

6-kHz NOTCH IN NOISE-INDUCED HEARING LOSS

by

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ABSTRACT

Audiograms from 49 711 workers exposed to industrial noise over 85 dB(A) and with no obvious ear pathology were analyzed by sex and age. It was found that the configuration of the mean audiograms shows a notch at 6 kHz instead of 4 kHz reported in previous studies. When the mean audiograms were corrected for presbycusis, the notch shifted from 6 kHz to 4 kHz only for the age groups over 45 years. The reasons for the difference between results of previous studies and this study are discussed.

SOMMAIRE

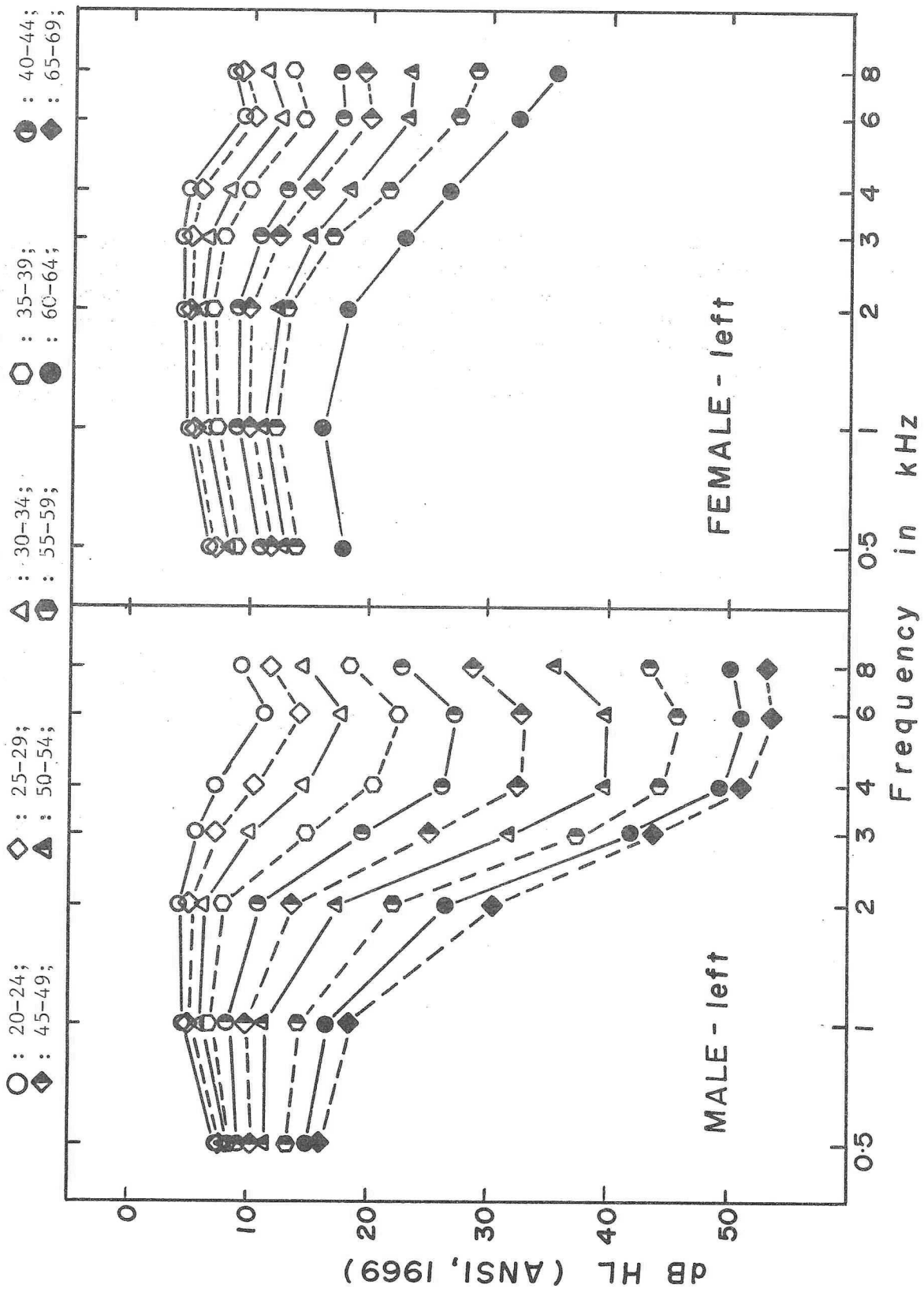
Les audiogrammes de 49 711 travailleurs qui étaient exposés aux bruits industriels de plus de 85 dB(A) étaient analysés par genre et par âge. Cette population de travailleurs n'avait aucune pathologie de l'oreille évidente. Le résultat était que la configuration de la moyenne des audiogrammes indique un 'notch' à 6 kHz au lieu d'un à 4 kHz comme il y était rapporté par les recherches précédentes. Quand la moyenne des audiogrammes était corrigée pour 'le presbycusis', le 'notch' se déplaçait de 6 kHz à 4 kHz seulement pour les groupes de personnes âgées de plus de quarante-cinq ans. Les raisons pour la différence entre les résultats des recherches précédentes et de cette recherche sont examinées.

