

# Development and validation of a screening questionnaire for noise-induced hearing loss

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<b>Background</b>	An audiometric health surveillance programme can be perceived to be a relatively costly exercise and employers, especially in developing countries, might therefore be reluctant to undertake this. A questionnaire might be a cheaper alternative.
<b>Aims</b>	To develop a questionnaire to help determine the prevalence of noise-induced hearing loss (NIHL) in the vernacular (language) of a developing country and to validate it against an audiometric standard.
<b>Methods</b>	A questionnaire was developed, translated and administered in a face-to-face interview. Otoscopic examination was followed by conventional pure-tone audiometry (at 0.25, 0.5, 1, 2, 4 and 8 kHz) for both ears of each respondent. The questionnaire responses were compared to the audiometric standard.
<b>Results</b>	Two hundred and fifty workers from three companies (two printing and one woodworking) participated in this study. The sensitivity of the hearing loss questionnaire in detecting noise-induced hearing loss was 32%, while its specificity was 79%. There was an evidence to suggest good agreement ( $r = 0.523$ ) between the total number of years worked in noisy jobs and NIHL ( $P < 0.05$ ).
<b>Conclusions</b>	The questionnaire developed in this study was found to have an unacceptably low sensitivity for noise-induced hearing loss and therefore cannot be a valid substitute for audiometry. Pure tone industrial audiometry needs to be used more widely than currently in developing countries.
<b>Key words</b>	Hearing loss; noise; questionnaire.

## Introduction

Noise is perhaps the most common occupational and environmental hazard [1]. In 2004, it was estimated that in the UK, '1.1 million people were exposed to excessive noise at work and of which 170 000 will suffer significant ear damage as a direct result of the noise' [2]. Noise-induced hearing loss represents a much heavier burden in developing countries than in developed regions of the world. The difference is mainly due to lack of noise prevention programmes and awareness of the consequences of excessive noise exposure [3]. According to the Maltese Labour Force Survey of October to December 2007 out of a total working population of 155 968 [4], there were at least 43 670 (28%) workers in noisy industries [5]. Maltese industries considered as 'noisy' include construction, shipyards, manufacturing industries, transport, entertainment industry and power generation. As a recent European Union accession state, through its Work Place

(Noise) Regulations 2006 Malta implemented Directive 2003/10/EC of the European Parliament and of the Council and replaced Noise Regulations 2004 [6]. The Noise regulations applied only to people at work and with risks to their hearing, except to ships at sea or aircraft in flight. However, there is a specific requirement for employers to provide adequate health surveillance, for which a code of practice to provide criteria that determine when this should be done has not yet been developed in Malta. The ideal comprehensive approach would be one which includes workplace assessment, controlling noise at source and an audiometric programme [7].

Audiometric testing, as part of health surveillance, can be a very costly exercise and many employers in Malta and possibly elsewhere are therefore reluctant to undertake it. A cheaper alternative in the form of a questionnaire might be more appealing if it was specific enough to pick up those workers with no hearing loss and thus eliminating the need to perform audiometry in these workers.

There may thus be a need for supplementary methods in the interim, such as a hearing loss questionnaire. A questionnaire survey might also help highlight unrecognized risks to hearing and facilitate the case for audiometry. Moreover, it might be a useful epidemiologic tool to help determine the burden in the country as a whole if used in conjunction with audiometric surveys in a subsample for study. Voeks *et al.* [8], Nondahl *et al.* [9] and Ahmed *et al.* [10] concluded from their studies that where audiometry is not routinely available, costly or time consuming, self-report data can provide a relatively quick and inexpensive means of identifying subjects with hearing loss and estimating the prevalence of hearing loss.

The aim of this study was to develop and validate a screening questionnaire for noise-induced hearing loss (NIHL) against an audiometric gold standard [11].

## Methods

The design consisted of a cross-sectional comparison of noise-induced hearing loss status determined by an interviewer-administered questionnaire compared with the criterion gold standard of pure-tone audiometry.

