NHCA POSITION STATEMENT
Recreational Firearm Noise

March 16, 2017

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National Hearing Conservation Association (NHCA)
Task Force on Prevention of Noise-Induced Hearing Loss from Firearm Noise

This document was prepared by The National Hearing Conservation Association (NHCA) Task Force on Prevention of Noise-Induced Hearing Loss from Firearm Noise and approved by the NHCA Executive Council, March 16, 2017. The judgments expressed here represent the best available evidence at the time of publication and shall be considered the position of NHCA and not the individual opinions of the contributing authors or their respective institutions. The contributing authors declare no conflict of interest.

EXECUTIVE SUMMARY

Recreational firearm use is a popular leisure-time activity in the United States today. Millions of Americans of all ages enjoy shooting sports including target practice, competitive shooting, and hunting. While participation in the shooting sports can be an enjoyable recreational pursuit, it can also put an individual at risk for noise-induced hearing loss (NIHL) and tinnitus resulting from unprotected exposure to high-intensity firearm noise. Almost all firearms generate impulse levels in excess of 140 dB peak SPL. Hearing loss may occur gradually over time due to repeated unprotected exposure to firearm noise. Hearing loss also may occur suddenly due to acoustic trauma from a single unprotected gunshot. The hearing loss is often characterized by normal or near normal hearing sensitivity in the lower frequency range with severely impaired hearing in the higher frequency range which results in difficulty hearing speech clearly.

NHCA developed this guidance document to assist hearing conservationists, audiologists, physicians and other hearing conservation professionals, in managing and mitigating the risk of NIHL associated with recreational firearm noise. Several strategies can be employed to reduce the risk of acquiring NIHL and associated tinnitus from firearm noise exposure. These include wearing hearing protection devices (HPDs), using firearms equipped with suppressors, choosing smaller caliber firearms, using subsonic ammunition, shooting in a non-reverberant environment, and avoiding shooting in groups. In addition, several commercially-available HPDs are specifically designed for the shooting sports. These include conventional passive earmuffs and earplugs, level-dependent devices that attenuate high level sound while providing audibility for lower level sound, and electronic devices that amplify low level sounds and attenuate high level hazardous sounds.

The key to preventing NIHL and tinnitus secondary to excessive firearm noise exposure is to educate firearm users about the auditory hazard associated with firearm noise and provide them with strategies to protect their hearing. Educational programs may be offered through hunter safety courses, hunting clubs, or during training. A special firearm noise topic section should be included in occupational educational training for individuals who use firearms as part of their jobs. Finally, clinical audiologists should educate their patients who use firearms regarding the hazards and ways to prevent hearing loss. Several educational tools are available on the National Hearing Conservation Association website including a hearing loss simulator, a tinnitus simulator, posters and slides of inner ear structures damaged by firearm noise, a hearing protection brochure, a hunting and hearing video and links to other educational resources. Firearm NIHL is almost completely preventable if necessary precautions are taken.

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Abstract

Recreational firearm use is a popular leisure-time activity in the United States enjoyed by millions of individuals across all age groups. Recreational firearms produce impulse noise levels that exceed 140 decibels peak sound pressure levels (dB peak SPL). Unprotected ear exposure to this high-level impulse noise can cause immediate and irreversible damage to delicate inner ear structures of both the shooter and bystanders in close proximity. This damage includes noise-induced hearing loss (NIHL) and tinnitus. The potential increased risk of NIHL and tinnitus associated with recreational firearms noise may not be evident to recreational shooters, or nearby bystanders such as instructors and spectators. NHCA developed this guidance document to assist hearing conservationists, audiologists, physicians and other hearing conservation professionals, in managing and mitigating the risk of NIHL associated with recreational firearm noise.

Recreational Firearm Prevalence in the United States

Recreational firearm use by civilians is prevalent in the United States. Americans own an estimated 270-310 million firearms (Jütersonke *et al*., 2007; Krouse, 2012), more than any other country in the world. Data collected by the U.S. Fish and Wildlife Service (2011) revealed that approximately 15.7 million individuals over the age of 16 years used several types of firearms (rifles, shotguns, pistols, muzzle loaders) for hunting purposes while approximately 7.1 million people participated in target shooting in preparation for hunting. According to the National Shooting Sports Foundation (2009), over 30 million Americans are actively involved in the shooting sports. Several states allow children 10 years of age and younger to use firearms for hunting when accompanied by an adult family member (National Shooting Sports Foundation, 2010).

