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Asymmetry in noise-induced hearing loss: Evaluation of two competing theories

Richard L. Berg, William Pickett[1,2], James G. Linneman, Douglas J. Wood[3], Barbara Marlenga[4]

Biomedical Informatics Research Center, [4]National Farm Medicine Center, Marshfield Clinic Research Foundation, [3]Department of Audiology, Marshfield Clinic, Marshfield, Wisconsin, USA, Departments of [1]Emergency Medicine, and [2]Department of Public Health Sciences, Queen's University, Kingston, Ontario, Canada

Abstract

Competing theories exist about why asymmetry is observed in noise-induced hearing loss (NIHL). We evaluated these theories using a cohort of young workers studied over 16 years. The study aim was to describe and evaluate patterns of hearing loss and asymmetry by gender, agricultural exposure and gunfire exposure. This was a secondary analysis of data collected from young adults during follow-up of a randomized controlled trial. This follow-up study evaluated long-term effects of a hearing conservation intervention for rural students. The sample consisted of 392 of 690 participants from the original trial. In total, 355 young adults (aged 29-33 years) completed baseline and follow-up noise exposure surveys and clinical audiometric examinations. Data are displayed graphically as thresholds by frequency and ear and degree of asymmetry between ears (left minus right). In the primary group comparisons, low and high frequency averages and mean high frequency asymmetry were analyzed using mixed linear models. At frequencies >2000 Hz, men showed more hearing loss, with greater asymmetry and a different asymmetry pattern, than women. For men with documented hearing loss, there was a trend toward increasing asymmetry with increasing levels of hearing loss. Asymmetry at high frequencies varied substantially by level of shooting exposure. While "head shadowing" is accepted as the primary explanation for asymmetric hearing loss in the audiologic and related public health literature, our findings are more consistent with physiological differences as the primary cause of asymmetric hearing loss, with greater susceptibility to NIHL in the left ear of men.

Keywords: *Agriculture, asymmetry, noise-induced hearing loss, young workers*

Introduction

Millions of people in the United States have hearing loss caused by exposure to loud noise from occupational or recreational activities.[1] Gender differences in hearing have long been noted, even among subjects presumed to be ontologically normal[2,3] and an asymmetric phenomenon in noise-induced hearing loss (NIHL) has been observed.[4-10] Men tend to lose their hearing differentially between the left and right ears, with more evidence of NIHL in the left ears. Interestingly, this asymmetric pattern is less evident among women.[7] The most common explanation for this asymmetry in NIHL among men is that their left ears are differentially exposed to more loud noise (see review by McFadden 1993).[7] Possible physiological explanations have also been proposed,[7,8,11,12] but these explanations have not been widely accepted.

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In agriculture, NIHL is an important public health concern. Indeed, agriculture has been identified as an industry with among the highest exposure to dangerous noise levels.[13] Many studies have documented a high prevalence of NIHL among farmers (see review by McCullagh)[14] and identified an asymmetric pattern of hearing loss that is worse in the left ear. The predominant explanation for this asymmetric pattern in NIHL among farmers is that while operating tractors, farmers turn their heads to monitor trailed equipment, resulting in the left ear being exposed to engine noise and the exhaust system.[15-19] The right ear is presumably shielded by a phenomenon referred to as "head shadowing."

Among gun users, NIHL has been documented as a similar health concern. Gun use, along with other high noise exposures, places those in military service at high risk for occupational NIHL.[13] Similarly, recreational target shooters and hunters are also at high risk for NIHL.[1] Asymmetric patterns of NIHL in those exposed to gunfire have also been observed, with more hearing loss noted in the left ears.[20] The prevailing explanation for this phenomenon is another expression of the "head shadowing" theory in that predominantly right-handed shooters tilt their heads to the right, thereby more directly exposing the left ear to the impulse noise of the firearm.[16,19-23]

As noted above, there are competing theories (physiology vs. the physics of noise exposure) about why patterns of asymmetry are observed in NIHL. We had an opportunity to evaluate these theories using an existing cohort of young workers. Our objectives were to describe and evaluate patterns of hearing loss and asymmetry by

1. Gender,
2. Exposure to agriculture and
3. Exposure to gunfire.

Methods

Overview

This study is a secondary analysis of data collected from young adults during a follow-up of a randomized controlled trial. The trial and its long-term follow-up were designed to evaluate the effects (up to 16 years) of a hearing conservation intervention for rural high school students.[24] The current analyzes related gender, historical exposure to agriculture and historical exposure to gunfire as possible determinants of asymmetric patterns of NIHL. The study protocol was approved by the institutional review boards of the two participating organizations.

