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Comparison of Muzzle Suppression and Ear-Level Hearing Protection in Firearm Use

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Abstract

Objective. To compare noise reduction of commercially available ear-level hearing protection (muffs/inserts) to that of firearm muzzle suppressors.

Setting. Experimental sound measurements under consistent environmental conditions.

Subjects. None.

Study Design and Methods. Muzzle suppressors for 2 pistol and 2 rifle calibers were tested using the Bruel & Kjaer 2209 sound meter and Bruel & Kjaer 4136 microphone calibrated with the Bruel & Kjaer Pistonphone using Military-Standard 1474D placement protocol. Five shots were recorded unsuppressed and 10 shots suppressed under consistent environmental conditions. Sound reduction was then compared with the real-world noise reduction rate of the best available ear-level protectors.

Results. All suppressors offered significantly greater noise reduction than ear-level protection, usually greater than 50% better. Noise reduction of all ear-level protectors is unable to reduce the impulse pressure below 140 dB for certain common firearms, an international standard for prevention of sensorineural hearing loss.

Conclusion. Modern muzzle-level suppression is vastly superior to ear-level protection and the only available form of suppression capable of making certain sporting arms safe for hearing. The inadequacy of standard hearing protectors with certain common firearms is not recognized by most hearing professionals or their patients and should affect the way hearing professionals counsel patients and the public.

Keywords

tinnitus, sensorineural hearing loss, noise-induced hearing loss, firearm suppression, hearing protection

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Noise-induced inner ear injury is a substantial cause of preventable disability in the United States. Approximately 15% of Americans between the ages of 20 and 69 years—or 26 million Americans—have hearing loss that may have been caused in part by exposure to loud sounds or noise at work or in leisure activities.[1] Subjective tinnitus affects approximately 50 million Americans (12%-15% of the adult population)[2-4] and often accompanies sensorineural hearing loss in patients with a history of loud noise exposure.[5-9]

Recreational use of firearms is a significant cause of noise and related ear injury in America.[10] There are approximately more than 250 million privately owned firearms in the United States,[11,12] and the number increases about 4.5 million per year.[13] This rate of increase rose by 14% for 2007-2008.[14] Unlike industrial exposure, hearing protection during recreational firearm use is not regulated or enforced. This represents one of the largest neglected areas of advocacy for prevention of ear injury.

Ear-level hearing protection is poorly understood by patients and hearing specialists alike. Far from being a panacea, ear-level protection rarely, if ever, confers the level of protection or noise reduction ratio (NRR) advertised. NRRs are determined using laboratory tests in continuous noise (not impulse sounds such as gunfire) and are not useful for determining the actual level of protection achieved by a given individual in a particular environment.[15]

How much protection is afforded by ear-level protection? The National Institute of Occupational Safety and Health (NIOSH) recommends that earmuffs be considered to have 25% less NRR than stated and formable earplugs 50% less.[16] The most common commercially available ear protection has an advertised NRR of 19 to 25 dB. The highest rated NRR are 31 dB and are less common. The Occupational Safety and Health Administration sets 140 dB

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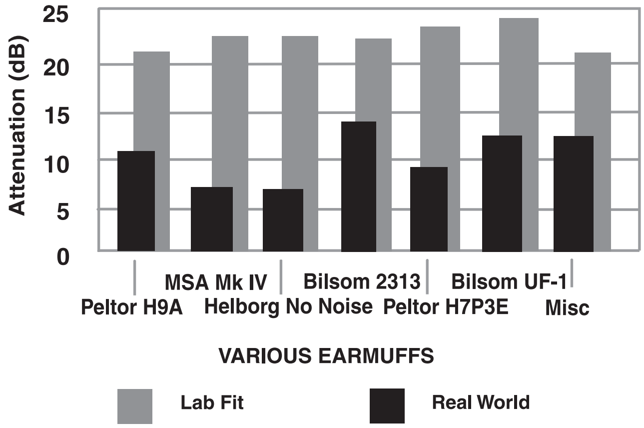

Figure 1. Noise reduction ratio (NRR) hearing protection provides in the real world: earmuffs.

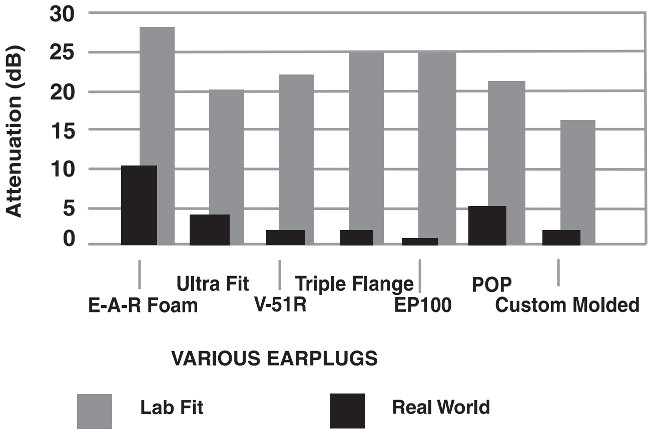

Figure 2. Noise reduction ratio (NRR) hearing protection provides in the real world: earplugs.

