

# Hearing Loss and Use of Hearing Protection Among Career Firefighters in the United States

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**Objective:** To determine the prevalence and characteristics of noise-induced hearing loss (NIHL) and the use of hearing protection devices (HPDs) among career firefighters. **Methods:** A Web-based survey and a standard audiometric test were performed with 425 firefighters from three states in the United States. **Results:** More than 40% showed hearing loss in the noise-sensitive frequencies (4 and 6 kHz). The left ear showed significantly poorer hearing than the right ear. Firefighters having longer years of work in fire services demonstrated significantly worse hearing. Reported use of HPDs was 34% of the time that was needed. Firefighters who used HPDs less were significantly more likely to have hearing loss. **Conclusions:** This study demonstrated a considerable NIHL problem and low use of HPDs in firefighters. More comprehensive hearing conservation programs should be implemented to reduce NIHL for firefighters.

Noise-induced hearing loss (NIHL) remains a major occupational health problem. In the United States, approximately 10% (22 million) of adults aged between 20 and 69 years have permanent hearing loss due to exposure to loud noise at work or during leisure activities.<sup>1</sup> Noise-induced hearing loss is one of the most prevalent occupational injuries among more than 1 million firefighters in the United States.<sup>2</sup> Noise-induced hearing loss is an irreversible chronic injury caused by repeated exposure to loud noise for a prolonged period, but it is completely preventable.<sup>3</sup>

Firefighters are routinely exposed to high level of intermittent noise on the job, particularly during emergency responses when sirens, air-horns, and vehicle engines are running.<sup>4-9</sup> An earlier qualitative study with firefighters in a Midwestern state<sup>5</sup> identified common sources of noise in fire service, which include fire truck sirens, air horn warning signals, and powered tools. Furthermore, ventilation (ie, cutting holes in roofs with power tools), extraction (ie, use of power tools and air chisels), fire attack jobs (ie, use of high-pressure fire hoses), station tasks (ie, filling air bottles and maintaining trucks, equipment, and the fire house), and miscellaneous tasks such as starting/idling trucks and setting air brakes were also identified noisy tasks.<sup>5</sup> A recent noise monitoring study using task-based exposure assessment modeling showed that firefighters have a risk potential of 85 dBA time-weighted average on any given day. The study finding revealed that firefighter's noise exposure ranged from 82 to 109 dBA, with the highest levels resulting from the use of saws and pneumatic chisels.<sup>6</sup> These risks of exposure to loud noise may cause permanent hearing impairment among firefighters.

Many studies in the United States have demonstrated that firefighters' noise exposure results in increased risk of hearing loss, and have recommended the wide implementation of hearing conservation programs for firefighters that include both engineering controls to reduce noise exposures and use of hearing protection devices (HPDs).<sup>7-10</sup> Although one study from Clark and Bohl<sup>11</sup> has reported no risk of increased occupational NIHL in FF, this result seems contrary to the preponderance of the literature.

Studies in other countries such as the United Kingdom and South Korea have also reported significance of occupational NIHL problem in firefighters. For example, a recent study<sup>12</sup> reported that significant hearing losses occurred in Scottish firefighters during the early stages of their careers. Another study from Korea<sup>13</sup> has demonstrated that firefighters with longer work experience in fire service (20 years or more) showed statistically significant hearing loss compared with other subgroups of firefighters when age and other risk factors were controlled for. Nevertheless, studies that quantified the NIHL problem are limited. We found one such study that reported that hearing loss among fire brigades in the United Kingdom accounted for 4% of ill-health retirements.<sup>14</sup> But the study has reported that the magnitude of hearing loss as a cause of accidents and near misses is very low (0.13%).<sup>14</sup> This may be due to a possible underreporting of the accidents and near misses due to hearing difficulty. Even though firefighters are having difficulty with the job because of hearing loss, they tend not to report the problem for fear of losing their jobs.