Sample

The sample consisted of 392 of 690 (57%) participants who took part in the original randomized controlled trial from 1992 to 1996 and were successfully located and recruited for the 2009-2010 follow-up study after exhaustive efforts. In total, 355 (91%) young adults (aged 29-33 years) completed both the survey and the clinical audiometric examination at follow-up and their records are analyzed here.

Data sources

In the original trial, participants completed noise exposure surveys and audiometric examinations at entry (baseline) and 3 years later. At the long-term follow-up, participants completed an exposure history survey covering the 13 years since last contact in 1996. The survey focused on high noise level occupational and recreational exposures as well as use of hearing protection devices for each exposure. All exposure measures were collected using numeric quantities, time periods and duration of exposures over the 13-year survey period, thus permitting the development of summary metrics that accounted for both intensity and duration of each exposure.

At the long-term follow-up, participants were also scheduled for audiometric examinations in clinical audiology departments to obtain measures of hearing sensitivity and any NIHL. Examinations were conducted by licensed audiologists using standard operating procedures.[25] Audiometric results were thus available for participants at baseline (when ages 12-16 years) and approximately 16 years later (when ages 29-33 years).

Statistical analyzes

Audiometry results are summarized by gender, by agricultural work history and by shooting exposure. These data are displayed graphically as both the thresholds by frequency and ear and in terms of the degree of asymmetry between ears (left minus right). In the primary group comparisons, the low (500, 1000, 2000 Hz) and high (3000, 4000, 600, 8000 Hz) frequency averages and the mean high frequency asymmetry were analyzed using mixed linear models. These models included school as a random effect, in keeping with the randomization by school in the original study design.

Results

Table 1 describes the 355 participants by gender with respect to age, education, smoking history, shooting exposure and occupational exposure. Ages at follow-up ranged from 29 to 33 years and consistent with the original cohort, the majority (68.5%) were men. As previously reported,[10] men reported substantially more exposure to noisy recreational and occupational activities.

Figure 1a summarizes the current audiometric results by gender. While men and women were similar at low frequencies (in the mixed model analysis, $P = 0.358$ for low frequency average [LFA]), there were substantial and highly significant differences at high frequencies ($P < 0.001$ for high frequency average [HFA]), with men showing higher thresholds. Figure 1b is a profile plot showing the mean thresholds for right ears on the right and means for left ears on the left; the pattern in women (shown by shading) is quite symmetric at all frequencies while men show substantial asymmetry at frequencies above 2000 Hz. Figure 1c summarizes high

Table 1: Description of the study population

Characteristic	Women (*n* = 112)	Men (*n* = 243)
Age (years)		
Median	30.7	31.2
Range	29-32	29-33
Technical/college degree (%)	66.1	48.1
Smoking (% ever)	26.8	34.7
Any gun use (%)	27.7	84.8
Agriculture job (%)	67.9	81.9
Construction job (%)	6.3	46.3
Manufacturing job (%)	31.3	43.2
Occupational hearing test (%)	10.7	23.5

