

A Looming Epidemic: Personal Music Player Use in Young Adults and Concern for Future Noise-Induced Hearing Loss

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ABSTRACT: Noise-induced hearing loss is a preventable cause of permanent deafness. Hearing loss is debilitating and correlated with depression, dementia, and deterioration in cognitive performance. The widespread use of personal music players (PMPs), such as earbuds, threatens hearing. The use of PMPs may result in exposure to damaging noise levels. Usage patterns of contemporary PMPs by young adults are understudied. Sixty-two anonymous surveys from young adults revealed these usage patterns. Average daily use was 3.1 hours, and maximum consecutive use averaged 4.3 hours. Sound output from four PMPs was measured in dBA using a sound mannequin and an attached sound meter. Data was obtained across three music genres and a podcast at four intensity levels, producing 64 trials. The peak recorded volume was 101.2 dBA, equivalent to noise from a motorcycle. Most respondents used their PMPs at 50-100% capacity, and 11.3% listened within the 75-100% range. Nearly 60% listened at levels associated with potential noise-induced hearing loss. This study highlights the association of seemingly innocuous PMP use with possible future deafness. Guidelines for safe use are offered, which, when coupled with public education, may favorably impact a looming epidemic of hearing loss.

KEYWORDS: Translational Medical Sciences; Disease Prevention; Noise-Induced Hearing Loss (NIHL); Safe Personal Music Player (PMP) Use.

■ Introduction

Daily use of earbuds and headphones, also known as personal music players (PMPs), is the norm in society, with 90% of adolescents declaring they regularly listened to music via a PMP, as reported in one sample of 1,687 by Breinbauer *et al.*¹ Sales and popularity of PMPs are bolstered by wireless devices, cellphones, and streaming music services, such as Spotify and Pandora, which together make using PMPs increasingly accessible and alluring. The implications of this constant, widespread use of PMPs on the hearing of young adults are worthy of investigation. It is estimated that around 50% of people aged 12 to 35 are at risk of hearing loss because of persistent and excessive exposure to loud noise, such as music played through PMPs.² Noise-induced hearing loss occurs after repetitive exposure to a noisy environment (often from occupational or recreational noise). No treatment can reverse noise-induced deafness, as the destruction of the inner ear sound-perceiving hair cells is irreparable. It is reported that individuals exposed to sound exceeding 89 dBA for more than 5 hours weekly can develop enduring hearing damage over time.³ Hearing loss affects quality of life and is linked to depressive symptoms and dementia.⁴ Hearing loss of roughly 25 dB HL has been associated with an adverse effect on cognitive performance equal to around seven years of aging, as concluded through studies on the elderly who suffer from noise-induced hearing loss (NIHL).⁵

To protect against NIHL in the workplace, the Occupational Safety and Health Administration (OSHA) requires that employers must provide their employees with hearing protectors when sound exposure reaches an 8-hour time-weighted

average of 85 decibels or greater.⁶ However, this is an occupational standard, and no regulation in the US sets a maximum output for PMPs.⁷

This research into the PMP habits of Generation Z, young adults born from 1997 to 2012, first quantifies the frequency and volume at which young adults listen with PMPs to identify whether they are listening at unsafe levels. Additionally, data was gathered to see if young adults were educated on safe listening levels and durations and whether this education has influenced their listening patterns. Then, PMPs at different volumes and various recordings were tested with a sound meter attached to a sound mannequin to track dBA and how loud PMP volumes can become. This research addresses the potential risk of an epidemic of NIHL among Generation Z. It investigates whether young adults use earbuds and headphones at sound levels and for durations potentially conducive to hearing loss.

■ Methods and Materials

Survey:

To gather data on young adult PMP listening patterns, an anonymous 26-question survey was completed via Google Forms by 62 adult participants. Before survey completion, each participant provided informed consent and verified that they were older than 18. No teenagers younger than 18 years old participated in this study, as they would have required parental consent to complete the survey. Their average age was 21.5 years old, with the youngest participants 18 years and the oldest 25 years old. The survey involved questions regarding daily PMP usage, symptoms of hearing loss, listening preferences, and education on safe sound levels. Forty-two females partic

ipated, along with 19 males and one individual who classified their sex as 'other.' Of the surveyed population, 4 (6%) people labeled themselves as exclusively headphone users; a large majority, 44 (71%), used only earbuds, and 14 (23%) individuals listened with both earbuds and headphones. Around half, 35 (56%), used devices with noise-canceling capabilities.