Firefighting requires good hearing abilities to determine the nature of an emergency, to make critical decisions in a chaotic and potentially life-threatening situation, to hear and respond to moans and cries in a rescue search, and to listen and respond to mission-critical radio communications and warning signals. The current National Fire Protection Association 1582 Standard<sup>15</sup> precludes a firefighter from performing as a member in a training or emergency operational environment if they have hearing loss (greater than 40 decibels [dB] at 0.5 to 2 kHz in the better ear). The rate of hearing loss for firefighters at noise-sensitive frequencies of 3 to 6 kHz is much higher than that for the general population.<sup>7</sup> In the fire ground, conditions are commonly such that smoke reduces or removes all visual cues. Thus, it is easy to get lost in a fire scene, especially if one loses contact with the water line (hose). In these situations, the ability of the firefighter to follow the sound of the duty partner's voice to lead them to safety is critical. As hearing is critical for safe and effective job performance for firefighters, significant loss of hearing can be a career-ending disability as well as impact public safety. Thus, it is important to assess current hearing ability among firefighters. The purpose of this study was to determine the prevalence and characteristics of hearing loss among career firefighters.

## METHODS

### Study Design and Participants

This cross-sectional study included the audiometric test results and survey data that were obtained from firefighters as a part of their hearing protection training. For the purpose of testing the effectiveness of the intervention in the original study from which this study data were drawn, the sample size was determined through the power analysis using Personal Alert Safety System (PASS) software

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(Number Cruncher Statistical Software [NCSS], Kaysville, UT).<sup>16</sup> The initial target sample size was 412.

The study participants were recruited from occupational health clinics, fire departments, or audiologists' hearing test clinics in three states (California, Illinois, and Indiana) of the United States. More elaborated description on the recruitment approaches including unexpected challenges and successful resolutions are reported elsewhere.<sup>17</sup> The preintervention data collected from March 2010 to November 2011 were included in the analysis for this study. Approximately 722 firefighters from more than 35 fire departments were recruited. Among them, a total of 425 had actually participated in this study, resulting in a response rate of 59% (425/722). The research protocol for this study was approved by the Committee of Human Research of the University of California at San Francisco and the institutional review board of NorthShore University Health System in Evanston, Illinois, in the United States. Participation was voluntary and all interested volunteers had completed informed consents before the preintervention survey and audiometric tests were given. All participants received a \$25 gift card for their contribution to the study.

## Measures

### Hearing Ability

Hearing ability was assessed by a standard pure-tone audiometric test. The audiometer was calibrated according to the American National Standards Institute S3.6-1969-2004 standard.<sup>18</sup> Audiometric tests were administered by Council for Accreditation in Occupational Hearing Conservation–certified medical technicians or audiologists in the occupational health clinic, hearing clinic, or fire stations.

The participants were instructed to have a period of at least 14 quiet hours without exposure to loud noise or to use HPDs at least on the day of the audiometric test to minimize contamination of hearing loss due to temporary exposure to loud noise. Audiometric hearing tests were performed using a microprocessor pure-tone audiometer in both ears at frequencies of 0.5, 1, 2, 3, 4, 6, and 8 kHz. Hearing threshold levels (HTLs) were measured in decibels. Hearing threshold levels were reported in 5-dB increments, and HTLs were obtained between 0 and 95 dB. A higher threshold level indicates poorer hearing status.

### Use of Hearing Protection Devices

Frequency of HPD use when exposed to high noise levels was measured by two questions regarding the self-reported percentage of time (0% to 100%): "What percentage of the time did you actually use hearing protection on your most recent emergency or run?" and "What percentage of the time did you actually use hearing protection in the past 3 months when you were working in a noisy situation as a firefighter?" As the scores of these two questions were highly correlated ( $r = 0.73$ ,  $P < 0.001$ ), the mean score of the two items was used to reflect firefighters' use of HPDs.

### Demographic and Hearing-Related Characteristics

*Demographic characteristics* included age, sex, ethnicity, and years in fire services. Ethnicity was categorized as Asian/Pacific Islanders, African American, Caucasian or white, Hispanic or Latino/a, Native American or American Indian, and Other. Years in fire services were categorized into five groups: less than 5, 5 to 9, 10 to 19, 20 to 29, and 30 years and more.

*Noise exposure at work* was measured by a single question, "How often are you exposed to loud noise when working as a firefighter?" Loud noise was defined as needing to shout to be heard by someone within 3 ft away. Responses include daily, weekly, monthly, yearly, and rarely or never.

