Gender Affects Audiometric Shape in Presbyacusis

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Abstract
A review of large-scale surveys of hearing over the past 50 years reveals a "gender-reversal" phenomenon in the average audiograms of the elderly. Above 1 kHz males show greater average loss than females, but below 1 kHz females show greater average loss than males. The effect increases with both age and degree of hearing loss. The difference is present whether or not the elderly persons complain of a hearing problem and remains after persons with a history of noise exposure are excluded from the analysis. A possible explanation, based on the greater likelihood of cardiovascular disease in the elderly female, is considered.

Key Words: Aging, audiogram, elderly, gender, sex

Surveys of hearing in the general population consistently show that males have poorer high-frequency sensitivity than females, and that the gap widens with age. Conventional wisdom attributes this age-related difference to the greater lifetime noise exposure typically experienced by males in the workplace, in the military, and in leisure activities.

In contrast to the considerable study of this age-related male–female difference in the 3000 to 6000 Hz region of the audiogram, relatively little attention has been directed toward a possible age-related gender difference in the low-frequency region, below 1000 Hz. It has been our clinical impression, for a number of years, however, that elderly females typically show poorer hearing sensitivity than elderly males at 250 and 500 Hz (Jerger and Jerger, 1981, p.148). A similar observation was recently made by Willott (1991, p. 169).

The purpose of the present communication is to review the evidence for such a low-frequency gender effect from previous survey data, and to analyze our database in an effort to differentiate among various factors that might be related to the phenomenon.

METHOD

Previous Surveys

We analyzed audiometric data provided by the Public Health Service survey of 1935–36 (Beasley, 1940; Glorig et al., 1957), the Finnish survey (Leisti, 1949), the Sudan survey of the Maabans (Rosen et al., 1962), the Goetzinger study (Goetzinger et al., 1961), the National Health survey of 1960–62 (Glorig and Roberts, 1965), the Jamaican survey (Hinchcliffe and Jones, 1968), the North Scotland survey (Kell et al, 1970), the Scottish survey of 1975 (Milne and Lauder, 1975), and the National Health survey of 1971–75 (Rowland, 1980). Table 1 summarizes the number of individuals tested in each of these studies, and their age ranges. We include the data of Goetzinger et al. (1961), in spite of the relatively small number of subjects (90), because the observations are concentrated in the age range of interest.

Present Database

Data from our laboratory include the audiometric thresholds for the right and left ears of 885 individuals in the age range from 50 to 89 years. There were 420 males and 465 females. We divided this total group into two subgroups according to whether the individuals came to
our audiology service with a hearing complaint (n = 687) or whether the individuals were recruited for research studies in aging (n = 198). The latter individuals typically had few or no auditory complaints and had not previously sought help for a perceived hearing problem. Additionally, all subjects in the latter group responded to a questionnaire probing, among other factors, any previous history of significant noise exposure.

All of the audiometric data in the present database were gathered by standard clinical technique (Carhart and Jerger, 1959) using conventional clinical audiometers in which intensity was varied in 5-dB steps. We attempted to minimize the possibility of significant middle-ear disorder in any subject by the requirement that immittance audiometric results, including tympanograms and acoustic reflex thresholds at 500, 1000, and 2000 Hz, be within normal limits (Jerger et al, 1972). Immittance results met these criteria in all but 9 of the 885 elderly subjects. In the 9 subjects with abnormal immittance findings, the gap between air-conduction and bone-conduction thresholds never exceeded 10 dB at any test frequency.

**Right versus Left Ear**

Some surveys tabulated data for both ears, others only for the right ear. In those studies where both right- and left-ear data were available, we compared the two ears. Invariably the left ear showed slightly greater loss than the right ear, but the trends with age, and the interactions with audiometric frequency were the same for the two ears. In all subsequent figures, therefore, we present only right-ear data.

Finally, statistical significance was evaluated at an alpha level of 0.05.

### RESULTS

#### Previous Surveys

Figure 1 summarizes the results of the 1960–62 and 1971–75 National Health surveys. Data take the form of the percent prevalence of hearing threshold levels exceeding 25 dB HTL as functions of age. Note that, in Figure 1, at 1 kHz, prevalence of loss shows the expected increase with age, and that there are no systematic gender differences at any age in either survey. At 2 and 4 kHz the expected gender difference appears in both surveys. The prevalence of loss exceeding 25 dB is greater in males than in females. Note, also, that over the age range from 45–74 years, the gender difference in both surveys is approximately constant.