Device Testing:

Four different devices were tested at four varying volume levels, with four other recordings spanning disparate genres, to gauge the intensity at which PMPs generate sound. This data was measured by plugging the PMPs into the ear of a mannequin with an attached sound meter, which recorded the sound in dBA. Once the song began to play, the dBA levels were displayed by the sound meter.

Survey participants mainly listed their PMP as an Apple product, especially Apple AirPods and Apple AirPods Pro (both in-the-ear devices). Thus, the four different PMPs utilized for trials were Apple AirPods 2nd generation (wireless), Apple AirPods Pro (with noise canceling technology and wireless), Apple earbuds (with wires), and Bose Ice Queen Headphones (over the ear and with noise canceling abilities).

Survey participants mainly employed PMPs to listen to music, but the second most frequent use of PMPs was to listen to podcasts. Accordingly, three songs were tested alongside one podcast. The three songs fit into the categories of Hip Hop, Rock, and Pop music/today's hits; all popular genres streamed on music services, such as Spotify or Pandora. To quantify sound levels, the three songs, each played for 25 seconds, were 'Blinding Lights' (by The Weeknd), 'Goosebumps' (by Travis Scott), and 'Thunderstruck' (by AC/DC). The tested podcast was December 31, 2021, iteration of 'The Daily.'

Each song/podcast was tested at all four volume levels available on each device (25%, 50%, 75%, and 100% of the maximum) with all four instruments, making 64 trials. For each trial, the maximum and minimum dBA produced by the PMP during the 25 seconds was recorded, culminating in 128 data points. All data were tabulated and analyzed via the Google Sheets program. Below are images of the PMPs tested with the mannequin and sound meter.

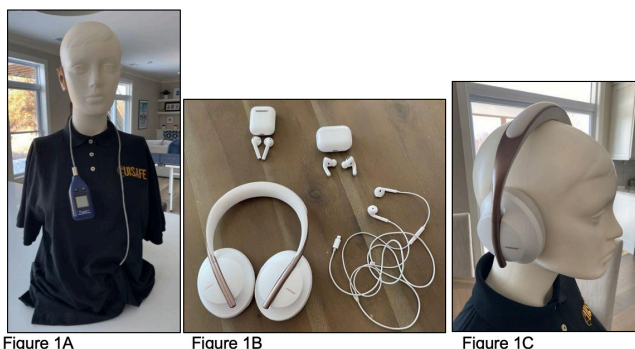


Figure 1: 1A displays the mannequin and attached sound meter used for testing; Figure 1B shows the devices used for testing (from top left to bottom left, clockwise): Apple AirPods, Apple AirPods Pro, Apple earbuds, and Bose Ice Queen Headphones. Figure 1C shows the mannequin being tested with the Bose Ice Queen Headphones.

Results

Survey Results:

The average number of hours daily spent listening to PMPs for those surveyed was 3.1 hours (totaling 21.7 hours weekly). The longest span in a row people typically used PMPs was, on average, 4.3 hours. Figures 4 and 5 depict the distribution of PMP usage in hours.

Typical Daily Usage of Personal Music Players

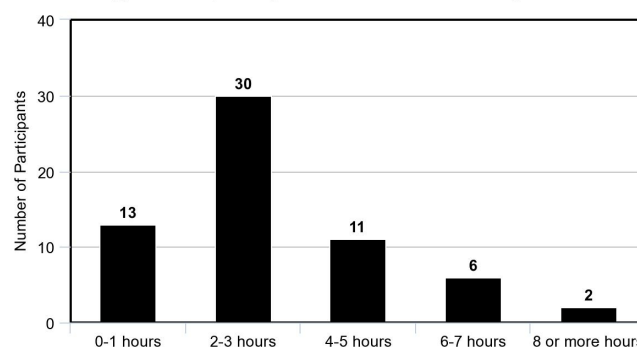


Figure 2A: 2A displays the typical daily usage of PMPs (in hours) of survey participants.

Maximum Number of Consecutive Hours Spent Listening to Personal Music Players

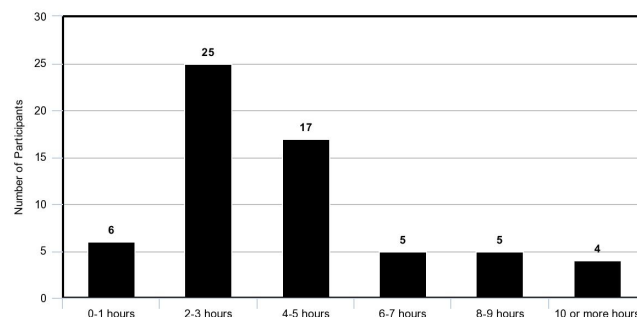


Figure 2B: 2B shows survey participants' maximum consecutive PMP usage (in hours).