*Perceived hearing* was measured by a single question, "How good is your hearing?" Responses were measured using a 5-point rating scale (1 = excellent, 2 = very good, 3 = good, 4 = fair, and 5 = poor).

## Data Analyses

Data analyses were conducted using the SPSS, version 19.0 (SPSS Inc., Chicago, IL). Descriptive statistics were analyzed for all study variables. Values for continuous variables such as age, use of HPDs, and HTLs were presented as means and standard deviations. In addition, median and interquartile range (IQR) were also calculated to present the central tendency because continuous variables mentioned previously did not have normal distributions. The IQR, a measure of statistical dispersion, is the difference between the third (75th percentile) and first (25th percentile) quartiles.<sup>19</sup> All categorical variables were summarized by frequencies and percentages. Differences in means of HTLs between left and right ears were explored using paired-samples  $t$  test.

Hearing loss was defined as an HTL of 25 dB or greater on the basis of HTLs in the worst ear. Hearing losses at 0.5, 1, 2, and 3 kHz (low frequencies; LF) and 4 and 6 kHz (higher frequencies; HF) were calculated. As NIHL affects HF earlier and more severely than the lower frequencies,<sup>3</sup> this study was particularly interested in firefighters' hearing status at 4 and 6 kHz. The study was also interested in hearing loss at speech frequencies (0.5 to 3 kHz) because understanding verbal communication on the job is a critical function for firefighters. The extent of hearing loss was assessed using the grading system proposed by the World Health Organization<sup>20</sup>: less than 25 dB (normal), 25 to 40 dB (mild), 41 to 60 dB (moderate), 61 to 80 dB (severe), and above 80 dB (extreme).

Asymmetric hearing loss was calculated using the American Academy of Otolaryngology-Head and Neck Surgery's (AAO-HNS's) definition. According to the AAO-HNS,<sup>21</sup> asymmetric hearing loss is defined as HTL difference of greater than 15 dB at 0.5, 1, or 2 kHz or 30 dB at 3, 4, or 6 kHz between two ears.

Differences in means of HTLs at all frequencies by years in fire services were calculated using analysis of variance. Differences in prevalence of hearing loss at LF (0.5 to 3 kHz) and HF (4 and 6 kHz) by years in fire services were examined using chi-square analysis. The mean differences of HPD use between hearing loss and normal groups were examined, using  $t$  test. A  $P$  value of 0.05 or less was considered statistically significant.

## RESULTS

### Characteristics of the Study Participants

A total of 425 firefighters participated in the study. Table 1 summarizes their demographic, occupational, and hearing-related characteristics. The majority of the participants were middle aged (median = 45 years; IQR: 40 to 51 years), male (92%), and non-Hispanic white (80%) firefighters who had worked in fire services for a long period of time (median = 16 years, IQR: 11 to 23 years). About 85% of participants reported that they were exposed to loud noise daily or weekly on their job site. The majority (84%) of participants perceived their hearing as good or better. The reported mean use of HPDs was only 34% of the time (median = 25%, IQR: 0% to 61%) that was needed when they are exposed to loud noise. About one third of the participants reported that they never used HPDs when they were exposed to loud noise at work.

### Firefighters' Perception and Attitude on Importance of Hearing

The majority of firefighters (96%) agreed that good hearing would be important when they performed their job as firefighters.

About 91% of firefighters perceived that hearing loss could contribute to work-related injuries or safety problems.

### Hearing Loss at Single Frequencies

Table 2 presents the means and standard deviations of HTLs for left, right, and worst ear, mean difference between left and right ears, and the frequencies of hearing loss at each of tested frequencies. The left ear showed significantly poorer hearing ability at frequencies of 2 to 6 kHz than the right ear ( $P < 0.05$ ). The differences of the mean HTLs between the two ears are clearly larger at HF, specifically

at 3 to 6 kHz. In both left and right ears, the greatest mean HTL (the poorest hearing) occurred at 6 kHz, causing a V-shape notch. Mean HTLs for both ears were within the range of normal hearing status (<25 dB) at all frequencies. Only mean of HTL in the worst ear at 6 kHz showed above 25 dB (mean = 25.4 dB).