Recreational Firearm Noise Sound Pressure Levels

Although firearms are used by millions of U.S. citizens for recreational activities related to the shooting sports, these individuals may not be aware that exposure to high-level firearm noise can be hazardous to their hearing. This need for awareness also extends to those that are exposed as nearby bystanders, e.g. instructors, spectators. Almost all firearms generate peak impulse noise levels that exceed the 140 decibel peak sound pressure level (dB peak SPL) exposure limit mandated by the Occupational Safety and Health Administration (OSHA. 1983) and the A-weighted 140 decibel (dBA) limit recommended by the National Institute for Occupational Safety and Health (NIOSH, 1998) for adults in occupational settings. The World

Health Organization (WHO, 1997) recommends a 120 dB peak SPL maximum exposure limit for children. Several studies involving the measurement of firearm noise have found levels between 160 and 170 dB peak SPL for big bore rifles, pistols, and shotguns (Murphy and Tubbs, 2007; Flamme *et al*., 2009; Schulz, Murphy, Flamme 2013; and Meinke *et al.,* 2014). Additionally, Meinke *et al.,* (2013) found that some models of starter pistols can generate impulse levels exceeding 160 dB peak SPL at the shooters' ears. Many large bore firearms that generate peak noise levels above 160 dB peak SPL at the shooters' ear, closest to the muzzle, result in maximum permissible exposures (MPEs) of less than one shot when applying an A-weighted 8-hour equivalent energy level, L_{Aeq8}, and a limit of 85 dBA (Meinke *et al.*, 2014). Flamme *et al.*, (2011) employed three different damage risk criteria (DRC) and also calculated MPEs of one or less for a variety of large bore rifles and shotguns at the bystander position (1 meter behind the shooter). In addition, some air rifles have been found to exceed the 120 dB peak SPL limit for children (Lankford *et al*., 2016). Despite the recognition that firearms, including air rifles, can produce hazardous sound levels that can permanently damage the auditory system, 38% of target shooters and 95% of hunters reported never wearing hearing protection while shooting when asked about the previous year (Nondahl *et al.*, 2000).

Recreational Firearm Noise-induced Hearing Loss and Tinnitus

High-level impulse noise generated by recreational firearms is one of the leading causes of NIHL in the U.S. today. Several studies have found recreational firearm use can lead to NIHL (Prosser *et al*., 1988; Dancer *et al*., 1991; Kryter, 1991; Cox and Ford, 1995; Stewart *et al*., 2001; Stewart *et al*., 2002). Nondahl *et al*., (2000) reported that the risk of having a significant high-frequency hearing loss increased by 7% for every 5 years the study participants had hunted. The audiometric configuration of firearm NIHL is characterized by normal or near normal hearing sensitivity in the lower frequencies with a precipitous drop in the higher frequencies. Affected individuals often deny their hearing loss because they can easily hear the higher intensity, low-frequency vowel sounds in speech, but often do not hear the lower intensity, high-frequency consonants which are important for clarity of speech. The result is that they perceive others are mumbling when speaking. High-frequency hearing loss also makes it difficult to localize sound and to understand speech, especially in the presence of competing background noise, such as encountered when riding in a car or dining in a restaurant. The hearing loss worsens with continued unprotected exposure to firearm noise and ultimately impacts the speech frequency hearing range. Analysis of the 2011-2012 National Health and Nutrition Examination Survey (NHANES) data by Hoffman *et al*., (2016) found the prevalence of high-frequency (3000-6000 Hz) hearing loss to be 50%, 95% Confidence Interval (CI 40-59) among firearm users who reported having fired at least 1000 rounds in their lifetimes, 32% (95% CI 27-38) among firearm users reporting having fired fewer than 1000 rounds, and 26% (95% CI 24-29) among people who reported never having used firearms. The prevalence of speech-frequency (500-4000 Hz) hearing loss was also higher among people reporting having fired at least 1000 rounds (26% versus 11%), and these same individuals had higher odds of hearing impairment even after adjusting for age, gender, ethnicity, educational level, cardiovascular risk factors, and other noise exposures (Odds Ratio: 1.8; 95% CI 1.1-3.0).

The left ear of right-handed shooters often exhibits more hearing loss because it is slightly closer to and receives a direct exposure from the muzzle of a rifle or shotgun while the right ear is partially protected by the head shadow effect (Rasmussen *et al*., 2009). The opposite is true for a left-handed rifle shooter. An asymmetrical hearing loss is less evident among people only firing handguns or pistols. The hearing loss from firearm impulse noise is greater in those who work in noisy environments when compared to those who do not (Stewart, Konkle, and Simpson, 2001). In addition to NIHL, firearm noise exposure can also lead to tinnitus (Smith *et al*., 2000; Olsen-Widen and Erlandsson, 2004; Stewart *et al*., 2009; Stewart *et al*., 2014). In fact, tinnitus is one of the early warning signs of NIHL (Griest *et al*., 1998).

