Analysis of Personal Listening Devices (PLDs) Use During Exercise and Hearing Screening in Runners

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Track Record Article

Revised: 31 July 2026
Accepted: 23 September 2026
Published: 30 September 2026

How to cite :
Kristianti, A., Sweetasari, A. G., Sintauly, K., Nurrokhmawati, Y., & Shavilla, E. (2026). Analysis of Personal Listening Devices (PLDs) Use During Exercise and Hearing Screening in Runners. *Contagion : Scientific Periodical of Public Health and Coastal Health*, 8(3), 178–190.

Abstract

Noise-induced hearing loss (NIHL) is increasingly reported among adolescents and young adults, particularly due to recreational noise exposure from Personal Listening Devices (PLDs). NIHL may result in permanent threshold shift (PTS), which can adversely affect quality of life. The use of PLDs during exercise may increase the risk of excessive noise exposure. This study aimed to determine the association between PLD use during exercise and hearing screening results using the ScreenOut application among runners. This study employed a cross-sectional study. Data were collected using a structured questionnaire, otoscopic examination, and hearing screening with the ScreenOut application in a quiet environment. Logistic regression analysis was performed to evaluate the association between PLD use and hearing screening results. A total of 94 runners were examined, and 64 met the inclusion and exclusion criteria. The results showed that 65.6% of runners had normal hearing, while 34.4% had hearing impairment. Based on duration of use, 68.8% of runners used PLDs for ≤60 minutes and 31.3% for >60 minutes (OR = 2.59; 95% CI: 0.848–7.968; p = 0.095). Regarding listening volume, 59.4% of runners used PLDs at ≤60% of the maximum volume and 40.6% at >60% (OR = 1.13; 95% CI: 0.382–3.380; p = 0.819). No statistically significant association was found between PLD use and hearing impairment. However, longer duration and higher listening volume showed a trend toward increased odds of hearing impairment, suggesting that further studies with larger sample sizes are warranted.

Keywords: Hearing Loss, Noise Induced, Personal Audio Devices, Running, Mass Screening

INTRODUCTION

Noise-induced hearing loss (NIHL) is a sensorineural hearing disorder caused by exposure to excessive noise intensity over a prolonged period. Noise exposure sources are generally divided into occupational and recreational noise (WHO, 2019). Occupational sources include machinery, engines, and industrial equipment, whereas recreational sources include music concerts, cinemas, entertainment venues, and Personal Listening Devices (PLDs). Unsafe PLD use, particularly listening durations exceeding 60 minutes and volumes above 60% of maximum, has been associated with temporary auditory symptoms such as tinnitus and with permanent threshold shift (PTS) due to damage to cochlear outer hair cells, especially in the basal cochlear region (Kristianti & Nurrokhmawati, 2020; Putri, 2023; Zachreini, 2016). Persistent tinnitus and hearing impairment may contribute to anxiety, sleep disturbances, concentration difficulties, communication problems, and reduced quality of life (Zachreini, 2016).

According to the WHO, hearing loss is defined as a hearing threshold greater than 20 dB. Globally, an estimated 2.5 billion people are projected to experience hearing loss by 2050, with more than 700 million requiring rehabilitation services (WHO, 2025a). Within this burden, unsafe PLD listening habits are a growing concern: approximately 0.67–1.35 billion adolescents and young adults are potentially at risk of hearing loss from unsafe listening practices, and many users remain unaware of the associated auditory risks despite the widespread popularity of PLDs (Dillard et al., 2022; El-Mawgoud, 2020).

In Indonesia, hearing loss remains a significant public health problem. Based on Riskesdas 2013, the prevalence of hearing loss among the population aged over 5 years reached 2.6%, with 4.6% experiencing deafness and 16.8% experiencing hearing impairment (Malik et al., 2026). Consistent with the global pattern above, local research in Cimahi similarly linked unsafe PLD use, including listening durations over 60 minutes and volumes above 60%, to both auditory and non-auditory complaints among students, reinforcing that this risk increases with unsafe PLD use among adolescents and young adults (WHO, 2025b).

