NHCA POSITION STATEMENT
Recreational Music Exposure

January 12, 2018

Brian Fligor, Colleen G. Le Prell, Frank Wartinger, Cory Portnuff, Elliott Berger, and Michael Santucci

National Hearing Conservation Association (NHCA)
Task Force on Prevention of Music-Induced Hearing Disorders

This document was prepared by The National Hearing Conservation Association (NHCA) Task Force on Prevention of Music-Induced Hearing Disorders and approved by the NHCA Executive Council, January 12, 2018. The judgments expressed here represent the best available evidence at the time of publication and shall be considered the position of NHCA and not the individual opinions of the contributing authors or their respective institutions. The contributing authors declare no conflict of interest.

Summary

There is widespread concern regarding risk to hearing health due to the increasingly common worldwide use of personal audio systems (PAS) (e.g., iPods, tablets, smartphones) and other recreational music listening behaviors. The World Health Organization (WHO) estimates that 1.1 billion young people worldwide may be at risk for hearing loss due to unsafe listening habits. On October 2, 2015, the WHO invited stakeholders, including PAS manufacturers, earphone manufacturers, hearing experts, and others to Geneva, Switzerland, to develop standards for the WHO's "Make Listening Safe Initiative"; this meeting was followed by a strategic planning meeting on March 6-7, 2017 (see http://www.who.int/pbd/deafness/mls_consultation/en/).

This NHCA position statement briefly reviews the literature and summarizes NHCA's recommendations for safe listening in recreational music environments to prevent music-induced hearing disorders (MIHDs). Specific recreational music environments are reviewed, along with suggestions for preventing MIHDs in each setting. This position statement is focused on the consumer of music in a recreational setting, and thus intentionally does not include recommendations for music performance settings (e.g., occupational, hobby, or music education)

Music as a Risk to Hearing Health

It is clear that noise overexposure can damage the human auditory system and cause hearing loss (for review see Ward et al., 2003), although much of our understanding of noise-induced pathology comes from studies using animal models (see, for example, Wang et al., 2002). Several studies suggest that recreational music exposure can also damage hearing, with damage typically first appearing in and around 4 kHz. Additional recent research suggests the earliest signs of hearing loss may actually first appear at high frequencies beyond the range that is commonly tested across clinical settings, but these frequencies are outside the range necessary for speech understanding and thus changes may be an "early warning" rather than a clinically significant deficit (for review, see Le Prell et al., 2013). Although a detailed review by Carter et al. (2014) raises doubt about the extent to which leisure-noise in adolescents is widespread or increasing in prevalence, it is clear that a subset of adolescents and young adults experience noise overexposure resulting in permanent hearing loss or other auditory symptoms such as "ringing" in one's ears ("tinnitus") (for discussion see Portnuff, 2016). Regardless of increasing or decreasing hearing loss prevalence over time, an examination of the nationally representative NHANES 2011-2012 data shows audiometric notches suggestive of noise-induced (though not necessarily music-induced) hearing loss for *24% of the US population* (Carroll et al., 2017). NHCA is in agreement with the U.S. Centers for Disease Control in recommending that all possible steps be taken to prevent hearing disorders from exposure to loud sound (Carroll et al., 2017).

Since music has been identified as a potential cause of hearing disorders in music performers (e.g., professional musicians, music students), as well as recreational music consumers, such as PAS users, concert attendees, and dance club patrons (Bhagat & Davis, 2008; Emmerich et al., 2008; LePage & Murray, 1998; Meecham & Hume, 2001; Mercier et al., 2003; Phillips et al., 2010; Royster et al., 1991). As a result, many researchers have concluded that there is a measureable risk of hearing disorders from recreational music exposure (Zhao et al., 2010).

Given the evidence, it is clear that there are subsets of music consumers who are at risk for MIHD - a 100% preventable disorder. For this reason, education on safe listening behavior is critical. While some municipalities set standards for community noise exposures (consisting of vehicle traffic noise, aircraft noise, industrial noise, etc.), there are rarely regulations in place to protect individuals exposed to music, and thus consumers must choose their own safe listening behaviors.