At 500 Hz, however, there is a gender difference in the opposite direction. As age increases from 45 to 74 years, the prevalence of loss increases more rapidly for females than for males. The gender difference at this frequency is about the same in both surveys. Thus, although the prevalence of loss in these two surveys was greater for males than for females in the frequency region above 1 kHz, the same individuals showed that the prevalence of loss was greater in females than in males in the frequency region below 1 kHz.

We found the same evidence of a reversal in gender difference in several studies. Figure 2 compares data from the 1935–36 Public Health Service survey, the 1970 study of Kell et al, and the 1961 study of Goetzinger et al. Data are plotted as the female–male difference between average hearing threshold levels (HTLs) as functions of age, with audiometric frequency as the parameter. Thus a difference in the negative direction indicates that hearing sensitivity was poorer for males than for females, while a difference in the positive direction indicates that

#### Table 1: Age Ranges and Number of Individuals Tested in Selected Previous Hearing Surveys

<table>
<thead>
<tr>
<th>Study</th>
<th>Total N</th>
<th>Males</th>
<th>Females</th>
<th>Age Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1935–36 PHS (USA)</td>
<td>10,638</td>
<td>4,402</td>
<td>6,236</td>
<td>20-59</td>
</tr>
<tr>
<td>1949 Leisti (Finland)</td>
<td>451</td>
<td>211</td>
<td>240</td>
<td>16-92</td>
</tr>
<tr>
<td>1961 Goetzinger (USA)</td>
<td>90</td>
<td>45</td>
<td>45</td>
<td>60-89</td>
</tr>
<tr>
<td>1962 Rosen et al (Sudan)</td>
<td>1,024</td>
<td>748</td>
<td>276</td>
<td>10-79</td>
</tr>
<tr>
<td>1961-62 National Health survey (USA)</td>
<td>6,672</td>
<td>292</td>
<td>384</td>
<td>25-74</td>
</tr>
<tr>
<td>1968 Hinchcliffe and Jones (Jamaica)</td>
<td>676</td>
<td>376</td>
<td>276</td>
<td>15-75+</td>
</tr>
<tr>
<td>1970 Kell et al (Scotland)</td>
<td>852</td>
<td>317</td>
<td>476</td>
<td>25-74</td>
</tr>
<tr>
<td>1971–75 National Health survey (USA)</td>
<td>6,913</td>
<td>3,171</td>
<td>3,742</td>
<td>25-74</td>
</tr>
<tr>
<td>1975 Mine and Lauder (Scotland)</td>
<td>487</td>
<td>215</td>
<td>272</td>
<td>62-90</td>
</tr>
<tr>
<td>Present database (USA)</td>
<td>885</td>
<td>420</td>
<td>465</td>
<td>50-89</td>
</tr>
</tbody>
</table>

*Gender distribution not given.
hearing sensitivity was poorer for females than for males. In the 1935–36 survey the gender reversal is evident at 500 Hz. As age increases, the difference favors females at 2 and 4 kHz but favors males at 500 Hz. A similar effect is seen at 500 Hz in the Kell et al study. At virtually all ages above 24 years, males show more loss than females at 4 kHz, but in the older age groups females show more loss than males at 250 and 500 Hz.

Finally, the 1961 study of Goetzinger et al shows the effect quite clearly in the age range from 60–89 years. At 2 and 4 kHz the average loss is greater for males, but at both 500 and 250 Hz females show greater average loss, and the difference increases with age.

Note, also, that in all three of the studies summarized in Figure 2, 1 kHz is the fulcrum. There is virtually no gender difference at any age at this pivotal frequency.

In summary, each of five previous surveys of hearing across age groups shows a reversing gender difference. As age increases males show progressively more loss than females in the

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**Figure 2** Differences between average hearing levels of males and females as functions of age and audiometric frequency in two large-scale surveys (PHS survey of 1935–36, Kell et al [Scotland], 1970) and one small-scale study (Goetzinger, 1961).
frequency range above 1 kHz, but females show progressively more loss than males in the frequency region below 1 kHz.

