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REVIEW

Reducing the risk of music-induced hearing loss from overuse of portable listening devices: understanding the problems and establishing strategies for improving awareness in adolescents

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Abstract: Hearing loss from the overuse of portable listening devices (PLDs), such as MP3 players or iPods, is of great concern in the popular media. This review aims to discuss the current state of scientific knowledge about music-induced hearing loss from PLD use. This report evaluates the literature on the risk to hearing from PLD use, the individual and psychological factors that influence PLD usage, and strategies for reducing exposure to music through PLDs. Specific interventions are reviewed, and several recommendations for designing interventions and for individual intervention in clinical practice are presented. Clinical recommendations suggested include the "80–90 rule" and the use of isolator-style earphones to reduce background noise.

Keywords: hearing loss, mp3 player, noise-induced hearing loss, music

Introduction

As a public health concern, the potential for portable listening device (PLD) use to cause music-induced hearing loss (MIHL) has been a recent topic of concern in both popular and peer-reviewed literature. At present, a significant body of literature has established that exposure to high levels of sound and music can have a substantial, damaging effect on the auditory system. Moreover, the current generation of PLDs are capable of producing high-enough output levels to cause MIHL with extended exposure.[1,2] To date, a small body of literature has identified that some, though certainly not all, PLD users have listening patterns that would put them at risk of developing hearing loss. This review aims to discuss the problem of MIHL due to overuse of PLDs, review the individual factors that influence adolescent attitudes and behaviors about PLD use, report on existing interventions aimed at reducing PLD use, and present guidelines for designing new interventions.

What is the risk from portable listening device use?

Auditory system dysfunction attributed to use of PLDs

With the exception of age-related hearing loss, noise-induced hearing loss (NIHL) is the most common form of acquired hearing impairment.[3] A significant body of research indicates that adults exposed to high levels of sound for long durations are at a significant risk of hearing loss.[4] Overexposure to sound can cause both temporary and permanent hearing loss by damaging structures within the cochlea, including outer hair cells, the stria vascularis, and the supporting cellular structures. More specifically,

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a subset of research has examined the changes in the auditory system related to PLD use. In order to evaluate the potential effects of PLD use on a larger scale, studies using large population samples have evaluated the differences in the auditory system between PLD users and nonusers.

Research using otoacoustic emissions (OAEs) as biomarkers for cochlear damage due to overuse of PLDs has identified clinically significant differences between PLD users and nonusers. LePage and Murray[5] identified decreased click-evoked OAE levels in some groups of personal stereo users compared to similar, nonexposed peers. In the youngest listener group, age 10–19 years, no significant differences in OAE levels were noted between PLD-exposure groups. In older listener groups up to age 59 years, listeners who reported little use of PLDs had significantly higher OAE levels than listeners reporting moderate or heavy PLD use. The authors suggested that a clear age effect was present in OAE levels for heavy PLD users compared to light users. Similar results were identified by Santaolalla Montoya et al,[6] who found decreased OAE levels in listeners who had used MP3 players for longer periods of time compared to listeners who had not used MP3 players. In this sample, the incidence of decreased OAE levels was greater for listeners who had used MP3 players for longer periods of time and for more hours per week. These age and overall-exposure effects suggest that cochlear damage occurring due to PLD use may not show evidence in teenage years, but is measurable after an extended period of exposure.

Evaluation of hearing thresholds across populations can be used to observe the differences between people exposed to music from PLDs and people who do not use PLDs. Using a large sample, Meyer-Bisch[7] found increased hearing thresholds in groups that used portable cassette players, groups that attended discotheques, and groups that attended rock concerts when compared to age-matched control groups who did not participate in similar music-listening activities. An effect of duration of use of cassette players was also found, with subjects who used the devices more than 7 hours per week incurring worse hearing thresholds than those who listened between 2 and 7 hours per week. In a study with a smaller sample, Vinay and Moore[8] found significantly worse hearing thresholds above 2,000 Hz in a group of eight men reporting use of PLDs than a similar group of six nonusers. The authors also identified that the group of PLD users had significantly higher frequency-discrimination thresholds for frequencies at 3–8 kHz than the control group of nonusers.

