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Pilot task-based assessment of noise levels among firefighters

RL Neitzel[1,*], **O Hong**[2], **P Quinlan**[3], and **R Hulea**[4]

[1]Risk Science Center and Department of Environmental Health Sciences, School of Public Health, University of Michigan, Ann Arbor MI 48109

[2]Department of Community Health Systems, School of Nursing, University of California, San Francisco, CA 94143

[3]Division of Occupational and Environmental Medicine, School of Medicine, University of California, San Francisco, CA 94143

[4]Office of Regulatory Affairs, Medical School, University of Michigan, Ann Arbor MI 48109

Abstract

PURPOSE—Over one million American firefighters are routinely exposed to various occupational hazards agents. While efforts have been made to identify and reduce some causes of injuries and illnesses among firefighters, relatively little has been done to evaluate and understand occupational noise exposures in this group. The purpose of this pilot study was to apply a task-based noise exposure assessment methodology to firefighting operations to evaluate potential noise exposure sources, and to use collected task-based noise levels to create noise exposure estimates for evaluation of risk of noise-induced hearing loss by comparison to the 8-hr and 24-hr recommended exposure limits (RELs) for noise of 85 and 80.3 dBA, respectively.

METHODS—Task-based noise exposures (n=100 measurements) were measured in three different fire departments (a rural department in Southeast Michigan and suburban and urban departments in Northern California). These levels were then combined with time-at-task information collected from firefighters to estimate 8-hr noise exposures for the rural and suburban fire departments (n=6 estimates for each department). Data from 24-hr dosimetry measurements and crude self-reported activity categories from the urban fire department (n=4 measurements) were used to create 24-hr exposure estimates to evaluate the bias associated with the task-based estimates.

RESULTS—Task-based noise levels were found to range from 82–109 dBA, with the highest levels resulting from use of saws and pneumatic chisels. Some short (e.g., 30 min) sequences of common tasks were found to result in nearly an entire allowable daily exposure. The majority of estimated 8-hr and 24-hr exposures exceeded the relevant recommended exposure limit. Predicted 24-hr exposures showed substantial imprecision in some cases, suggesting the need for increased task specificity.

CONCLUSIONS—The results indicate potential for overexposure to noise from a variety of firefighting tasks and equipment, and suggest a need for further exposure characterization and additional hearing loss prevention efforts.

*Corresponding author. rneitzel@umich.edu, Address: Risk Science Center, Department of Environmental Health Sciences, School of Public Health, University of Michigan, 1415 Washington Heights, Ann Arbor MI 48109 Phone: 734-763-2870, Fax: 734-763-8095.

RELEVANCE TO INDUSTRY—Firefighters may be at risk of noise-induced hearing loss, which can affect their fitness for duty and ability to respond effectively to emergencies. The results of this study suggest that additional efforts at hearing loss prevention among firefighters are warranted.

Keywords

Noise; exposure; hearing loss; task-based assessment; firefighter; emergency response

1. INTRODUCTION

Firefighting is a dangerous occupation, and is associated with a variety of hazards, including rigorous physical training activities and exercise and emergency situations involving high temperatures, smoke and other air contaminants, ergonomic issues, and others (Brandt-Rauf, Fallon et al. 1988; Matticks, Westwater et al. 1992; Szubert and Sobala 2002; Poplin, Harris et al. 2011). As a result, the roughly 1.1 million firefighters in the US (NFPA 2005) are known to be at elevated risk of a number of occupational injuries and illnesses (Leigh and Miller 1997; Karter and Badger 2000; Poplin, Harris et al. 2011). While the potential for many of these health outcomes is relatively obvious given the inherently hazardous and physically demanding nature of firefighting work, one health outcome that may not be as obvious is noise-induced hearing loss (NIHL). NIHL is a permanent, irreversible disease that develops slowly over time and may affect over 10 million individuals in the United States (Nelson, Nelson et al. 2005); the total US population exposed to hazardous noise may exceed 30 million workers (NIOSH 1996). NIHL has been shown to have a profound impact on affected individuals, primarily through the social handicap resulting from inability to comprehend speech (Passchier-Vermeer and Passchier 2000), and has been linked to depression, anger, social withdrawal, and other adverse quality of life outcomes (Hetu, Getty et al. 1995). Studies of firefighters' noise exposure and hearing ability conducted by the US National Institute for Occupational Safety and Health (NIOSH) (NIOSH 1991; Tubbs 1991; Tubbs 1992) and others (Reischl, Bair et al. 1979; Reischl, Hanks et al. 1981; Pepe, Jerger et al. 1985; Ewigman, Kivlahan et al. 1990; Kales, Polyhronopoulos et al. 1997; Kales, Freyman et al. 2001; Ide 2007; Rocha, Atherino et al. 2010; Ide 2011; Ide 2011; Chung, Chu et al. 2012) have documented evidence of NIHL, though many of these studies have failed to find an association between firefighting noise exposure and observed hearing loss. Other studies have documented low use of hearing protection devices among firefighters (Hong, Samo et al. 2008; Hong, Chin et al. 2011), despite an acknowledgement by many surveyed firefighters of the potential for NIHL.