Exercise has become an important part of a healthy modern lifestyle, and running is among the most popular recreational sports, with rapidly growing communities worldwide (Gajdek et al., 2024). Its popularity increased further during and after the COVID-19 pandemic, as restrictions on outdoor activity encouraged new physical activity habits, including running (Adriani & Irwandy, 2024). Fakerunners, an active running community in Bandung established on January 22, 2017 with approximately 250 members, reflects this trend. Alongside this growth, PLD use, including bone conduction headphones, earphones, and in-ear monitors (IEMs), has become increasingly common among runners (Adriani & Irwandy, 2024; Chen et al., 2023; Flowers & Pillay, 2021; Haruna et al., 2023).

Runners represent a unique population for studying PLD-related hearing risk because their listening behavior differs from that of daily activities. Running often occurs amid considerable environmental noise (traffic, wind, surrounding activity), which can mask perceived music clarity and prompt runners to raise their listening volume; motivational music is also commonly used to enhance performance and reduce perceived exertion (Clark et al., 2021; Flowers & Pillay, 2021). Supporting this, Flowers and Pillay (Flowers & Pillay, 2021) found that average listening volume during exercise reached approximately 70% of maximum. The combination of environmental noise, elevated listening volume, and prolonged PLD use during exercise may therefore increase runners' risk of auditory damage.

Audiometric examination remains the gold standard for diagnosing hearing loss. In NIHL, audiograms commonly demonstrate a characteristic notch at the 4000 Hz frequency due to cochlear damage (Kristianti & Nurrokhmawati, 2020). However, pure-tone audiometry requires specialized equipment, trained personnel, and controlled acoustic conditions, which may limit its application for large-scale community screening. Recent technological developments have introduced application-based hearing screening tools, including ScreenOut, Hearing Test, Mimi Hearing Test, Jacoti Hearing Center, and hearWHO, which may facilitate early detection of hearing impairment (Irace et al., 2021; Rahim et al., 2023).

ScreenOut is a hearing screening tool developed by PT Inovasi Kesehatan Digital to detect hearing impairment through an accessible and practical approach. Website-based hearing screening has been proposed as an alternative method in Indonesia because it does not require complex equipment and can facilitate broader community-based screening (Haruna et al., 2023). Research conducted at Muhammadiyah Hospital Bandung in 2022 demonstrated that ScreenOut had a sensitivity of 90.9% and specificity of 98.9% in detecting hearing impairment (Rahim et al., 2023). Although ScreenOut provides only a screening classification result (normal/hearing loss) and cannot replace diagnostic audiometry, previous studies have shown a strong correlation between ScreenOut hearing thresholds and audiometric measurements ($r = 0.843–0.899$), supporting its feasibility for early detection and mass screening (Rahim et al., 2023). These characteristics make ScreenOut suitable for field-based research among active communities, including runners, because it is practical, requires relatively short examination time, and can be applied outside clinical settings.

Although previous studies have investigated the relationship between PLD use and hearing impairment among adolescents, students, and young adults, evidence regarding PLD use specifically during exercise remains limited. Most previous studies have focused on general listening behavior rather than exercise-related listening patterns. Furthermore, limited research has evaluated hearing screening using application-based technology among sports communities in Indonesia. Therefore, further investigation is needed to understand whether PLD usage patterns during exercise are associated with hearing impairment among runners.

The primary objective of this study was to evaluate whether PLD-use duration and self-reported listening volume during exercise were associated with abnormal ScreenOut hearing-screening results among runners. Secondary objectives were to describe participant characteristics, smoking history, PLD type, data completeness, and the distribution of ScreenOut screening outcomes. Age, sex, and smoking history were considered potential confounders, while PLD type was considered an additional exposure characteristic because of differences in sound-delivery mechanisms.

METHOD

This analytical observational study used a cross-sectional design. Data were collected during three sessions: September 6, 2025, at Mojo Bandung, Jl. Prof. Eyckman No. 38, Bandung; September 20, 2025, at Madalangu Bake House, Jl. Pager Gunung No. 3, Bandung; and September 23, 2025, at Laoban Kopitiam, Jl. Brigadier Jend. Katamso No. 25, Bandung. Ethical approval was obtained from the Research Ethics Committee of the Faculty of Medicine, Jenderal Achmad Yani University (No. 038/UMI.08/2025), and all included participants provided written informed consent.

