Self-recording audiometry in industry

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Pelmeare, P. L. and Hughes, Brenda J. (1974). *British Journal of Industrial Medicine*, 31, 304-309. **Self-recording audiometry in industry.** A study of initial and repeat audiograms of 118 drop forge employees using fixed frequency self-recording audiometry showed that the mean of the differences at the test frequencies 0.5, 1, 2, 3, 4, and 6 kHz ranges from -0.47 dB to +0.61 dB. The largest standard deviation was 6 dB at 6 kHz and the lowest 3 dB at 2 kHz.

The results also confirmed that temporary threshold shift effects may be minimized if audiograms are obtained at the beginning of a shift or within two hours provided the subject is protected with ear muff defenders up to the time of the test.

The practical advantages to industry of using self-recording audiometry for audiometric screening and the reliability of single audiograms for threshold determination are discussed.

If audiometry is to be used in industry to detect hearing losses and to monitor subsequent change, the accuracy of measurement and the repeatability must be acceptable. Atherley and Dingwall-Fordyce (1963) from an examination of 12 otologically normal young men found the variance of repeated threshold determinations of a single ear to be 8.5 (dB)^2 at 0.5 kHz, 6 (dB)^2 at 3 kHz, and 23 (dB)^2 at 8 kHz. Differences between consecutive determinations extended to 25 dB. These results were obtained apparently under conditions which, in their opinion, practically precluded all sources of variation other than that due to the inherent uncertainty of audiometric measurements. They suggested therefore that if an apparent drop in threshold in one ear is to be considered as significant evidence for real change, the difference would have to be at least 17.5 dB at the higher frequencies. This level could possibly be reduced to 10 dB if a change occurs simultaneously at both 4 000 and 6 000 Hz. Howell and Hartley (1972), in a study of initial and repeat audiograms by two operators on 143 young male new entrants to industry (free of previous occupational exposure), found that the mean values (mean of both ears, readings at 3 and 4 kHz) differed significantly. For nearly half the employees the difference between the results obtained by the two operators amounted to

5 dB or more, with differences up to and including $21\frac{1}{2}$ dB. In their view, with such variability in audiometric recordings, some of which may be attributable to variation in the patients' responses, small changes in recorded hearing levels would not give confident early indication of deterioration in a susceptible ear.

Subsequently Hartley, Howell, Sinclair, and Slattery (1973) suggested that 'single audiogram examination should be replaced by two audiograms routinely carried out at a single session, and that in the absence of any large difference (say 5 dB) between the two readings the second should be adopted'. The object of this paper is to ascertain the advantages, if any, of two readings over a single observation with self-recording audiometry in an industrial setting.

Subjects and method

In a drop forging factory where peak pressure levels of 125 dB SPL and equivalent continuous noise levels (ECNL) of 109 dBA have been recorded, monitoring audiometry is undertaken. One hundred and eighteen employees with otologically normal ears who attended for a routine audiometric examination were repeat tested at the first available opportunity. The age grouping and distribution are shown in Table 1. Subjects below 18 years and over 65 years were excluded.

TABLE 1
DISTRIBUTION OF SUBJECT BY AGE

	Age group (years)				
	18-24	25-34	35-44	45-54	55-64
Number	15	35	30	26	12

All tests were done using an Interacoustics BA3 fixed frequency self-recording audiometer,* which was calibrated to ISO standards before and after the series of repeat tests. A GKN Sankey booth provided sufficient background noise attenuation to meet the BSI scales BS 2980: 1958 and BS 2497: 1954 for pure tone audiometry.

Occupational health nurses operated the audiometer and briefed the subjects on entering the booth. The basic instruction for self-recording audiometry was given. After a trial period with the left ear at 0.5 kHz a self-recorded audiogram was obtained, first for the left and then for the right ear at 0.5, 1, 2, 3, 4, and 6 kHz. The left ear 0.5 and 1 kHz frequencies were retested as a routine and the retest thresholds were accepted. If there was a large discrepancy (over 10 dB) between ears at any frequency, the higher threshold was rechecked prior to the release of the subject from the booth. The same procedure was used for both the initial and repeat tests.