As shown in Table 2, the prevalence of hearing loss increased as frequencies got higher. More than 40% of participants showed hearing loss at 4 to 8 kHz. Mean HTLs for the both ears and the worst ear at all single frequencies are also presented in Fig. 1 to aid in the visualization of the trend across frequencies. As shown in Fig. 1, mean HTLs significantly increase between 2 and 4 kHz.

On the basis of the definition proposed by the AAO-HNS,<sup>21</sup> asymmetric hearing loss was assessed. About 13% of the firefighters (53/425) had asymmetric hearing loss.

**TABLE 1.** Characteristics of Study Participant (N = 425)\*

Characteristics	N (%)
<b>Sex</b>	
Male	389 (92.0)
Female	34 (8.0)
<b>Ethnicity</b>	
Asian/Pacific Islander	26 (6.2)
African American or black	21 (5.0)
Caucasian or white	339 (80.3)
Hispanic or Latino/a	31 (7.3)
Native American or American Indian	1 (0.2)
Other	4 (0.9)
<b>Noise exposure at work</b>	
Daily	218 (51.3)
Weekly	145 (34.1)
Monthly	42 (9.9)
Yearly	8 (1.9)
Rarely or never	12 (2.8)
<b>Perceived hearing</b>	
Excellent	42 (9.9)
Very good	144 (34.0)
Good	171 (40.3)
Fair	56 (13.2)
Poor	11 (2.6)
	<b>Mean (SD); median (IQR)</b>
Age (25–70 y)	44.8 (7.98); 45 (40–51)
Years in the fire service (0–38 y)	17.1 (8.02); 16 (11–23)
Use of HPDs†(0–100%)	33.8 (33.72); 25 (0–61.25)

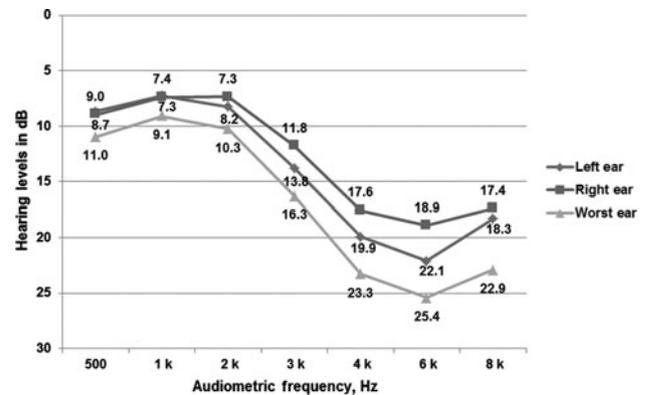
\*Total number does not add up to the same number due to missing data.

†Measured by percentage (0% to 100%) of the time.

IQR, interquartile range; SD, standard deviation.

### Hearing Loss at LF (0.5 to 3 kHz) and HF (4 and 6 kHz)

Table 3 presents the distribution of hearing loss prevalence at LF and HF. The means of HTLs at LF (0.5 to 3 kHz) and HF (4 and 6 kHz) were 11.6 and 24.3 dB, respectively. About 41% of firefighters showed hearing loss in the noise-sensitive frequencies, HF (4 and 6 kHz), whereas only 6.5% showed hearing loss at LF (0.5 to 3 kHz). Severity of hearing loss is greater at HF (4 and 6 kHz). About 15% showed moderate hearing loss (HTLs 41 dB or greater) at HF (4 and 6 kHz). Although all participants (100%) with hearing loss at LF (0.5 to 3 kHz) also showed hearing loss at HF (4 and 6 kHz), only 16% of participants with HF hearing loss had hearing loss at LF (0.5 to 3 kHz).