As with other dangerous occupations such as construction and agriculture, firefighting safety and health programs have historically focused on reducing the risk of acute injuries and safety hazards, and have placed less emphasis on preventing chronic diseases such as NIHL. However, there is increasing evidence that NIHL may actually increase injury risk, suggesting that an increased emphasis on hearing loss prevention is warranted. Additionally, some firefighting jobs may be considered hearing critical, and individual firefighters who develop NIHL may as a result no longer be considered mission capable (Tufts, Vasil et al. 2009). There is also evidence that NIHL from noise may be worsened by co-exposures to certain ototoxic chemical agents and gases, such as solvents and carbon monoxide, which may be encountered during certain firefighting operations (Fechter, Cheng et al. 2000; EASHW 2009; Johnson and Morata 2010; Kim 2010; Metwally, Aziz et al. 2011).

To protect firefighters against NIHL, the National Fire Protection Association (NFPA) has adopted Standard 1582, which sets forth comprehensive occupational medical programs for fire departments (NFPA 2007). However, this standard largely references the occupational noise exposure regulation (29 CFR 1910.95) promulgated in 1971 by the US Occupational Safety and Health Administration (OSHA) (OSHA 1971), which is widely acknowledged as providing inadequate protection against NIHL (Suter 1988; Suter and Johnson 1996; NIOSH 1998). A more protective Recommended Exposure Limit (REL) for noise has been established by NIOSH (NIOSH 1998). This recommended limit is an equivalent continuous average (L_{EQ}) 8-hr time weighted average (TWA) noise exposure of 85 A-weighted decibels (dBA) and a 3-dB exchange rate. In other words, for every 3 dB increase or decrease in the average noise exposure, the allowable exposure time is halved or doubled, respectively to keep the risk of hearing loss constant. For example, an 8-hr exposure at 85 dBA is considered equivalent to 24 hours at 80.25 dBA and four hours at 88 dBA. Allowable exposure durations at levels are extremely short at high levels (e.g., 28 seconds at 115 dBA, and less than 1 sec above 130 dBA). Note that the REL is not designed to protect all individuals against any hearing loss; rather, it is estimated to protect 86% of exposed workers from a material hearing impairment (NIOSH 1998). Several NIOSH studies of firefighter noise exposure in individual fire departments in the 1980s and 1990s found noise levels during firefighting operations to be highly variable (NIOSH 1982; NIOSH 1985; NIOSH 1995; NIOSH 1995). These studies by NIOSH, as well as studies by others (Reischl, Bair et al. 1979; Jerger, Jerger et al. 1986; Ewigman, Kivlahan et al. 1990; Kirkham, Koehoorn et al. 2011) have generally focused on sources of very high levels of noise associated with emergency operations (e.g., sirens and extraction equipment), and have not thoroughly characterized other, more routine activities or time spent in the fire station. Despite almost uniformly commenting on the potential for high exposure from emergency situations, these studies have often found 8-hr time-weighted average (TWA) noise exposures to be below regulatory or recommended limits, a curious finding given the many reports of NIHL among firefighters (Reischl, Bair et al. 1979; Reischl, Hanks et al. 1981; Pepe, Jerger et al. 1985; Ewigman, Kivlahan et al. 1990; NIOSH 1991; Tubbs 1991; Tubbs 1992; Kales, Polyhronopoulos et al. 1997; Kales, Freyman et al. 2001; Ide 2007; Ide 2011).

One of the main reasons for this lack of agreement between exposure assessments and hearing loss evaluations among firefighters may be exposure misclassification. The measurement and evaluation of hazardous noise in the workplace is the foundation of occupational hearing loss prevention programs, which also include noise control efforts, regular audiometric testing and record keeping of the results, worker training, and use of hearing protection devices. In industrial settings with relatively steady and continuous noise exposures, such as manufacturing, evaluation of noise levels is relatively straightforward. However, in non-industrial operations characterized by highly variable and intermittent noise, such as firefighting, noise exposure assessment is more challenging (Arezes, Bernardo et al. 2012). In these industries, full-shift personal noise measurements, often considered the gold standard of exposure assessment (Nieuwenhuijsen, Paustenbach et al. 2006), may miss infrequent but intense exposure situations which can result in substantial overexposures to noise. In other words, on any given day, a firefighter may or may not be exposed to sound levels exceeding recommended limits due to the nature of the job performed on that particular day. This is especially true for industries such as firefighting, where noise exposure potentials are often dictated by the type and frequency of emergency response and job tasks corresponding to a specific type of call. For work situations such as these, a task-based exposure assessment methodology is desirable. In this approach, a comprehensive catalog of potential job tasks is developed, and exposure levels are evaluated for each of these individual tasks. The amount of time workers typically spend doing these tasks (e.g., time-at-task) is then estimated over the work period of interest. By combining these two streams of information, typical or worst-case exposures can be estimated for workers with irregular or highly variable job tasks and activities (Smith, Hammond et al. 1991). This approach has already been successfully used to evaluate a number of occupational exposures, including ergonomic hazards (Fallentin et al. 2001), air

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contaminants (Johnson, Reynolds et al. 2000; Verma, Cheng et al. 2004), and noise (Virji, Woskie et al. 2009; Neitzel, Daniell et al. 2011).