In a study of 490 middle and high school students, Kim et al[9] identified significant worsening of hearing thresholds at 4 kHz in students who reported PLD use for greater than 5 years compared to those who reported no PLD use. In addition, a group of students reporting greater than 15 years of PLD use had significantly worse hearing thresholds at 4 kHz than students reporting less than 15 years of PLD use. A similar study by Peng et al[10] of 150 university students compared the hearing of a control group of students who had not used PLDs and groups of students reporting 1–5 years of PLD use. In these subjects, significantly worse hearing thresholds at 3–20 kHz were identified in the PLD users than the control group. An additional study examining 237 Canadian children found a similar association between hearing acuity and PLD use.[11] Overall, these studies looking at audiometric thresholds consistently indicate that there is a significant impact of PLD use on hearing.

Sound-exposure levels from PLD use

When exposure due to PLD use is evaluated, the actual exposure measured over time must be considered. If the output levels of a device exceed the recommended exposure level (REL) for a specified damage-risk criterion (DRC), some concern arises that users could put themselves at risk of hearing loss. While several damage-risk criteria exist for industrial noise exposure across the world, there is no specific DRC that has been established for recreational noise exposure or music exposure. For the purposes of this review, risk of hearing loss will reference the DRC established by the US National Institute for Occupational Safety and Health (NIOSH).[12] The NIOSH REL is set at a maximum exposure to 85 dBA for 8 hours a day with a 3 dB time-intensity trading ratio (exchange rate), which represents the increment of decibels that results in a halving of exposure time. Using the DRC, an individual's exposure can be represented as a noise dose, where a 100% noise dose is equivalent to an 8-hour exposure at the REL. Noise dose is a cumulative measure, and exposures from individual activities in a given day are added together to calculate a total noise dose. Noise doses exceeding 100% would generally be considered to place the exposed individual at a higher-than-normal risk of acquiring hearing loss. Therefore, while it is indeed accurate to say that exposure to high levels of sound (>85 dBA) could increase the risk of MIHL, knowing an individual's actual exposure is critical for assessing the true potential for MIHL.

It has been well established that PLDs are capable of producing high output levels. A significant body of literature in the 1970s–1990s identified high output levels from tape players, with maximum output levels ranging from 98 to 114 dBA.[13–17] Similarly, Fligor and Cox[18] identified maximum-output levels of compact disc players of between 91 and 121 dBA, with significant variation in output levels from different styles of headphones. The current generation of digital PLDs is also capable of producing output levels that could increase the risk of acquiring MIHL when used for extended durations. Portnuff et al[2] reported that current devices produce maximum levels ranging from 97 to 107 dBA, with average levels at 101.5 dBA for earbud-style earphones and 97 dBA for supra-aural-style earphones. Significant differences were noted for the output levels of earbud style, isolator style, and supra-aural-style earphones. Very similar output levels were identified by Keppler et al,[19] who found average maximum-output levels of 102.5 dBA for earbud-style earphones and 97 dBA for supra-aural-style earphones when coupled to an iPod Nano. In a larger study of output levels, Keith et al[1] reported that output levels of PLDs could exceed those reported by both Portnuff et al[2] and Keppler et al[19] when using various aftermarket earphones. This study found output levels with stock earbuds ranging from 101 dBA to 107 dBA, with maximum-possible output levels reaching 120 dBA using a combination of players and higher-output earphones. These high levels underscore the presence of increased risk of MIHL for users listening at high levels.

While recognizing that the output levels of current-generation PLDs are high enough to cause damage to the auditory system, we must evaluate how listeners use their devices to understand the actual risk of MIHL. Survey-based methods of assessment provide a view into the past behavior or future (intended) behavior of listeners. Generally, surveys of PLD users have reported an average of about 2 hours per day of listening time, though a substantial percentage of each sample had longer daily listening times, up to 8 hours per day.[2,20–24] Considering the high potential output levels reported for digital PLDs, it is likely that some of these young adults would be exceeding a 100% noise dose.

