Law Enforcement Firearms Training and Noise-Induced Hearing Loss

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Firearms training is among the highest liability areas to which law enforcement agencies expose their employees. While much attention is spent on training firearms proficiency, little attention is spent on hearing conservation or the hearing protection devices used by officers and their instructors during this training. Because firearm discharges produce extreme sound pressure levels that can result in permanent and severe noise-induced hearing loss (NIHL), law enforcement agencies bear responsibility to their employees to reduce the impact and incidence of training-related hearing loss.

Anecdotally, we all know that firearms blasts are loud. And I think intuitively most people can connect exposure to repeated firearms blasts to acquiring hearing problems. But haven't we mitigated all that danger by wearing a set of earmuffs or earplugs? I once thought so.

After many years as a law enforcement firearms instructor, all while wearing standard passive earmuffs, I started to question if I had enough protection. After a few years of teaching at the local police academy and interacting with countless law enforcement officers and firearms instructors, many of whom had significantly more years of firearms experience than I had, I noticed almost all of them had significant hearing loss and were wearing hearing aids. After some discussions of what noises they had been exposing themselves to, and what hearing protection devices they were using, it became apparent to me that there was a deficiency in the amount of protection they were successfully achieving.

This awareness led me to study the effects of noise on hearing and hearing loss prevention, important issues within the field of audiology. This research also led me to team up with some of the best audiologists and hearing scientists at the University of Florida – Dr. Colleen Le Prell, Dr. Edward Lobarinas, and Dr. Christopher Spankovich. As part of this partnership, I started to review the available literature on the issue of firearms sound pressure levels, suppressor testing, and NIHL. I soon realized not only was more research was needed, but more sharing of the existing research findings needed to occur within the law enforcement community – not just the academic / scientific community! Below I will share some of the highlights of this research, which should be useful in grasping the magnitude of this problem and starting down a course to mitigating it.

The concern-

What are some departments pondering? These are the most common comments I've heard:

I'm an agency administrator and some of my firearms training staff are complaining of having a hard time hearing.

I have numerous employees after 20 years on the force, having to purchases hearing aids at $5000 apiece.

I have countless other employees which seem to be affected and can't seem to understand speech as clearly, especially in environments with background noise.

Just as importantly, a review of the different environments and exposure profiles these employees are training in might be important:

I have special teams / SWAT members which may be shooting hundreds of rounds a month to maintain their proficiency.

I have firearms instructors who are on the shooting range teaching for up to 40 hours a week.

I have users who might train in highly reverberant, indoor environments, close to one another.

Each of these users presents a complex profile of hearing hazards, and each may require a specific hearing protection solution.

Consequences of inadequate protection–

In 2013, the United States – the Veteran's Administration spent over $2 billion dollars in disability payments for hearing loss and tinnitus that were primarily accrued by blast and firearm exposures. The law enforcement community similarly has the potential to be financially affected when officers request compensation for damage acquired from firearm discharge exposures during training and qualifications. More importantly, as any agency surely desires, we want all our employees to maximize their on-duty survival efficiency by protecting one of their most important sensory perceptions to preserve situational awareness. Of course, protecting and preserving their hearing also protects their hearing for their off-duty time too. But how do we provide the proper protection to our employees? To best explain protection, it helps to understand the noise insult.

How sound is measured – Sound Pressure Level (SPL) -

One issue is how we measure sound. Typically sound is measured using units that reflect pressure applied to the eardrum, but because of the immense range of sensitivity of the human auditory system, sound is typically reported on a logarithmic scale – using decibels (dB). Because of the exponential relationship, every 10-dB increase in sound level is actually a 100-fold increase in pressure. This exponential increase in pressure is what partially makes the extremely high pressure values difficult to fathom for non-scientific personnel.

Most people intuitively understand linear relationships, with a 1-to-1 (linear) scale. For instance, if I had 100 lbs of weight and then added 10 more lbs, I would have 110 lbs and I could perhaps feel the small increase in how much weight was added.