INTRODUCTION

In a previous paper (Chung et al., 1981) the hearing conservation program (HCP) administered by the Workers' Compensation Board of British Columbia (WCB) was described. The WCB has copies of all audiograms of workers participating in the HCP of the WCB along with other information on medical history, shooting history, smoking history, and the use of hearing protectors. These data are recorded on an optical scan form (Appendix I) by technicians trained by the WCB and are stored on disc for record and for statistical analysis.

In this study we examined an industrial noise-exposed population in British Columbia by age and sex and discussed the possible use of these functions in a HCP. We also described the distribution of workers by hearing level and age for each test frequency.

Fig. 1. Mean audiograms of BC industrial workers by sex and by age group.



METHOD

Since only workers exposed to a time-weighted average (TWA) of 85 dB(A) or more for eight hours are required to be included in the HCP, all cases included in this study are believed to have a noise exposure of 85 dB(A) (TWA) for eight hours.

The type (manual vs automatic) and the make of audiometers used by different firms vary in BC. However, all facilities are inspected annually by industrial audiometric inspectors from the WCB to ascertain conformity to regulations. Audiometers and sound booths are checked as to whether they meet the CSA standard 107.4-1975 (1980 amendment).

Not all workers in our industrial audiometric data bank were used in the analyses. Only those who met the following criteria were selected. The selection criteria were: (1) answering "NO" to questions: Have you ever had A, B, C, D, E, F, G, and J, and Do you now have C and D, in the medical history (hearing) section in Appendix I; (2) between the age of 20 - 70 years. A total of 49 711 cases out of a total of 54 761 met the selection criteria.

The majority of the workers are exposed to a TWA (8 hours) from 85 to 100 dB(A). The type of noise varies with the industry. The industries that employ the largest number of noise-exposed workers in BC in decreasing order are: (1) sawmills, (2) steel fabrication and foundry, (3) logging, (4) pulp and paper, (5) heavy construction, (6) plywood, (7) shipbuilding, and (8) shake and shingle mills. Personal hearing protection has only been used extensively in BC for the past ten years.

RESULTS AND DISCUSSION

Mean audiograms by age and sex:

Fig.1 shows the mean audiograms by age and sex. The number of workers in each age group is shown in Table I.

Certain features can be recognized in Fig.1.

- (1) As the age increases, the hearing threshold level also increases, particularly at the higher frequencies.
- (2) The configuration of the mean audiograms shows a notch at 6 kHz instead of 4 kHz reported in previous studies (Burns, 1968; Robinson and Shipton, 1977) particularly in the younger age groups in which presbycusis is not a factor. However, when the audiograms are corrected for presbycusis (Robinson and Shipton, 1977) the notch shifts from 6 kHz to 4 kHz only for groups over age 45 years (Fig.2).
- (3) Female workers as a group have far less hearing loss than male workers. A notch at 6 kHz is also apparent in the younger age groups but the notch disappears in the older groups.

The presence of a notch at 6 kHz in the younger population has been shown previously (Axelsson et al, 1981; Roberts and Huber, 1970; Gasaway, personal communication). In the present study we have also shown that such a 6 kHz notch is also present in both the young noise-exposed male and female workers. In examining the mean audiograms of the male workers, hearing loss would seem to commence at 6 kHz. Then damage at 4 kHz begins to catch up until presbycusis starts in the older groups and the hearing at 6 and 8 kHz begins to deteriorate more rapidly.

TABLE I Number of workers in each group.