A minimum target of 62 participants was obtained using the single-population proportion formula; recruitment is reported as convenience sampling. A total of 94 runners were assessed for eligibility; 30 were excluded (17 non-PLD users, 7 with a history of hearing loss, 2 hearing-aid users, and 4 with hypertension), leaving 64 eligible participants included in the final analysis (Figure 1, consistent with STROBE item 13). Eligible participants were active runners aged 17–45 years who used PLDs during exercise and agreed to complete all study procedures. Exclusion criteria were outer- or middle-ear abnormality, a history of hearing loss, hearing-aid use, or a metabolic condition considered capable of affecting hearing, including diabetes mellitus, hypertension, hyperlipidemia, hyperuricemia, or obesity. The primary outcome was the ScreenOut screening classification (normal vs abnormal). The primary exposures were PLD-use duration (≤60 vs >60 minutes) and self-reported volume setting (≤60% vs >60% of the participant's own device maximum). PLD type was recorded as a separate categorical exposure characteristic. Age, sex, and smoking history were identified as potential confounders. Data were collected using a structured self-administered questionnaire; educational level was not collected.

After questionnaire completion, participants underwent otoscopy followed by researcher-guided ScreenOut screening. At each public venue, the research team selected a room or area judged to be relatively quiet. Consistency across the three sessions was sought by using the same eligibility criteria, questionnaire, examination sequence, ScreenOut procedure, and screening hardware. All 64 examinations used the same iPhone 12 Pro and Apple AirPods (2nd generation). ScreenOut presents tones at 500, 1,000, 2,000, 4,000, and 8,000 Hz at discrete application levels of 35, 55, and 75 dB. The study used the published 35-dB ScreenOut cutoff: detection at this level was treated as a normal result, while a result requiring a higher application level was treated as abnormal. Frequency- and ear-specific raw response data were not available in the manuscript for re-analysis. For PLD volume, participants estimated their usual listening setting during exercise as a percentage of their own device's maximum (0-

100%); categorized as ≤60% or >60%. PLD type was recorded as earphones, earbuds, headphones, bone-conduction headphones, or mixed device use (Rahim et al., 2023).

Several aspects of the protocol relied on practical judgment rather than instrumental verification. Background sound pressure at each venue was not measured with a sound-level meter, no objective dBA acceptance threshold was specified, and no ambient-noise log was retained. Screening was researcher-guided, but the available record does not document formal operator certification, a dedicated training course, or inter-rater reliability testing. Device firmware, browser/application build, and an external electroacoustic calibration record were not documented for the iPhone/AirPods combination; consequently, the 35/55/75-dB ScreenOut levels should not be interpreted as independently verified audiometric dB HL thresholds. Similarly, the self-reported volume percentage was not validated against device logs or measured acoustic output no sound-level meter, acoustic coupler/artificial ear, or dosimeter was used to convert the reported percentage to dB SPL.

The model is multivariable, containing two predictors, but is not confounder-adjusted: age, sex, and smoking history were not added because only 22 abnormal outcomes were observed, and including additional parameters, particularly the multi-category PLD-type variable, risked unstable or overfitted estimates in this small sample. PLD type was therefore analyzed descriptively as a separate categorical exposure; device-specific inferential estimates were not calculated because several categories were sparse (headphones n = 2, bone-conduction headphones n = 9, mixed use n = 6). Residual confounding and device-specific effects therefore remain unresolved. All collected variables shown in the analytic tables have totals of n = 64, with no item-level missing values evident in the tabulated dataset; complete-case analysis was used and no imputation was performed.