Several studies have attempted to evaluate listeners' chosen listening levels (CLLs) using direct measurement. Multiple researchers have evaluated this in a naturalistic environment, such as stopping PLD users on the street and taking measurements of their devices. Williams[25] measured the CLLs of adult PLD users passing through noisy public areas by placing earphones on a mannequin, and found a mean CLL of 86.1 dBA. When self-reported listening times were taken into account, 25% of users exceeded 100% noise dose. A follow-up to this study using the same methods found a significantly lower mean CLL of 81.3 dBA, with 17% of listeners exceeding 100% noise dose.[26] Several recent studies have used a similar paradigm of mannequin measures in a public place to assess sound exposures. Levey et al[27] measured the CLLs of people entering an urban university campus in New York City. The researchers found average CLLs of 92.6 dBA and an average weekly noise dose of 157%. Of this group of listeners, 51.9% exceeded a 100% weekly NIOSH noise dose from their PLD exposure. In a follow-up study with a similar paradigm, 57.2% of listeners exceeded a 100% weekly noise dose.[28] Using similar methodology, Kähäri et al[29] used a mannequin to measure the CLLs of PLD users in the central hall of a train station in Stockholm, Sweden. This study identified an average CLL of 83 dBA (range 73–102 dBA), and 46% of participants had CLLs exceeding 90 dBA.

Measurements in the laboratory of CLLs provide a more controlled view of how listeners use PLDs in varied environments. Several laboratory studies have identified that college-age students choose levels to ensure audibility of music in a noisy environment. Specifically, as background-noise levels increase, so do CLLs.[2,30,31] Additionally, when listeners use earphones that provide isolation from background noise, CLLs tend to be lower than when listeners use earphones with lower isolation.[2,30]

While these studies do suggest that there is significant concern that a substantial group of music consumers choose listening levels that are potentially hazardous to hearing, none of these studies reflects measures of behavior over time. In order to address this, Portnuff et al[2] used a novel system of dosimetry to monitor the PLD use of a group of young adults (aged 18–29 years). Of the group of 24 subjects, 16.7% exceeded a 100% weekly noise dose. Furthermore, survey questions asking participants to describe their listening habits showed similar estimates of sound exposure to the dosimetry results. The authors thus suggested that self-reported LL and duration could be an accurate metric for estimating individual noise doses. In combination with the aforementioned studies, the data suggest that a small but substantial group of PLD users are exposed at a level that could increase their risk of acquiring MIHL.

Understanding individual factors that may influence listening behavior

Demographic factors

With the acknowledgment that at least a small group of adolescents and young adults are putting themselves at risk of MIHL due to their PLD-use patterns, the immediate concern for intervention is to determine why this group engages in risky behavior. Certainly, more knowledge about this group would be useful in order to create interventions. To date, little research has focused on understanding the differences between listeners who are at risk of MIHL and listeners who are not at risk. For large-scale educational interventions, demographic details of these groups could provide some useful information. Indeed, some research suggests that certain groups may choose higher PLD LLs than others. Age, for example, has been suggested anecdotally as a factor that may affect LLs. Limited research has supported this claim, showing that older teenagers choose higher levels than younger teenagers, though this finding has not been replicated in users of digital PLDs.[32,33] Mixed results have been found looking at sex differences, where several studies have found that males have higher overall calculated exposure than females.[7,21,25,26,30,34] Other studies found some divided results, where males chose higher levels in quiet environments, but no differences were present in background noise.[30,35] In contrast, other similar studies found no significant differences in CLL between males and females.[36] One study in New York found that African-American PLD users were more likely to exceed RELs than Hispanic or white PLD users, but no sex differences were noted in listening patterns.[28] More research is needed to assess whether there is any true difference in CLL related to sex, age, or ethnicity.

