Hearing loss is more common than ever before. About 16% of American adults have an impaired ability to hear speech, and more than 30% of Americans over age 20 — an estimated 55 million people — have lost some high-frequency hearing, according to a new study published Monday in the *Archives of Internal Medicine.* The finding has got experts — and concerned parents — wondering anew: Does listening to loud music through headphones lead to long-term hearing loss? **Brian Fligor,** director of diagnostic audiology at Children's Hospital Boston, explains how much damage your headphone habit might cause — and how to mitigate your risk.

Q: How much hearing loss does an iPod cause?

A: It depends on the person, it depends on how long you're listening, and it depends on the level at which you're setting your iPod.

If you're using the earbuds that come with an iPod and you turn the volume up to about 90% of maximum and you listen a total of two hours a day, five days a week, our best estimates are that the people who have more sensitive ears will develop a rather significant degree of hearing loss — on the order of 40 decibels (dB). That means the quietest sounds audible are 40 dB loud. Now, this is high-pitched hearing loss, so a person can still hear sounds and understand most speech. The impact is going to be most clearly noted when the background-noise level goes up, when you have to focus on what someone is saying. Then it can really start to impair your ability to communicate.

This would happen only after about 10 years or so or even more of listening to a personal audio device. One patient I had used his headphones instead of earplugs when he was on his construction job. He thought as long as he could hear his music over the sound of his saws, he was protecting his ears — because he liked the sound of his music but didn't like the sound of the construction noise. He had a good 50 dB to 55 dB of noise-induced hearing loss at 28 years old. We asked a few pointed questions about when he was having difficulty understanding people, and his response was classic. "When I'm sitting at home with the TV off, I can understand just fine," he said, "but when I go out for dinner, I have trouble."

There is huge variation in how people are affected by loud sound, however, and this is an area where a number of researchers are conducting studies. Certainly a huge part of this is underlying genetics. We know how much sound causes how much hearing loss based on studies that were conducted in the late '60s and early '70s, before employers were required to protect workers' hearing in noisy work environments. What was found is that when people are exposed to a certain level of noise every day for a certain duration, they're going to have a certain degree of hearing loss on average. But the amount of hearing loss might differ by as much as 30 dB between people who had the toughest ears and those with the most tender ones — a huge variation. Unfortunately, we don't know who has the tougher ears and who has the tender ones until after they've lost their hearing. So, as a clinician, I have to treat everyone as if they had tender ears.

Particularly with noise-induced hearing loss, the primary area where the ear is damaged is not the eardrum, not the part of the ear that you can see and not the bones that are inside the middle ear — it is actually deeper inside. It's where the nerve that brings the sound message up to the brain connects with the inner ear, and it involves some very specialized cells. These are hair cells, and specifically we're looking at the outer hair cells. When they're overexposed or stimulated at too high a level for too long a duration, they end up being metabolically exhausted. They are overworked. They temporarily lose their function, so sound has to be made louder in order for you to hear it. These cells can recover after a single exposure, but if you overexpose them often enough, they end up dying, and you lose that functional ability inside your inner ear. The cells that die are not replaceable.

As far as a rule of thumb goes, the figures we got in our studies were that people using that standard earbud could listen at about 80% of maximum volume for 90 minutes per day or less without increasing their risk for noise-induced hearing loss. But the louder the volume, the shorter your duration should be. At maximum volume, you should listen for only about 5 minutes a day.

I don't want to single out iPods. Any personal listening device out there has the potential to be used in a way that will cause hearing loss. We've conducted studies of a few MP3 players and found very similar results across the MP3 manufacturers. Some in-the-ear earphones are capable of providing higher sound levels than some over-the-ear earphones. That said, studies we've done on behavior show that the type of earphones has almost nothing to do with the level at which people set their headphones. It's all dictated by the level of background noise in their listening environment. When we put people in different listening environments, like flying in an airplane — we used noise we'd recorded while flying on a Boeing 757 commercial flight, and we simulated that environment in our lab — 80% of people listened at levels that would eventually put their hearing at risk. On the subway system here in Boston, the ambient noise levels are very comparable to the level on an airplane, although it sounds very different. The noise is sufficiently high that it induces people to listen to their headphones at excessively loud volume.