**FIGURE 1.** Mean of hearing threshold levels in both ears and worst ears at all test frequencies.

**TABLE 2.** Mean, Standard Deviation of HTLs, and Prevalence of Hearing Loss at All Test Frequencies (N = 425)

HTLs, dB	Test Frequency, Hz						
	0.5 k	1 k	2 k	3 k	4 k	6 k	8 k
Left ear, mean (SD)	8.7 (8.1)	7.3 (7.4)	8.2 (9.7)	13.8 (13.5)	19.9 (16.8)	22.1 (17.4)	18.3 (17.0)
Right ear, mean (SD)	9.0 (8.2)	7.4 (7.4)	7.3 (8.7)	11.8 (12.2)	17.6 (15.4)	18.9 (15.6)	17.4 (15.6)
Mean difference between two ears, <i>t</i> test ( <i>P</i> value)	-0.8 (0.436)	-0.40 (0.691)	2.3 (0.020)	3.8 (<0.001)	3.8 (<0.001)	4.9 (<0.001)	1.0 (0.319)
Worst ear, mean (SD)	11.0 (9.0)	9.1 (8.1)	10.3 (10.2)	16.3 (14.3)	23.3 (16.9)	25.4 (17.4)	22.9 (17.3)
Hearing loss, * <i>N</i> (%)	42 (9.9)	24 (5.6)	44 (10.4)	100 (23.5)	181 (42.6)	212 (49.9)	170 (40.4)

\* Hearing loss was calculated on the basis of HTLs in the worst ear between left and right ears.

HTL, hearing threshold level; SD, standard deviation.

### The Relationship Between Hearing Loss and Years in Fire Services

Figure 2 shows the trends of the mean HTLs in the worst ear at the single test frequency by years worked in fire services. The longer years in fire services, the more HTLs increase. The pattern of mean HTLs dramatically increases at HF (4 and 6 kHz) among firefighters who had worked in fire services for longer than 20 years.

Table 4 presents the extent of hearing loss at LF and HF by years worked in fire services. The hearing loss prevalence at LF and HF among firefighters who had longer work experiences is significantly more than that in firefighters with shorter years in fire services. The majority of firefighters who had worked in fire services for a longer period (over 20 years) showed hearing loss at noise-sensitive frequencies HF (4 and 6 kHz). As presented in Table 4, firefighters who show hearing loss spent significantly more years in fire services, compared with those with normal hearing: 23.8 versus 16.7 years for lower-frequency hearing loss, and 20.5 versus 14.5 years ( $P < 0.001$ ) for HF hearing loss.

### Hearing Loss and Use of HPDs

Table 5 shows the relationship between hearing loss at LF (0.5 to 3 kHz) and HF (4 and 6 kHz) and use of HPDs. As stated earlier, firefighters in this study reported that they used HPDs about 34% of the time when they should have in high noise. Firefighters who showed hearing loss were significantly less likely to use HPDs than

**TABLE 4.** Prevalence of Hearing Loss at LF (0.5, 1, 2, and 3 kHz) and HF (4 and 6 kHz) by Years in Fire Services

Years in Fire Services	Age, Mean (SD), y	N (%)	Hearing Loss, N (%)	
			LF (0.5, 1, 2, and 3 kHz)	HF (4 and 6 kHz)
<5	32.5 (4.8)	20 (4.7)	0 (0.0)	1 (5.0)
5–9	37.4 (6.5)	51 (12.1)	0 (0.0)	13 (25.5)
10–19	42.8 (6.3)	183 (43.4)	7 (3.8)	59 (32.2)
20–29	49.2 (4.8)	129 (30.6)	14 (10.9)	68 (52.7)
≥30	55.6 (4.5)	39 (9.2)	6 (15.4)	29 (74.4)

HF, high frequency; LF, low frequency; SD, standard deviation.

**TABLE 5.** Relationship Between Hearing Loss and Use of HPD

	Use of HPD, Mean (SD)	t Test (P)
LF (0.5, 1, 2, and 3 kHz)		
Normal (<25 dB)	34.9 (33.9)	–3.03 (0.005)
Hearing loss (≥25 dB)	18.1 (27.6)	
HF (4 and 6 kHz)		
Normal (<25 dB)	37.5 (34.2)	–2.73 (0.007)
Hearing loss (≥25 dB)	28.4 (32.4)	

HF, high frequency; HPD, hearing protection device; LF, low frequency; SD, standard deviation.

those with normal hearing: 18.1% versus 34.9%,  $P = 0.005$  at LF (0.5 to 3 kHz); 28.4% versus 37.5%,  $P = 0.007$  at HF (4 and 6 kHz).