Age in Years	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69
Number	8 630	8 445	7 526	5 790	4 621	4 459	4 211	3 359	2 301	369

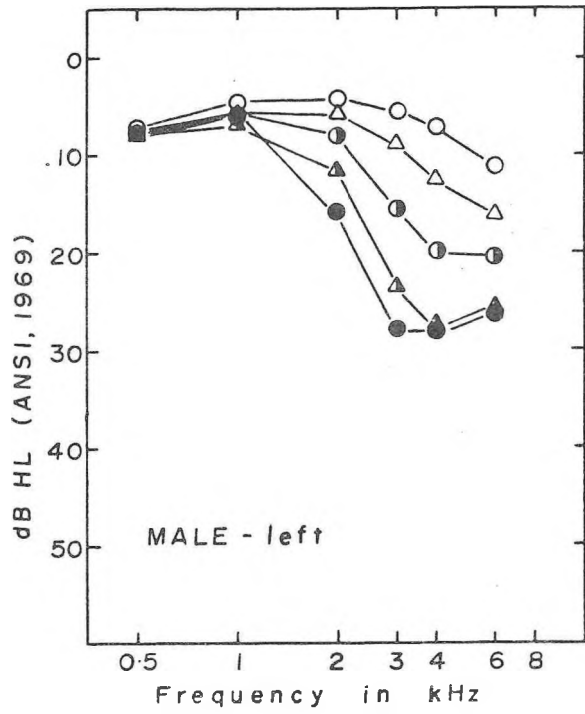
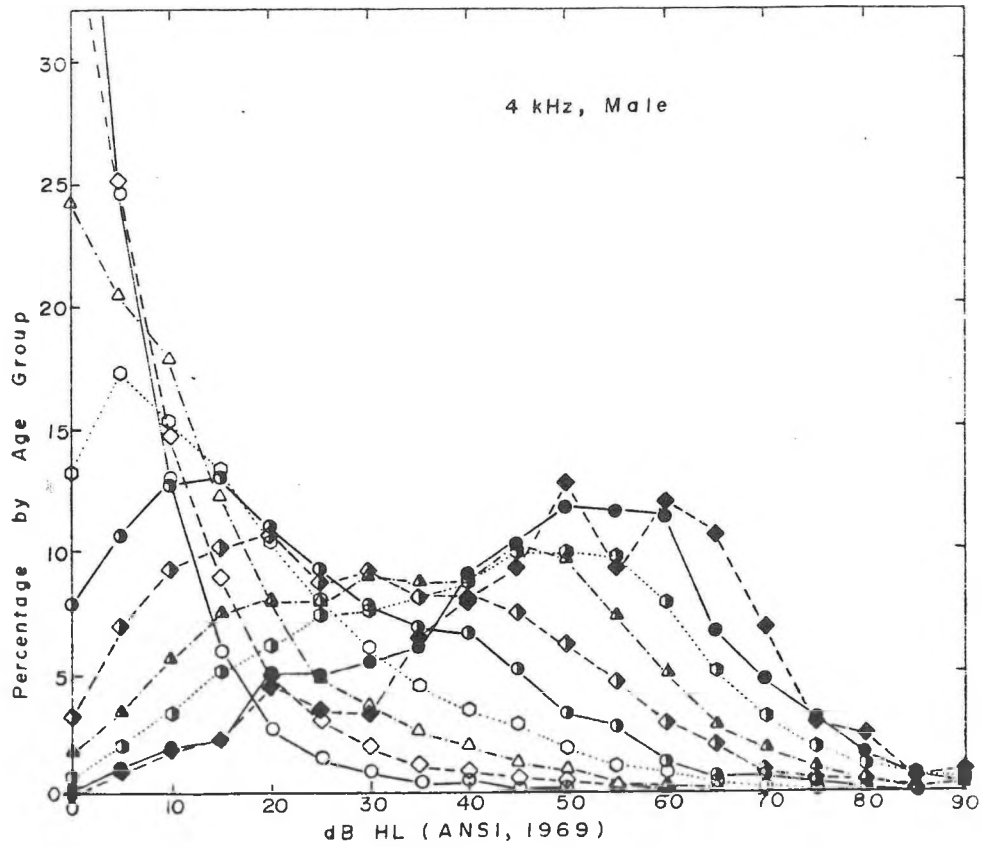


Fig. 2. Mean Audiograms of male BC industrial workers corrected for presbycusis. Refer to Fig.1 for symbol representation.