Attitudes toward noise and music

Individual attitudes toward noise and hearing loss may have an effect on the levels that listeners choose for their PLDs. In order to investigate attitudes regarding noise, Widén and Erlandsson[37] created the Youth Attitudes to Noise Scale (YANS). The primary use of the YANS is to evaluate attitudes toward environmental sound exposure, but findings of this survey also provide a window into youth attitudes that may transfer to PLD use. In a survey of American college students, Widén et al[38] combined the YANS with a survey of auditory symptoms and hearing-protector use. When compared to the results of the YANS, individuals reporting no hearing-loss symptoms had more positive attitudes toward noise than those who had self-reported hearing symptoms, regardless of whether or not they passed the hearing screening. Overall, self-experienced symptoms, including hearing loss, were more strongly related to antinoise attitudes than hearing loss alone. The authors suggested that a self-experienced symptom could serve as a trigger for later injury-preventive behaviors, and noted that this finding was consistent with Widén's[39] theory that self-experience may change an individual's self-perception of vulnerability to consequences of a risk-taking behavior. This theory explains the results of a survey by Bogoch et al,[40] which showed that concert patrons who reported experiencing hearing loss were 3.2 times more likely to wear hearing protection than those who had not experienced hearing loss. Similarly, Rawool and Colligon-Wayne[41] found a significant association between the use of hearing protection during occupational noise exposure and experience with hearing loss in college students.

Overall, several trends appear in the limited research looking at adolescent attitudes toward PLD use. First, there seems to be a relatively high number of students who report understanding that high levels of sound can cause hearing loss, and that PLDs are capable of producing that level of output.[23] Young adults tend to perceive hearing loss as a significant problem, though the level of concern about MIHL tends to be somewhat lower.[24] Furthermore, several studies have suggested that teenagers and young adults may have a sense of invulnerability to hearing loss. In a series of structured interviews, Vogel et al[42] asked adolescents about their PLD use and found that the teenagers underestimated their risk of and vulnerability to MIHL. Moreover, though the teenagers reported that problems related to hearing loss would be severe, few reported regular concern about MIHL due to their own use patterns. The lack of concern for MIHL in students who had not experienced symptoms of hearing loss is consistent with Widén's[39] theory that a sense of vulnerability comes from experience. However, some interviewees who reported having experienced temporary symptoms, such as tinnitus, assumed that the symptoms were always temporary, rather than an indicator of ongoing damage to the auditory system. The lack of concern in this subgroup may suggest that an individual's change in mindset toward vulnerability requires a more permanent impact from PLD use to trigger a feeling of vulnerability.

In concert with this theoretical basis that experience mediates behavior, Widén and Erlandsson[43] interviewed a set of young adults to assess how risk perception, self-image, and socially normative behavior influenced the perception of music as a means to create identity. The authors suggested that as discussed earlier, individuals who perceive a significant impairment from listening to loud music perceive themselves as vulnerable, and are more likely to take preventive actions. Similarly, the interviewees who reported that they considered the risk of exposure to loud sound as significant were more likely to demonstrate an external locus of control and could be influenced by external messaging. These interviewees also were more likely to effect changes to their environment via hearing protection or behavior modification. However, socially normative behaviors mediated the actions taken to reduce risk. The interviewees reported that when hearing protection use was not an acceptable norm, they were much less likely to use it. Similarly, individuals stated that they were likely to follow the example of a social group instead of taking preventive behavior. The authors proposed that the impact of socially normative behavior on taking preventive actions must be considered in any intervention or model of behavior.[43] Looking at a large survey data set, Gilliver et al[44] suggested that misperceptions of social norms related to listening behavior may decrease individual listeners' perceptions of susceptibility to MIHL from PLD use. Specifically, these data suggest that individuals who believe that their peers listen at high volumes choose to mimic what they believe to be the social norm for listening behavior.