Is the effect limited to populations where noise exposure is endemic or can it be found also in populations where noise exposure is minimal? To answer this question we contrast, in Figure 3, the results of two surveys from countries where noise exposure is minimal (Sudan and Jamaica) with the results of two surveys where noise exposure is greater (Scotland and Finland). Although the Sudanese and Jamaicans show less high-frequency loss than the Scots and the Finns, all four surveys show the same gender effect in the region below 1 kHz. It is interesting to observe, in the data from Scotland, that the low-frequency effect is present even though sensitivity is virtually identical in the two genders above 1 kHz.

There is, however, a problem with the interpretation of these data. We cannot know the extent to which undetected, perhaps gender-related, middle ear disorder may have influenced these survey data since most were carried out before the advent of immittance audiometry.

In an effort to sort out these various factors we addressed our database of audiometric data on elderly listeners.

**Present Database**

Figure 4 shows the average right-ear audiograms of 341 males and 346 females who came to the Methodist Hospital Audiology Service with the chief complaint of hearing loss. Ages ranged from 50 to 88 years. Mean age was 68.7 years for females and 65.9 years for males. In all but 9 cases the possibility of middle ear disorder was minimized by the requirement that the tympanogram must be of normal morphology in both ears and that crossed acoustic reflex thresholds, at the frequencies of 500, 1000, and 2000 Hz must not exceed 100 dB HTL in either ear. In the 9 subjects with abnormal immittance findings, the air-bone gap at any test frequency never exceeded 10 dB. We believe, therefore, that the loss we are studying is primarily sensorineural in both gender groups.

Figure 4 epitomizes the gender reversal phenomenon noted in the earlier surveys. At 1 kHz the average loss is about the same for males and females. Above this pivotal frequency males show greater average loss, and below it females show greater average loss. Comparison
of data from the two genders, by means of unpaired, two-tailed, t-tests, showed that at both 250 and 500 Hz the difference in mean threshold levels was significant (at 500 Hz, \( t = 5.35, p = .0001 \); at 250 Hz, \( t = 5.90, p = .0001 \)).

**Effect of Degree of Loss**

To study the effect of degree of sensorineural hearing loss on the phenomenon, we grouped the 687 subjects into four subgroups, based on the conventional average pure-tone threshold level (PTA) at 500, 1000, and 2000 Hz. Figure 5 plots threshold at each of the six individual audiometric frequencies as functions of overall PTA. There were 135 females and 144 males in the 0 to 20 PTA group, 136 females and 124 males in the 21 to 40 PTA group, 64 females and 62 males in the 41 to 60 PTA group, 11 females and 11 males in the greater-than-60 PTA group. Again, 1 kHz was the pivotal frequency. There was no systematic gender difference at this frequency. Nor was the gender difference systematic at 2 kHz. At 3 and 4 kHz we saw the expected greater loss in males except in the subgroup with the greatest loss, where the gender difference disappeared. Note that at the two lowest frequencies, 250 and 500 Hz, the gender reversal is evident. Now females show more average loss than males. Here, however, the difference was greatest in the subgroup with the most loss. This interaction between gender and degree of loss is best seen at 250 Hz, but is also evident at 500 Hz. Two-factor analyses of variance, carried out separately at 250 Hz, 500 Hz, and 1 kHz, revealed no significant gender difference at 1 kHz (\( F = 0.134, p = .714 \)) but significant gender differences at 250 Hz (\( F = 46.6, p = .0001 \)) and at 500 Hz (\( F = 55.54, p = .0001 \)). At all three frequencies the interaction between gender and degree-of-loss group was significant (250 Hz, \( p = .0484 \); 500 Hz, \( p = .022 \); 1 kHz, \( p = .0280 \)).

It is perhaps noteworthy that the effect of increasing overall loss was to attenuate the gender difference at high frequencies but to exacerbate the effect at low frequencies. Finally, because of the ubiquitous strong correlation between degree of loss and age one cannot say to what extent these trends are age-related versus degree-of-loss related.