Survey participants also indicated at what percentage of their device's full volume they typically

listen to. This fell within one of four ranges: 0-25%, 25-50%, 50-75%, and 75-100%. These broad ranges were chosen because it would have been difficult and subjective for those surveyed to list precise dBA ranges. Most participants, around 59%, listened to their devices at 50-100% of full volume, with the remainder of the participants typically using their devices at under 50%. Refer to Table 1A for specific breakdowns between the four-volume ranges.

Although most participants know that recommendations are in place to guide safe PMP listening habits, only a minority could correctly list 70 dBA as a level unlikely to result in NIHL. Two-thirds of participants, or 41 (66%), acknowledged safe listening levels, yet only 6 (9.7%) could correctly identify 70 dBA as the maximum volume unlikely to result in NIHL. This shows a significant and potentially dangerous disconnect between a safe listening level and having a specific enough understanding to make an informed decision. However, most respondents, 41 (66%), agreed that they would be willing to al

ter their PMP usage patterns in accordance with safe listening levels following education.

Finally, a potentially concerning proportion of survey respondents, 53 (85%), signaled they listen with PMPs in noisy environments where they are required to increase the PMP's output to reach the desired sound level. This means their listening volumes may be even higher than the averages described.

Results from testing various PMPs:

Figures 3A and 3B display the data regarding PMP testing for the songs 'Blinding Lights' and 'Goosebumps.' Data on dBA output was collected across four devices and four-volume ranges by grouped song.

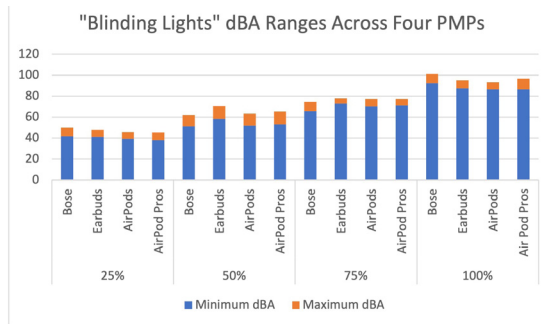


Figure 3A: 3A displays, across four different volume ranges tested with four different PMPs, the maximum and minimum dBA produced for the song "Blinding Lights."

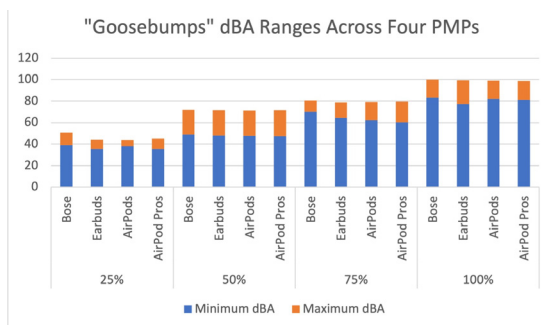


Figure 3B: 3B displays, across four different volume ranges tested with four different PMPs, the maximum and minimum dBA produced for the song "Goosebumps."

Table 1: To help understand the levels produced by some everyday sounds, Table 1 compares sound levels into more easily understood sound equivalents.³

Sound level (dBA)	Source
0	Quietest sound audible
30	Whisper
50-65	Normal conversation
80-85	City traffic noise
95-110	Motorcycle
110-120	Nightclub
110-140	Rock concerts
150	Firecracker

As observed via the histograms in Figures 3A-3B, across all songs and devices: 0-25% of full volume correlates roughly with a range of 35-45 dBA, 25-50% of the full volume has a range of about 50-70 dBA, 50-75% of the full volume has volumes of about 65-80 dBA, and 75-100% of the full volume has a range starting around 85 dBA and peaking at about 95 dBA. The peak recorded volume occurred during the song 'Blinding Lights' (from the Today's Hits Genre) at 100% volume, with the Bose Headphones at 101.2 dBA.

This data supports that those playing their PMPs at 0-50% of full volume are unlikely to develop NIHL. However, the majority, 37 (59.7%), of survey respondents used their PMPs at volumes from 50-100% of full capacity, and a smaller subset of 7 people (11.3%) listened within the range of 75-100% of full volume. Therefore, this population of listeners using devices at 50-100% has a potential risk of NIHL due to their current PMP use.