### DISCUSSION

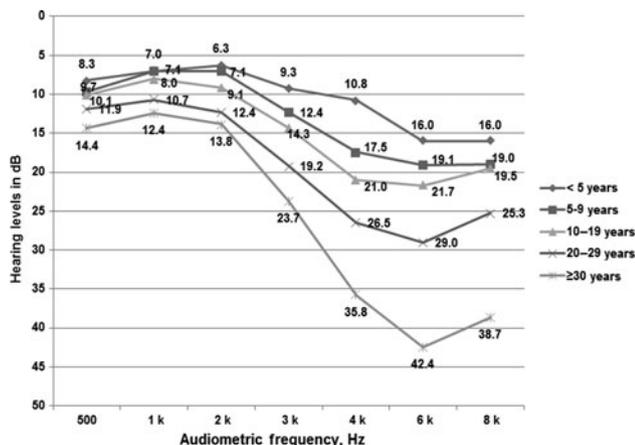
The findings of this study indicate that firefighters have a considerable risk of NIHL problem. More than 40% of firefighters in this study have hearing loss at noise-sensitive frequencies (4 and 6 kHz), which is higher than that of other study. Using slightly different combination of frequencies (3, 4, and 6 kHz), Kales et al<sup>7</sup> reported that 14% of firefighters had high-frequency hearing loss. Noise-induced hearing loss in FF is not a newly discovered problem. This study also showed that severity of NIHL significantly accelerated as years of firefighting service increases. This is consistent with earlier studies, which reported the significant association between the extent of hearing loss and years of firefighting service remained even after controlling for age-related hearing loss.<sup>7,9,22</sup>

The high rate of hearing loss among firefighters, in particular, is a serious concern because firefighting is a hearing-critical job that requires the ability to detect, recognize, and localize sounds, and to understand speech, commonly in background noise.<sup>23</sup> Firefighters work in an environment that can render most of their senses non-functional. Because of fire smoke, firefighters may commonly be in a zero-visibility circumstance. In addition, being totally encapsulated in turnout gear and self-contained breathing apparatus reduces or removes the senses of smell, taste, touch, heat, cold, and vibration. Thus, firefighters' hearing status, although also impacted, may become the critical remaining sense that is relied on for safety. Consequently, hearing loss may increase the risk of occupational injury among firefighters by increasing the chance of missing an auditory cue that could allow them to escape injury or death.<sup>24</sup> In the present

**TABLE 3.** Distribution of Hearing Loss at LF (0.5, 1, 2, and 3 kHz) and HF (4 and 6 kHz)

Extent of Hearing Loss	LF (0.5, 1, 2, and 3 kHz), n (%)	HF (4 and 6 kHz), n (%)
Normal (<25 dB)	397 (93.4)	252 (59.3)
Hearing loss		
Mild (25–40 dB)	24 (5.6)	109 (25.6)
Moderate (41–60 dB)	4 (0.9)	50 (11.8)
Severe (61–80 dB)	0 (0.0)	12 (2.8)
Extreme (>80 dB)	0 (0.0)	2 (0.5)
Mean ± SD (range)	11.6 ± 8.2 (0–56.3)	24.3 ± 15.9 (0–90)

HF, high frequency; LF, low frequency; SD, standard deviation.



**FIGURE 2.** Mean of hearing threshold levels in worst ears at all frequencies by years in fire services.

study, the majority of firefighters believed that good hearing would be important to perform their job and perceived hearing loss as a contributor to occupational injuries or safety problems. Faced with other on-the-job life-threatening circumstances, however, firefighters are apt to ignore noise exposure and its negative effect on their hearing.

About 13% of the study participants demonstrated asymmetric hearing loss. Their left ear showed significantly poorer hearing ability than the right ear and the differences between the two ears were clearly larger at HF. Asymmetrical hearing loss is an area that has not received as much attention as regular hearing loss. Nevertheless, it is of critical importance for the firefighter because asymmetrical hearing loss impacts the ability to localize sounds.<sup>25–28</sup> This loss will impact several of the essential job functions as well as the health and safety of the firefighter. The main impact on the firefighter's essential job functions would be on search and rescue. Firefighters need to find civilian victims and fallen coworkers often just by sound (eg, cries for help, PASS alarms). This can also be a life-and-death problem for a firefighter him/herself. When a firefighter is in a live fire situation, which creates an Immediately Dangerous to Life or Health environment, being able to get out is critical. If the firefighter loses contact with the hose line, the path of egress may be lost. In this situation, following verbal cues from coworkers will lead the trapped firefighter to the way out. If firefighters are unable to localize sound, they will not be able to get out, with obvious dire consequences.