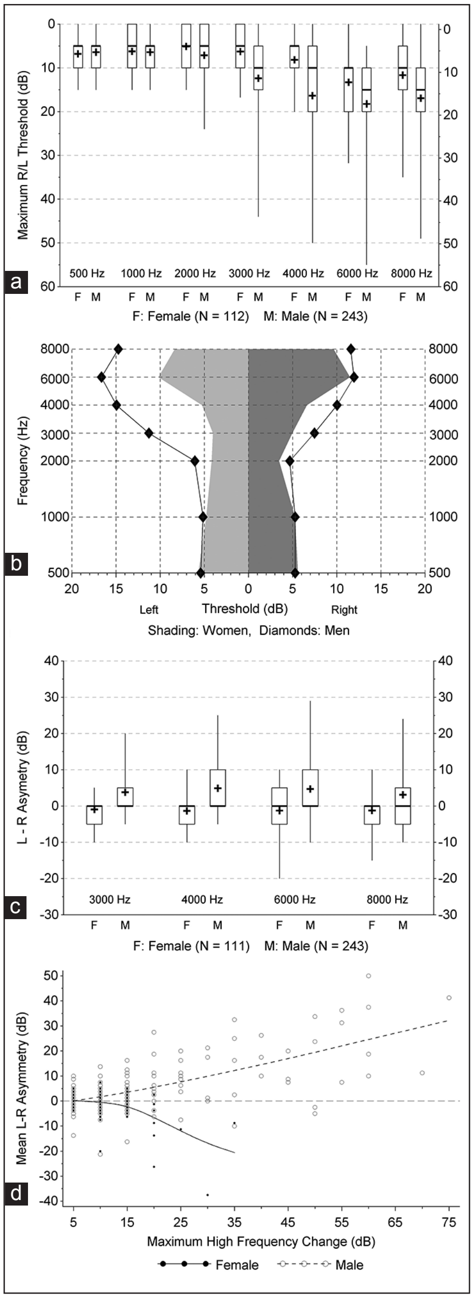

Figure 1: Patterns of hearing loss and asymmetry by gender. (a) Thresholds by gender — summary box plots extend from the 25th to 75th percentiles, with a midline at the median, "+" at the mean and vertical lines extending to the 5th and 95th percentiles. (b) Mean thresholds by ear and gender — shaded region extends to the mean for women at each frequency, while "♦" shows the corresponding mean for men. (c) Asymmetry by gender — individual subject differences between ears (left minus right) are summarized with box plots (described in a). (d) Mean asymmetry by gender — for individual subjects showing at least a 5 dB change from baseline at one or more high frequencies (3-8K Hz), the mean asymmetry (left minus right ear) over the high frequencies is plotted versus the maximum change from baseline. Filled (open) circles show results for women (men), while solid (dashed) lines illustrate trends using a cubic spline smoothing function for women (men)

frequency asymmetry in terms of the individual differences between ears (left minus right); the gender differences in asymmetry are highly significant ($P < 0.001$ for the high frequency mean) as demonstrated by values >0 (left threshold higher) in men and less strong but negative means (right threshold higher) in women. These gender differences in asymmetry are further illustrated in Figure 1d for those with documented hearing loss (at least one frequency showing change from baseline ≥5 dB); there was a strong trend in men for increasingly positive asymmetry with increasing level of observed hearing loss, contrasting with a weaker trend in the opposite direction in women.

Given the substantial differences between men and women and the fact that over two-thirds of the cohort were men, subsequent analyzes are limited to the 243 male subjects. Figure 2 summarizes the final audiometric results for men by history of work in agriculture (where most machinery exposures exceed 85 dB) during the 13 years from the end of the original trial to the follow-up survey and audiometric examination. Work history is summarized in three groups from lowest to highest exposure: Low, reporting a median of 0 full-time equivalent weeks (range 0-24.6); medium, with median 104 weeks (range 29.5-256); and high, with median 650 weeks (range 260-676). Figure 2a shows similar thresholds by level of agricultural exposure and this is true for both low frequencies ($P = 0.578$ for LFA) and for high frequencies ($P = 0.858$ for HFA). The profile plot in Figure 2b shows asymmetry at high frequencies that is very consistent regardless of agricultural exposure. This consistency is also clear in the summary of differences between ears in Figure 2c ($P = 0.789$ for the mean). The similarity in trends for asymmetry by level of hearing loss is shown in Figure 2d.

Figure 3a summarizes the current audiometric results for men by exposure to shooting in three groups from lowest to highest exposure. The first group included all those reporting no shooting in the last 16 years while shooters were divided into two groups based on the median number of shots fired: Low, with median 182 shots (range 2-455); and high, with median 1398 shots (range 500 to >40,000). Figure 3a shows relatively little difference at low frequencies by level of shooting exposure ($P = 0.076$ for LFA), but substantial differences at high frequencies ($P < 0.001$ for HFA). The profile plot in Figure 3b shows asymmetry at high frequencies that differs substantially by level of shooting exposure ($P = 0.008$ for the mean high frequency difference between ears).