Imposing regulatory standards for recreational music exposure is challenging in several ways. Seemingly, the most obvious solution would be to adopt the occupational noise damage-risk criteria for music exposure. However, most evidence relating human hearing loss to noise exposure is based on retrospective epidemiological studies of workers exposed to occupational noise (Carter et al., 2014). There are fewer evaluations of loud music as a potentially traumatic stimulus (see for example Johnson et al., 1985; Schmidt et al., 2014; Halevi-Katz et al., 2015; Szibor et al., 2017). In general, these studies include relatively fewer participants and thus lack the statistical strength of the long-term epidemiological studies in the occupation sector. A small number of studies assessing temporary effects of music and noise on hearing provide limited evidence suggesting that the effects of music overexposure on hearing are somewhat less severe than those of occupational noise (Lindgren & Axelsson, 1983; Strasser, et al., 2008); however, more controlled data collection in animal models is necessary to confirm this preliminary observation. In theory, if this observation was found to be true, then occupational guidelines may be overly protective if applied to recreational music exposure.

Another factor to consider with respect to music exposures is that recreational music listening patterns differ from occupational exposure patterns. Typically, recreational music exposure is not as regular, frequent, or continuous as occupational noise. However, recreational noise has the potential to yield significantly more exposure than that of an average workday given the potentially high listening levels that can be selected. Indeed, music exposure at a single recreational event can significantly exceed the exposure limits permitted for occupational exposure during a single work day (World Health Organization, 2017). Recently, Grinn et al. (2017) documented acute, recreational music exposure with accrued noise doses averaging 476% at bars with live music and 875% for concert attendees, using the damage-risk criterion promulgated by the U.S. National Institute for Occupational Safety and Health (NIOSH, 1998).

The NIOSH criteria includes a recommended exposure limit (i.e., 100% daily noise dose) of 85 dBA over an 8-hour period, with a 3-decibel exchange rate. This guideline is consistent with maximum occupational exposure limits of many industrialized countries, but is more conservative than the occupational limits in the United States (OSHA, 1983). Other damage-risk criteria, such as those in the European Union, are even more conservative than the NIOSH guidelines (EU, 2003). NHCA is in agreement with the WHO - the use of occupational damage risk criteria is appropriate for music damage risk criteria at the present time, although additional exploration of the dose-response relationship between music exposure and hearing loss is needed. NHCA recommends consideration of a conservative damage-risk criteria in the development of standards or regulations for recreational music exposure.

Specific Risk of Personal Audio Systems (PAS)

PAS devices are capable of producing high-level sound that can increase the user's risk for MIHDs, such as hearing loss and tinnitus (Jiang et al., 2016). Data on PAS usage patterns suggest that 16-25% of PAS users may be at increased risk for MIHD from daily use (i.e. >100% daily noise dose) (Portnuff, 2016; Portnuff et al., 2013; Williams, 2009).

As with any noise exposure, risk for MIHDs is based on both *sound level* and *exposure duration*, as these parameters define a user's overall "noise dose." If an earphone were to be considered truly "safe" for all listening durations, it would require an output sound level limit of 70-75 dB of A-weighted sound pressure (dBA) (as per the 1978 EPA 550/9-79-100 guidance document, limiting 8-hr exposures to 75 dBA and 24-hr exposures to 70 dBA). Such an earphone would actually be unusable in many listening environments due to overpowering background noise; even if audible, it might undergo amplitude compression to the point of poor sound quality. Thus, safety and sound quality require a balance between the design of the PAS and responsibility of the user. One rule-of-thumb is the "80/90 Rule": users can listen at 80% of the PAS's maximum volume for 90 minutes per day, which results in approximately one-half of the safe daily noise dose[1], when using earbud earphones (Fligor, 2009). While the 80/90 Rule is a reasonable public health message, it is specific to earbud earphones and does not apply to all types of earphones. Safe-listening durations (50% dose accrual) for isolator noise-attenuating earphones are approximately half the duration of earbuds, given the same volume setting on the PAS (see Portnuff et al., 2011). Earphones with higher sensitivity may output overall higher sound levels, thus requiring an even more conservative limit on playback sound level and/or

[1] A music dose of 50% is recommended to allow both for a margin of safety, and the understanding that during any given day there will likely be exposure to other sounds that may comprise the other 50% of the permitted exposure.

duration of use to prevent MIHDs. High sensitivity earphones, some of which are marketed to disc jockeys (DJs), should be used with caution.