RESULTS

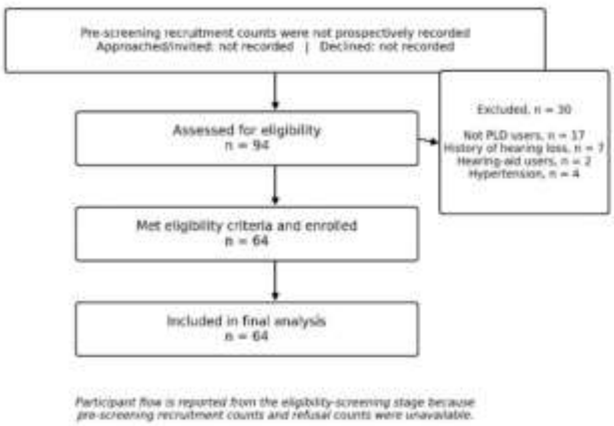

Figure 1. Participant flow through the study

A total of 94 runners were assessed for eligibility. Thirty were excluded: 17 because they did not use PLDs during exercise, 7 because of a history of hearing loss, 2 because of hearing-aid use, and 4 because of hypertension. The remaining 64 participants met the eligibility criteria and were included in the final analysis. The number initially approached or invited and the number declining before eligibility screening were not recorded; therefore, no recruitment response rate can be reported.

Table 1. Characteristics of participant

Variable	Categories	n	%
Age	17 – 25 years old	14	21.9
	26 – 35 years old	29	45.3
	36 – 45 years old	21	32.8
Gender	Male	31	48.4
	Women	33	51.6
PLDs use	Yes	64	100
	No	0	0
Outer & middle ear abnormalities	Yes	0	0
	No	64	100
History of hearing loss	Yes	0	0
	No	64	100
Metabolic disease	Yes	0	0
	No	64	100
Smoking	Yes	17	26.6
	No	47	73.4
Education level	Not collected	-	-
Total		**64**	**100**

The characteristics of respondents in this study are described based on age and gender to provide an overview of the demographic distribution of participants. This information is important to illustrate the composition of the study population and to support the interpretation of subsequent analytical findings. The detailed distribution can be seen in Table 1 below.

Among the 64 participants, 14 (21.9%) were aged 17–25 years, 29 (45.3%) were aged 26–35 years, and 21 (32.8%) were aged 36–45 years. Thirty-one participants (48.4%) were male and 33 (51.6%) were female. By design, all included participants used PLDs during exercise, and none had a recorded outer-/middle-ear abnormality, prior hearing loss, or metabolic disease meeting the study's exclusion criteria.

Seventeen participants (26.6%) reported smoking and 47 (73.4%) reported no smoking; smokers in the analytic sample were in the light-consumption category (<10 cigarettes/day) (Ningsih et al., 2018), Four screened individuals with hypertension were excluded before formation of the analytic sample and therefore do not appear as hypertensive participants in Table 1. Education level was not collected (n = 64 unavailable for that variable), whereas no missing values were evident for the other variables presented in Table 1.

Table 2. PLDs exposure characteristic and devices type

Variable	Categories	n	%
Duration of Use	≤60 minutes	44	68.8
	>60 minutes	20	31.3
Volume of PLDs Use	≤60%	38	59.4
	>60%	26	40.6
Type of PLDs	Earphones	20	31.3
	Earbuds	27	42.2
	Headphones	2	3.1
	Bone conduction headphone	9	14
	Mixed	6	9.4
Total		**64**	**100**

PLD exposure characteristics are shown in Table 2. Duration and volume were the two primary exposure variables used in the logistic-regression analysis. PLD type was retained as a separate categorical exposure because ear-canal air-conduction devices and bone-conduction headphones have different sound-delivery mechanisms. Based on Table 2, 44 participants (68.8%) had a PLD-use duration of ≤60 minutes, while 20 (31.3%) had a duration of >60 minutes. Most runners, 38 (59.4%), used PLDs at a volume ≤60% of their device's maximum, while 26 (40.6%) used >60%. These are behavioral categories based on self-report; the reported volume percentage was not converted to dB SPL and should not be interpreted as a standardized acoustic exposure threshold.

PLD type was available for all 64 participants: earbuds were used by 27 (42.2%), earphones by 20 (31.3%), bone-conduction headphones by 9 (14.1%), mixed device types by 6 (9.4%), and headphones by 2 (3.1%). The available dataset did not retain IEM as a separate category. Device type was therefore analyzed descriptively; a valid outcome-by-device-type inferential model could not be estimated from this small sample without unstable sparse-cell estimates, so device-specific odds ratios are not reported.

