Noise and Hearing Loss: A Review

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ABSTRACT

BACKGROUND: Noise-induced hearing loss is a major cause of deafness and hearing impairment in the United States. Though genetics and advanced age are major risk factors, temporary and permanent hearing impairments are becoming more common among young adults and children especially with the increased exposure to portable music players. Though treatment options are limited for most people with noise-related hearing loss, several modifiable health behaviors that should begin in childhood might prevent or delay the onset of hearing impairment. The purpose of this article is to review modifiable and nonmodifiable risk factors, comorbidity, and the role of health education in the prevention of noise-induced hearing loss.

METHODS: Review of current literature in the etiology, prevention, and treatment of noise-induced hearing loss as well as the role of health education.

RESULTS: Nonmodifiable risk factors related to noise-related hearing loss include increasing age, genetics, male gender, and race. Modifiable risk factors are voluntary exposure to loud noise, nonuse of hearing protection, smoking, lack of exercise, poor diet, tooth loss, and the presence of diabetes and cardiovascular disease.

CONCLUSIONS: As hearing impairment among children and teenagers rises due to mostly voluntary exposure to loud noise, there are many implications for health education. Health educators need to address barriers to the use of hearing protection, deliberate exposure to loud music, and other modifiable risk factors, which cause and exacerbate hearing loss among those exposed to loud noise.

Keywords: noise-induced hearing loss; hearing protection; hearing conservation; tinnitus.

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While noise-induced hearing loss is most prevalent among individuals over the age of 65 and the incidence is expected to rise as the population ages, the number of children and young adults with hearing loss is increasing.\(^1\)\(^2\) This appears to be correlated to the increase in the amounts of hazardous levels of noise exposure from infancy through early adulthood.

Approximately 28 million Americans have impaired hearing and about half of these cases are at least partly related to damage from short-term or chronic exposure to loud noise.\(^1\) The National Institute of Occupational Safety and Health (NIOSH) reports that approximately 30 million Americans are exposed to daily noise levels that will likely lead to hearing loss. Adults are going deaf at earlier ages than in the past while 1 in 8 children and teenagers between the ages of 6 and 19 already have some level of hearing loss.\(^2\) Hearing loss, whatever the cause, can give rise to a number of handicaps. Studies have shown that children and adults with impaired hearing have a poorer quality of life related to reduced social interactions, isolation, a sense of exclusion, depression, and possibly impaired cognitive function.\(^3\)

The mechanism of noise-induced hearing loss involves the destruction of hair cells in the Organ of Corti within the cochlea of the inner ear. Chronic exposure to loud noise initially damages the hair cells, which are responsible for high-frequency sounds. Over time, continued contact with excessive noise may lead to impaired transmission of both low- and high-frequency sounds to the brain. While the average person is born with approximately 16,000 hair cells, up to 30-50% can be damaged or destroyed before any measurable level of hearing loss is detected.\(^4\) There is, unfortunately, limited ability to detect the beginning stages of noise-induced hearing loss. By the time a sufficient number of hair cells are destroyed to be noticeable, the damage has been done. Hearing loss related to hair cell destruction is not reversible and cannot typically be restored by the use of a hearing aid.

Sound intensity is measured in decibels (dB), which is used to indicate how humans hear a given sound. A dB of 0 is considered the point at which a person starts to hear sound while a whisper at 3 feet is equal to 30 dB and an average rock concert can measure up to 140 dB (Table 1). NIOSH defines hazardous noise as sound that exceeds 85 dB over a typical 8-hour day.\(^1\) The agency's data also indicate that prolonged exposure to noise over 85 dB can change the structure of hair cells, resulting in often irreversible hearing loss. It can also cause tinnitus, a ringing or buzzing in the ears, which affects an estimated 12 million Americans, many of them are children and teenagers.\(^4\) Of those, at least 1 million experience tinnitus to the extent that it interferes with their daily lives. While constant exposure to loud noise exacerbates the risk of hearing loss, single exposures can also cause auditory changes. A recent study determined that children and teenagers exposed to a single intense sound event experienced both hearing loss and tinnitus.\(^5\) These individuals, who ranged from 1 to 16 years, maintained a slight hearing loss and a hypersensitivity to sound after 1 year.