With respect to safer listening choices, some earphones advertise an 85 dBA output sound level limit in the ear canal. Use of such earphones could extend the safe listening duration for a PAS user. Given the lack of regulations for such labeling claims, some caution is warranted regarding claims of advertised sound levels. Regardless of volume limits, if temporary changes in hearing, a feeling of "fullness" in ones ears, or tinnitus are experienced after music player use, sound levels and listening durations should be decreased to reduce the risk of permanent damage. Some users may find volume limits to be unacceptable for their preferred listening levels; this should serve as a warning that the PAS user's listening levels may put them at risk for MIHD, depending on the duration and frequency of use. Of note, individuals that listen to music via earphones during the entire work day may be at increased risk for MIHD relative to those with shorter listening durations, and are especially encouraged to consider volume limited earphones to prevent over-exposure.

A PAS user's chosen listening level is based, in part, on the signal-to-noise ratio of the music compared to the background noise; PAS users invariably choose higher output levels in noisier environments than in quieter environments in controlled laboratory studies (Portnuff et al., 2011), and in real-world settings (Epstein et al., 2010; Park et al., 2017). Thus, earphones designed to reduce background noise may result in reduced chosen listening levels and overall sound exposure levels. There are multiple types of earphones designed to reduce background noise, including passive (non-electronic) attenuation and active (electronic) attenuation. Such technology is available in devices with both custom-fit and non-custom earpieces. It is unknown if there is any difference in chosen listening levels for earphones with active noise cancellation versus earphones with passive noise isolation, or between those with custom-fit earpieces versus non-custom earpieces.

A common piece of advice is that "If someone else can hear your music from your earphones, the level is too high." This advice is as common as it is inaccurate, given its overly conservative nature (Weiner et al., 2009). As explained by Fligor (2010), music is frequently detectable to an "observer" when the headphone user sets the music to 85 dBA or higher (correct identification of "risky" sound levels), but the music from the headphones is also detectable most of the time when the music is set at levels less than 85 dBA; i.e., even when it was not considered to be a potentially risky sound level. A second problem is that this advice cannot be applied when the music listener is using noise-attenuating earphones; the earpiece that seals the ear canal to prevent environmental sound from leaking in simultaneously prevents sound from leaking out.

A second common piece of advice is that "If you can't hear someone speaking to you while listening to music from your earphones, the level is too high." When listeners are playing their music so loudly that someone at arm's length has to shout to be understood, the levels are likely to be 85 dBA or greater and extended listening durations may be hazardous. However, if the PAS user is using noise-blocking earphones, these will attenuate speech as well as background noise, and reduce the utility of this advice as well. Listeners are advised to monitor their own music exposure (using the 80/90 rule for example) and to choose earphones that provide some background noise attenuation. If temporary changes in hearing, a feeling of “fullness” in ones ears, or tinnitus are experienced after music player use, sound levels and listening durations should be decreased to reduce the risk of permanent damage.

Specific Risk in Amplified Music Environments: Concerts, Dance Clubs, and Fitness Facilities

Sound levels at modern rock concerts are typically 100 – 105 dBA (Berger et al., 2016; Fligor & Wartinger, 2011) and can reach levels of 120 dBA; these levels increase the risk of MIHDs (World Health Organization, 2015; Zhao et al., 2010). Even orchestras and small acoustic groups are capable of reaching high sound levels, although they are likely to do so for briefer periods of time. Amplified music poses a greater risk to hearing, as sound levels can remain high for the entire duration of the event such as in dance clubs where levels range from 90-120 dBA (Clark, 1991). Attendees should therefore take precautions such as HPD use, increased distance from sound sources, and quiet breaks to reduce their overall sound exposure.

Fitness facilities also play loud music as an integral part of exercise classes, often accompanied the fitness instructor’s amplified voice. Sound levels in these settings have been recorded from 95 - 100 dBA (World Health Organization, 2015), which may result in overexposure in less than one hour. Participants in exercise classes may be at high risk for MIHDs if they regularly attend these classes. Reports of high sound levels specifically at “spin” classes are also beginning to emerge (see for example, Sinha et al., 2017); some facilities have begun to provide disposable earplugs for attendees.