Table 2A: Table 2A depicts the number of survey participants listening to their PMPs within one of four volume ranges, 0-25%, 25-50%, 50-75%, and 75-100%.

Percent of Full Volume	Number of Participants	Percent of Total
0-25%	2	2/62= 3.2%
25-50%	23	23/62= 37.1%
50-75%	30	30/62= 48.4%
75-100%	7	7/62= 11.3%

Table 2B: 2B displays across the four devices and songs the approximate ranges of dBA played and whether or not these ranges are conducive for NIHL, using the standards listed below in the implications portion of the discussion.

Percent of Full Volume	Approximate dBA Correlations	Risk for NIHL
0-25%	35-45 dBA	Unlikely
25-50%	50-70 dBA	Unlikely
50-75%	65-80 dBA	Potentially
75-100%	85-95 dBA	Potentially

■ Discussion

Implications:

Duration of safe PMP usage varies with device, output levels, and genre of music. The higher the volume, the shorter the safe listening interval. For example, levels of 100 dBA (the sound produced by a subway train) can only be safely listened to for 15 minutes daily.⁸ Once sound exposure reaches 105 to 110 dBA, damage can follow after only five minutes.⁹ However, as long as the volume peaks at around 70 dBA, significant hearing damage is unlikely to occur.⁹

One study, by testing various PMPs with different music genres, attempted to set basic listening guidelines that varied in conjunction with the type of music and device. For example, for high-output music, such as the popular categories of Rock and HipHop, it was recommended that for in the ear PMPs music could only be played for 57 minutes at 70% of full volume.¹ Once the volume was turned to its highest degree, safe listening time was reduced drastically: to 2.5 minutes.¹ Importantly,

these suggestions were outlined in 2012 by testing PMPs considered antiquated by today's standards.

This data poses a serious concern, for nearly 60% of survey participants indicated they listened within 50-100% of their PMP's total output, with the average listening period being 3.1 hours daily.

Across all devices tested, 50-75% of full volume equated to around 65-80 dBA, meaning safe listening time would fall under two hours for earbuds (according to the guideline for 70% volume described above). Yet the average listening time for respondents was 3.1 hours. Thus, they exceeded a safe duration for the corresponding volume.

Of greater concern is an 11% subset who listen at 75-100% of full volume, or roughly 85-95 dBA. This group reaches their maximum, healthy daily exposure in under 10 minutes (by the aforementioned guidelines), far before 3.1 hours, which was found to be the average usage period of survey participants.

By investigating the PMP listening habits of Generation Z, strong evidence of potentially dangerous volume levels and listening durations that may lead to NIHL was identified in possibly 60% of young adults.

Additional Insight on PMP Usage Patterns:

This study involved a degree of subjectivity; participants were asked to estimate approximate ranges at which they listened to PMPs. More exacting studies have been conducted, where subjects are required to choose volume levels in the presence of researchers. In one such study, 17.8% of volunteers spontaneously selected a listening level above 85 dBA, even though the background was silent.¹ Furthermore, when background noise was heightened to 90 dBA, 40% of participants picked a volume level above 94 dB where dangerous exposure ensues in under an hour.¹

An additional study examined the influence type of device played on listening preferences. Typically, participants had increased preferred listening levels (PLLs) with earbuds compared with over-the-ear headphones.¹⁰ Furthermore, this study supported that PLLs were higher in street noise than in multi-talker background noise, with both exceeding the PLLs for quiet conditions.¹⁰ It must be noted that the listening environment and type of PMP play a key role in dictating chosen volume levels. Thus, optimal listening conditions are in areas of limited background noise, with music played through over-the-ear headphones, which are better at dampening background noise.

Noise-Canceling Technology:

Background noise can rarely be kept to a minimum, and people continue to utilize PMPs in noisy environments with rapidly fluctuating decibel levels. To counteract loud surroundings, noise-canceling technology has been implemented in many PMPs, including two tested throughout these trials (Bose Ice Queen Headphones and Apple Airpod Pros). Active noise-cancellation (ANC) uses the design of an active noise controller to discern undesired outside noise and to counter or cancel that noise with an anti-phase signal.¹¹

One study, which sought to test the reliability of the noise-canceling feature in various sound environments, concluded that no significant improvement in noise attenuation

was found when ANC was activated. This held across all tested headphones.⁹ However, results demonstrated that ANC headphones were predictable when they performed in stable noise environments in contrast to surroundings with highly transient noise.¹¹ PMPs with ANC capabilities may have a false allure, as they need help accurately combating variable background noise. This has the potential for adverse outcomes on the listener's hearing, for the listener may believe the ANC technology is more effective than it is, especially regarding background noise in flux.