Table 3. Hearing screening results using ScreenOut on runners

Screening Results	n	%
Normal	42	65.6
Hearing Loss	22	34.4
Quantity	64	100

ScreenOut classified 42 participants (65.6%) as having a normal screening result and 22 (34.4%) as having an abnormal result, based on the application's 35-dB screening cutoff. The 34.4% value should not be interpreted as the prevalence of audiometrically confirmed hearing loss: ambient noise at the public testing venues was not measured and could have masked low-level stimuli, potentially increasing false-positive abnormal classifications. Because the study did not independently calibrate the iPhone/AirPods output to dB HL, the ScreenOut application levels should not be interpreted as equivalent to a conventional audiometric threshold obtained in a calibrated test environment. An abnormal ScreenOut result indicates a need for further assessment but does not by itself establish the exact hearing threshold, degree, type, or etiology of hearing loss; diagnostic pure-tone audiometry remains necessary to confirm and characterize any impairment.

Table 4. Exploratory binary logistic regression of PLDs duration and self-reported volume with abnormal ScreenOut results

Variable	B	p-value	OR	95%CI
Duration >60 min vs ≤60 min	0.955	0.095	2.599	0.848 – 7.968
Volume >60% vs ≤60%	0.127	0.819	1.136	0.382 – 3.380

For PLD-use duration, the estimated odds ratio (OR) was 2.599 (95% CI: 0.848–7.968; p = 0.095) for participants reporting >60 minutes of use compared with ≤60 minutes. Although the point estimate exceeded 1, the confidence interval included 1, indicating no statistically significant association between PLD-use duration and abnormal ScreenOut results. For self-reported PLD volume, the estimated OR was 1.136 (95% CI: 0.382–3.380; p = 0.819) for participants reporting >60% of device maximum compared with ≤60%. This association was also not statistically significant. As noted above, because this measure was self-reported and not calibrated to dB SPL, the estimate reflects an association with reported device volume rather than with a standardized acoustic intensity.

These findings should be interpreted in light of the study's sample and model limitations. Of the 64 participants, 22 had abnormal ScreenOut results. Age, sex, and smoking history were identified as potential confounders but were not included as model covariates, given the limited number of abnormal outcomes relative to the total sample; PLD type was likewise excluded from the inferential model for the sparse-cell reasons noted earlier. The regression estimates therefore provide exploratory information on the associations between PLD-use duration, self-reported volume, and abnormal ScreenOut results, while residual confounding and device-specific associations remain unresolved.

DISCUSSION

The present study found no statistically significant association between PLD-use duration or self-reported PLD volume and abnormal ScreenOut results. Although the point estimates for both exposure variables were greater than 1, the findings do not provide sufficient statistical evidence of an association. The relatively wide confidence intervals indicate uncertainty around the estimates, which should be considered in the context of the small sample size and the limitations of exposure and outcome measurement.

These findings can be compared with those reported by Engdahl and Aarhus (2021) from the HUNT Cohort Study, which included 26,606 participants in the cross-sectional analysis and 12,115 participants in the 20-year follow-up cohort and assessed hearing using pure-tone audiometry. Their study found no association between personal music player use or duration of use and 20-year progression in hearing thresholds, whereas higher listening volume was associated with higher hearing thresholds in the cross-sectional analysis. The findings are therefore not directly contradictory to those of the present study. Differences in sample size, population, study design, exposure categorization, and hearing assessment may contribute to the different findings. The present study included only 64 runners from one running community and used application-based hearing screening, whereas the HUNT study used pure-tone audiometry in a substantially larger population.