A two-part questionnaire was developed which has been described in full elsewhere [11]:

- (i) Part 1 included demographic data, occupational history, hobbies and leisure, general medical history and aural medical history. The questions were derived from a literature search of previous studies or related to evidence-based causes of hearing loss or of associated symptoms, e.g. tinnitus [11].
- (ii) Part 1 (see below) included questions intended to screen for physiologic hearing loss namely high tone questions and questions which screen for functional hearing loss namely social situation, family situation and personal attitude questions. This was taken almost exclusively (except the last two questions) from the online test produced by Hearing Aids Central.com [12]. This was the most comprehensive hearing loss questionnaire located by the author to date. What made this questionnaire unique was that it had a set of four high tone questions which could be used to detect high-frequency hearing loss which is characteristic of noise-induced hearing loss. A question about temporary threshold shift was added in order to increase the sensitivity of this questionnaire for mild NIHL. The question 'I have been exposed to high levels of noise' was also included because this question was found to be most sensitive by another study in correctly identifying subjects exposed to a noise level of >85 dB(A) (sensitivity = 93%) [10].

The English version was translated into Maltese (the vernacular language) followed by 'back translation' by a different person.

Both language versions underwent validity testing. Feedback was sought from 12 ENT specialists and 2

audiologists of whom 11 responded and consequently amendments were made to the questionnaires.

For reliability testing, both language versions were administered to 15 people on two separate occasions 3 weeks apart. The answers of the questionnaires from both occasions were found to be identical.

The second part of this study was carried out in a target population of Maltese workers who were to undertake audiometry as part of good occupational health practice because of their occupational exposure to noise [6].

The minimum sample size required for this study worked out to be 369 where the confidence level required was set at 95%, the estimated prevalence of NIHL in the project area was 60% and a margin of error of 5% was established. Three companies were selected for this study, two of which were printing companies and the third one was a woodworking factory. All the employees working in these noisy companies including those in administration were eligible to participate. A subject information sheet was sent out by the company management to their employees. The author sought informed written consent from those employees who came forward to participate in this study.

The questionnaires were administered by the author in a face-to-face interview. The language choice of the questionnaire was determined by the respondent. A definition list of technical or difficult words contained in the questionnaire was prepared to standardize responses if clarification was requested. Nine respondents were eliminated from this study because they had one or more conditions which met the exclusion criteria (see Figure 1).

Following verbal administration of the questionnaire, otoscopy and removal of any ear wax pure-tone audiometry was carried out to determine the hearing thresholds in the conventional frequencies 0.25, 0.5, 1, 2, 4 and 8 kHz for both ears of each respondent.

Audiometric tests were performed after a lapse of 18 h from the last exposure to noise to allow recovery from any temporary threshold shift. Advice was given to all respondents on this issue at least 1 week prior to audiometry.

In the first printing company and woodworking factory, a digital audiometer (Digital Recording, Canada, Professional v.6.0) was used, while in the second printing company, the device used was an ASRA audiometer with audiocups. Standard techniques were applied [11].

Hearing levels of 25 and 40 dB hearing loss (HL) are often used as screening criteria for mild and moderate hearing loss. For the purposes of this study, hearing loss was classified into: mild ( $\geq 25$  but  $\leq 40$  dB HL), moderate ( $> 40$  but  $\leq 55$  dB HL) and severe ( $> 55$  dB HL) measured over the conventional frequencies mentioned above (see Figure 2).

The data were inputted using SPSS (version 16.0) software. The chi-squared test was used to determine whether a difference between two categorical variables (or a combination of categorical and ordinal variables) in this sample was likely to reflect a real difference between these two variables in the population.