With dBs being logarithmic in nature, it's calculated very differently.

As an example, if I had 140 dB and then added an additional 6 dB of sound pressure, this would actually be double the sound pressure of the previous 140 dB. If I had 140 dB sound pressure and added 10 dB of pressure, this would be 10 times as much power, and the 150 dB sound would be perceived as twice as loud as the 140 dB sound!

If we were to convert dB into a linear scale of pressure Pascals (Pa), it becomes easier to appreciate the magnitude of these pressure increases.

In our previous example 140 dB = 200 Pa. If I added 6 dB of pressure again, 146 dB = **400 Pa of pressure**. This doubling of pressure becomes a major concern at these high pressures.

As a note: most government regulations limit impulse exposure to less than 140 dB SPL. Any exposure above 140 dB SPL is considered to carry a risk for causing some amount of permanent damage to the human auditory system. That's not to say that sound at 139 dB SPL is "safe." Allowed exposure durations at such levels might be less than 1 second at that sound pressure, per day.

To put the potential hazard of firearm discharge into perspective, consider that some AR-15 rifle combinations are producing over 180 dB of sound pressure!

Some might say, well that's only 40 dB greater than that 140 dB (200 Pa) limit. But, 180 dB SPL is actually 20,000 Pa of pressure pushing on the eardrum! Hopefully, this example helps you understand and appreciate the magnitude and impact of that 40 dB increase, at the edge of this logarithmic scale. ***The 20,000 Pa pressures we are dealing at 180 dB SPL with are 100 times greater than what is considered the threshold for causing permanent hearing damage (140 dB SPL, 200 Pa).***

Human Ear workings and Inner Hair Cell damage –

The ear works by converting the changes in air pressure into an electrical signal the brain can interpret. The normal frequency range for the human auditory system is 20-20,000 Hz, and the ear is more sensitive to some frequencies than others. The lowest sound pressure that a listener can reliably detect is defined as the "threshold" for that listener, and threshold is measured at a variety of frequencies from 125 to 8,000 Hz. At the "best" frequencies, from 500 to 6000 Hz, normal hearing listeners can detect sounds around 0 dB SPL whereas at other (higher or lower) frequencies, some 40-60 dB SPL might be the smallest detectable sound pressures. To make it easier to explain hearing loss, the average threshold value for a large group of normal hearing listeners is defined as 0 dB hearing level (0 dB HL), and individual hearing loss is measured as the difference in thresholds for an individual listener compared to that population. Any thresholds that are within 25 dB of that average level are considered "within normal limits." Any sound pressures over 140 dB can cause some amount of permanent change in thresholds due to damage to the inner ear.

The basic process is that when air molecules vibrate, and enter the outer ear, they are focused via the ear canal onto the ear drum. The ear drum (tympanic membrane) vibrates when air molecules push on it, and then converts these air pressure changes back into mechanical movement of the tympanic membrane is directly propagated. That movement is translated into and amplified by the three bones of the middle ear. At the end of the third bone structure, these mechanical movements are transferred to the cochlea. The cochlea is filled with fluid, and those vibrations of the middle ear bones create pressure waves within this fluid. Within the cochlea are sensory cells, with small hair-like projections (stereocilia) which are deflected during the fluid movement. The deflection of the stereocilia causes the release of an excitatory neurotransmitter substance from the hair cells, and this excitatory substance stimulates nerve cells to produce an electrical signal that is sent upwards to the brain via the nervous system. In the brain, the electrical signal is processed and analyzed.