I'm a self-professed loud-music listener. I use my iPod at the gym, and I love it. I think it's one of the greatest inventions ever. I even advocate that people listen to music as loud as they want. But in order to listen as loud as you want, you need to be careful about how long you're listening. I would also strongly recommend that people invest in better earphones that block out background noise. Some of the research we did studied earphones that completely seal up the ear canal. These are passive sound-isolating earphones, as opposed to the ones that are active noise cancelers that block out some of the noise. As far as I can tell, both would allow people to listen to their headphones at their chosen level — and more likely at a lower volume than if they were using the stock earbuds.

Use the 60/60 Rule – Since the combination of volume and length of exposure can cause hearing loss, researchers recommend applying the 60/60 rule: listen to an iPod for 60 minutes at 60% of max volume and then take a break. Ears that get a rest have time to recover and are less likely to be damaged.

5. Don’t Use Earbuds – Despite them being included with every iPod and iPhone, researchers caution against using Apple’s earbuds (or those from other manufacturers). Earbuds are more likely to cause hearing damage than headphones that sit over the ear and they can also be up to 9 db louder than over-the-ear headphones (not such a big deal when you’re going from 50 to 60 db, but much more serious going from 70 to 80).

6. Use Noise Dampening of Cancelling Headphones – The noise around us can contribute to cause us to change how we listen to an iPod. If there's a lot of noise nearby, it's likely that we'll turn up the iPod's volume, thus increasing the chances of hearing loss. To cut down on, or eliminate, ambient noise, use noise-deadening or –cancelling headphones. They're more expensive, but your ears will thank you.

Noise-canceling headphones reduce background sounds such as the roar of an airplane engine, the rumble of a train and highway noise. They do this by producing an "anti-noise" sound wave that interferes with and cancels out unwanted background noise. They contain a microphone placed near the ear and electronic circuitry that generates the opposing sound. Unlike cell phones, noise-cancelling headphones do not emit low level radiation and do not pose any of the potential hazards that could stem from frequent use of a cell phone held next to the ear.

Actually, noise-cancelling headphones can be beneficial, since both loud noises and constant low-level noise can lead to health problems. Acute loud noises can damage hearing, interfere with sleep, raise blood pressure and stress levels and cause headaches. As for low-level noise, a study published in the *Journal of the Acoustical Society of America* in March, 2001, found that Austrian children who live in neighborhoods with constant low-level noise (mostly from automobile and train traffic) had higher levels of the stress hormone cortisol than youngsters who lived in quieter neighborhoods. And a study published in the February, 2006, issue of the *European Heart Journal* found that heart attack risk was higher among people exposed to chronic noise.

I actually recommend noise-canceling headphones to help avert the health problems noise exposure can present. By neutralizing surrounding noise, kids can listen to music without turning up the volume so high that poses a risk to their hearing. The sound quality of the music (or whatever else you're listening to) may not be as good as it is with non-canceling high quality audio headphones, according to a 2007 review of these products I read in *The New York Times*, and with some of these devices you can hear a hissing noise when music is not playing. But overall, I think you would be doing your kids (and their hearing) a favor by giving them noise-canceling headphones.

Noise-canceling headphones come in either **active** or **passive types**. Technically speaking, any type of headphone can provide some passive noise reduction. That's because the materials of the headphones themselves block out some sound waves, especially those at higher frequencies. The best passive noise-canceling headphones, however, are circum-aural types that are specially constructed to maximize noise-filtering properties. That means they are packed with layers of high-density foam or other sound-absorbing material, which makes them heavier than normal headphones. The tradeoff of all that extra weight is a reduction in noise of about 15 to 20 decibels (dB). But considering jet engines create 75 to 80 dB of noise inside the aircraft cabin, passive models have some serious limitations. That's where active noise-canceling headphones come in.

Active noise-canceling headphones can do everything that passive ones can do -- their very structure creates a barrier that blocks high-frequency sound waves. They also add an extra level of noise reduction by actively **erasing** lower-frequency sound waves. How do noise-canceling headphones accomplish this? They actually create their own sound waves that mimic the incoming noise in every respect except one: the headphone's sound waves are 180 degrees out of phase with the intruding waves.

The consumer audio market has also embraced the technology during the past 10 years, with every major audio manufacturer offering noise-canceling headphones for use on airplanes and in other low-frequency noise environments where consumers are using portable audio devices. These noise-canceling headphones range in price from $39 to $299 and have varying levels of performance.

Although the technology is commonplace in the aviation, military, and consumer worlds, ANR has not been widely available to the industrial worker. This is now beginning to change with cost-effective ANR ear muffs, priced in the $149 range, that are self-contained, conveniently powered, and relatively lightweight.