EXCLUSION CRITERIA	
1.	Visible congenital or traumatic deformity of the ear
2.	A history of active drainage from the ear within the previous 90 days
3.	A history of sudden or rapidly progressive hearing loss within the previous 90 days.
4.	Acute or chronic dizziness
5.	A sudden loss of hearing in one ear in the past 90 days.
6.	An audiometric air-bone gap equal to or greater than 15 decibels at 500Hz, 1000Hz, and 2000Hz. (This result will only be known if the subject has already been to a hearing specialist and been tested).
7.	Visible evidence of heavy ear wax (cerumen) or any foreign body in the canal.
8.	Pain or discomfort in the ear.

Figure 1. Exclusion criteria.

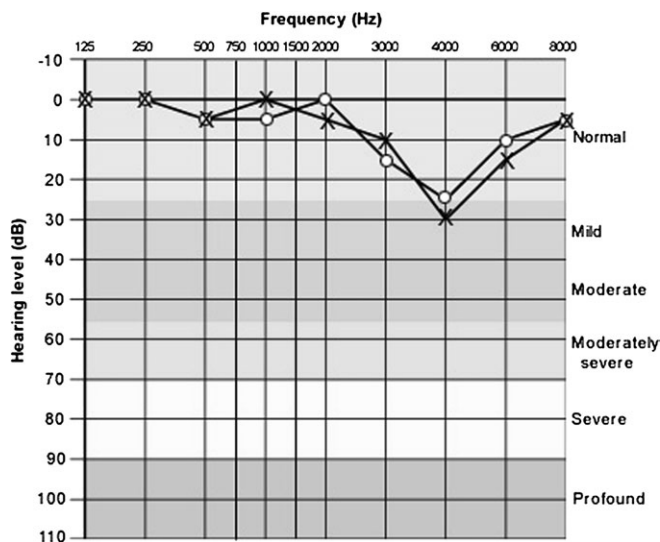


Figure 2. Classification of hearing loss.

Spearman’s rank-difference coefficient of correlation was the non-parametric test used for determining if there was an association between phenomena. The level of agreement was measured using the indices of sensitivity, specificity, positive predictive value and negative predictive value.

Ethical approval for this research was sought and obtained from the Research Ethics Committee of the University of Malta. Positive outcome for this approval was followed by registration with endorsement by the Research Ethics Committee of the University of Manchester.

**Results**

Of the 688 workers invited to participate in this study, 250 (36%) participated. The participation rates between the three firms varied as follows: 27 (93%) from the first printing company, 156 (27%) from the second printing company and 67 (85%) from the woodworking factory. Eighteen of the respondents who were interviewed failed to attend for audiometric testing.

Table 1. Presence and degree of noise-induced hearing loss based on audiometry

	Frequency	n (%)
NO NIHL	72	32
Mild NIHL	56	25
Moderate NIHL	57	26
Severe NIHL	38	17
Total	223	100.0

The ages of the participants ranged from 19 to 64 years with a mean of 42.4 years. The study population consisted of 12% females (30) and 88% males (211).

The presence and degree of noise-induced hearing loss based on audiometry are presented in Table 1. Only one-third (32%) of employees did not have NIHL.

Hearing scores were determined by the sum of the points accumulated in Part 2 of the questionnaire (see below; Questionnaire Part 2 is available as supplementary data at *Occupational Medicine* online). As seen in Figure 3, the highest frequencies of hearing scores of the study population have a hearing score between 0 and 4. The majority (98%) of the workers preferred the questionnaire to be administered in the Maltese language. For responses to hearing, questionnaire Part 1 refer to Table 2.

The relation between age and NIHL was explored using a chi-square test. This was statistically significant at a 5% level using a two-tailed continuity corrected chi-squared test with  $P < 0.001$ .