To more directly address the hypothesis that these shooting-associated differences may result from tilting of the head, Figure 3c and d reclassify shooters into those who reported shooting right-handed and those who reported shooting left-handed. Although the number of left-handed shooters is small (20 men), Figure 3c shows similar levels of high frequency asymmetry in right- and left-handed shooters ($P = 0.518$ for the mean). Furthermore, right- and left-handed shooters

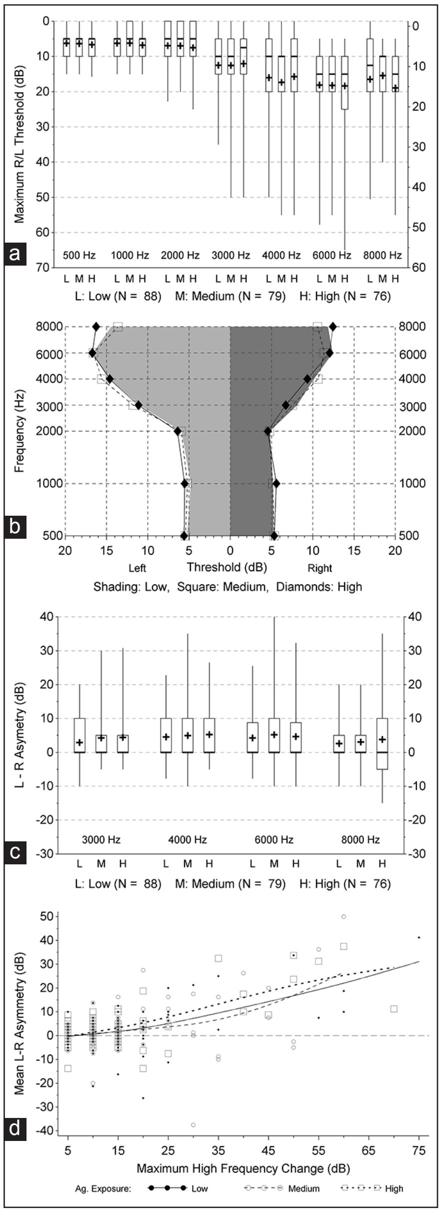

Figure 2: Patterns of hearing loss and asymmetry by exposure to agriculture, men only. (a) Thresholds by level of exposure — summary box plots extend from the 25th to 75th percentiles, with a midline at the median, "+" at the mean and vertical lines extending to the 5th and 95th percentiles. (b) Mean thresholds by ear and level of exposure — shaded region extends to the mean for the low exposure group at each frequency, while "□" shows the corresponding mean for the medium exposure group and "♦" shows the corresponding mean for the high exposure group. (c) Asymmetry by level of exposure — individual subject differences between ears (left minus right) are summarized with box plots (described in a). (d) Mean asymmetry by level of exposure — for individual subjects showing at least a 5 dB change from baseline at one or more high frequencies (3-8K Hz), the mean asymmetry (left minus right ear) over the high frequencies is plotted versus the maximum change from baseline. Filled circles and the solid line show subjects with low exposures, open circles and the fine dashed line show subjects with medium exposures and squares and the heavy dashed line show subjects with high exposures. Lines illustrate trends using a cubic spline smoothing function