The current pilot study had two aims. The first was to apply a task-based noise exposure assessment methodology to firefighting operations to evaluate potential exposures associated with infrequent, variable noisy tasks as well as more routine tasks with lower noise levels. The second was to use task-based noise levels to create full-shift and 24-hr noise exposure estimates and compare these to the NIOSH REL to evaluate the risk of NIHL among firefighters.

2. METHODS

The data presented here were collected in two different geographic locations. The first location was Southeast Michigan, where task- and tool-based noise measurements were made at a rural fire department in 2008. This portion of study was approved by the University of Michigan Institutional Review Board of the University of Michigan. The second was in Northern California, where task-based noise measurements were made at one suburban fire department and short-term and 24-hr noise measurements were made at one urban fire department in 2010 and 2011. The protocol of the second study was approved by the University of California San Francisco. All study procedures were conducted in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans (http://ohsr.od.nih.gov/guidelines/helsinki.html), and participating subjects provided informed consent. Data collection methods in each of these locations are described in detail below. Our noise measurement strategy was guided by a list of routine job assignments, tasks, and durations for work routinely performed by firefighters which was created from discussions with two focus groups of firefighters in Southeast Michigan (Hong, Samo et al. 2008) and key informant interviews and discussion with a battalion chief and two fire captains in Northern California. Based on this list, we focused on tasks within a number of different job types, including ventilation, vehicle extraction, on-scene work preparation, fire suppression, fire engine operation, as well as several common daily jobs, including testing personal alert safety systems, self-contained breathing apparatus (SCBA), and other emergency equipment. Tools required for these activities include various types of powered saws (chainsaws, circular saws, and reciprocating saws), pneumatic chisels and hydraulic spreaders (commonly referred to as the Jaws of Life™), air blowers, fire hoses and pumps, generators, and various alarms and sirens.

All noise measurements collected in this study were made using integrating sound level meters or dosimeters, and all instruments were configured to make time-integrated L_{EQ} measurements according to the criteria set forth in the NIOSH REL: A-frequency weighting, an 85 dBA criterion level, a 3 dB exchange rate, and an 80 dBA threshold. During noise measurements, microphones were placed within eight inches of the ear canal on the most-exposed side of the measured firefighter’s body.

2.1 Data collection in Southeast Michigan

We made personal noise measurements at one fire station in a rural fire department in Southeast Michigan. We obtained task-based L_{EQ} data using a Larson-Davis Model 712 (Larson-Davis, Inc, Depew, NY, USA) Type 2 integrating sound level meter (ISLM). We also made an additional area measurement in a break room in the station to evaluate likely exposures during periods between emergency responses. To ensure that our measurements adequately captured variability in SPL during our measurements, tasks were measured for the entire duration of the task or for a period that was sufficiently long to obtain a stable average level of noise. The ISLM was calibrated immediately before and after each monitoring session. A single sampling session was conducted at each of the two fire houses.

2.2 Data collection in Northern California

We collected additional personal noise measurement data at two stations in a suburban fire department in Northern California, and at two stations in an urban fire department in Northern California. Measurements were made using a Quest Technologies NoisePro DLX (Quest Technologies, a 3M Company, Oconomowoc, WI) datalogging noise dosimeter which datalogged noise levels at 1-min intervals during each measurements, and also provided an average L_{EQ} noise level for each measurements. Volunteer firefighters at the suburban fire department wore the noise dosimeters while conducting specific tasks of interest on two sampling days. Volunteers at the two participating fire stations in the urban fire department wore dosimeters for different amounts of time on three monitored days. On two days, firefighters wore the dosimeters while they performed a sequence of related tasks that represented typical daily fire station activities. Tasks in each sequence were recorded by research staff observing the monitored firefighter. As in rural Michigan, we made an additional area measurement in a break room in the fire station. On a third sampling day, firefighters wore the dosimeters for an entire 24-hr shift (starting at about 8 AM on the first day and ending at about 8 AM the following morning), and self-reported the times spent in the station and out of the station responding to medical or fire calls.