as the safe threshold for single-impulse sound exposure. Using the adjusted NRR levels, most hearing protection (NRR 19-25 dB) is unable to make hearing safe a firearm producing an impulse sound louder than 149.5 to 154 dB. The best available ear-level protection (earmuffs, NRR 31 dB) is unable to make hearing safe any firearm louder than 163 dB under the best of conditions. According to Berger et al,[16] even these adjusted figures are likely unrealistic. This review of 20 published studies demonstrated far worse performance than the corrected NRR suggests: the laboratory NRRs consistently overestimated the real-world NRRs by 140% to 2000% (**Figures 1** and **2**).[16] It is unlikely, however, that most consumers of hearing protection have any idea what the NRR is of the products they purchase or what level of protection is necessary to make their particular firearm safe for hearing.

Hiram Maxim first introduced and marketed muzzle suppressors in the 1920s in the United States. These devices either attach to the muzzle (by way of threading the barrel or by proprietary quick attachment mechanisms) or are integrated into the barrel. Muzzle suppressors allow the heated gases from the barrel to expand into a series of chambers or baffles, cooling and slowing the gas's exit from the barrel. The result is a shorter, quieter sound signature. The basic design of suppressors has changed little over the years, but modern design and manufacturing have improved their sound reduction effectiveness. Unlike ear-level protection, muzzle suppressors are relatively easy to use in a consistent, repeatable fashion. They confer protection for the shooter and bystanders alike and allow interpersonal conversation and situational awareness of sounds not afforded by ear-level devices. They are also legal in most states, although their ownership and transfer are regulated by the Bureau of Alcohol, Tobacco, Firearms and Explosives (BATF&E) and requires a $200 tax and somewhat lengthy process for registration, delaying use of the device for weeks or months from the time of purchase. Importantly, it is relatively simple to demonstrate their actual noise reduction capability compared with ear-level devices.

Study Design

We hypothesized that modern muzzle suppression has a demonstrable superiority to ear-level protection due to the unpredictable protection of ear devices and improbability of one-size-fits-all products. We tested common pistol and rifle calibers with and without muzzle suppression using strict military/industrial standard sound measurement for impulse noise. We recorded the impulse noise in decibels and compared the sound levels with and without suppression. We then compared the average noise reduction of the suppressors to likely NRR levels of ear-level products.

Methods

The tests were conducted using the Bruel & Kjaer (B&K) 2209 sound meter with a B&K 4136 microphone calibrated with the B&K 4220 Pistonphone. Calibration was checked after the tests to verify there were no shifts in calibration during the tests. All equipment has been certified and tested so that it can be traced back to the National Institute of Standards and Technology's standards. The meter and weapon are also placed in accordance with Military-Standard 1474D protocol. Five shots were fired to establish the unsuppressed level, and then 10 shots were fired with the suppressor attached.[17]

For the pistol tests, we used 9 mm and 45 ACP semiautomatic pistols (**Table 1**). These are very popular sporting rounds as well as common military standard calibers. The rifle tests were performed with a semiautomatic 5.56 mm/223 caliber round, as is used in the AR-15 style civilian rifle and the NATO military M16/M4 carbine rifle, and a bolt-action 7.62 × 51 mm/308 caliber rifle, also a common sporting round and NATO military standard round.

The suppressors used are commercially available and legally obtained by way of the standard BATF&E registration process for civilian ownership. No institutional review or ethics committee approval was deemed necessary or sought for this study.

Table 1. Firearms (Caliber, Manufacturer), Ammunition, and Suppressors Used

	Caliber	Manufacturer	Ammunition	Suppressor
Pistol	9 mm	Sig Sauer P226, Exeter, NH	Remington UMC 147 gr ball, Lonoke, AK	Advanced Armament Ti-Rant, Norcross, GA
	45 ACP	Glock 21, Smyrna, GA	Remington UMC 230 gr ball, Lonoke, AK	HTG Cycle-2, Boise, ID
Rifle	5.56 mm/223	Colt M4 16 inch barrel, Hartford, CT	M855 NATO 62 gr steel core penetrator, Independence, MO	Gemtech G5, Eagle, ID
	7.62 × 51 mm/308	Remington Model 700, Madison, NC	Remington 168 gr BTHP MK, Lonoke, AK	HTG M-30, Boise, ID