The relationships between the sum total of the number of years worked in past and present jobs, hours of exposure to noise per day, total noise exposure (years in present job × hours of exposure per year) and NIHL were explored by calculating Spearman’s rank correlation coefficient. Results indicated that there was an evidence to suggest good agreement ( $r = 0.523$ ) between the total number of years and NIHL ( $P < 0.05$ ). There were also significant correlations ( $r = -0.175$ ) between hours of exposure per day and NIHL ( $P < 0.05$ ) and between total noise exposure and NIHL ( $r = 0.440, P < 0.05$ ). The sensitivity of the hearing loss questionnaire (second part) in detecting noise-induced hearing loss was 32%, while its specificity was 79%. Its positive predictive value was 76%, while its negative predictive value was 36%.

The sensitivity of the question ‘Do you feel you have a hearing loss?’ in detecting noise-induced hearing loss was 29%, while its specificity was 82%. Its positive predictive value was 76%, while its negative predictive value was 37%.

The relation between the question ‘Do you feel you have a hearing loss?’ and hearing score was explored by calculating Spearman’s rank correlation coefficient. There was an evidence to suggest good agreement ( $r = 0.501$ ) between this question and the hearing score ( $P < 0.05$ ).

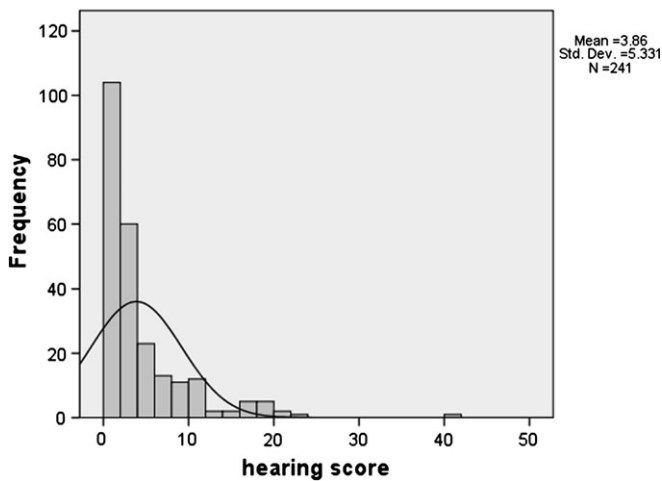


Figure 3. Histogram of frequencies of hearing score.

Table 2. Responses to hearing questionnaire Part 1

Questions asked	Positive response (%)
Been in their present job for at least 16 years	44
Ranked their current noise exposure as high	83
Reported that speech was not possible with someone at arm's length (one metre) without having to shout	60
They work regularly with noisy tools or machinery at work	60
Wear hearing protection in their present job	43
Wear hearing protection in past noisy job	28
Had past employment in noisy job	57
Use of personal HiFi equipment	29
Attendance at discos and noisy nightclubs	12
Past medical conditions	42
Present smokers	64
Ototoxic drugs	56
Contact with organic solvents	70
Felt that they had hearing loss	26
Tinnitus	21
Recurrent dizziness	4
Relative who was deaf when young	1

## Discussion

In this study, the sensitivity of the hearing loss questionnaire in detecting noise-induced hearing loss was 32%,

while its specificity was 79%. The single question 'Do you feel you have hearing loss?' was found to have similar sensitivity and positive predictive value for NIHL as the hearing loss questionnaire (Part 2).

The study showed a good correlation between both the total number of years worked in noisy jobs and total noise exposure on the one hand and NIHL ( $P < 0.05$ ) on the other hand. This underlines the validity of the data collected through the questionnaire and the audiometry.

A possible explanation for the low participation rate of workers from the second printing company is that at the time of the study, the line managers of the second printing company were under intense pressure to boost production to meet deadlines and thus were reluctant to release workers from the production line to participate in this study. If this explanation is correct, this could lead to a potential source of bias as the characteristics of workers who participated might differ from those who did not.

However, in spite of the limited availability of volunteers ( $n = 250$ ), this study showed conclusively that the questionnaire was not sensitive enough to be used as a pre-audiometric screening tool for NIHL, so to that extent, the primary research objective was achieved.