This study showed beneficial effects of the use of HPDs. Firefighters who were more likely to use HPDs had significantly better hearing status. This is consistent with earlier reports on the importance of personal use of HPDs in preventing NIHL. Brink and colleagues<sup>29</sup> and Hong and Kim<sup>30</sup> reported that nonuse of HPDs was the most significant contributor to hearing loss. Other studies<sup>31,32</sup> also reported that workers who always wore HPDs showed significantly better hearing than those who did not.

Although firefighters were aware of the importance of hearing and the beneficial effects of HPD use is obvious, the reported compliance with use was low, only using HPDs one-third of the time that they are needed. According to focus group discussions with firefighters,<sup>5</sup> their low use of HPDs may be due to several factors: the belief that HPDs interfere with the ability to communicate and to perform duties effectively; a risk-taking culture unique to firefighting; and/or a lack of understanding about the damage caused by noise. Firefighters' biggest concern was that the use of HPDs may interfere with their ability to hear critical auditory cues. This would include hearing radio transmissions, verbal orders or communications with coworkers, alarms, victim's cries for help, and sounds of impending structural collapse, among many others. It is necessary to teach firefighters about the variety of HPDs from conventional types of HPDs (earplugs and earmuffs) to the two-way communication system or vehicle intercom system designed to provide them with clear communication and hearing protection both en route to and at the fire scene.<sup>5</sup> A second issue is a culture problem in which losing hearing is a part of their work and using HPD is not macho enough. There is also the mistaken idea that firefighters do not need to use HPDs because their exposure is short and using HPDs will not make any difference. For firefighters, in particular, the ease of use/insertion and comfort of these devices are a problem especially when using self-contained breathing apparatus and full encapsulating turnout gear. Although the HPD can be inserted before gearing up, once the gear is on, adjusting the HPD is not possible.

Noise-induced hearing loss results in significant costs in dollars and human suffering. Although we could not find the data on monetary cost for firefighter group, according to the National Institute on Deafness and Communication Disorders, when deafness occurs during a person's working career, the estimated cost in lost opportunity over a lifetime could be \$453,000.<sup>33</sup> It is well established that hearing loss causes communication interference that can substantially affect social integration, functional ability, self-image,

depression, and quality of life. Hearing loss affects not only those individuals who have lost their hearing, but also their fellow workers, family members, and society as a whole.

Several study limitations should be noted. Because the sample of this study included a convenience sample of firefighters, the findings from this study might not be representative of the general firefighter population. Nevertheless, the study drew from 34 diverse fire departments in three states (two in the Midwest and one in the west) in United States. A high prevalence of NIHL and low use of HPDs are still considerable problems among firefighters in general and findings from this study provide baseline information that would be important to develop and implement effective hearing prevention intervention programs in fire services. The participants of this study were predominantly middle-aged white male firefighters; thus, the findings of the study may not be generalizable beyond the white male firefighters. It was anticipated because the fire service has limited numbers of women and people with different ethnic backgrounds. According to the US Bureau of Labor Statistics from 2006 to 2011, average 4.3% of US firefighters were female, 7.1% were African American, and 8.9% were Hispanic.<sup>34</sup> Also, a higher proportion (53%) of firefighters in the age groups is the middle-age group (30 to 49 age group).<sup>35</sup> Although the current study did not apply a random sampling to select representative firefighter samples, it should be noted that the reported profiles for the study participants were very similar to national firefighter population.

This study suggests that effective hearing conservation programs should be widely implemented for firefighters. While irreversible, NIHL is entirely preventable through both engineering controls and wearing HPDs. In the absence of engineering control, the use of HPDs such as earplugs and muffs is the only way to protect hearing from hazardous noise. Firefighters need to be fully informed about the hazards of noise and about protection strategies, assume responsibility for using HPDs, and develop ingrained habits of use whenever they are exposed to loud noise (both on and off the job). Furthermore, the fire service should change the culture of accepting the loss of hearing as a normal way of doing business, through incorporating leadership, management, supervision, accountability, and personal responsibility.

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