This basic overview of how the ear works is important for an analysis of firearms pressure affects. When the ear receives too much noise, the pressure created in the cochlea can cause mechanical damage to the hair cells. Additionally, these blasts can result in trauma to the junctions where the hair cells communicate with the neurons. Unfortunately, when hair cells are destroyed, they do not grow back. Each of these hair cells are located within specific regions of the cochlea and respond to certain sound frequencies. The number of surviving hair cells (and neurons) in each specific area of the cochlea determines how well you can hear those specific frequencies. When the hair cells have not been damaged and the auditory system is intact, softer sounds can be heard. However, hair cell loss after noise exposure causes NIHL, and this NIHL

typically is a cumulative process of increasing hearing loss with increasing years of exposure. Usually by the time you've noticed a deficiency, significant amounts of auditory damage have already occurred.

Said another way - even if each time out at the shooting range damages only a small number of hair cells, over months and years of exposure, the cumulative effects will be noticed. Unfortunately there is not a cure, and the only readily available method of "improving" NIHL is the use of hearing aids that are programmed to amplify sounds you can no longer detect. Hearing aids are essentially miniature amplifiers programmed to serve as equalizers and attempt to and overcome the loss of gain your natural auditory system would normally provide.

It has been reported by numerous audiological journals and audiology awareness programs that NIHL is completely preventable with proper hearing protection devices. But which devices are available, and how much protection is really needed?

Law Enforcement Firearms and Hearing Studies –

There are numerous studies on the issue of law enforcement firearms noise exposure, but they are not frequently, nor effectively, shared with the law enforcement community. I will outline a few of the most helpful studies below.

The Centers for Disease Control - National Institute for Occupational Safety and Health (NIOSH) have been looking at some of these basic hearing protection device issues for law enforcement firearms use. In 2013, their study found a significant deficiency in the amount of hearing protection devices being utilized by firearm instructors with testing typical handguns and rifles which law enforcement and military uses. Their recommendations included the following conclusions:

1) Law enforcement should be wearing double hearing protection every time they are out on the firearms range. Double protection includes the use of both a set of properly fitted earmuffs and a pair of properly fitted earplugs.
2) Firearms suppressors should be utilized whenever possible to further reduce the sound pressure exposures these officers are receiving.
3) Proper fit testing and product education needed to be instilled on these end users.
4) This study also found that that if only a single hearing protection device was used, either earmuffs or earplugs, these firearms instructors would have exceeded the recommend exposure profile every time!

One of the biggest problems I've noticed is that most agencies are only providing a single hearing protection device to most of their employees! And those devices are not

fitted to users, nor are they educated about how to properly wear them. More on this later.

In 2007, in an article within the National Hearing Review, a series of important hearing protection advice was discussed in the shooting context for law enforcement. The review of findings of previous studies concluded that law enforcement officers are occupationally exposed to hazardous noises and the current protection devices employed are frequently inadequate!

Also of note was a 2002 CDC-NIOSH study for the Fort Collins Police Services, and although some of the sampling rates / technology were older, it did an excellent job in describing some of the interplay between protective hearing devices and protective eyewear. The study demonstrated that under ideal conditions, there was a significant correlation regarding the interplay between wearing earmuffs, earplugs or both of these devices simultaneously. Not surprisingly, they reported the greatest amount of protection was conferred by wearing both earmuffs and earplugs together. ***Moreover, it showed that by using typical earmuffs and while wearing the standard safety glasses we typically do while shooting, an almost 2/3 loss in hearing protection can occur!***

Something as simple as wearing safety glasses with typical earmuffs, which breaks the seal of the earmuffs, can allow significant amounts of unsafe sound pressure levels to enter the shooters auditory system. Any leaks or breaking of the earmuff seals will be hazardous in that it can allow unfiltered noise directly back into the auditory system. Earplug performance is similarly compromised if earplugs are not properly fitted and deeply inserted.

Size and Fit matters!