*The Kamplex BA3 audiometer used in the investigation was obtained from the UK distributor—P. C. Werth Limited, 17 Stratford Place, London W1N 0DH.

To avoid any variation due to temporary threshold shift the subjects were tested at the beginning of the shift or within two hours provided muffs were worn up to the time of test. The noise exposure time was recorded as no noise exposure (0), not exceeding 1 hour (1), and not exceeding 2 hours (2). Repeat tests were done on the same day of the week, but the time interval between the initial test and recall varied from one to 15 weeks because of the shift system and sickness absence.

Results

The average dB loss at each frequency by age group from the initial test results is shown in Figure 1. The contours are typical for a working population who have been exposed to noise. The thresholds rise with age, particularly in the upper frequencies.

Figure 2 shows the standard deviation for each ear and test frequency by age group. It can be seen that the standard deviations were smallest for the youngest age group and largest for the 45-54 age group. Only when compared with the 18-24 age group, and then not at the lowest frequency, were these standard deviations statistically significantly larger ($P = 0.05$).

Sixty-eight of the employees were repeat tested with the same noise-free or noise-exposed interval, and the remainder with different intervals, as listed in Table 2. The statistical analysis showed no significant effect of the wearing of ear muff defenders on the threshold differences.

The threshold level differences between the original

FIG. 1. Mean hearing loss thresholds at six frequencies for five age groups, right and left ears.

FIG. 2. Standard deviation of the hearing thresholds at six frequencies for five age groups, right and left ears.

TABLE 2
NOISE EXPOSURE TIME—INITIAL AND REPEAT TESTS

Test times (hr)	No. of subjects
0—0	46
1—1	10
2—2	12
0—1	4
0—2	17
1—0	6
2—0	7
1—2	6
2—1	10

TABLE 3
MEAN DIFFERENCE: BY FREQUENCY AND EAR

	kHz					
	0.5	1	2	3	4	6
Left ear	0.61	0.51	-0.11	0.04	0.40	-0.08
Right ear	-0.17	-0.34	-0.47	-0.30	0.34	-0.47

and repeat tests at 4 000 Hz for the left ear (Fig. 3) are typical of all the frequencies for both ears, and demonstrate that there is no correlation between time interval and repeatability.

For all test frequencies the threshold differences between the original and repeat audiograms were within a maximum of ± 15 dB (Fig. 4), with the mean differences in decibels as shown in Table 3.

FIG. 3. Distribution of hearing threshold level differences between the original and repeat tests at 4 000 Hz for the left ear in all subjects.

In this series the 95% limits for repeat threshold determinations were ± 12 dB at 6 000 Hz and ± 6 dB at 2 000 Hz (Fig. 5). The individual subject differences between tests is shown in Table 4a for both ears, and the cumulative percentages in Table 4b. It can be seen that except for the 6 kHz frequency for the right ear 90-99% of the differences are 7.5 dB or less, and only 27 recordings (less than 2%) had

FIG. 4. Maximum hearing threshold differences between the original and repeat audiograms at six frequencies for all subjects, right and left ears.

FIG. 5. Ninety-five per cent confidence limits for the differences between the original and repeat audiograms at six frequencies for all subjects, right and left ear.

TABLE 4a
DISTRIBUTION BY STATED DIFFERENCES BETWEEN TESTS

Difference between tests (dB)	Left ear (kHz)						Right ear (kHz)					
	0.5	1	2	3	4	6	0.5	1	2	3	4	6
0	33	38	45	54	38	35	39	49	62	51	34	35
2.5	34	38	40	26	34	27	30	27	30	29	33	19
5.0	38	29	29	31	27	28	32	27	17	23	30	29
7.5	4	9	2	3	10	17	5	10	8	9	14	10
10.0	7	3	1	2	6	7	8	3	1	6	6	18
12.5	—	1	1	1	1	—	3	1	—	—	1	5
15.0	2	—	—	1	2	4	1	1	—	—	—	2