The Technology's Evolution

Electronic noise reduction technology is not a new idea. The concept of creating a copy of a sound and using that copy to cancel the original sound dates back to the early 1900s. These first electronic noise cancellation systems used a simple "delay and invert" approach that was limited in its effectiveness. In the mid- 1970s, rapid advancement of ANR systems was achieved with the use of adaptive filters to generate the antinoise. This allowed the systems to adapt continuously to changes in their external world and in their own components.

A second breakthrough in the mid- 1970s was the recognition that many noises, particularly those produced by man-made machines, are periodic or tonal. This tonal noise allowed for a more effective solution because each repetition created a predictable harmonic pattern, which enabled the electronic system to generate a more accurate anti-noise signal.

As was previously mentioned, by the early 1990s, the technology was commonly seen in aviation and the military; by the mid-1990s, consumer noise canceling audio headphones were a widely known and well-understood product category.

Low-frequency Noise

Low-frequency noise from engines, motors, and fans can dominate many industrial settings, yet this component of the noise spectrum is largely unaddressed by passive hearing protection. Some of the loudest low-frequency environments and equipment include airfields, forestry, payloaders, diesel locomotives, forges, factories, highways, ship engine rooms, and heavy tractors.

In addition to hearing loss, prolonged exposure to noise, including low-frequency noise, is known to cause many detrimental psychological and physiological effects, including fatigue, anxiety, depression, loss of concentration, reduced productivity, headaches, and high blood pressure. Low-frequency noise is also particularly detrimental to communication because it masks consonant sounds—the sounds that make speech intelligible.

In most environments, there is noise in a wide frequency range. As previously discussed, most currently available hearing protection products are passive devices intended to prevent noise from entering the ear, making them effective against the mid and high frequencies but ineffective against the low frequencies. Aside from the fact that passive hearing protection does not address the full range of noise frequencies, the measure of effectiveness for these devices, the Noise Reduction Rating (NRR), cannot be taken at face value. The hearing protection level is often degraded because of improper insertion of ear plugs and wear and tear on the clamping force and ear seals of ear muffs. The most complete hearing protection currently available to workers is a device that combines ANR and passive noise control methods. Figure 2 shows a cross section of an ANR ear muff.

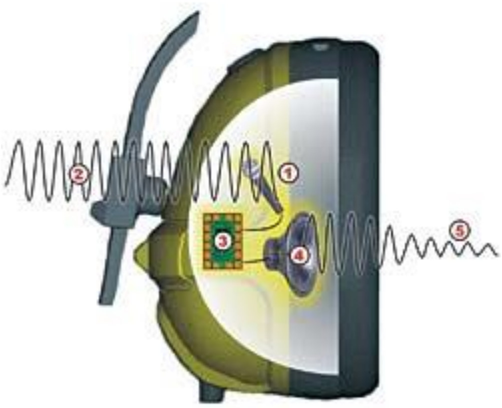

Figure 2

This type of ear muff uses a microphone inside the ear cup (1) to listen to noise coming into the ear (2). Using electronics (3), the system takes that information and uses it to create a noise wave that is identical to, but directly opposite of, the one coming into the ear. The "anti-noise" wave is output through a speaker (4), also located in the ear cup. When the two waves (the noise wave and the anti-noise wave) meet, the noise is significantly reduced (5).

Figure 3 is a photograph of an ANR ear muff. As you can see, the outer appearance of an ANR ear muff is virtually identical to that of a standard passive ear muff; however, ANR ear muffs deliver 20dB of electronic noise cancellation within the 20-800 Hz range. For the most complete hearing protection, these ear muffs also deliver a passive NRR of as high as 26. Additionally, these ear muffs feature an audio input so workers who are allowed to listen to music on the job can listen at safe volume levels.

Figure 3

Conclusion

ANR is the next technological breakthrough in industrial hearing protection because it remedies the noise problems that previously had no solution. There have been no significant advances in passive hearing protection, because passive is well understood and has been fully exploited. The only opportunity to provide workers with the next generation in hearing protection will be through electronic means such as ANR.

Currently available ANR ear muffs provide a greater level of hearing protection at a reasonable cost. As hearing loss continues to be a problem and noise standards become more stringent, we expect advanced hearing protection will be more widely adopted and even required in certain noise environments.

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