It's something you might have heard before! One of the challenges in product selection is that the testing of the earmuffs and earplugs we all typically wear is conducted in controlled laboratory settings based on standards that specify specific continuous noise environments for determining the Noise Reduction Rating (NRR) of a product. Attenuation is measured in relatively low noise backgrounds, given that NRR is calculated based on a change in threshold sound levels when hearing protection is added. Impulse noise is different, and while there has been progress in developing a new standard for measurement of impulse peak insertion loss (IPIL), there is almost no product packaging that provides data on attenuation of impulse noise. In many cases, earplugs may not be properly fit to the end-user, and with that improper fit **- frequently up to 80 % of the noise attenuation is lost!** Data from real-world settings show many users of earplugs and earmuffs achieve only a fraction of the protection the product is capable of providing.

Electronic earmuffs are a big buzz-word currently. Electronic earmuffs do not necessarily provide any more impulse noise attenuation than a passive earmuff of the same size and profile, but, what they can do differently is allow better understanding of speech and better situational awareness by users while they are wearing their hearing protection. When an impulse occurs, and once a blast is detected, the electronic amplification settings **turn off to prevent the amplification** of that sound. When the electronics are shut off, the electronic earmuff works just like a passive earmuff and attenuate sound. Some of the advertising of these products can be deceiving which we will cover later on.

*****It's not just about buying a set of earmuffs and earplugs and saying "I've given my employees all the protection they need - assignment complete!" There is a significant education component for the end users to teach them how to properly wear these hearing protection devices. There are users with higher exposure profiles who may need some custom made protection devices which have greater noise attenuation, fit, and comfort for their longer exposure times.**

One of the challenges in selecting appropriate hearing protection for high noise environments is something call bone conduction. When sound is present in the environment, it is not just entering the ear canal. It is also "striking" and reflecting off the head and torso of personnel in that environment. The cochlear bone is embedded in the temporal bone, which is part of the skull, and when very loud sound strikes the skull, these vibrations are relayed to the inner ear even if sound is prevented from entering the ear canal. Therefore, for these very high level weapon discharges, lowering the sound level at its source has important advantages. Utilizing combinations of technology, including suppressors, can potentially provide an even safer listening environment for these officers.

But, there must be a systematic data-based approach to suppressor selection; this is not just a quick purchase at the local police supply shop. The use of suppressors on many types of firearms with gas cycling and back pressure issues can be remedied with special bolt carriers and adjustable gas blocks; multiple issues must be considered. Testing and evaluating needs to be thorough, not hurried, and only then can proper protection and related purchasing decisions be made! ***

Our Research on Suppressors –

For the past few years, Dr. Colleen Le Prell, Dr. Edward Lobarinas, and Dr. Christopher Spankovich and I have been studying the efficiency of firearms suppressors as a method of firearms noise attenuation. We found that the average suppressor we tested provided approximately a 20 dB reduction in the peak pressure. We completed initial

studies with local support and later studies with direct connection with numerous suppressor manufactures and industry partnerships that were made possible by the American Suppressor Association. Some of the results of those tests were described in a recent article titled "*Differential effects of suppressors on hazardous sound pressure levels generated by AR-15 rifles; Considerations for recreational shooters, law enforcement and the military*" which was published in the International Journal of Audiology.

During accuracy testing we tested over 50 shots (10 – 5 shot groups) per condition at 100 yards with both 10.5" and 16" AR15s. We found the suppressors tested did not cause a significant change in accuracy and all shots maintained a similar group size to the non-suppressed rifle.

We also found that, contrary to the marketing and advertising claims of some suppressor manufacturers, **none of the suppressors we tested for the AR15, using either - .223 REM or 5.56x45 mm ammunition, were "hearing safe!"** Despite this, my honest belief is that many suppressors do an excellent job of attenuating the impulse noise from firearms when the gas discharge is controlled, and **every agency should start using suppressors!**

I would caution everyone that the metric many manufactures use to define "hearing safe" is that the blast is under 140 dB SPL. As previously stated above, 139 dB SPL is less than 140 dB SPL, but that doesn't mean you can safely be exposed to hundreds of blasts at 139 dB SPL per day and not acquire some auditory damage and a corresponding -NIHL. The full findings of our suppressor research would require many additional articles and hours of discussion.