Recreational Firearm NIHL and Tinnitus Prevention Strategies

Hearing Protection Devices (HPDs)

Fortunately, NIHL and tinnitus caused by firearm noise exposure are largely preventable with the use of appropriately fitted hearing protection devices (HPDs). HPDs may be earplugs or earmuffs. Murphy *et al*., (2012) measured the amount of sound attenuation or protection (impulse peak insertion loss) using an acoustic mannequin, fit with conventional HPDs (insert earplugs and earmuffs), and found impulse peak insertion loss values greater than 35 dB for 170 dB peak SPL firearm noise. The protected levels were less than the OSHA dB peak SPL and NIOSH 140 dBA exposure limit. Murphy and Tubbs (2007) also found peak impulse reduction values of approximately 30 dB using an acoustic mannequin with correctly fit earmuffs or earplugs. Moreover, they found insert earplugs used in combination with circumaural earmuffs ("double protection") provided approximately 50 dB of peak reduction, an effect greater than either earplugs or earmuffs alone. A subsequent study (Murphy *et al.*, 2015) also reported more than 50 dB of impulse peak insertion loss when double protection was employed.

Appropriate use of HPDs can be effective in preventing NIHL caused by exposure to high-level impulses generated by firearms. However, HPDs must be worn properly and consistently by the recreational firearm user to achieve any benefits. Recent studies investigating the shooting habits of adult recreational firearm users noted that they do not consistently wear HPDs while hunting. Stewart *et al.*, (2011) found over 70% of shooters reported never using HPDs while hunting and only 50% reported consistent use of HPDs during target practice. Stewart *et al*., (2009) also found only 40% of adult waterfowl hunters reported using HPDs consistently while target shooting and only 20% consistently wore HPDs while hunting ducks and geese. This particular population of recreational firearm users is at increased risk of NIHL because they often hunt in groups, in enclosed hunting blinds, and use large bore, semi-automatic weapons capable of rapid firing. Stewart *et al*., (2014) surveyed youth shooters 10-17 years of age and found results similar to adult recreational firearm users; 56% reported consistent use of HPDs while target practicing and only 16% while hunting. The majority of individuals in these studies were unaware of advancements in hearing protector design that overcome some of the conventional barriers toward wearing hearing protection in this population.

Because hearing protectors reduce the awareness of important environmental sounds, such as the approach of game, many recreational firearm users are reluctant to wear HPDs while hunting. However, several commercially available HPDs are specifically designed for the shooting sports that largely circumvent this problem. Electronic HPDs can provide mild amplification of ambient sound in quiet to allow the hunter to hear, but attenuate intense firearm impulse noise (and other high-intensity sound) by employing electronic peak clipping and passive attenuation when sound levels exceed a high-intensity threshold (Murphy *et al.*, 2015; Murphy and Tubbs 2007). Electronic devices are available in a variety of styles including circumaural headphones, insert earplugs, custom in-the-ear devices, and behind-the-ear devices. Passive (non-electronic) level-dependent (also called non-linear) HPDs are less expensive than the electronic devices and allow softer sounds to be heard while attenuating high-level sound such as firearm noise via specially designed physical apertures and filters. These level-dependent HPDs provide increasing attenuation with increased sound level (Murphy *et al*., 2012; Murphy *et al.*, 2016b; Fackler *et al.*, 2017). These technologies allow hunters to monitor their auditory environment and allow target shooters to hear conversation and instructions at the firing range while providing hearing protection when guns are fired.

The noise reduction rating (NRR) listed on the packaging or in the manufacturer's specifications provides the consumer guidance when selecting hearing protection for shooting sports. For continuous or constant noise, the NRR informs the consumer about the potential performance of the protector when properly worn. For impulse noise, the attenuation will be similar to the NRR rating, but can be higher (Murphy *et al*., 2012; Murphy *et al*., 2015; Fackler *et al*., 2017). Some HPDs are designed with filters that provide increased attenuation with higher peak impulse levels. The attenuation for these types of filtered HPDs will not exceed

that for the same protector with the filter completely closed or blocked. Earmuffs tend to exhibit increased attenuation with increasing impulse level. An adequate seal in the ear (for earplugs) or over the ear (for earmuffs) is essential for optimal hearing protection and the wearer should evaluate both comfort and seal when choosing an HPD. Dual hearing protection (earplugs plus earmuffs) will provide the greatest protection. Electronic devices may also be worn in combination with passive HPDs providing the best audibility for soft sounds and greatest degree of hearing protection.