2.3 Data analysis

Descriptive statistics were computed for the task-based noise measurements made at the rural fire department in Southeast Michigan and the suburban fire department in Northern California. Descriptive statistics were also computed for the short-term measurements of typical daily fire station task sequences measured at the urban fire department in Northern California, and for the 24-hr dosimetry measurements made at the urban fire department in Northern California. Means and standard deviations were computed arithmetically for the task-based levels, as is appropriate for noise data where dose does not accumulate (e.g., across independent, repeated measurements of a task, or across independent exposure measurements on individual workers). Due to the small number of samples collected in this pilot effort, we did not evaluate statistical significance of differences in measured noise levels and estimates of 8- and 24-hour average exposures.

A task-based exposure approach was used to estimate 8-hr time weighted average (TWA) exposures for six different types of jobs using a combination of typical time-at-task (obtained through focus group discussions) with measured task-based noise levels. Task-based L_{EQ} estimates were created using equation 1:

$$L_{ij,TB}=10\log_{10}\left[\frac{1}{M_{ij}}\sum_{t=1}^{T}M_{ijt}10^{L_t/10}\right] \quad (1)$$

where L_t, the mean noise level for task t, is applied to the period 8-hour period M_{ijt} in which that task was reported by individual i on shift j. L_t values were drawn from measurements made at the rural fire department in Southeast Michigan as well as the suburban fire department in Northern California to evaluate the potential effects on regional-specific task-based noise levels on estimated full-shift exposures. Use of a 3 dB time-intensity exchange rate, consistent with the exposure limit recommendations of NIOSH (NIOSH 1998), EPA (EPA 1974), and many international agencies (Suter 2003), is implicit in equation 1, and the results of this equation can be compared to the 85 dBA 8-hour criterion level specified in most occupational noise standards (Suter 2003), including NIOSH (NIOSH 1998).

Finally, the equation 1 (with a 24-hour period M_{ijt}) was used to estimate 24-hr exposures for the firefighters who participated in 24-hr dosimetry measurements at the urban Northern California fire department. Individual estimates for L_{EQ} exposures during time spent in the station and time spent on call were created by combining the firefighters' reported times in both of those two activities with average L_{EQ} noise levels measured during the activities. To reduce the statistical optimism that results from using an individual's measured noise levels to predict an exposure for that same individual, we excluded each individuals' own measured noise levels while creating estimates, and relied on average noise levels measured on the other firefighters. We then compared the measured and estimated 24-hr L_{EQ} levels, and evaluated bias in the estimates as (estimated 24-hr L_{EQ} – measured 24-hr L_{EQ}) (Hornung 1991). Note that the estimates presented must still be considered statistically optimistic, as the data they are based on were collected from a fire crew working out of a single fire station on a single shift. As with the task-based measurements and full-shift exposure estimates, we summarized variability in measured and estimated 24-hr L_{EQ} exposures using arithmetically computed standard deviations, the appropriate approach for summarizing the distribution of noise exposures across individuals.

3. RESULTS

Table 1 shows personal task-based L_{EQ} noise levels measured at the fire departments in rural Michigan and suburban Northern California, in addition to one area measurement in a break room. Sawing metal, concrete, wood, and dry wall during ventilation activities produced some of the highest task-based noise levels (between 105 and 109 dBA) measured in the study. One other task (use of a pneumatic chisel for vehicle extraction, which was measured only at the rural Michigan fire department), produced levels in excess of 106 dBA. Average sound levels for the fire engine air horn and electric sirens were measured to be about 98 dBA inside the engine's crew cab and about 115 dBA outside the cab. The outside cab measurements should not be considered reflective of the firefighters' noise exposure while operating the vehicle, but are indicative of the sometimes extreme levels of noise produced during firefighting operations. One routine task that is conducted daily by firefighting staff is test personal alert safety alarm systems; this task was found to produce noise levels of 101 dBA on average. Direct comparisons between levels measured at the two fire departments are challenging due to differences in jobs, equipment types, and the types of calls made. Noise levels measured for tasks that were evaluated at both the rural Michigan and suburban and urban Northern California fire departments varied widely, and did not suggest that one fire department had higher exposure levels than the other. All tasks demonstrated noise levels that were high enough to present the potential for full-shift exposure to noise in excess of the NIOSH REL given sufficient exposure durations. Most of the tasks with multiple measurements also demonstrated large variability (as evaluated by the within-task standard deviation, SD), with many tasks having SDs of 5 dBA or greater.

The results of short-term personal measurements of typical daily task sequences performed at the urban Northern California fire department are shown in Table 2, along with a single area measurement made in a break room. Measurements ranged in duration from 5.5 to 33 minutes. Measured L_{EQ} levels ranged from 68.4 dBA for the office measurement to 99.1 dBA for a task sequence that include testing a hydraulic spreader, chainsaw, circular saw, cement saw, and generator. As with the task-based levels presented in Table 1, the levels associated with the task sequences in Table 2 were all high enough to present a possibility of full-shift overexposure given sufficient duration of exposure. Indeed, the equivalent 8-hr time-weighted average for measurement two, which involved testing a band saw a generator, lights, an aerial, and the engine was over 83 dBA, indicating that a firefighter performing this task sequence receives almost the entire allowable full-shift exposure in just 33 minutes.