TABLE 4b
CUMULATIVE PERCENTAGE DISTRIBUTION OF DIFFERENCES BETWEEN TESTS

Difference between tests (dB)	Left ear (kHz)						Right ear (kHz)					
	0.5	1	2	3	4	6	0.5	1	2	3	4	6
0	28	32	38	46	32	30	33	42	52	43	29	30
2.5	57	64	72	68	61	52	58	64	78	68	57	46
5.0	89	89	97	94	84	76	86	87	92	87	82	70
7.5	92	97	98	97	92	91	90	96	99	95	94	79
10.0	98	99	99	98	98	97	97	98	100	100	99	94
12.5	98	100	100	99	98	97	99	99	100	100	100	98
15.0	100	100	100	100	100	100	100	100	100	100	100	100

differences of over 10 dB. Furthermore, the repeatability is independent of age (Fig. 6).

Discussion

With the publication of the Code of Practice for Reducing the Exposure of Employed Persons to Noise (1972) no employer should be unaware of his duties in respect of a hearing conservation programme. Although audiometry is not mentioned in the code, many companies have included clinical examinations and audiometry in their programme for specific reasons (Pelmeur, 1973). Some still question the need (Atherley and Dingwall-Fordyce, 1963), while Burns and Robinson (1973), with a view to minimizing the work load, have put forward suggestions 'indicating which industrial noise exposures merit or demand audiometric monitoring and those for which it may be considered dispensable'.

In large industries where thousands of audiometric examinations have to be undertaken the task is a formidable one. Subjects must have their auditory history taken, and the external meatus has to be

FIG. 6. Ninety-five per cent confidence limits for the differences between the original and repeat audiograms at six frequencies for the five different age groups, right and left ears.

examined. If there is partial or complete occlusion with wax it must be removed. This may require repeat attendances at the medical centre and an interval of 48 hours between syringing and audiometry. A further requirement is the avoidance of temporary threshold shift from noise.

When large numbers of subjects have to be screened it is not possible to examine them all on a Monday morning, or at the beginning of each shift before they start work. As it is unacceptable to keep employees away from noise for long periods before a test some relaxation is required, and the use of ear muffs prior to audiometric examination on any day up to a maximum noise exposure time of two hours has been adopted and evaluated in the present investigation. It was impracticable to test every employee on every day of the week, so the data from each age group were analysed separately and the assumption was made that the employees on each day were representative of that group. The resulting analysis provided no evidence for supposing that the day of the test influenced the threshold level. Furthermore, the random distribution of the threshold levels with interval time confirms that with ear muffs, as used in this investigation, up to two hours' noise exposure is acceptable on any day. In less noisy industries ear plugs or anti-noise wool used before the audiometric tests may provide sufficient protection.

The lack of audiometricians for large-scale screening programmes can be overcome by using occupational health nurses or technicians with self-recording audiometers. Accurate recordings are obtainable provided the subject is adequately instructed. Robinson and Whittle (1973), in a comparison of self-recording and manual audiometry, found zero dB differences at 0.25 kHz and 3 dB at the other frequencies (0.5, 1, 2, 3, 4, 6, and 8 kHz), the lower threshold being associated with the self-recording method. Another advantage is that the recording time may be as little as six minutes, so that subject error from fatigue is minimized.

Air conduction threshold audiometry in industry has to be acceptable to both management and employee. The procedure must be conducted with the minimum of interference to productivity and the employee must have confidence in the test to subject himself to the examination. Furthermore, the result must be meaningful if it is to be of any value in health counselling. The employer, while wishing the results to be successful in order to conserve the hearing of employees, will also desire reliable recordings as evidence in any subsequent litigation claims.

An acceptable single recording is important in the industrial situation. Re-attendances are usually difficult to arrange and there is a need to avoid extended absence from work. A second examination at the same session after a rest period, as suggested by Hartley *et al.* (1973), caters for the former but not the latter. Audiometry is not a very welcome or enjoyable experience, and although employees are remarkably tolerant towards research workers, few would agree to undertake two examinations within 40 minutes as a routine monitoring procedure. In these circumstances a single examination appears to us to be the only practical compromise. The results in this study support the view that the use of occupational health nurses with self-recording audiometers is a satisfactory method of audiometric screening in hearing conservation programmes.

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