As a brief summary, suppressors reduced sound levels across the platforms we tested, and while I believe that suppressors should be utilized whenever possible, I strongly advocate that they should immediately be used on AR15s / rifle systems as the sound pressures they generate result in dangerously high sound pressure levels. Because these sound levels are so high, it is absolutely imperative that ***additional earplug / earmuff combinations be used in addition to suppressor devices in order to provide adequate protection and minimize auditory damage. No single hearing protection system offers enough protection!***

Earmuffs and Earplugs –

Two of the more common devices that shooters are likely familiar with are earplugs and earmuffs. Although they are familiar, it is likely that many law enforcement personnel haven't received any extensive training on their evaluation, fit, use, and protection mechanism. This is a significant concern.

As public safety officers, we wouldn't send our officer into a hazardous materials scene without the proper training in the protection gear they needed to prevent themselves from being contaminated and injured. However, because it seems difficult to visualize the magnitude of sounds, and comprehend the immediate effects on the auditory system, we aren't aware as we should be. Our training on hearing protection simply is not as complete.

What is NRR? –

NRR is the Noise Reduction Rating, and it is detailed in the ANSI -1974 standard. It is derived in and meant to describe protection in continuous noise environments with relatively lower amounts of sound pressure (i.e., 105-100 dB SPL, versus weapon discharges that can exceed 180 dB SPL). This is the rating a hearing protection device will have listed on its packing. Product packaging also will have a more specific NRR specification sheet which displays its attenuation at specific frequencies. There are significant concerns with the relevance of the testing from laboratory conditions to the real world as field values often show significantly lower attenuation.

Elliot Berger, chief scientist for 3M hearing products divisions and likely one of the most knowledgeable hearing research scientists in the world, compiled data in an excellent paper in 1993. This review shows that across studies comparing products NRR to the achieved field attenuation, **the real-world performance achieved by the user is typically only about 50% of the attenuation the NRR indicates to be possible.**

Because of this gap in performance, the regulations enforced by the Occupational Safety and Health (OSHA), "recommend a 50% correction factor when estimating field attenuation from the product's stated NRR". Surprisingly enough some manufactures are getting wise to this difference in the laboratory values vs. field values and are actually placing these warnings on the product packaging itself.

What is IPIL? –

Impulse Peak Insertion Loss (IPIL) is a newer standard which attempts to look at the effectiveness of a product in impulsive noise environments; i.e., something more akin to what would occur during a firearms blast. And although the standard is not widely accepted / finalized yet, it is an interesting data set to start requiring the manufactures of HPD provide to the end consumer.

Taking fit into consideration –

The two biggest issues with fit that the law enforcement shooting market has, which is not always present in the typical industrial setting for hearing protection device use, are the dynamic components of law enforcement training, especially when shooting on the move or holding a cheek weld on the stock of a rifle which might break the seal of the earmuff again. The application of safety glasses and earmuffs, when used within impulsive noise environments, can also result in poor sealing hearing protection devices.

In the end, there are numerous products available for specific exposure profiles. Don't be tempted to just purchase some product from that product's advertising sheet! Make sure a conscientious review process has occurred to determine which combination of hearing protection devices will work best for that specific set of end-users within their exposure profile. Sales representatives can be very helpful resources, but make sure you independently verify product materials.

On advertising! –

(Be careful of manufactures advertisements & older technology used in studies and the applicability of their data)

What happens when the corporate advertising is not evidence based? Possibly poor terminology, or worse, possibly misleading data and conclusions. But the average consumer of this product likely doesn't have enough of an audiology or hearing science background to understand the technical issues. I can't overstate this issue enough! Most agencies will make horrible purchasing decisions based on misleading claims which may not adequately protect the end user. The most likely cause - if they just use the product advertising and don't understand what is really possible and scientifically supported.