Prevention of MIHDs

Individuals exposed to high sound levels of recreational music can often reduce their risk by reducing the music levels, increasing distance from the music source, and using hearing protection devices (HPDs). Individuals can use commercially available sound level meters or smartphone apps to measure and monitor their noise exposure (see discussion below) as an aid for informed decision making about safe exposure duration. PAS users should monitor device sound levels and reduce their chosen listening level and/or listening time to prevent MIHL. In high-level music environments, listeners should use HPDs to reduce their overall exposure.

Sound Level Monitoring with Smartphone Apps

While professional sound level meters (SLM) provide the most accurate measurements, most individuals do not have access to this type of equipment. There is ongoing research assessing whether SLM smartphone apps are accurate enough to be useful in guiding safe listening decisions for attendees of loud, recreational events.

Some investigators have reported smartphone apps to be accurate when compared to a Type II sound level meter (Ibekwe et al., 2016). However, both early investigations (Kardous et al., 2014; Nast et al., 2014) and studies with more recent technology (Neitzel et al., 2015; Murphy and King, 2016) have shown significant (up to 15 dB) error in in app-reported sound levels compared to measurements from professional (calibrated) SLMs or dosimeters meeting specific standards. An app's measurement accuracy can be improved by calibrating the phone's built-in microphone with a known noise level. An even more accurate approach is to use an external microphone coupled to the phone (Roberts et al., 2016; Kardous and Shaw, 2016); however, the willingness of a typical smartphone user to obtain, calibrate, and use an external microphone at a recreational event can be an issue. Refinement of SLM apps and calibration protocols is needed before apps can reliably provide consistent, accurate sound level measurements.

Hearing Protection Devices

Hearing protection devices (HPDs) are readily available. With respect to their noise attenuation for music listening they can be divided into two main categories: 1) products designed to maximize sound attenuation (i.e. "conventional" attenuation), and 2) products designed to allow a better listening experience by providing a relatively uniform level of noise reduction across frequencies with appropriate attenuation as a target, instead of maximum attenuation as the goal. Hearing protectors of the first type, such as roll-down foam earplugs, conventional premolded earplugs, and conventional earmuffs can be effective *when worn correctly*. Used primarily in noisy work environments, they are expected to be worn for an entire work shift and are generally low in cost. When listening to music, users typically find that these HPDs do not maintain music fidelity because they tend to attenuate high-frequency sounds more than low-frequency sounds, like wearing color-tinted sunglasses instead of neutral gray lenses. They also usually provide more noise reduction than is necessary.

Hearing protectors of the second type, namely the uniform-attenuation earplugs, are designed to allow for better enjoyment of music by reducing sound levels while maintaining the original fidelity of the music. The sound quality is preserved by providing a more equal noise reduction across the entire range of the musical spectrum, but these types of products generally have lower overall attenuation than conventional earplugs. Uniform-attenuation earplugs have been shown to improve music appreciation (Beach et al., 2010; Bockstael et al., 2015). Such earplugs are commercially available in generic-fit models, as well as custom-fit models. Custom-fit uniform-attenuation earplugs are more expensive than generic fit devices, but may offer higher comfort, improved sound quality, and reduced variability in the amount of attenuation from one insertion to the next. Verification of custom-fit HPDs should also be considered. Training the correct insertion of custom-fit HPDs improves achieved attenuation and decreases variability from insertion to insertion (Tufts et al., 2013). Active (electronic) earplugs are also available; these have the advantage of a more transparent response when sound levels are safe, and only provide attenuation when protection is needed. However, at high sound levels when the electronics shut down for protection of the wearer, they will sound a little different from the non-electronic uniform-attenuation devices.

The overall amount of attenuation should be appropriate for the sound exposure level. In an occupational setting, the goal of HPD use is to reduce exposure such that it does not exceed 100% of the daily permitted exposure. Earplugs are selected based on the Noise Reduction Rating (NRR) that is printed on the package. The achieved attenuation in practice is typically less than the NRR that is based on optimized testing in a laboratory. Therefore it is often recommend that NRRs be derated by anywhere from 20-50% (Berger, 2003). When listening to music, an earplug with a lower NRR is sometimes more acceptable to the end user. Given a choice, an earplug with a lower NRR - used consistently and correctly - is more effective than an earplug with a higher NRR if it is deemed unacceptable and removed during the recreational event. Both physical fit and actual use of the HPDs are critical to overall effectiveness in reducing risk of hearing loss. Verification of individual fit (i.e., individual achieved attenuation) for hearing protection is helpful in demonstrating HPD effectiveness to a user.