Fig. 3. The percentage of BC industrial workers in percentage by the degree of hearing loss at 4 kHz in each age group. Refer to Fig.1 for symbol representation.



The large disparity between the hearing levels of the male and female workers could not necessarily be viewed as reflecting the sex difference in susceptibility to noise damage. One important factor in the difference was the history of noise exposure in the two groups. Male workers had much higher noise exposure during their lifetime than female workers, both due to the job noise level and the amount of time spent in noise.

Mean audiograms of this type are very useful in a HCP, as it can be used to compare HCP performance of different industries, firms, and occupations.

There are different ways of presenting the audiometric data other than the more conventional one presented above. One is shown in Figs. 2 and 3 for frequencies of 4 and 6 kHz respectively. Each of the functions in the Figures represent an age group. Each data point represents the percentage of workers in that age group with hearing threshold levels at that frequency.

The curves shown in Figs. 2 and 3 display great smoothness and orderliness with the exception of the 65 - 69 year-old group, which had a sample size of only 369 (Table I).

The distribution of data points varies substantially from the low to the high frequencies. For the lower frequencies (0.5 and 1 kHz) the results, which are not presented here, show that the majority of workers have hearing threshold level of 25 dB HL (ANSI, 1969). For the higher frequencies, there is a shift of the peak along the abscissa from low to high HL as age increases. This is particularly well demonstrated in Fig.3 at 6 kHz.

By comparing Figs. 2 and 3 it can be observed that it is at 6 kHz that hearing starts to deteriorate first, and not at 4 kHz. At 6 kHz the function already peaks at 25 dB HL for the 25 - 29 year-old group. The peak shifts to higher dB HL with age at 6 kHz faster than the shifts at other frequencies.

The 6-kHz notch found in the mean audiograms of the large industrial noise-exposed population in BC is seemingly in disagreement with the classical finding that 4 kHz is statistically the frequency at which hearing is most susceptible to noise damage (Robinson, 1976; Robinson and Shipton, 1977). However, this apparent discord can be explained by data from other studies.

Data from the U.S. National Health Survey (Roberts and Huber, 1970) have shown a noticeable 6-kHz notch in the median audiogram for the sample of over 7000 children between 6 - 11 years of age. In the study the hearing thresholds are also represented in quartiles. It can be observed that the 6 kHz-notch increases its prominence as the representation of the audiogram increases from the 25th quartile to the 75th quartile. This suggests that the worse their hearing is, the greater the likelihood of getting a 6-kHz notch.

In another study Passchier-Vermeer (1968) compiled data from various sources relating to noise-induced permanent threshold shift to noise exposure. Her data suggest that at a moderate noise level (about 80 dB and below) hearing loss actually starts at 6 kHz. However, at higher noise exposure levels, hearing loss at 4 kHz increases at a much faster rate.

The results of these two studies suggest that the 6-kHz notch is at least partly an outcome of the calibration standard and that the notch seems to become more distinct in persons with moderate noise exposure. The results of this study are consistent with

such a notion. In the past 10 years, hearing protection has been used extensively in BC in industries where the unprotected TWA noise exposure level is over 85 dB(A). Therefore, the actual noise exposure of workers using hearing protection has been considerably reduced, possibly to 80 dB(A) or below. It is not surprising that the younger male and female groups have a notch of 6 kHz.

This is also consistent with Fig.1 in which the damage at 4 kHz begins to catch up with that at 6 kHz at a higher age group. This is likely the consequence of the fact that very few workers used hearing protectors 15 years or so ago. The high noise exposure then could have caused more damage at 4 kHz. It is entirely possible for a younger worker who uses proper hearing protectors to have a notch which remains at 6 kHz. Therefore, one should not predict, although it is tempting, the future hearing level of a younger worker on the basis of the audiological data from older workers.

Other studies which demonstrated a 6-kHz notch in the audiogram also involved populations with a moderate noise exposure and also the use of hearing protectors. There were 538 boys from trade schools (Axelsson et al, 1981) and the young U.S. Air Force Military Personnel (Gasaway, personal communication).

In many audiometric programs 8 kHz is not one of the test frequencies. In those cases a 6-kHz notch is not seen. Particularly when this 6-kHz notch in the younger group occurs mostly between 10 - 20 dB HL it is often regarded as insignificant.