Table 3 shows estimated full-shift exposure levels for six common firefighting jobs and a range of associated activities. A description of typical tasks and durations is provided, as is the estimated time spent in the fire station for an 8-hr day which includes the jobs and tasks described. Exposure estimates were created using noise levels measured in the rural Michigan and suburban Northern California fire departments (Table 1). Note that the 8-hr estimates shown assume an average of 5.7 hours of time spent in the fire station. Estimated 8-hr TWA exposures ranged from 82.4–98.2 in the rural Michigan fire department and 81.4–88.8 dBA in the suburban Northern California fire station. Overall, estimated 8-hr exposure levels at the suburban Northern California fire were on average about five dBA lower than those at the rural Michigan fire department, with one exception: vehicle extraction at the rural Michigan location, which assumed use of pneumatic chisels, was 15 dBA higher than the suburban Northern California location, which assumed use of hydraulic spreaders. The variability in estimated 8-hr LEQs (as measured by the SD across all estimates) was only about half as large for the suburban California estimates as for the rural Michigan estimates.

Results from the 24-hr measurements made at the urban Northern California fire department are shown in Table 4. Five 24-hr measurements with accompanying logs of time spent in the station and on calls were made. However, the dosimeter placed on the second firefighter evaluated failed during the shift, meaning only time log data were available from that shift. Total measured times and 24-hr average noise levels are shown, as well as average noise levels and the percentage of total time and total dose received during time in the station and time spent on calls. All of the monitored firefighters reported that the measured shift had a relatively small number of calls. Three of the firefighters were on the same engine and had a total of 6 calls ranging in duration from 15–45 minutes, for a total of 1.6 hours on calls over the entire shift. The second driver (whose dosimeter failed) had 17 calls, most of which lasted 15–30 minutes, for a total of 4.7 hours of calls. The incident command specialist had a total of five calls of 15–25 minutes for a total of 2 hours of calls. In addition to time spent in the station doing cleanup and other tasks, all five measured firefighters had approximately seven hours of sleep time on the measured shift.

The average 24-hr L_{EQ} across the four valid measurements was 84.5 dBA (Table 4), about 3 dBA higher than the allowable 24-hr NIOSH REL of 80.25 dBA (NIOSH 1998) The highest measured 24-hr L_{EQ} of 87.3 dBA was from the first driver, while the lowest (81.6 dBA) was from the tillerman; both were on the same engine during the monitored shift. On average, the measured firefighters spent about 90% of the evaluated shift in the fire station, with an average L_{EQ} of 84.0 dBA. However, this time only contributed about 33% of the total noise dose. Calls, which accounted for about 10% of the evaluated shift, contributed 67% of the total noise dose on average, and had an average L_{EQ} level of 88.5 dBA. Note that the difference in average levels between time in the station and time on calls was surprisingly small –less than 5 dBA on average across all measured shifts. The variability in exposures (as evaluated by the SD of the measurements) was relatively small (2.4 dBA); variability was greater during call periods (3.5 dBA SD) than during station periods (2.3 dBA).

Table 5 compares the four valid measured 24-hr L_{EQ} levels to task-based 24-hr L_{EQ} estimates for the same shifts. Note that on average the estimates are unbiased (e.g., the estimated and measured means are identical); this optimistic result is induced by using measured data from the group of measured firefighters to create exposure predictions for the same group of firefighters. Even given this optimism, there is still substantial imprecision in the individual exposure predictions – up to nearly 4 dBA for the 24-hr estimates for the tillerman and driver, and more than 5 dBA for the call time estimates for those two firefighters. Also evident in Table 5 table is the loss of exposure variability in the L_{EQ} estimates (the SDs associated with the estimates are only one-half to one-third as large as the SDs for the measured levels). This indicates that the task-based estimates showed limited success in incorporating the variability in the measured periods, despite the relatively limited variability (small SDs) across the measured 24-hour periods (Table 4),