Administering the second part of the questionnaire screening for physiological and functional hearing loss was a straight-forward exercise, as experienced by the author although the interviewer had to stress that the questions in Part 2 applied to a home environment rather than a work environment.

As can be seen in the Methods section, two different audiometers were used in this study. Possible implications of this are potential bias arising from use of different instruments as well as from the possible application of different procedures for testing.

One of the latest major studies on this subject by Ahmed *et al.* [10] focused on evaluating the performance of several questions in identifying subjects with hearing loss using pure-tone audiometry as the gold standard. In this study, the question 'Do you consider the noise level where you are working now high?' compared with the other questions evaluated was found to be a fairly good indicator of hearing loss, particularly when this loss is defined as pure-tone average of  $\geq 25$  dB HL at the 4 and 8 kHz (high-frequency average). Despite its low specificity (24%), it correctly identified  $>90\%$  of those with moderate-to-severe hearing loss and  $\sim 89\%$  of those with mild hearing impairment as assessed by audiometry. These results are broadly consistent with those obtained in this present study where the sensitivity of this question for NIHL was 80% and its specificity was 13%. This result was to be expected considering that a noise level of 90 dB(A) experienced every working day for 40 years, carries a 51% chance of a 30 dB(A) hearing loss [13].

In this present study, the author went further by asking the question 'What is the average number of hours of exposure to noise per week?' This question combined with

the other question 'how long have you been in your present job?' allowed the compilation of the total noise exposure (years in present job × hours of exposure per year).

Comparison of the finding in the present study with those in the literature is limited by differences in the definitions of hearing loss, in study populations and in the types of the questions used. Comparison of the sensitivity and specificity of the question 'Do you feel you have a hearing loss?' in the present study with the sensitivity and specificity of similar questions in other studies such as 'Do you consider your hearing abnormal?' (Ahmed *et al.* [10]) produced the results seen in Table 3.

Ahmed *et al.* explained the low sensitivities obtained in their study by the fact that the majority of their study population were expatriates, often described as economic migrants and as such avoid reporting and deny any work-related disease in order to hold on to their jobs. Another explanation put forward was that most of them had an average threshold in the 25–40 dB HL range (mild NIHL) and had as yet not reached the level of a hearing defect that can be perceived by them as hearing loss. The latter explanation would probably explain the high level of sensitivity obtained in the study by Sindhusake *et al.* [14] because it involved residents aged 55–99 years and thus, the prevalence of moderate and severe hearing loss would probably be higher than in the other studies involving workers and therefore, the perception of hearing loss is greater in this study. A similar explanation can be put forward for the high sensitivity obtained by Nondahl *et al.* [9] whose study population was aged 48–92 years.

This present study attempted to improve the sensitivity of the single question used in earlier studies to screen for hearing loss by asking a set of questions which can be grouped under high tone questions, social situation questions, family situation and personal attitude questions. As seen from the results above, the sensitivity of the hearing loss questionnaire (second part) in detecting noise-induced hearing loss was 32%, while its specificity was 79%. Its positive predictive value was 76%, while its negative predictive value was 36%. These results are almost identical to those obtained in this study for the single question 'Do you feel you have a hearing loss?' where the sensitivity in detecting noise-induced hearing loss was 29%, while its specificity was 82%. Its positive predictive value was 76%, while its negative predictive value was 37%. In fact when the relation between this question and hearing score was explored by

**Table 3.** Comparison of the sensitivity and specificity of questions probing the subject's assessment of his/her hearing ability

	Sensitivity (%)	Specificity (%)
Present study	29	82
Ahmed <i>et al.</i> [10]	5	99
Nondahl <i>et al.</i> [9]	71	71
Sindhusake <i>et al.</i> [12]	90	–

calculating Spearman's rank correlation coefficient, results indicated that there was an evidence to suggest good agreement ( $r = 0.501$ ) between this question and the hearing score ( $P < 0.05$ ). This can be explained by the fact that the answer to the single question is the logical conclusion reached by the same respondents who answered the hearing loss questionnaire. Hearing score as determined by the questionnaire was not significantly correlated with audiometric NIHL. Another result of note is the negative correlation using Spearman's rank relation coefficient between the hours of exposure to noise per day and NIHL. A possible explanation is the increased likelihood of workers who are exposed longer to noise to wear hearing protection than those workers who are exposed less to noise thus having less risk of developing NIHL.