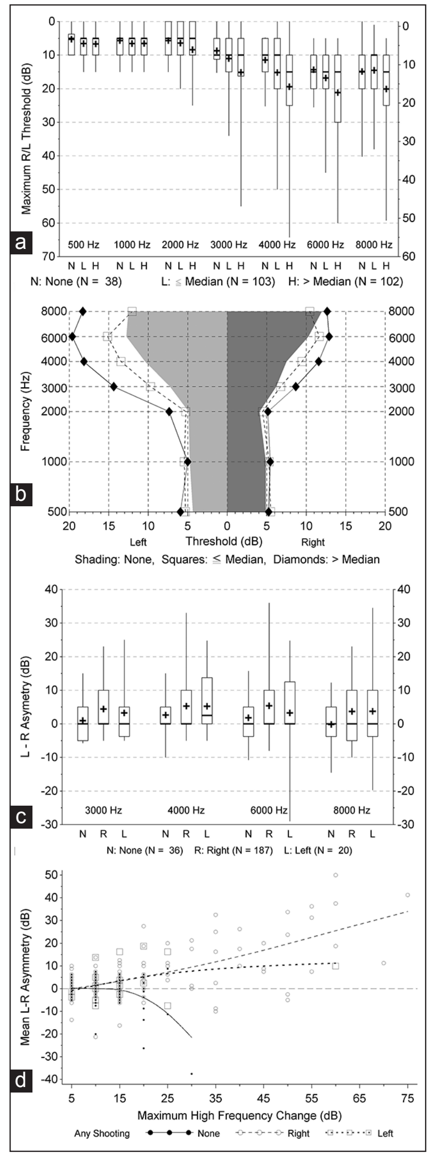

Figure 3: Patterns of hearing loss and asymmetry by exposure to gunfire, men only. (a) Thresholds by level of exposure — summary box plots extend from the 25th to 75th percentiles, with a midline at the median, "+" at the mean and vertical lines extending to the 5th and 95th percentiles. (b) Mean thresholds by ear and level of exposure — shaded region extends to the mean for men reporting no shooting, while "□" shows the corresponding mean for the low exposure group and "♦" shows the corresponding mean for the high exposure group. (c) Asymmetry by right or left shooting exposure — individual subject differences between ears (left minus right) are summarized with box plots (described in a) for those who reported no shooting and those who reported shooting right and those who reported shooting left. (d) Mean asymmetry by shooting exposure — for individual subjects showing at least a 5 dB change from baseline at one or more high frequencies (3-8K Hz), the mean asymmetry (left minus right ear) over the high frequencies is plotted versus the maximum change from baseline. Filled circles and the solid line show subjects reporting no shooting, open circles and the fine dashed line show subjects who reported shooting right and squares and the heavy dashed line show subjects who reported shooting left. Lines illustrate trends using a cubic spline smoothing function

showed similar trends for asymmetry by level of hearing loss [Figure 3d].

Although noise exposures may be mitigated to varying degrees through the use of hearing protection devices, the vast majority of male subjects reported only limited use of such devices [Table 2]. Analyzes of high frequency asymmetry were repeated after excluding those who reported always using hearing protection with guns and these analyzes continue to show significant differences by level of shooting exposure (P = 0.024) but not by handedness (P = 0.564).

Discussion

This analysis of audiometric data from our recent randomized trial provides new evidence about the phenomenon of asymmetry in NIHL among a large cohort of young workers followed for up to 16 years. The analysis was designed to examine the extent of the asymmetric pattern of NIHL in young workers and to test two competing theories about how such patterns of asymmetry might evolve over time. The first theory, which surrounds the practice of "head shadowing," suggests that differentially shielding the right ear from noise emitted from mechanized sources (e.g., tractors) and also gunshots leads to higher levels of NIHL in the left ear.[7] The second theory involves a physiological explanation. This latter theory suggests that the left ear, particularly among males, is somehow more susceptible to NIHL than is the right ear and this translates into an asymmetric pattern of hearing loss when workers face exposures that are detrimental to their hearing.[7,8,11,12]

While the "head shadowing" theory for asymmetry is accepted as fact in much of the audiologic and related public health literature, there is actually little published evidence that objectively supports this idea. Our findings build upon this apparent contradiction. If "head shadowing" was the primary explanation for asymmetry, in our analyzes we expected to observe the following: That men and women who experienced NIHL would demonstrate a similar asymmetric pattern, with more hearing deficits observed at high frequencies in the left ear than in the right ear; that the asymmetric pattern would increase in association with higher levels of NIHL for both genders; that asymmetry observed at high frequencies would be strongly correlated with historical exposures to agricultural work and also gunshots (both potential sources of "head shadowing" to protect subjects from noise); and that we would observe a different asymmetric pattern among left- and right-handed shooters. Our study findings were not consistent with these patterns. Indeed, we observed that the asymmetric pattern of NIHL was present, but only observed in men at higher frequencies; that men, but not women, showed a trend for positive asymmetry with increasing level of NIHL; that among men, the asymmetric pattern was consistent in groups defined by historical exposure to agriculture and presumably exposures to associated mechanized tasks such as tractor operation; and the asymmetric pattern of hearing loss to the left ear tended to be similar for left- and right-handed shooters. Quite surprisingly, this provided little compelling evidence to support the "head shadowing" effect in either agricultural work or shooting contexts as a credible explanation for the asymmetric pattern of NIHL in young workers.