Loud noise has other effects on the body unrelated to hearing. Nonauditory effects may include elevated blood pressure, loss of sleep, changes in brain chemistry, and increased heart rate.\(^6\) Other effects include impaired early development and learning disabilities among children. Noisy homes and environments may impede cognitive and language development and psychomotor tasks. There are many studies demonstrating that children living and attending schools near areas of loud noise such as airports have lower reading scores.\(^4\) To perform well academically, students need quiet places to learn and study.

While involuntary contact with loud noise puts children and adults at risk for hearing loss and other noise-induced health problems, much noise exposure is voluntary. Loud music, particularly portable music players, can expose listeners to potentially harmful sound for many hours of the day. Portable music players can store thousands of songs and can play for hours. Industrial regulations require employers to take action whenever their workers are exposed to noise over 85 dB for 8 hours a day.

### Table 1. Decibel Chart\(^*\)

<table>
<thead>
<tr>
<th>Decibel Level (dB)</th>
<th>Source</th>
<th>Typical Physical Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Softest sound that can be heard</td>
<td>Barely audible</td>
</tr>
<tr>
<td>10</td>
<td>Normal breathing</td>
<td>Very quiet</td>
</tr>
<tr>
<td>30</td>
<td>Whisper</td>
<td>Quiet</td>
</tr>
<tr>
<td>50-65</td>
<td>Normal conversation</td>
<td>Annoying</td>
</tr>
<tr>
<td>80-85</td>
<td>City traffic noise</td>
<td>Very annoying</td>
</tr>
<tr>
<td>95-110</td>
<td>Motorcycle</td>
<td>Very annoying</td>
</tr>
<tr>
<td>100</td>
<td>School dance, boom box</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>Busy video arcade</td>
<td>Very annoying</td>
</tr>
<tr>
<td>120</td>
<td>Nightclub</td>
<td>Can damage hearing after 15 minutes exposure per day</td>
</tr>
<tr>
<td>110-125</td>
<td>Stereo, personal music player</td>
<td>Can damage hearing after 15 minutes exposure per day</td>
</tr>
<tr>
<td>110-140</td>
<td>Rock concerts</td>
<td>Noise may cause pain and brief exposure can injure ears</td>
</tr>
<tr>
<td>150</td>
<td>Firecracker</td>
<td>Noise may cause pain and brief exposure can injure ears</td>
</tr>
</tbody>
</table>

Either ear protection has to be provided or the noise must somehow be reduced. Listeners using portable music players can expose themselves to the same level of loudness in 15 minutes of music at 100 dB that an industrial worker gets in an 8-hour day at 85 dB. The typical listener has the volume at a range between 75 and 105 dB.

In addition to portable music players, there are other recreational exposures that can negatively affect hearing. Playing with loud toys and games and attending rock concerts can contribute to sounds high enough to negatively affect hearing or cause tinnitus. A recent study found that in a typical nightclub, the sound intensity ranged from 104 to 112 dB. Researchers determined that exposure to loud leisure noise is correlated with hearing loss and tinnitus and the risk rises as noise exposure increases. Whatever the source, unlike workers who may have limited choice regarding noise exposure, young people often choose to expose themselves to loud sounds.

Mercier and Holhammer studied over 700 teenagers and young adults and determined that the majority regularly attended discotheques and rock concerts. The researchers found that while the subjects typically were exposed to sounds exceeding 87 dB, approximately 60% did not consider the noise to be too loud. While these individuals did not perceive the music as too loud, 71% suffered from tinnitus and 11% had hearing loss following attendance at a music event.

Takayuki Kageyama identified several psychological characteristics of young people who keep their volume high while listening to music with portable headphones. These included anxiety and sensation-seeking tendencies. Overall, those who turned up the volume the highest were males regardless of the type of music though rock and heavy metal was played the loudest by both males and females.