This work, together with that of Ahmed *et al.*, clearly shows that even after careful iteration and administration by a trained interviewer of questionnaire, the questionnaire is not adequate as a tool for detecting NIHL. An unacceptably large proportion of employees with NIHL would be missed by such a questionnaire. Efforts need to continue to be made to persuade authorities and employers to set up an audiometric programme using pure tone audiometry. Incidentally, the study demonstrated an unacceptably high prevalence of NIHL in the previously uninvestigated populations.

### Key points

- A questionnaire is not sensitive enough to be used as a pre-audiometric screening tool for noise-induced hearing loss.
- Pure tone industrial audiometry needs to be used (and more widely than it currently is) to screen for noise-induced hearing loss in developing countries, where noise-induced hearing loss remains a serious problem.

### Conflicts of interest

None declared.

### References

1. Rabinowitz PM. Noise-induced hearing loss. *Am Fam Physician*. 2000;**61**:2749–2756, 2759–2760.
2. South T. *Managing Noise and Vibration at Work*. Oxford, UK: Butterworth Heinemann Books, 2004.
3. Nelson DI, Nelson RY, Concha-Barrientos M, Fingerhut M. The global burden of occupational noise-induced hearing loss. *Am J Ind Med* 2005;**48**:446–458.
4. News Release. Malta: National Statistics Office. Malta: National Statistics Office is a Malta Government entity. [http://www.nso.gov.mt/statdoc/document\\_file.aspx?id=2375](http://www.nso.gov.mt/statdoc/document_file.aspx?id=2375) (3 April 2008, date last accessed).

5. Enterprise in Malta. *Malta—A Country of Business Opportunities*. San Gwann, Malta: Malta Enterprise, 2008.
6. Work Place (Minimum Health and Safety Requirements for the Protection of Workers from Risks Resulting from Exposure to Noise) Regulations. *Occupational Health and Safety Authority Act (CAP 424). L.N. 158 of 2006*. 2006.
7. *Noise-Induced Hearing Loss of Occupational Origin. A Guide for Medical Practitioners*. Occupational Safety and Health Service. Department of Labour, Wellington, New Zealand, 1994.
8. Voeks SK, Gallagher CM, Langer EH, Drinka PJ. Self-reported hearing difficulty and audiometric thresholds in nursing home residents. *J Fam Pract* 1993;**36**:54–58.
9. Nondahl DM, Cruickshanks KJ, Wiley TL, Tweed TS, Klein R, Klein BE. Accuracy of self-reported hearing loss. *Audiology* 1998;**37**:295–301.
10. Ahmed HO, Dennis JH and Ballal SG. The accuracy of self-reported high noise exposure level and hearing loss in a working population in Eastern Saudi Arabia. *Int J Hyg Environ Health* 2004;**207**:227–234.
11. MSc Thesis, University of Manchester, 2009.
12. Do You Need a Hearing Aid? or Do I Need a Hearing Aid? Hearing Aids Central.com Online Hearing Questionnaire. <http://www.hearingaidcentral.com/index.asp> (4 May 2008, date last accessed).
13. Godlee F. Noise: breaking the silence. *BMJ* 1992;**304**: 110–113.
14. Sindhusake D, Mitchell P, Smith W, Golding M, Newall P, Hartley D. Validation of self-reported hearing loss. The Blue Mountains Hearing Study. *Int J Epidemiol* 2001;**30**:1371–1378.