4. DISCUSSION

The results of this study indicate that firefighters are exposed to a range of tasks with noise levels high enough to present a risk of NIHL, and that this range extends well beyond the traditional foci of firefighting noise exposure assessment efforts, which have emphasized exposures such as sirens and extraction equipment. For some of the task sequences we measured, the exposure limit for an entire 8-hr workshift can be reached in as little as 30 minutes. Our task-based 8-hr TWA exposure estimates suggest that many jobs can result in 8-hr TWAs that exceed the NIOSH REL and potentially place firefighters at risk of NIHL after chronic exposure. Our data also suggest that there may be subtle differences in noise exposures between different types of fire departments (e.g., rural vs. urban/suburban). Finally, our data suggest that even when firefighters do not exceed the NIOSH REL on an 8-hr basis, they often do so over a 24-hr exposure period. The NIOSH REL permits an average exposure level of 80.3 dBA over a 24-hr period. Of the four valid 24-hr dosimetry measurements made as part of this study, 100% exceeded the 24-hr REL, while only 75% exceeded the 8-hr REL. The REL is estimated to have an excess risk of 14%; that is, 14% of workers exposed at the REL will nevertheless develop a material hearing impairment (NIOSH 1998). To protect against any measurable hearing loss, a much lower 24-hr average exposure limit of 70 dBA is required (EPA 1974). Due to daily variability in emergency calls, and, by extension, noise exposure conditions, most firefighters are unlikely to experience high noise exposures on every shift. However, the data obtained in this study do suggest that firefighters may potentially be exposed to a high level of noise on any given day. This, combined with the existing literature documenting NIHL among firefighters, provide strong evidence that additional hearing loss prevention efforts are needed among firefighters.

Our data demonstrate that firefighting activities which account for as little as 1.5 to 3 hours out of an 8 hr shift can result in 8-hr TWA levels that exceed the REL. The situation is even more striking for certain extremely noisy tasks, such as vehicle extraction using a pneumatic chisel to cut through a steel vehicle door frame. In this case, where measured task-based levels were 114 dBA or greater on average, involvement with this activity for just 35 seconds accounts for an individual’s entire daily allowable noise exposure according to the NIOSH criteria (NIOSH 1998). The average firefighter is likely to be unaware that the full dose of noise exposure may be reached within minutes (or even seconds) of performing a high noise level task.

The noise levels measured in the current study suggest a need for ongoing hearing loss prevention programs in the firefighting industry. These programs should include regular noise monitoring and exposure assessment, baseline and annual hearing loss prevention training specifically focused on firefighting and providing task-based noise level information, and baseline and annual audiometric testing. Based on the available literature, these program elements appear to be in place in at least some fire departments (Pepe, Jerger et al. 1985; Ewigman, Kivlahan et al. 1990; Tubbs 1991; Hong, Samo et al. 2008; Ide 2011). However, there are two additional program elements which do not appear to be common, but which are nevertheless vitally important to the prevention of hearing loss among firefighters. These are noise control efforts and use of hearing protection devices. Continued efforts at creating quieter fire service equipment are warranted, based on the noise levels measured here and in other studies. Ideally, design specifications establishing acceptable noise emission limits should be integrated into purchase agreements for new equipment as part of a “Buy Quiet” program. Certain types of equipment – for example, sirens and other warning equipment – must by law produce noise levels exceeding specific criteria. However, most equipment does not fall under such specifications, and could be altered to produce less noise (or, in the case of fire trucks and engines, to better protect firefighter occupants). Finally, use of hearing protection devices should be increased among firefighters. We have recently explored reasons for the low use of hearing protection devices among firefighters, and the results of our analyses are presented elsewhere (Hong, Samo et al. 2008; Hong, Chin et al. 2011). Given the diversity of commercially-available hearing protection devices and current and emerging technologies which can enhance communication in noisy environments for users of hearing protection devices (HPDs), there should be no technical hurdles for increasing use of hearing protection among firefighters. However, further intervention research is needed to identify effective methods for promoting use of hearing protection.

Only one previous task-based study of firefighter noise appears to have been published. In 1979, Reischl et al (Reischl, Bair et al. 1979) estimated 40-hr task-based noise exposures for eight firefighters based on a set of four tasks (firefighting operations, fire scene environment, return travel to station, and station environment), and estimated exposures of 85–98 dBA, which spans a surprisingly similar range to our 8-hr estimates of 81–98 dBA (rural Michigan and suburban California, Table 3). No previous studies appear to have evaluated the imprecision of task-based estimates of exposure; the current results suggest that this imprecision can be large (up to 5 dBA or more), which reduces our confidence in task-based estimates of firefighting noise exposure, particularly when such estimates are based on a small number of task-based noise measurements. This issue is further compounded by potential imprecision in estimated exposure durations; errors in estimated durations for particularly noisy tasks (e.g., vehicle extraction) may have large and undesirable effects on task-based exposure estimates.

Time spent in the fire station has traditionally been assumed to be in noise levels that are effectively quiet – that is, low enough to allow the ears to recover from any temporary hearing loss from earlier exposure to hazardous level of noise, and to not present any risk of additional hearing damage regardless of exposure duration. This level has been estimated to be approximately 75 dBA (Stephenson, Nixon et al. 1980). Measurements of fire station noise levels in the current study found average noise levels of about 68 dBA (short-term measurement, Table 2) to up to 86 dBA (average time spent in station during 24-hr measurement, Table 4). Previous studies which have evaluated noise in fire stations have generally found fire station noise levels to be quieter, typically between 40 and 70 dBA (Reischl, Bair et al. 1979; Tubbs 1992). It should be noted that these previous studies are 20–30 years old, and that many changes in noise associated with social settings like fire stations (e.g., the introduction of 24-hr television programming, MP3 players and portable stereos, cellular telephones, etc.) have occurred in the intervening period. These possible changes may have resulted in increases in fire station noise levels over time (and a subsequent increase in risk of NIHL), and may help explain some of the temporal differences in observed fire station noise levels. These possible changes, as well as differences in noise measurement protocols, may also help to explain why we found higher 24-hr average noise exposures than some earlier studies of firefighter noise (Tubbs 1991; NIOSH 1995).