Firearm Noise Suppressors

Another device that may reduce the risk of acquiring NIHL is the firearm suppressor, which is commonly, and inaccurately, known as a silencer. Discharging a firearm produces a high-level acoustic impulse generated by the sudden release of gases that propel the projectile out of the barrel of the gun. A suppressor affixed to the end of the barrel can reduce the noise from the pressure of the escaping gases by coupling a chamber with a large volume to the muzzle of the firearm. In addition, a series of baffles within the chamber act as a muffler to further reduce the impulse noise level. Suppressors cannot reduce the noise caused by the supersonic flight of the projectile breaking the sound barrier once it leaves the barrel of the firearm. However, subsonic ammunition can be used to avoid this from occurring, thus reducing the overall SPL. Using subsonic ammunition in conjunction with a suppressor can collectively reduce firearm noise over either approach alone.

Recently, two studies have examined the effectiveness of firearm suppressors in reducing firearm noise. Lobarinas *et al.,* (2016) measured firearm noise using a variety of AR-15 firearms with different calibers (5.56 mm and 7.62 mm), types of ammunition (sub and supersonic), suppressors, and barrel lengths. The authors found suppressors reduced peak sound pressure levels from 7 to 32 dB relative to various unsuppressed conditions at three microphone locations (right and left ear and at 1 meter left of muzzle). However, several measurement conditions using suppressors still yielded levels above 140 dB peak SPL, especially for guns firing supersonic ammunition and guns with shorter barrels. Murphy *et al.,* (2016a) measured suppressed and unsuppressed firearm noise with two different rifles (.223 and .308 caliber) using subsonic and supersonic ammunition at three different microphone locations (shooter's right ear, left ear, and at the instructor's position 1 meter behind the shooter). Impulse levels for the subsonic ammunition ranged from 100 to 132 dB peak SPL in the suppressed conditions across microphone locations. The levels were 127 to 149 dB peak SPL for the unsuppressed conditions. Impulse levels for the supersonic ammunition ranged from 120 to 137 dB peak SPL in the suppressed conditions compared to 148 to 161 dB peak SPL for the unsuppressed conditions. The sound levels of firearm noise for supersonic ammunition can be reduced by approximately 30 dB with the use of suppressors. Coupling suppressors with subsonic ammunition can reduce levels further, compared to unsuppressed, supersonic ammunition conditions. Other suppressors not evaluated in the above studies and future technologically advanced suppressors may not provide the same reduction of firearm noise.

It is important to note that the use of a suppressor does not eliminate the risk of NIHL; it only reduces the risk by reducing the intensity of the sound emission. There currently are no standardized protocols to measure the degree of attenuation (noise reduction) firearm noise suppressors provide. This means that manufacturers cannot guarantee that noise suppressors make a firearm safe to use without the wearing of hearing protection; that is, manufacturers cannot guarantee that use of noise suppressors alone will prevent hearing loss.

To properly protect their hearing, consumers must regard attenuation data published by firearm noise suppressor manufacturers with caution, and wear hearing protection whenever shooting firearms, including when employing a noise suppressor device.

Choice of Caliber of Rifle, Pistol or Gauge of Shotgun

Most hunting rifles, pistols and shotguns produce dangerously high levels of impulse noise. Magnum calibers increase noise levels significantly. Using smaller caliber firearms for target practice can lower the risk of NIHL. Hunters must balance their choice of caliber with other factors, but a smaller caliber with an adequate effective range might be a smart decision. Consistent use of appropriate hearing protection must be stressed. The use of double hearing protection is especially important when shooting large bore firearms.

Muzzle Brakes (Ports)

Muzzle brakes (ports) can reduce recoil but generally at the cost of increased noise hazards. The associated opening in the barrel/port allow for the escaping gases to be ejected closer to the ear and also radiates more sound energy back toward the shooter. Consequently, muzzle brakes often increase the peak sound pressure levels measured at the ears of the shooter. This condition is exacerbated when using short barrels.

Shooting Environment

Almost any firearm can be hazardous to hearing, especially if it is capable of rapid fire or is fired in a reverberant environment, such as a hunting blind. Firing indoors in a room without sound treatment versus firing in open outdoor areas also increases the risk. Shooting in a reverberant environment will result in longer impulse durations and may contribute to higher sound pressure levels which can increase risk of hearing loss. When shooting in a small enclosed hunting blind, it is important to make sure the gun barrel is outside of the blind before firing. Sound treatments on the walls of indoor firing ranges can also reduce the risk of hearing loss.