Sensation seeking and risk judgment

The CLLs of PLD users may also be reflective of the individual's personality, with specific focus on risk-taking and sensation-seeking preferences. Sensation seeking has been identified as a personality trait defined by the seeking of varied, novel, complex, and intense sensations and experiences and the willingness to take risks for the sake of having these experiences.[45] The act of listening to loud music at the risk of MIHL can be considered a sensation-seeking behavior.[41] The Arnett Inventory of Sensation Seeking itself makes the assumption that listening to loud music is a sensation-seeking behavior, and includes a question about preferring music to be loud.[46] An offshoot of sensation seeking, the personality trait of risk taking, is also associated with a preference for loud sound. Adolescents who listen to heavy-metal music have been identified to score higher on the sensation-seeking inventory, as well as in an inventory of reckless behavior.[47] Bohlin and Erlandsson[48] combined the Adolescent Risk-Taking Questionnaire with the YANS and a survey of symptoms of auditory effects of noise. The Adolescent Risk-Taking Questionnaire measures risk judgments and risk behaviors by assessing how often the subject participates in a set of risky activities.[49] Bohlin and Erlandsson[48] identified a correlation between generalized risk-taking behavior and risky behaviors related to loud noise, such as attending concerts and discos. Additionally, within the adolescents studied, women were more likely than men to judge noisy situations as risky. Though not yet studied systematically, it seems likely that CLLs for PLD use would be related to an individual's sensation-seeking or risk-taking attributes.

Psychological aspects of music listening

A wide variety of theoretical bases for the appeal of loud music have been presented from a large set of sources. As a part of youth culture, the loudness of music functions as a way to express deviance and separation from an older generation.[50] Anecdotally, adolescents and young adults have a higher tolerance for and enjoyment of music played at high volume than children and older adults, and loud music can be a defining characteristic for the identity of "youth".[51] Music is a powerful stimulus for altering mood, and can even be used as treatment for auditory hallucinations.[52,53] For the listener, a PLD can be used to drown out external noise and allow for the exertion of control over the individual's auditory environment. In the urban environment, PLD use allows for the individual to shape their experiences through music.[54] Furthermore, PLD users report using their music as a tool to regulate affect, including moods and emotions.[55] Beyond an individual's perception, Hétu and Fortin[56] described the experience of listening to amplified music in a discotheque as an immersion in a shared musical sound field. In the discotheque, music is a type of "mechanoacoustic arouser" that is energizing to young people. As dance-club music tends to have more salient low frequencies with rapid rhythm, the pulsation of music is perceived by the auditory and proprioceptive systems as acoustic and vibratory sensations.[56] As the vestibular (balance) system is sensitive to loud auditory input, as seen in the vestibular-evoked myogenic response, loud music may stimulate a pleasurable sensation from the saccule and utricle, the gravity-sensing organs within the vestibular system.[57] Furthermore, movement can influence the auditory system's perception of meter and rhythm, which may be mediated by the vestibular system.[58]

Loud music has also been recognized as having similar properties to addictive substances, such as drugs and alcohol. Certainly, loud music has commonalities with the major properties of addictive substances described by Donovan:[59] capacity to induce rapid changes in mood and level of arousal, ability to reduce negative states, and ability to induce the experience of craving. Adorno[60] described an addiction to the distraction provided by music that comes from constant listening. One PLD user described her devices as "like a psychotropic drug", and described cravings occurring when she did not have her device for an extended period of time.[54] To examine music listening as an addictive behavior, Florentine et al[61] adapted a validated alcoholism-screening test to develop the Northeastern Excessive Music Listening Survey. Of the 90 participants who completed the survey, eight scored in a range suggestive of maladaptive behavior, which is consistent with addiction.

When framed as an addictive behavior, listening to loud music can also be looked at as a psychological trade-off between the negative effects and the positive rewards on the body and mind. The negative consequences, both physical and perceived, have been described earlier in this paper.

Blesser and Salter[62] provided a structure for understanding these rewards, framing the rewards within the categories of "altered states of consciousness" and "controlling the experience of social space". The authors proposed that listeners' emotional responses to music could be mediated and amplified by loudness, suggesting that loudness represents a psychological construct of power and machismo, and that higher levels tend to intensify the enjoyment of music. An alteration of the listener's state of consciousness is achieved by enhanced sensory input, fulfilling the need for sensation-seeking behavior.[45] The authors also considered the concept of soundscapes, or aural space, as an integral part of the perceived environment, and identify that music can change a perception of space by masking environmental sounds. Aural space can be shared with others in our "social space". A loud music environment, then, changes the dominant auditory characteristics of the social space, altering a person's perception of that space by focusing on the music rather than the venue. The use of headphones has the ability to modify one's aural space and experience of the world, both by providing an altered soundscape and by modifying our ability to interact with others. As Blesser and Salter[62] further suggested, any intervention to reduce music exposure must take into account the psychological rewards from music listening.