It should also be noted that noise-canceling headphones are designed for sounds that do not change level randomly and quickly. Therefore, they will not be effective for canceling most variable ambient noise.

Impulsive Noise:

Another type of dangerous noise is referred to as 'impulsive' noise. Sounds with a rapid onset (rise time) (like metal banging on metal in factories or gunfire) are more damaging than continuous noise. Some music examples include striking a symbol or a drum. Special equipment is required to measure dB Peak SPL. This couldn't be measured in the current study but should be considered by PMP users.

Negative Impacts of Hearing Loss:

Not only does NIHL impair listening and speaking abilities, with chronic symptoms including debilitating tinnitus (ringing in the ears), but its ramifications also extend to mental health and cognitive function deterioration. A cross-sectional study observing the prevalence of depressive symptoms among occupational NIHL patients found that 53.8% demonstrated depressive tendencies.¹² Among the 57 patients with depression, 27.4% suffered from mild depression, 19.8% experienced moderate depression, and 6.6% had severe depression.¹² Sleep disorders were also present in 84.2% of patients with occupational NIHL.¹² More severe depression demonstrated a positive correlation with tinnitus. However, the degree of depression correlated not with the severity of tinnitus but with its duration.¹²

Another study anonymously gathered the testimonies of musicians suffering from tinnitus. Their quality of life was found to be diminished, with one sharing, 'I am in mourning for the loss of personal peace and quiet.'¹³ Another musician described their experience: 'At times, the tinnitus can make you feel very isolated, alone, and extremely drained.'¹³

As an independent risk factor for dementia, hearing loss is also linked to the cognitive decline observed in the elderly.¹⁴

If PMP usage remains unchecked, generations may face the harsh reality of NIHL, including tinnitus, cognitive decline, and depression, as NIHL is irreversible.

Safer Ways to Use PMPs:

To make PMP listening as safe as possible, the volume should not be over 50%, over-the-ear headphones should be utilized, listeners should avoid areas with rapidly fluctuating background noise, and ANC technology can be helpful when employed in environments with stable background sound. Throughout testing and regardless of device, when PMPs were played at 50% of full volume, decibel output rarely reached above 70 dBA, meaning NIHL is unlikely.⁹ When

objectively measured in other studies, listeners chose quieter PLLs with over-the-ear headphones.¹⁰ The average PLL was reduced even further when the noise-reduction circuit was used in tandem with the over-the-ear headphones.⁸ ANC did perform consistently in stationary noise environments, meaning it could still be helpful to combat constant ambient noise.¹¹ Listening to PMPs in noisy environments with loud, oscillating noise levels should be avoided, for listeners are more prone to increase PMP output to dangerous levels.

■ Limitations

The limitations of this research primarily come from the survey conducted to determine the PMP listening habits of young adults.

First, the survey's downfall was that its anonymous participants were not chosen randomly and were contacted via email. Thus, its results were subject to voluntary response bias, meaning individuals decided whether or not they would participate in the survey. Further, the survey sample size was relatively small, at 62 participants, making it less likely to be representative of the population, young adults as a whole. Another limitation of the sample is that the number of female-to-male responses was nearly 2:1, creating a potential bias if genders utilize PMPs differently. Finally, participants were required to estimate their listening levels and daily usage, and these responses were subject to response bias, an issue with any survey.

■ Future Recommendations

Currently, literature investigating PMP usage patterns among young adults is limited and becomes nearly nonexistent when it involves testing contemporary devices. In response to the unprecedented levels at which people are listening to PMPs, further studies must be undertaken to document usage patterns, signs of NIHL among PMP users, and PMP outputs to disseminate up-to-date safety guidelines. With further research, if concrete evidence of NIHL (like temporary threshold shift or tinnitus) is found among habitual PMP users, PMP producers should be called upon to limit their devices' outputs to safe levels or to require labels warn of potential NIHL with persistent PMP use. For now, as a preventative measure, PMP users must be educated on the safe intensity range and durations of use. This can be done through public service campaigns or advertising digital health apps alerting users when their PMP usage exceeds safe levels.

As PMP usage becomes increasingly widespread, safe listening guidelines must be investigated and established. This must be coupled with user education to prevent a PMP-induced NIHL epidemic that will potentially impact nearly 60% of today's young adults.

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