Recent studies have shown prevention measures, including consistently using hearing protection, can minimize the negative effects of exposure to loud noise. Avoiding tobacco, getting regular exercise, and eating a healthy diet and/or nutritional supplement use may also decrease an individual’s risk of developing noise-induced hearing loss or delay its onset even if exposed to consistent levels of noise loud enough to damage hearing. The presence of diabetes, heart disease, and tooth loss may increase the risk of deafness following noise exposure. Understanding the risk factors is especially important, as there are limited effective treatments or cure for most sufferers once a noise-induced hearing loss occurs. The purpose of this article is to review modifiable and nonmodifiable risk factors, comorbidity, and the role of health education in the prevention of noise-induced hearing loss.

**NONMODIFIABLE RISK FACTORS**

Nonmodifiable risk factors for noise-induced hearing loss include age, genetics, gender, and race. Of these factors, age plays the most significant role. The risk of developing noise-induced hearing loss typically increases with advancing years. Among individuals between the ages of 65 and 75, approximately 23% suffer from partial or full loss of hearing. Over age 75, about 40% are hearing impaired or deaf. However, studies have shown that increasing numbers of children and teens are showing signs of tinnitus, temporary threshold shift, and hearing impairment. In a large, national population-based study, researchers estimated that approximately 12% of 6- to 12-year-old children had experienced noise-induced threshold shifts. Chung et al determined that a majority of teenagers and young adults in their study suffered from tinnitus and impaired hearing after exposure to loud music.

Although age is correlated with hearing loss, genetics and gender also have been linked. Studies have shown that there are considerable differences in susceptibility to noise damage between individuals, between the left and the right ear, and at different times of day within the same person, indicating the possibility of genetic variability to response to noise exposure. Dogru et al determined that there may be a correlation between blood group and noise-induced hearing loss. The researchers found that noise-induced hearing loss was significantly more frequent among subjects with blood group O who may be more prone to noise-related hearing impairments. A recent National Health and Nutrition Study III indicated that boys were more likely to show signs of early hearing loss than girls, possibly due to the kinds of activities in which they engage. Finally, researchers found a positive association between hearing loss and short stature. While genetics or other variables may play a role, they theorized that mechanisms linked to prenatal growth retardation during fetal life may have caused both the short stature and the damage to the development of the cochlea.

A racial difference in hearing loss when exposed to loud noise has been observed in the workplace. Researchers determined that non-whites suffered a greater degree of hearing loss after adjusting for years of employment. Helzner et al found that other variables were better predictors than race and included concomitant high blood pressure, diabetes, and smoking.

**MODIFIABLE RISK FACTORS**

Several modifiable risk factors relate to noise-induced hearing loss. These include the nonuse of
Nonuse of Hearing Protection

While ear protection has been found to reduce the risks associated with loud noise, many people do not wear them, especially teenagers. Several studies have shown that even when individuals are aware of the risks of noise exposure, they are reluctant to use hearing protection. Reasons include discomfort, safety concerns, lack of knowledge related to noise-induced hearing loss, and peer pressure. These barriers exist even when individuals perceive themselves to be at risk for hearing loss.

Olsen and Erlandsson found that teenagers with a high socioeconomic status were more likely to use hearing protection and were more concerned about hearing loss related to exposure to loud noise. Peters determined that most people were not sufficiently aware of the dangers of noise, which contributed to their not using hearing protection. A website survey conducted by Chung et al found that most teens responding to questions about general health did not consider hearing loss a major concern. This was despite the fact that about 60% had experienced temporary hearing loss or tinnitus while attending loud concerts or clubs. Many of these respondents claimed they might consider hearing protection if they believed they were at risk for permanent as opposed to temporary hearing loss (66%). Peters found that individuals who expose themselves to loud noise during their leisure time were unlikely to consider the need for hearing protection.

Smoking

Cigarette smoking is a major risk factor for many health problems, including hearing loss. Smoking exposes smokers to distinct substances in mainstream smoke, which may synergistically affect hearing when combined with loud noises. Non-smokers exposed to both noise and secondhand smoke are also more likely to have hearing loss. Researchers tested the hearing of over 3700 adults who began smoking in their teens and found they were more likely to have hearing loss than non-smokers. Nonsmokers who were exposed to second-hand smoke were also more likely to experience loss of hearing.