**Complaint versus No Complaint**

We considered the possibility that the gender reversal phenomenon might be explained by some gender difference in the degree of loss causing the individual to seek help for his or her perceived hearing problem. To this end, we compared the average audiogram of our 687 clinic patients (the “complaint” group) with the
average audiogram of 198 elderly persons who had volunteered as subjects in our aging research program, did not consider themselves in need of hearing help, and had not previously sought help (the “no-complaint” group). Figure 6 shows the result of this comparison. Not unexpectedly there was less sensitivity loss in the no-complaint group, but the difference was surprisingly small, less than 5 dB at 1 kHz. In any event, the gender reversal phenomenon was evident in both groups. And again, in both groups, the pivotal frequency was 1 kHz. Unpaired t-tests of the difference between male and female average losses at 250 and 500 Hz in the no-complaint group were significant (at 250 Hz, t = 2.51, p = .0128; at 500 Hz, t = 2.54, p = .0119).

Effect of Previous Noise Exposure

It is not unreasonable to suppose that more males than females have been exposed to hazardous noise levels during their lifetime. Could this difference explain the gender reversal phenomenon? To examine this possibility we searched the questionnaires of the 198 individuals in our no-complaint group and discarded the data of any individual who reported significant noise exposure. The audiograms of 16 females and 59 males were discarded on this basis, leaving a total of 103 females and 20 males in a “non-noise-exposed” subgroup. Figure 7 compares the average audiograms of this subgroup (n = 123) with the average audiograms of the full no-complaint group (n = 198). As a result of the exclusion of subjects with previous noise exposure histories, there was considerably less loss in the males at 2, 3, and 4 kHz, but the gender reversal phenomenon at 250 and 500 Hz remained.

Distributions of Thresholds

It is of interest to compare the distributions of sensitivity loss for males and females at low and high frequencies. At 250 Hz, for example, is the distribution for females shifted uniformly, or is the difference in means due to a subsample of females with greater loss? Figure 8 compares the distributions of male and female threshold levels at two frequencies, 250 and 3000 Hz. Data are for right ears of the 687 patients with an auditory complaint. Note that at 3000 Hz the expected greater probability of more severe losses in males appears. At this frequency females are more likely to have mild and moderate losses, while males are more likely to have moderate and severe losses. Of greatest interest to the present report, however, is the distribution of threshold levels at 250 Hz. Here we see a relatively uniform shift of the female distribution toward greater loss than the male distribution. Starting at the left side of the graph (i.e., at −5 dB HTL), the male distribution shows a steep rise
to a mode at 10 dB HTL, then a more gradual decline with a skew in the direction of mild and moderate loss. The female distribution on the other hand, shows a more gradual rise to a mode at 20 dB HTL, then a relatively symmetric decline in the direction of moderate loss. There is little to suggest the presence of a bimodal distribution (i.e., a subsample of females whose loss is on a different basis, or more severe, than the overall group).

**DISCUSSION**

The examination of hearing survey data from several countries over a period of more than 50 years shows a consistent gender reversal phenomenon. Males show more loss than females at frequencies above 1 kHz, but females show more loss than males below 1 kHz. At 1 kHz, there is typically no gender difference. The effect increases with both age and hearing threshold level, is present in the elderly with hearing loss whether they regard the loss as sufficient to seek help or not, and remains after persons with a history of noise exposure have been removed from the analysis.

This curious difference in audiometric shape suggests the possibility that different factors may be involved in the age-related loss of hearing sensitivity in males and females. Differences above 1 kHz may be related to greater accumulated noise exposure, which the individual may not regard as sufficient to report. The greater loss in females, below 1 kHz, however, is less easily explained.

A possible mechanism to consider is atrophy of the stria vascularis. In their analysis of the Framingham cohort (Dawber, 1980), Gates et al (1992) noted that low-frequency hearing loss (average of 250, 500, and 1000 Hz) was slightly greater in women than in men, and that such loss was related to cardiovascular disease events in both genders, but more in women. They theorized that a logical mediator of low frequency sensorineural loss would be microvascular disease affecting the capillaries and arterioles of the stria vascularis. Schuknecht (1964) described such strial atrophy in the elderly, terming it "metabolic presbycusis." The present results would be explainable by the observations of Gates et al, that, as a result of greater cardiovascular disease events, such strial atrophy may be more likely in elderly women.

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