This study has a number of limitations. Chief among them is the small sample size, which limits the generalizability of the results. The task-based assessment conducted here cannot be considered comprehensive, and almost certainly missed some high- and moderate-noise tasks that may occur routinely or infrequently in fire departments around the US. The results here may not be applicable to fire departments in different regions of the US, though it seems likely that they are representative of noise exposures in rural Michigan and suburban and urban Northern California. Finally, the noise exposures presented here do not consider any exposure attenuation that might be achieved through use of hearing protection devices. Though use of such devices by firefighters appears to be rare (Hong, Samo et al. 2008; Hong, Chin et al. 2011), regular users of hearing protection devices could have substantially lower exposures than those estimated here.

5. CONCLUSIONS

The results of this study suggest that many tasks and pieces of equipment used in firefighting are associated with noise levels that are high enough to present a risk of NIHL after chronic exposure. The noise levels measured here, combined with evidence of low use of hearing protection among firefighters and high rates of NIHL, indicate that additional efforts are warranted to protect hearing among US firefighters. In particular, identification of effective intervention efforts to increase the use of hearing protection and implementation and evaluation of noise control technology are needed.

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Table 1

L_{EQ} levels (dBA) during select firefighting job types measured in fire departments in rural Michigan and suburban California

		Rural Michigan				Suburban California			
Job type	**Equipment/tasks***	**N task-based meas.****	**Mean**	**SD**	**Max**	**N task-based meas.****	**Mean**	**SD**	**Max**
Total		21				70			
Ventilation	Sawing metal	1	91.8	--	--	4	104.9	5.3	111
	Sawing concrete	1	108.5	--	--	6	106.1	4.1	111.6
	Sawing wood/dry wall	2	108.9	1.2	109.7	4	105.5	8.7	113.9
	Operating electric blower	1	87.3	--	--	--	--	--	--
	Operating electric blower	--	--	--	--	6	93.5	6.6	105.4
	Operating gas blower	--	--	--	--	6	97.0	3.7	102.4
Vehicle extraction	Using pneumatic chisel to open vehicle	2	106.2	11.9	114.6	--	--	--	--
	Using hydraulic spreader to open vehicle		--	--	--	6	90.3	3.9	97.6
Preparation at scene	Setting outriggers and ladders	2	82.0	3.3	84.3	19	89.5	4.3	97.1
Fire suppression	Suppress fire, monitor water supply, search for embers	4	90.8	4.3	95.6	4	89.1	4.0	93
Operating fire engine	Respond to scene in cab	--	--	--	--	15	84.0	5.4	96.3
	Siren (inside cab)	1	98.2	--	--				
	Siren (outside cab)	2	115.0	1.0	115.7	--	--	--	--
Test personal safety system	Test personal alert safety system alarm	3	101.0	7.4	109.5	--	--	--	--
Check and fill SCBA	Check and fill self-contained breathing apparatus equipment	2	87.7	6.1	92.0	--	--	--	--
Fire station	Break room measurement	1	66.7	--	--	1	68.4	--	--

* All measurements of tasks and equipment represent personal exposures at the ear except the fire station measurement, which was an area measurement made in the center of a large break room occupied by several firefighters.

** Each measurement represents a separate instance of the specific task shown

Table 2

Measured L_{EQ} levels of typical daily fire station task sequences in urban California

		Short-term exposure		Equivalent 8-hr TWA
Measurement sequence number*	**Tasks/equipment and duration (minutes)****	**Total duration (minutes)**	**L_{EQ} (dBA)**	**L_{EQ} (dBA)**
1	Check engine (9.5), test generator (2)	11.5	87.8	71.6
2	Test diesel band saw, test generator, test aerial, test lights (20); check engine (13)	33	95.0	83.4
3	Test alarm (7); inspect engine test generator, test chain saw, test hydraulic outrigger (8.5); test gas blower and generator (7)	22.5	94.4	80.0
4	Cleaning up in kitchen and around station (20); check engine (10); test alarm (0.5)	30.5	90.1	78.0
5	Test hydraulic spreader (1); test generator (1); test chain saw (1.5); test circular saw (1); test concrete saw (1)	5.5	99.1	69.5
6	Test SCBAs (3); test engine (10); test engine cab tilt (5)	18	85.9	70.9
7	Test SCBAs (4); check engine and siren (1.5); test reciprocating saw (2.5); test chainsaw (2); test circular saw (1); test hydraulic spreader (1)	12	93.1	76.3
8	Test pneumatic chisel (1); test generator (2); check engine and test air brakes (8); test aerial (12)	23	89.8	70.1
9	Area measurement in fire station break room (16)	16	68.4	54.0

* Each task/equipment sequence was conducted over a single continuous measurement using a single firefighter

** All measurements of tasks and equipment represent personal exposures at the ear except the break room measurement in the fire station (number 9), which was an area measurement made in the center of a break room occupied by several firefighters.