A study involving steel workers found that smoking was associated with increased odds of having high-frequency hearing loss. Researchers determined that there was a synergistic effect on hearing with exposure to smoking and industrial noise. Researchers found similar results in a study involving male metal factory workers. They determined that there was a synergistic effect of smoking and noise exposure on hearing loss.

Exercise and Nutrition

A limited number of studies were identified, which linked physical fitness and prevention of hearing loss. Cristel et al found that after 2 months of fitness training, teens and young adults improved both their level of cardiovascular fitness and their hearing. Kolkhorst et al determined that there was an association between physical fitness and diminished temporary hearing loss experienced after noise exposure. The researchers theorized that exercise training causes the inner ear to receive more oxygen-rich blood, which enhances hearing.

In addition to exercise, diet may also play a role in mitigating the effects of noise exposure. Researchers believe that exposure to loud noise can damage inner ear hair cells via processes related to free radicals, unstable oxygen compounds, which can attack or react with healthy body cells. Antioxidants such as vitamins A, C, and E and the mineral selenium protect the body against damage caused by free radicals. Kopke et al similarly found that antioxidants helped reduce hearing damage after exposure to loud noises. The mineral magnesium has also been shown to lessen the damaging effects of noise exposure. Two studies have demonstrated the prophylactic effects of magnesium on noise-related hearing damage in humans.

In addition to magnesium, the mineral zinc and two B vitamins may also play a role in lessening the impact of noise exposure and resulting hearing loss. Vitamins B9 (folate) and B12 have been studied in relationship to hearing loss. Data indicate that while further studies are needed, there may be some therapeutic value in the use of these two vitamins.

Comorbidity

There is a well-established relationship between hearing loss and tooth loss, diabetes, and heart disease. Lawrence et al observed nearly twice as much hearing loss among patients shifting from greater than 17 to less than 17 teeth. Schell et al found that hearing loss was more pronounced among those with the highest number of teeth lost. The authors suggested that tooth loss causes hearing impairment because of a lack of muscle activity of the palate on the auditory tube.

Among individuals with diabetes, there appears to be an increased risk of hearing loss and loss of hearing at an earlier age. High blood sugar may cause blood vessels in the inner ear to narrow, which disrupts the normal transmission of sound. Diabetes
is of particular concern since its incidence has been increasing significantly among young children and teens.31 Similarly, cardiovascular disease can also increase the risk of hearing loss. People with cardiovascular-induced circulatory problems are more likely to suffer hearing loss due to diminished circulation and narrowing of the blood vessels in the inner ear.33

IMPLICATIONS FOR HEALTH EDUCATION

While age and hearing loss is linked, there appears to be a rise in hearing impairment among children and teenagers, usually related to recreational noise exposure. Unlike industrial contact, many young people voluntarily expose themselves to loud noise via headphones, car sound systems, loud concerts, and nightclubs. The most effective way to lower the incidence of noise-induced hearing loss among this population is to reduce the exposure to loud noise by having them turn down the volume, avoid the source of the loud noise, or the consistent use of hearing protection. Unfortunately, many listeners who deliberately expose themselves to loud noise appear unwilling to do any of these. It has been determined that many young people believe music is enhanced when played very loudly.8

There also appear to be barriers to the use of hearing protection. Major limitations to the consistent and effective use is discomfort, the lack of easily accessible health information, advice and guidance on the risk from loud noise during leisure activities, lack of knowledge of the function of the ear, the need for regular hearing assessments, and lack of hearing conservation programs.18 Hearing conservation programs focusing on the prevention of hearing loss have traditionally been offered in the workplace but are also offered in some school districts.34 School-based hearing conservation programs are designed for children and teens to emphasize consequences of hearing loss and the types of noise that are most likely to cause temporary and permanent impairment. Numerous studies have evaluated the efficacy of hearing conservation programs and determined that they significantly improve knowledge and have measurable, positive effects on behavior.10,34 While the benefits of hearing conservation programs are clear, there are too few school districts including them in their curricula.35 That may be related to lack of public awareness about how excessive sound exposure damages hearing and the impact of hearing loss. Both children and parents should be educated on the various means to prevent noise-induced hearing loss at home, school, and during recreational activities.