Conclusion

There is increased risk for MIHD from unregulated music exposures, such as PAS devices, concerts, dance clubs, and fitness facilities. Music listeners must make safe listening decisions to reduce the risk of permanent MIHDs from significant (unprotected) sound overexposure. ***Individuals who experience tinnitus, aural fullness, or a decrease in hearing following recreational sound exposure have likely experienced greater than 100% of their daily allowable noise dose. These individuals should reduce their recreational sound exposure and have their hearing evaluated by an audiologist.*** Based on data showing the earliest changes may accrue at frequencies above the standard range that extends to only 8000 Hz, we advocate that monitoring for the purposes of hearing loss prevention should also include the audiometric frequencies extending up to 20,000 Hz when feasible.

Overall, NHCA recommends the following:

- Be aware of your music exposure, including the level of sound you are exposed to and how long you are exposed to it. Remember that sound exposures are cumulative throughout the day, and injury from excessive sound exposures is cumulative over one's lifetime.
- For PAS users listening *with earbuds*, remember the 80/90 rule: You can listen at 80% of the maximum volume for 90 minutes per day; increased volume results in lower permissible listening time, decreased volume results in longer permissible listening time.
- If you are using typical earbuds that provide little noise reduction, and someone at arm's length has to shout for you to understand them, then your sound exposure level may be at or above 85 dBA and you should limit your listening time.
- Decrease music exposure by:
    - Reducing sound levels when possible
    - Increasing your distance from the music source
    - Using hearing protection
- Always use the right size and right kind of HPD for you and your listening environment.
- When using hearing protection, ensure that it is properly fit in your ears. Fit testing and verification of attenuation can help ensure that hearing protection is worn properly.

These guidelines provide recommendations for safer participation in recreational music exposures by means of current technology and knowledge. Further refinement and modification of this document is anticipated as new knowledge and technology become available.

References

Beach, E. F., Williams, W., & Gilliver, M. (2010). Hearing protection for clubbers is music to their ears. *Health Promotion Journal of Australia, 21(3),* 215-221.

Berger, E. H. (2003). "Hearing protection devices," in The Noise Manual, 5th ed., edited by E. H. Berger, L.H. Royster, J.D. Royster, D.P. Driscoll, and M. Layne, Am. Ind. Hyg. Assoc., Falls Church, VA, 379-454.

Berger, E. H., Neitzel, R., & Kladden, C. A. (2016). "Noise Navigator™ Sound Level Database with over 1700 measurement values," 3M Company, http://multimedia.3m.com/mws/media/1262312O/3m-noise-navigator.xlsx

Bhagat, S. P., & Davis, A. M. (2008). Modification of otoacoustic emissions following ear-level exposure to MP3 player music. *International Journal of Audiology*, *47*, 751–760.

Bockstael A, Keppler H, & Botteldooren D. (2015). Musician earplugs: Appreciation and protection. *Noise & Health. 17(77)*:198-208. doi: 10.4103/1463-1741.160688.

Carroll, Y. I., Eichwald, J., Scinicariello, F., Hoffman, H. J., & Deitchman, S. (2017). Vital Signs: Noise-Induced Hearing Loss Among Adults — United States 2011 – 2012. *MMWR Morbidity and Mortality Weekly Report*, *66*. http://dx.doi.org/10.15585/mmwr.mm6605e3

Carter, L., Williams, W., Black, D., & Bundy, A. (2014). The leisure-noise dilemma: hearing loss or hearsay? What does the literature tell us? *Ear and Hearing, 35(5)*, 491–505. https://doi.org/10.1097/01.aud.0000451498.92871.20

Clark, W. W. (1991). "Noise Exposure from Leisure Activities: A Review," *Journal of the Acoustical Society of America, 90,* 175–181.

Emmerich, E., Rudel, L., & Richter, F. (2008). Is the audiologic status of professional musicians a reflection of the noise exposure in classical orchestral music*? European Archives of Otorhinolaryngology, 265,* 753–758. Journal Article.