Table 3

Full-shift task-based L_{EQ} exposure estimates for six common firefighting jobs using noise levels from rural Michigan and suburban California

Job	Major activities	Tasks and durations (hours)*	Assumed time in fire house (hours)	Estimated 8-hr TWA L_{EQ} (dBA)***	
				Rural MI	Suburban CA
Overall			5.7 (0.7)	88.4 (5.8)	84.6 (2.5)
Fire suppression	Monitor platform and ladder	Respond to scene (0.12), set outriggers (0.25), position ladder (2), check SCBA (0.1), fill SCBA (0.25)**	5.3	82.4	84.5
	Engineer	Respond to scene (0.12), monitor water supply (2), check SCBA (0.1), fill SCBA (0.25)**	5.5	86.3	85.2
	Water brigade	Respond to scene (0.12), fire suppression with hose (2), search for embers (0.5), check SCBA (0.1), fill SCBA (0.25)**	5.0	87.0	84.6
	Grass fire	Respond to scene (0.12), monitor water supply (1), check SCBA (0.1), fill SCBA (0.25)**	6.5	84.5	81.4
Ventilation	--	Respond to scene (0.12), ventilate roof (0.15), search for embers (0.5), fire suppression with hose (1.75), check SCBA (0.2), fill SCBA (0.25)**	5.1	92.2	88.8
Vehicle extraction	--	Respond to scene (0.12), open vehicle (1.25), monitor generator (0.5), check SCBA (0.2), fill SCBA (0.25)**	6.6	98.2	83.1

* Noise levels used to create exposure estimates are presented in Table 1.

** Noise levels for tasks “check SCBA” and “fill SCBA” were only measured in rural Michigan.

*** Each TWA represents the estimated full-shift personal L_{EQ} exposure for a single firefighter performing each of the specified tasks for duration indicated.

Table 4

24-hr L_{EQ} exposures results (mean, [standard deviation]) from dosimetry measurements in urban northern California

		Total		Station				Calls				
		Time	Noise	Time		Noise		Time			Noise	
Job title	N 24-hr meas.*	Hours	L_{EQ} (dBA)	Hours	% total time	L_{EQ} (dBA)	% total Dose	N Calls	Hours	% total time	L_{EQ} (dBA)	% total dose
Overall	5	23.7 (4.1)	84.5 (2.4)	22.6 (1.3)	90.2 (5.4)	84.0 (2.2)	33.0 (8.3)	8 (5)	2.3 (1.4)	9.8 (5.3)	88.5 (3.5)	67.0 (8.0)
Tillerman	1	24.2	81.6	22.6	94.2	81.3	32	6	1.6	6.4	84.6	68.3
EMT	1	23.8	85.3	22.3	93.8	85.0	31.5	6	1.6	7.8	88.5	69.7
Driver (1)	1	23.5	87.3	21.9	93.0	86.4	45.8	6	1.6	7.3	93.1	55.6
Incident scene specialist	1	23.2	83.8	21.2	91.5	83.2	26.5	5	2	9.2	87.7	74.1
Driver (2)	1	24.0	--	19.4	81.2	--	--	17	4.7	19.4	--	--

*Each personal L_{EQ} measurement represents a unique 24-hour period for a single firefighter in the measured job title

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Table 5

Measured versus task-based estimates of 24-hr L_{EQ} exposure (mean and [standard deviation], dBA)

Job title	L_{EQ} Measurement			L_{EQ} Estimate			L_{EQ} estimate-measurement		
	24-hr	**Station time**	**Call time**	**24-hr**	**Station time**	**Call time**	**24-hr**	**Station time**	**Call time**
Overall	84.5 (2.4)	84.0 (2.2)	88.5 (3.5)	84.5 (0.8)	84.0 (0.7)	88.5 (1.2)	0.0 (3.2)	0.0 (3.0)	0.0 (4.7)
Tillerman	81.6	81.3	84.6	85.4	84.8	89.8	3.8	3.6	5.2
EMT	85.3	85.0	88.5	84.2	83.6	88.5	−1.1	−1.3	0.0
Driver (1)	87.3	86.4	93.1	83.5	83.1	86.9	−3.8	−3.3	−6.2
Incident scene specialist	83.8	83.2	87.7	84.9	84.2	88.7	1.0	1.0	1.0

*Each personal L_{EQ} estimate represents a unique 24-hour period for a single firefighter in the measured job title