Number of Shots Fired

The more shots fired, the higher the risk for NIHL. Each shot fired potentially contributes to the hearing loss. For example, waterfowl hunters who shoot hundreds of shots each season may be at greater risk of hearing loss than large game hunters who only fire their rifle a few times a season. Target shooting may present the opportunity for firing a large number of rounds, and hearing protection is essential during these sessions. HPDs can also improve accuracy by reducing flinching due to the lower noise level reaching the shooter's ears.

Hunting and Shooting in Groups

Waterfowl and upland bird hunters are high-risk shooting populations because they often hunt in groups, may fire multiple shots in a single hunt, and almost exclusively use rapid-fire, large-bore firearms. In this case, shooters are not only exposed to the high level impulse noise from their own firearms, but also to the impulses from nearby shooters. Increasing the distance between shooters and making sure both shooters and bystanders are wearing hearing protection are important to reducing exposure levels.

Handgun Use

Any caliber of handgun generates hazardous levels of impulse noise because the muzzle of a short barrel is closer to the ears than for a long gun. Big-bore pistols (for example, the .357, .44 caliber magnum and .50 caliber), can expose the shooter to impulse levels greater than 170 dB peak SPL. It is important to wear double hearing protection when firing big-bore handguns to prevent NIHL. It is also worth noting that shooting over a surface such as a table or bench versus standing over open ground will also increase the peak SPL reaching the ear (Meinke *et al*., 2014).

Educational Information for Firearm Users

TIPS FOR SHOOTERS TO REDUCE RISKS FOR HEARING LOSS
Keep hearing protection devices on hand and use them correctly.
Use earplugs and earmuffs together (double protection) when using large-caliber guns or when many shots will be fired.
Consider smaller calibers or gauges during target practice.
Choose a single-shot or bolt-action over a semi-automatic weapon to help reduce the numbers of shots and increase the quiet time between shots.
Avoid shooting in large groups, especially at indoor or enclosed firing ranges, and if you do be especially aware of those who may be shooting near you so you can have your ears protected when their guns discharge.
Select a firing range with noise control treatments on the walls and ceilings.
Choose firearms with longer barrels and no ports or muzzle brakes.
Consider using low-recoil (low-noise) ammunition.
Consider the use of a firearm suppressor for use in combination with HPDs, where suppressor use is legally permitted.
When hunting in a blind, make sure the muzzle is outside the blind before pulling the trigger.
Use well-fitted, nonlinear or electronic ear protection designed for hunting/shooting.

Hearing Healthcare

Hearing loss prevention programs for recreational firearm shooters should include annual audiometric testing and hearing protector fit testing to monitor hearing levels and make sure the hearing protection devices are providing adequate protection. Any reduction in hearing sensitivity or sudden onset of tinnitus (especially immediately after shooting) necessitates a hearing test, a re-evaluation of shooting habits and hearing protection device fitting. Other health issues (diseases) can cause hearing loss, so recreational shooters should never assume their hearing loss is solely from firearms. Shooters should be advised to see an audiologist whenever a hearing loss is suspected. There are practical rehabilitation approaches options available to shooters with hearing loss.

Hearing Aids

Audiologists are skilled in fitting hearing aids and also offer treatment and counseling for bothersome tinnitus. Hearing aids can help compensate for the loss of hearing but are unable to restore natural healthy hearing. Fitting amplification to individuals with precipitous hearing loss can be challenging especially when high frequency audiometric thresholds are severely impaired as in the case of NIHL. Recent availability of frequency shifting capability in advanced technology hearing aids that move sounds from areas of severely degraded hearing to areas of better residual hearing may offer some promise in remediation of this type of hearing loss. Sophisticated digital programing and other features can provide individualized tailoring of the hearing aid to the fit the person's needs and lifestyle. Sound therapy and counseling are also available to help individuals with tinnitus better manage their symptoms.

Resources

Several educational tools, effective in motivating firearm users to protect themselves from firearm noise, are available on the National Hearing Conservation Association website. These include:

NHCA EDUCATIONAL TOOLS
NIOSH hearing loss simulator.
A tinnitus simulator.
Posters and slides of inner-ear structures damaged by excessive firearm noise.
A brochure on hearing protection devices for shooting sports.
A hunting and hearing video.
Links to other educational resources.

Conclusion

Noise-induced hearing loss from high level firearm noise can be prevented by employing effective strategies aimed at reducing the sound level produced by the firearm and protecting the ears of the recreational shooter and bystanders.

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