that wearing hearing protection devices only 'sometimes' is, in practice, similar to non-use (Berger, 1980). It is thus, apparent that any hearing conservation program must address the issue of continuous use of hearing protection devices. Education if not followed by close supervision or surveillance for non-users, will not be effective in preventing NIHL.

CONCLUSION

This study has clearly shown that the workforce within both factories included in this study are at high risk of developing noise induced hearing loss due to excessive occupational exposure to noise. Though legislation to control noise exposure exists in Saudi Arabia, poor compliance in relation to wearing and enforcement of wearing and/or attitude and education to hearing loss and noise exposure suggests legislation is poorly enforced. A well-defined, comprehensive, and enforcable noise regulations should be developed and applied. In addition a hearing consevation program could be usefully established within the two factories. The components of which might include; noise assessment, hearing protection devices, education to raise the awareness of the employees about the adverse effects of noise and audiometry.

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