Examples :

Is the sound safe?

How does the "electronic" protection work?

Can't I wear just any old earmuffs or earplugs and be properly protected from my AR-15 rifle training?

Much of the existing testing was conducted according to MIL-STD 1474D which was crafted during the 1960s. The medical understanding of the ear, technology for recording / analyzing firearms blasts, and methods for preventing damage created by high pressure noise is significantly more advanced today than it was 50 years ago. A major concern for some of the older studies and even data collected with newer technology are the sampling rates and sound pressure sensors used to measure sound levels, the location at which sound level is measured, the choice of whether to apply weighting that "discounts" some of the energy (A-weighting, and C-weighting filters), and associated interpretation of data. A-weighted and C- weighted filters were developed as an effort to "discount" energy at frequencies that ear is less sensitive to, based on the reduced likelihood of damage to the ear by the sounds that are less detectable (perceptually not as loud). However, A-weighting is based on the perceived loudness of a given tone relative to a 1000 Hz tone at 40-dB SPL, and C-weighting is based on the perceived loudness of a given tone relative to a 1000 Hz tone at 100-dB SPL; both are significantly lower than the discharges of up to 185 dB SPL produced by an AR-15. Although many entities will apply filtering, or weighting, to artificially lower the measured sound level, this filtering was never designed for application to such high pressure noise. Moreover it is predicated on the perception of a sound, not the actual sound pressure received!

With respect to sampling rate, most sound level meters being used today are excellent for continuous noise calculations; a calibrated device appropriate for occupational noise monitoring can run about $4,000, and it will likely have a fast setting, or even an impulse setting based on measurements collected at a rate of approximately 50,000 samples per second. While this sounds impressive, to accurately capture the firearms noise you need at least 100,000 samples per second (preferably 200,000), the microphone, or more likely pressure probe, must have a dynamic range of at least 190 dB to avoid saturating, and to accurately capture the true peak the response time must be less than 1 microsecond. To achieve these technical parameters, advanced scientific recording equipment is necessary; our tests comparing sound level meters showed errors routinely exceeding 10 dB. In the end, there are only a handful of researchers who have both the technical knowledge and the appropriate equipment, which can easily exceed $30,000, to conduct these tests properly.

Recommendations –

*Every law enforcement agency should conscientiously determine the best hearing protection products and create a comprehensive hearing conservation plan for their officers!

*They should each continue to receive feedback, work on new solutions for the more difficult to protect users and address the challenges of their unique environments.

*They should revaluate these products and programs yearly – as research and technology will change.

--- **Most of these solutions are relatively inexpensive and easy to implement. However, the proper education, training, documentation and compliance components must be properly understood for an effective program to exist.** ---

Conclusions –

Hearing protection in law enforcement is a significantly more in-depth issue then I can explain in just a few pages of writing. My overarching goal is to provide law enforcement agencies with exposure to and information on this issue, so that these concerns can be understood and properly addressed. Towards that end, I am doing what I can to present this data to as many law enforcement agencies as possible and help them start down the path of creating an excellent hearing protection program of their own.

For the past few years, I have been volunteering my time for this research and outreach. And there is still more planned: from upcoming one hour long presentations, more in-service training programs in development, some newly planned hearing protection studies, and additional product testing and development. If at any time I can be of help to you or your agency, please don't hesitate to ask.

In the end, I hope through the brotherhood of the law enforcement community, agencies will work together to create novel solutions to these common problems. It is my hope that these meaningful solutions will keep our officers safer throughout their careers and into retirement. At the very least, perhaps we can leave the profession a little better for the next generation of officers who will replace us. And hopefully they too will continue to make improvements for the safety of a profession which is crucial for American's safety. Ryan Lee Scott is with the Alachua County Sheriff's Office in Gainesville, Florida and can be reached at rscott2@acso.us.