Table 2: Use of hearing protection in men

Frequency of use	Activity			
	Gun use		Agriculture	
	N	%	*N*	%
Never (0%)	69	33.5	67	35.1
Sometimes (1-33%)	16	7.8	71	37.2
Often (34-66%)	28	13.6	30	15.7
Frequently (67-99%)	39	18.9	20	10.5
Always (100%)	54	26.2	3	1.6
NA[a]	37		52	

[a]No exposure or otherwise not available

Evidence in support of the physiological explanation for asymmetric NIHL was admittedly somewhat less direct in our study than would be optimal. It was not feasible to obtain and interpret direct measures of the ear and its structure and function in our setting on all of these workers. However, our findings for male versus female workers were of interest here. Although limited somewhat by our modest number of female participants, even fewer of whom experienced NIHL, men and women exhibited different patterns of hearing loss. Women who experienced NIHL tended to exhibit symmetry in NIHL or arguably a pattern that trended toward more observed hearing deficits in the right ear. Men who experienced NIHL exhibited the more classic occupational pattern that was asymmetric with deficits observed in the left ear. However, among men, the left-oriented asymmetric pattern occurred even among those with historical exposures to left-handed shooting that would be expected to lead to differential loss of hearing in the right ear if those environmental explanations (e.g., the "head shadowing" effect) were the total cause of the asymmetry. Hence, in the absence of an environmental explanation that is supported by the fact, the physiological explanation remains as the more credible (but at this stage unproven) alternative.

Strengths of this analysis warrant comment. First, this study is novel in that it applies audiometric assessment combined with noise exposure histories to a clinical phenomenon that has often been approached and interpreted anecdotally. Second, this cohort of young workers is one of the largest of its kind, with 16-year audiometric follow-up conducted to modern professional standards on 355 participants. Third, our graphical and statistical approaches to the study of asymmetry are also novel and are meant to provide a simple visual summary that can be easily translated to audiology and other clinical communities. Limitations of this study include our reliance on self-report measures used to summarize historical exposures to noise. Some misclassification will exist for many of these exposures, although grouping exposures into large categories would be expected to minimize the effects of such misclassification. Second, while our exposure history contained measures for general occupational environments (e.g., agriculture), details on specific exposures (e.g., tractors) were limited. We, therefore, did not employ direct measures of "head shadowing" practices for mechanized tasks within our data collection. Third, we recognize that the size of the study was limiting for some analyzes, leading us to exclude women when evaluating agriculture and shooting and limiting our statistical power in comparisons of right- and left-handed shooters. Finally, our study did not include any direct measures of the physiology of the ear, nor changes to that physiology over time, which limited our potential to investigate the latter theory.

Conclusions

Findings from our study point to the need to re-examine the prevailing explanations for asymmetry in NIHL among occupational workers. From a research perspective, they point to the need for more in-depth studies, including potential variations between men and women that might further illuminate natural risk and protective factors for NIHL. This might confirm or refute physiological explanations of the asymmetry in NIHL. From a clinical perspective, resolution of this may also have implications for how workers are counseled with respect to the prevention of hearing loss in high risk occupational and recreational settings.

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Address for correspondence:
Dr. Barbara Marlenga,
National Farm Medicine Center, Marshfield Clinic Research Foundation, 1000 North Oak Avenue, Marshfield, WI 54449, USA.
E-mail: marlenga.barbara@mcrf.mfldclin.edu