Identifying education strategies to prevent or delay onset of noise-induced hearing loss will have important effects on the numbers of Americans who develop noise-induced hearing loss. These strategies may include the integration of hearing conservation into existing health education and science classes, raising awareness of the relationship between other modifiable risk factors and hearing loss, and mandating hearing conservation instruction during elementary and secondary schools.

Though knowledge of the relationship between noise and hearing loss is an important component of health education, it does not always facilitate change. For over half a century, the Health Belief Model (HBM) has been used to better understand health behavior and factors related to compliance and non-compliance with recommended health behaviors.36 The model offers guidelines for the development of programs, which address compliance issues. For instance, this model suggests that young people voluntarily exposed to loud noise are more likely to take action (ie, use hearing protection or turning down the volume) if they believe they are susceptible to permanent hearing loss. In addition, if they are aware that developing a hearing impairment could negatively affect their quality of life and may not be treatable, that would increase their sense of susceptibility. Next they must perceive the benefits of taking action (avoiding loud noise or the use of ear protection) as outweighing the barriers (ie, peer pressure).

Hearing conservation programs based on the HBM and administered in school-based settings could be designed with two components: knowledge (ear anatomy, relationship between noise and hearing loss, and hearing loss and modifiable risk factors) and skill building (turning down the volume, proper use of ear protection, ways to add vitamin and mineral-rich foods to the diet, exercise programs, and good oral hygiene). If available, hearing testing, particularly before and after exposure to loud noise, could provide a strong illustration of the relationship between noise and temporary hearing loss. Program evaluation should address knowledge of ear anatomy, the effects of loud noise on ear cells, and behaviors (use of hearing protection, turning down the volume, diet, exercise, and dental care). Most school-based hearing conservation programs conclude that compared to pretest responses, students’ performance on knowledge and awareness questionnaires improves significantly as measured by posttests.34 In addition, several studies have determined that a significantly larger number of students used hearing protection following conservation instruction than among control groups.35 This is significant since personal hearing protection devices are one of the most important behavioral changes that can be made to prevent noise-induced hearing loss.18
Offering school-based programs is an opportunity to reach children and help them develop the knowledge and skills to conserve their hearing. Although most students are aware of the relationship between smoking and cancer, information about the correlation with hearing loss is not as well disseminated. Active and passive smokers are exposed to several toxic substances that have been linked to hearing loss. Smoke increases the risk of cardiovascular disease and tooth loss, which are also correlated to hearing impairment. School-based smoking prevention and cessation programs should consider addressing the issue of the relationships between hearing loss, noise, and tobacco use.

Studies examining the role of exercise and nutrition in preventing noise-induced hearing loss indicate that increased consumption of antioxidant vitamins might help mitigate the effects of exposure to loud noise. The mineral magnesium and the B vitamins folate and vitamin B12 may also play a similar role. Exercise also appears beneficial since it enhances the circulation and may improve the availability of oxygen-rich blood to the ears. Exercise and a healthy diet rich in antioxidants also decreases the risk of cardiovascular disease and diabetes, which have also been linked to hearing loss.

Increasing hearing conservation education and reducing the aforementioned risk factors might prevent or delay the onset of noise-induced hearing loss. Since hearing loss can lead to a number of disabilities, prevention can enhance the quality of life. Although effective treatment is currently limited, prevention offers hope for the future. Information summarized implies that many cases of noise-induced hearing loss should be preventable. Avoiding and/or minimizing exposure to loud noise whenever possible, the use of hearing protection where appropriate, smoking cessation, dietary changes, exercise, and good oral hygiene are lifestyle factors that can reduce the risk of developing this condition. Although it is hoped an effective early diagnosis and treatment will be developed for noise-induced hearing loss, until that occurs, prevention can and should play a major role.

REFERENCES