Epstein M., Marozeau J. & Cleveland S. (2010). Listening habits of iPod users. *Journal of Speech, Language, and Hearing Research*, 53, 1472-1477.

EU (2003). On the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). *European Union Directive 2003/10/EC*.

Fligor, B. J. (2009). Personal listening devices and hearing loss: Seeking evidence of a long term problem through a successful short-term investigation. *Noise & Health*, *11*, 129–131.

Fligor, B. J. (2010). Recreational noise and its potential risk to hearing. *Hearing Review, 17(5),* 48-55.

Fligor, B.J. & Wartinger, F. (2011). Musicians' Hearing Program. *Audiology Today 23(3)*, 30-39.

Grinn, S., Baker, J., Wiseman, K., & Le Prell, C. G. (2017). Hidden hearing loss? No effects of recreational noise exposure on ABR wave-I amplitude in humans. *Frontiers in Neuroscience, 11, article 465.*

Halevi-Katz, D.N., Yaakobi, E., & Putter-Katz, H. (2015). Exposure to music and noise-induced hearing loss (NIHL) among professional pop/rock/jazz musicians. *Noise & Health, 17(76),* 158-64.

Ibekwe, T.S., Folorunsho, D.O., Dahilo, E.A., Gbujie, I.O., Nwegbu, M.M., & Nwaorgu, O.G. (2016). Evaluation of mobile smartphones app as a screening tool for environmental noise monitoring. *Journal of Occupational and Environmental Hygiene, 13,* D31-6.

Jiang, W., Zhao, F., Guderley, N., & Manchaiah, V. (2016). Daily music exposure dose and hearing problems using personal listening devices in adolescents and young adults: A systematic review. *International Journal of Audiology*, *55*(4), 197–205.

Johnson, D.W., Sherman, R.E., Aldridge, J., & Lorraine, A. (1985). Effects of instrument type and orchestral position on hearing sensitivity for 0.25 to 20 kHz in the orchestral musician. *Scandinavian Audiology, 14(4),* 215-21.

Kardous, C.A., & Shaw, P.B. (2014). Evaluation of smartphone sound measurement applications. *Journal of the Acoustical Society of America – Express Letters,* 135, EL186-EL192.

Kardous, C.A., & Shaw, P.B. (2016). Evaluation of smartphone sound measurement applications (apps) using external microphones-A follow-up study. *Journal of the Acoustical Society of America – Express Letters*, *140,* EL327-EL333.

Le Prell, C.G., Spankovich, C., Lobarinas, E., & Griffiths, S.K. (2013). Extended high frequency thresholds in college students: effects of music player use and other recreational noise. *Journal of the American Academy of Audiology, 24(8),* 725-739.

LePage, E. L., & Murray, N. M. (1998). Latent cochlear damage in personal stereo users: A study based on click-evoked otoacoustic emissions. *Medical Journal of Australia, 169,* 588–592.

Lindgren, F., & Axelsson, A. (1983). Temporary threshold shift after exposure to noise and music of equal energy. *Ear & Hearing, 4(4),* 197-201.

Meecham, E. A., & Hume, K. I. (2001). Tinnitus, attendance at night-clubs and social drug taking in students. *Noise & Health, 3,* 53–62.

Mercier, V., Luy, D., & Hohmann, B. W. (2003). The sound exposure of the audience at a music festival. *Noise & Health, 5,* 51–58.

Murphy, E., & King, E.A. (2016). Smartphone-based noise mapping: Integrating sound level meter app data into the strategic noise mapping process. *Science of the Total Environment, 562,* 852-9.

Nast, D.R., Speer, W.S., & Le Prell, C.G. (2014). Sound level measurements using smartphone "apps": useful or inaccurate? *Noise & Health,* 16, 251-6.

Neitzel, R.L., Heikkinen, M.S., Williams, C.C., Viet, S.M., & Dellarco, M. (2015). Pilot study of methods and equipment for in-home noise level measurements. *Applied Acoustics,* 102, 1-11.

NIOSH (1998). Occupational *Noise Exposure: Revised Criteria 1998.* Cincinnati, OH: US Department of Health and Human Services.

OSHA (1983). "Occupational noise exposure; hearing conservation amendment," *Federal Register, 48(46),* 9738-9783.