References

1. National Institute on Deafness and Other Communication Disorders, National Institutes of Health [NIDCD/NIH Web site]. Noise-Induced Hearing Loss. Bethesda, MD: NIH Pub. No. 97-4233; 2008. Available from: http://www.nidcd.nih.gov/health/hearing/pages/noise.aspx. [Last cited on 2012 Jun 05].
2. International Organization for Standardization Acoustics — Statistical Distribution of Hearing Thresholds as a Function of Age: ISO7029. Geneva: ISO; 2000.
3. Stenklev NC, Laukli E. Presbyacusis-hearing thresholds and the ISO 7029. Int J Audiol 2004;43:295-306.
4. Kannan PM, Lipscomb DM. Letter: Bilateral hearing asymmetry in a large population. J Acoust Soc Am 1974;55:1092-4.
5. Borod J, Obler L, Albert M, Stiefel S. Lateralization for pure tone perception as a function of age and sex. Cortex 1983;19:281-5.
6. Pirilä T, Jounio-Ervasti K, Sorri M. Left-right asymmetries in hearing threshold levels in three age groups of a random population. Audiology 1992;31:150-61.
7. McFadden D. A speculation about the parallel ear asymmetries and sex differences in hearing sensitivity and otoacoustic emissions. Hear Res 1993;68:143-51.
8. Nageris BI, Raveh E, Zilberberg M, Attias J. Asymmetry in noise-induced hearing loss: Relevance of acoustic reflex and left or right handedness. Otol Neurotol 2007;28:434-7.
9. Berg RL, Pickett W, Fitz-Randolph M, Broste SK, Knobloch MJ, Wood DJ, *et al*. Hearing conservation program for agricultural students: Short-term outcomes from a cluster-randomized trial with planned long-term follow-up. Prev Med 2009;49:546-52.
10. Marlenga B, Berg RL, Linneman JG, Wood DJ, Kirkhorn SR, Pickett W. Determinants of early-stage hearing loss among a cohort of young workers with 16-year follow-up. Occup Environ Med 2012;69:479-84.
11. Sato H, Sando I, Takahashi H. Sexual dimorphism and development of the human cochlea. Computer 3-D measurement. Acta Otolaryngol 1991;111:1037-40.
12. Morlet T, Perrin E, Durrant JD, Lapillonne A, Ferber C, Duclaux R, *et al*. Development of cochlear active mechanisms in humans differs between gender. Neurosci Lett 1996;220:49-52.
13. Centers for Disease Control and Prevention (CDC). Work Related Hearing Loss. [CDC Web site]. Atlanta, GA: NIOSH Publication Number 2001-103; 2001. Available from: http://www.cdc.gov/niosh/docs/2001-103. [Last cited on 2012 Jun 05].
14. McCullagh M. Preservation of hearing among agricultural workers: A review of literature and recommendations for future research. J Agric Saf Health 2002;8:297-318.
15. Broste SK, Hansen DA, Strand RL, Stueland DT. Hearing loss among high school farm students. Am J Public Health 1989;79:619-22.
16. Kerr MJ, McCullagh M, Savik K, Dvorak LA. Perceived and measured hearing ability in construction laborers and farmers. Am J Ind Med 2003;44:431-7.
17. Kumar A, Mathur NN, Varghese M, Mohan D, Singh JK, Mahajan P. Effect of tractor driving on hearing loss in farmers in India. Am J Ind Med 2005;47:341-8.
18. Lierle DM, Reger SN. The effect of tractor noise on the auditory sensitivity of tractor operators. Ann Otol Rhinol Laryngol 1958;67:372-88.
19. Marvel ME, Pratt DS, Marvel LH, Regan M, May JJ. Occupational hearing loss in New York dairy farmers. Am J Ind Med 1991;20:517-31.
20. Nondahl DM, Cruickshanks KJ, Wiley TL, Klein R, Klein BE, Tweed TS. Recreational firearm use and hearing loss. Arch Fam Med 2000;9:352-7.
21. Job A, Grateau P, Picard J. Intrinsic differences in hearing performances between ears revealed by the asymmetrical shooting posture in the army. Hear Res 1998;122:119-24.
22. Moon IS. Noise-induced hearing loss caused by gunshot in South Korean military service. Mil Med 2007;172:421-5.
23. Sataloff J, Hawkshaw MJ, Sataloff RT. "Gun-shooting hearing loss": A pilot study. Ear Nose Throat J 2010;89:E15-9.
24. Marlenga B, Linneman JG, Pickett W, Wood DJ, Kirkhorn SR, Broste SK, *et al*. Randomized trial of a hearing conservation intervention for rural students: Long-term outcomes. Pediatrics 2011;128:e1139-46.
25. American National Standards Institute (ANSI). American National Standard Methods for Manual Pure-Tone Threshold Audiometry. Melville, NY: Acoustical Society of America; 1978.p.S3.21.

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