Strategies for reducing music exposure in PLD users

Guidelines for reducing music exposure

There are several well-established clinical guidelines that can be conveyed to users of PLDs. These guidelines are derived from the literature reviewed herein, and can be recommended for individuals who are PLD users. The two most direct recommendations are monitoring LLs and using isolator-style earphones. Listeners can be advised to monitor their listening time and duration and to adhere to the "80–90 rule". This rule, derived from the data of Portnuff et al,[2] suggests that an individual will remain around a 50% noise dose with exposure at 80% of the maximum volume of their PLD for 90 minutes per day. Though this recommendation is not precise, and levels can vary by the earphones used, it is a functional and realistic recommendation that can be used to educate music consumers and maintain a reasonable and safe standard for listening. Messages that use maximum-volume levels, such as "do not exceed 60% of the maximum volume", may be scientifically correct, but are also highly restrictive and therefore may be ignored by adolescent PLD users.

The use of isolator-style earphones can significantly reduce LLs in noisy environments. Isolator-style earphones seal the ear canal and physically block out background noise. In most cases, CLL is related to the background-noise level rather than the absolute level of the playing device, and listeners prefer a significant, positive signal-to-noise ratio in order to hear and appreciate music. Indeed, in an 80 dBA environment, listeners choose an average level of 93 dBA, with over 80% of listeners choosing levels above 85 dBA in the ear.[63] In a noisy environment, the signal-to-noise ratio can be improved by reducing background noise through the use of isolator-style earphones, which physically block out background noise. Use of these earphones in a loud environment like an aircraft cabin or public transit can significantly reduce CLLs.[2,63] Adolescent PLD users should thus be advised to use isolating earphones in noisy situations, when ambient-noise reduction does not impede other safety concerns.

Established interventions: specific to PLDs

In order to report on interventions for preventing MIHL from PLD use, a variety of literature searches were conducted using various databases, including PubMed, Web of Science, and Google Scholar. Only one intervention program that was specific to PLD use was identified in the peer-reviewed literature. The Cheers for Ears curriculum (www.cheersforears.org.au) is a program of the Ear Science Institute Australia that consists of a multimodal classroom presentation that provides lecture, group discussions, written materials, and auditory simulations of hearing loss with the aim of raising knowledge about MIHL from PLDs and changing attitudes and behaviors in 9- to 13-year-old students.[64] In a pilot study of the Cheers for Ears program, program implementation led to a significant decrease in self-reported sound exposure 6 weeks following the classroom presentation. Unfortunately, though, that survey also showed that 26% of the program participants reported that their listening behavior was potentially damaging to hearing, reflecting that the program did not change the behavior of a significant portion of the students.

Other programs designed to reduce overall noise exposure in children and young adults have been presented in a variety of ways. Several of these programs include some information about PLD use in their curricula. The Dangerous Decibels program (www.dangerousdecibels.org) includes PLD safety as a part of overall NIHL prevention, and has shown significant changes in knowledge about NIHL and attitudes about hearing-loss prevention.[65–67] Moreover, music-safety curricula have been incorporated into programs designed to prevent hearing loss from farm noise, discotheques, and concert sound, as well as other areas.[37,38,68,69]

Additionally, several programs have created information campaigns to attempt to reduce sound exposure, including the It's a Noisy Planet: Protect Their Hearing program from NIOSH (www.noisyplanet.nidcd.nih.gov), the Iets Minder is de Max program of the Belgian government (www.ietsminderisdemax.be), the Turn It to the Left program of the American Academy of Audiology (www.turnittotheleft.org), and the Listen to Your Buds program of the American Speech–Language–Hearing Association (www.listentoyourbuds.org). Each of these, and certainly many other similar programs, is designed to educate children and adults about the risks of PLD overuse. The Iets Minder is de Max program showed an increase in intention to use hearing protection and in actual use of hearing protection for students who saw the campaign.[70] Beyond this program, though, there are few data that show that public-awareness campaigns lead to changes in attitudes and behavior related to PLD use, and more research is needed to evaluate long-term impacts from these types of campaigns.