There is always the possibility, although unlikely, that the presence of the 6-kHz notch in the industrial population in BC is a consequence of the noise spectra that are peculiar to BC industries. However, in searching through our records of the industrial noise spectra no major occupations show exposure to noise with energy concentrating above 4 kHz. Also the large number of workers and the variety of industries preclude the possibility of biased sampling.

CONCLUSION

There is evidence in this study which indicates that 6 kHz is the frequency first attacked by noise at moderate level. The 6-kHz notch often first occurs in young workers with moderate noise exposure. Even though the notch often occurs at a level below 20 dB HL in the younger population its significance should not be ignored. It serves as an early warning indicator of susceptibility to noise damage. In that respect testing at 8 kHz should be seriously considered in a HCP.

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APPENDIX I
 MEDICAL HISTORY (HEARING)

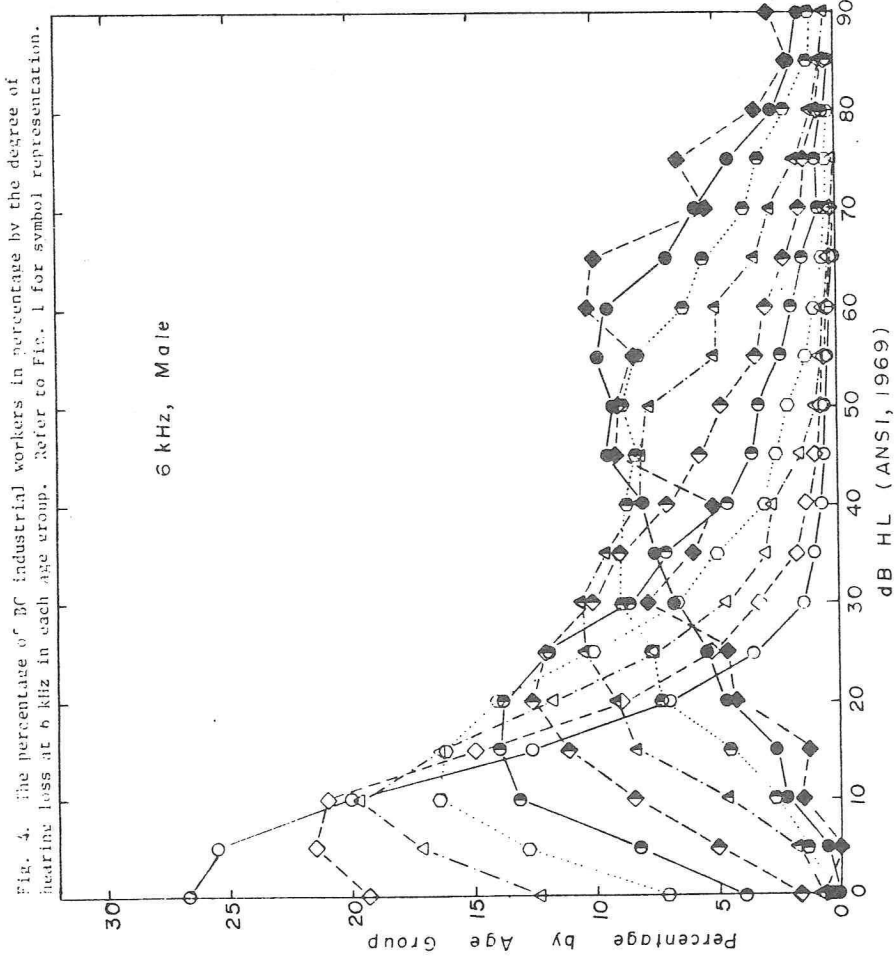


Fig. 4. The percentage of BC industrial workers in percentage by the degree of hearing loss at 6 kHz in each age group. Refer to Fig. 1 for symbol representation.

HAVE YOU EVER HAD:

- A) A hearing test by an ear specialist in the last 5 years
- B) A severe ear infection
- C) Ear drainage or pain
- D) Pressure in or around ears except altitude changes
- E) Ear surgery
- F) Dizziness or balance problems
- G) A serious head injury
- H) Exposure to loud blast or explosion
- I) A hearing aid now or in the past
- J) A relative with hearing loss before age 50

NO YES LEFT RIGHT

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DO YOU NOW HAVE:

- A) Trouble understanding speech
- B) Ringing in your ears
- C) Changes in hearing from day to day
- D) A ruptured ear drum

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