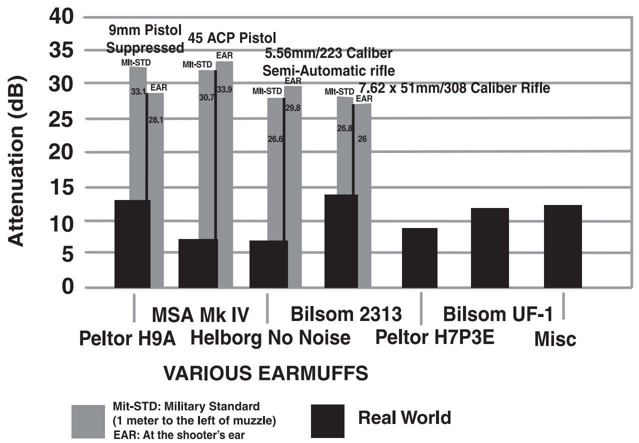

Figure 3. Firearm/suppressor attenuation compared with real-world earmuff attenuation. EAR indicates at the shooter's ear; MLT-STD, military-standard.

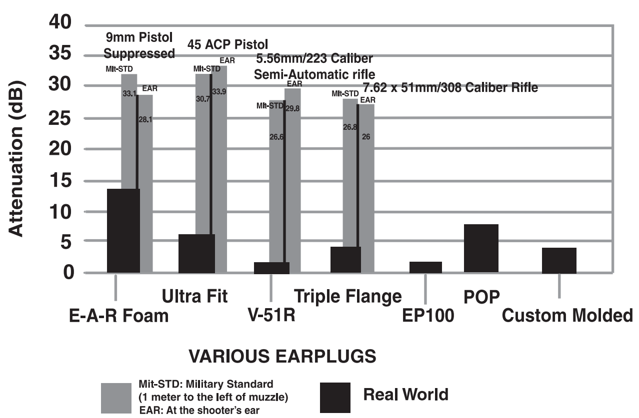

Figure 4. Firearm/suppressor attenuation compared with real-world earplug attenuation. EAR indicates at the shooter's ear; MLT-STD, military-standard.

Results

The average unsuppressed sound levels for the 9 mm pistol at military standard recording distance (1 m to the left of the muzzle) was 160.5 dB and 157.7 dB at the ear of the shooter. The average suppressed levels were 127.4 dB and 129.6 dB, respectively (difference of 33.1 dB and 28.1 dB).

The average unsuppressed sound levels for the 45 ACP pistol at military standard recording distance and the shooter's ear was 162.5 dB. The average suppressed levels were 131.8 dB and 128.5 dB, respectively (difference of 30.7 dB and 33.9 dB, respectively). The suppressor for the 45 ACP is also designed to function wet (filled with 10 mL of water for additional noise reduction). The average wet suppressed level was 121 dB (difference of 41.5 dB).

The average unsuppressed sound levels for the 5.56 mm/223 caliber semiautomatic rifle at the military standard recording distance was 164 dB and 155 dB at the shooter's ear. The average suppressed levels were 137.4 dB and 134.2 dB, respectively (difference of 26.6 dB and 29.8 dB, respectively).

The average unsuppressed sound levels for the bolt-action 7.62 × 51 mm/308 caliber rifle at the military standard recording distance was 165.7 dB and 157.2 dB at the ear. The average suppressed sound levels were 138.9 dB and 131.2 dB, respectively (difference of 26.8 dB and 26 dB, respectively). See **Figures 3** and **4**.

Discussion

The consistency of hearing protection use with recreational firearms is dismal.[18] We know that hearing compliance programs in industry rely on routine, supervised use of ear-level devices and periodic audiometric screening to assess effectiveness. No such programs exist for the recreational shooter. As the NIOSH Web site explains, the best hearing protection is the one the worker will wear.[16] But how do we motivate shooters to be compliant, especially in light of the data regarding the poor effectiveness of ear-level devices? Even compliant use of dual ear protection (plugs and muffs) over time leads to degradation of hearing.[19] Practical limitations of ear-level devices are myriad. Poor fit, migration of device due to activity or sweat, incorrect use, pain, heat, and loss of communication top the list.

Because of their use at the source of noise production, muzzle suppressors are much more effective at reducing noise. This facilitates communication and situational awareness, which can improve safety when operating firearms. Suppressors can easily and reliably be removed and transferred between multiple weapons of like caliber and reattached in a way that ensures proper fit and function. With suppression levels from 26 dB to 41 dB that are reliable and reduce impulse noise below 140 dB, all of the devices in our study are "hearing safe." However, weapon-suppressor combinations producing sound levels 130 dB or less (9 mm and 45 ACP wet) are much more comfortable to shoot without any hearing protection at all. In fact, the sound level of the 9 mm pistol's slide closing without any shot fired measured 124 dB. To our knowledge, this is the first time the efficiency of muzzle suppressors has been properly tested and compared with ear-level protection in any medical journal.

Conclusion

The muzzle-level suppressors studied on these weapons and calibers reduced sound levels well below the likely noise reduction of either earplugs or earmuffs.

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Author Contributions

Matthew Parker Branch, original concept, experimental design and execution, research, writing, editing entire text, final approval.

Disclosures

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