Guidelines for creating interventions

Examination of the interventions aimed at preventing MIHL from PLD overuse shows several aspects that are keys to programmatic success. First, any public health intervention should be based on an established health-behavior model, such as the health-belief model,[71] the theory of reasoned action,[72] or the protection-motivation theory.[73] Each of these models provides a set of underlying constructs that can be evaluated as outcomes of the program. Interventions may be large-scale public-awareness campaigns, smaller-scale classroom curricula, or individual intervention by medical providers. At present, there is a dearth of research on the effectiveness of interventions designed to prevent MIHL from PLD use, and future interventions should be designed with a plan to evaluate their effectiveness both at the time of the intervention and in the long term.

Though specific topic areas for a curriculum may vary based on the exact aims of the program, there are several key pieces to include. Table 1 shows a summary of the recommended content areas provided by Punch et al,[74] which provides a reasonable road map for a program that should be presented in multimodal, age-appropriate media.[65] Beyond those specific knowledge areas, gaining experience with the effects of hearing loss may help to change adolescent attitudes toward the severity of hearing loss. Adolescents may feel that they are invulnerable to MIHL, or that a cure for hearing loss will be available within their lifetimes. Conveying that hearing loss is permanent and likely is critical for confronting false beliefs about MIHL. Moreover, hearing-loss simulations may allow adolescents to see both the severity of hearing loss and that they are potentially susceptible to MIHL.

Furthermore, curricula should be formed with acknowledgment of the psychological and social issues surrounding music and PLD use, many of which have been reviewed herein. Any intervention must address socially normative issues, including addressing inaccurate beliefs about peer behavior.[43,44] If adolescents believe that all of their peers are listening at high levels, they have little social incentive to reduce their exposure. However, as reviewed herein, the vast majority of PLD users choose safe LLs, with only a smaller percentage (around 16%) choosing potentially unsafe levels.[2] Additionally, it would be detrimental to discount the importance of music listening to youth culture in general. Care should be taken to avoid demonizing music, PLDs, or PLD users, as this can result in rejection of the preventive message.

At the individual level, primary care and hearing health care professionals may have the opportunity directly to evaluate and counsel a PLD user about safe listening. This evaluation should include an audiological evaluation (including audiometry and OAEs) and an evaluation of how the listener uses his or her PLD. Evaluating usage patterns can help to assess whether the individual is at risk of MIHL from their usage. Individual counseling may include discussions of their own exposure, their earphones, and their listening environments (noting that listeners choose higher levels in higher background-noise environments). Furthermore, individuals who have preexisting hearing loss may incur greater impairment from hearing-loss progression caused by noise or music exposure. These individuals may be counseled to be conservative in their listening habits.

Table 1 Recommended curriculum components of a hearing-conservation program for portable listening device users

Hearing loss
Hearing loss occurs gradually, invisibly, and incipiently in development.
Hearing loss has significant impacts on communication and social relationships.
Prevention techniques
'80–90 rule' may help to prevent overexposure.
Use of isolating earphones in noisy environments is recommended.
Presence of temporary tinnitus suggests overexposure.
Healthy listening behaviors should extend to other noisy activities, including the use of hearing protection in noise.
Other safety messages
Music and earphones should not impede conversation.
Music can mask auditory warning signals, such as sounds of traffic on a busy street.
Earphones should not be worn when operating a motor vehicle or bicycle.

Note: Information summarized from Punch et al.[74]

Conclusion

Overall, research evidence is clear that a small but substantial group of adolescent PLD users place themselves at risk of MIHL from their daily listening habits. Furthermore, there are many factors that affect music-listener attitudes and beliefs toward hearing loss. Adolescents have an intricate relationship with music and portable devices, which has wide-ranging effects on their listening behavior. Interventions designed to reduce PLD overuse must recognize these psychological factors and incorporate pertinent aspects of an individual's beliefs into their program design. While several programs do exist, some of which have shown some good efficacy in early data, more research is needed to develop consistently successful interventions designed to promote healthy use of PLDs.

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