Park, Y., Guercio, D., Ledon, V., & Le Prell, C.G. (2017). Variation in music player listening level as a function of campus location. *Journal of the American Academy of Audiology, 28(4):295-313.*

Phillips, S. L., Henrich, V. C., & Mace, S. T. (2010). Prevalence of noise-induced hearing loss in student musicians. *International Journal of Audiology, 49,* 309–316.

Portnuff, C. D. (2016). 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. *Adolescent Health, Medicine and Therapeutics*, *7*, 27–35.

Portnuff, C. D. F., Fligor, B. J., & Arehart, K. H. (2011). Teenage Use of Portable Listening Devices: A Hazard to Hearing? *Journal of the American Academy of Audiology*, *22*, 663–677.

Portnuff, C. D. F., Fligor, B. J., & Arehart, K. H. (2013). Self-report and long-term field measures of MP3 player use: How accurate is self-report? *International Journal of Audiology*, (52), S33–S40.

Roberts, B., Kardous, C., & Neitzel, R. (2016). Improving the accuracy of smart devices to measure noise exposure. *Journal of Occupational and Environmental Hygiene,* 13, 840-6.Weiner, J., Kreisman, B.M.,

Royster, J. D., Royster, L. H., & Killion, M. C. (1991). Sound exposures and hearing thresholds of symphony orchestra musicians. *Journal of the Acoustical Society of America, 89(6),* 2793–2803.

Schmidt, J.H., Pedersen, E.R., Paarup, H.M., Christensen-Dalsgaard, J., Andersen, T., Poulsen, T., & Bælum J. (2014). Hearing loss in relation to sound exposure of professional symphony orchestra musicians. *Ear & Hearing, 35(4),* 448-60.

Sinha, S., Kozin, E.D., Naunheim, M.R., Barber, S.R., Wong, K., Katz, L.W., Otero, T.M.N., Stefanov-Wagner, I.J.M., Remenschneider, A.K. 2017. Cycling exercise classes may be bad for your (hearing) health. *Laryngoscope, 127(8),* 1873-1877.

Strasser, H., Chiu, M., Irle, H., & Wagener, A. (2008). Threshold shifts and restitution of the hearing after different music exposures. *Theoretical Issues in Ergonomics Science, 9,* 405–424.

Szibor, A., Hyvärinen, P., Lehtimäki, J., Pirvola, U., Ylikoski, M., Mäkitie, A., Aarnisalo, A., & Ylikoski, J. (2017). Hearing disorder from music; a neglected dysfunction. *Acta Otolaryngologica 31,* 1-4.

Tufts, J.B., Jahn, K.N., & Byram, J.P. (2013). Consistency of attenuation across multiple fittings of custom and non-custom earplugs. *Annals of Occupational Hygiene, 57(5)*, 571-80.

Wang, Y., Hirose, K., & Liberman, M.C. (2002). Dynamics of noise-induced cellular injury and repair in the mouse cochlea. *Journal of the Association for Research in Otolaryngology, 3(3),* 248-268.

Ward, W. D., Royster, J. D., and Royster, L. H. (2003). "Auditory and nonauditory effects of noise," in The Noise Manual, 5th ed., edited by E. H. Berger, L.H. Royster, J.D. Royster, D.P. Driscoll, and M. Layne, Am. Ind. Hyg. Assoc., Falls Church, VA, 123-147.

Weiner, J., Kreisman, B.M., & Fligor, B.J. (2009). If I can hear their headphones, it's too loud, right? *Audiology Today, 21(3),* 44-51.

Williams, W. (2009). Trends in listening to personal stereos. *International Journal of Audiology*, *48*, 784–788.

Williams, W. (2016). Hearing and leisure noise. *Spectrum, (July)*, 9–15.

World Health Organization. (2015). *Hearing loss due to recreational exposure to loud sounds: A review.* Geneva. SZ.

World Health Organization. (2017). *Determination of Risk of Noise-Induced Hearing Loss Due to Recreational Sound: Review.* Geneva. SZ.

Zhao, F., Manchaiah, V. K. C., French, D., & Price, S. M. (2010). Music exposure and hearing disorders: An overview. *International Journal of Audiology*, 49, 54–64.