The absence of a statistically significant association in the present study does not imply that prolonged or high-intensity sound exposure is biologically harmless. Repeated exposure to high-intensity sound may damage cochlear structures, particularly outer hair cells, and contribute to noise-induced hearing loss (Natarajan et al., 2023). Prolonged listening duration and high listening volume have also been identified as factors relevant to the risk of music-induced hearing damage (Portnuff, 2016; WHO, 2025b; Zachreini, 2016). This biological plausibility is reinforced by the technical output capacity of current PLDs: maximum output for earbuds ranges from 101–107 dBA, reaching up to 120 dBA with certain player–earphone combinations (Portnuff, 2016), well within levels capable of producing cumulative cochlear damage with prolonged use. NIHL itself involves several biological mechanisms, including oxidative stress, inflammation, mitochondrial dysfunction, and cellular injury, which may contribute to irreversible cochlear damage (Kishimoto-Urata et al., 2022; Natarajan et al., 2023; Zhou et al., 2023). However, these mechanisms were not directly assessed in the present study and therefore cannot be used to explain the observed findings conclusively.

The behavioral distribution observed in this sample offers additional context for the null association. Most runners reported durations and volumes within WHO's relatively safe thresholds (<60 minutes and <60% of maximum volume), though a notable proportion exceeded these limits and may therefore remain at risk of NIHL (Alshamrani et al., 2022; Dillard et al., 2022; Kristianti & Nurrokhmawati, 2020; Sparrow & Flenady, 2025; Zachreini, 2016). The characteristics of running activity may partly explain this pattern: runners often raise volume beyond safe limits to maintain listening clarity amid environmental noise (H. & Paul, 2021), and high-intensity, fast-tempo music is frequently chosen to enhance motivation, which may indirectly increase sound exposure (Clark et al., 2021). Even so, not all respondents with elevated exposure exhibited hearing impairment, suggesting that the impact of PLD use on auditory function may also depend on other factors such as cumulative exposure duration and long-term usage habits beyond what a cross-sectional design can capture (Alshamrani et al., 2022).

The interpretation of the abnormal ScreenOut results should also consider the conditions under which screening was performed. Screening took place in public café or food-service venues rather than sound-treated booths, and ambient noise was not objectively measured conditions that could have masked low-level stimuli and increased false-positive abnormal classifications. This differs from the ScreenOut validation study by Rahim et al. (Rahim et al., 2023), in which screening was conducted in an environment with noise levels below 50 dB and ScreenOut results were compared with audiogram findings; that study reported high diagnostic performance and a very strong correlation between ScreenOut and audiometry. Although these findings support the potential utility of ScreenOut for hearing screening, differences in testing conditions mean the 34.4% proportion of abnormal results in this study should not be interpreted as a definitive prevalence estimate of hearing impairment, but rather as a screening-level indicator warranting further evaluation.

Exposure measurement was another important limitation. PLD-use duration and volume were self-reported, and the volume percentage was not validated against device logs or calibrated to dB SPL; the same nominal setting may correspond to different sound-pressure levels under different listening conditions, meaning the present study assessed self-reported device settings rather than objectively measured acoustic exposure or sound dose. In addition, convenience sampling, the small number of abnormal outcomes, and the limited total sample restricted adjustment for potential confounders: age, sex, and smoking history were not included as additional model covariates, and PLD type was not analyzed inferentially because several device categories were small. These factors may have contributed to residual uncertainty in the observed associations.

Despite the absence of statistically significant associations, the findings have practical implications for hearing-health promotion among running communities. Respondents with abnormal screening results are advised to undergo further evaluation at an otorhinolaryngology (ENT) clinic for comprehensive audiometric testing, hearing rehabilitation, or pharmacological management as indicated. Audiometric examination remains necessary to quantitatively determine the degree of hearing loss (mild, moderate, severe, or profound) and to differentiate between conductive, sensorineural, or mixed hearing loss, since impairment is generally progressive and cumulative; early detection and intervention may prevent further deterioration of auditory function and enhance individual awareness regarding safer PLD usage practices. More broadly, hearing-health education can encourage runners to reduce listening volume and duration, take regular listening breaks, and use safe-listening features where available. For runners exercising in environments with substantial ambient noise, volume should not simply be increased to overcome environmental noise, while adequate awareness of surrounding sounds should be maintained. WHO emphasizes that both sound level and duration contribute to hearing risk and recommends reducing exposure to loud sounds, monitoring sound exposure, and taking listening breaks; WHO has also recommended that PLD manufacturers promote safe listening, such as incorporating warning messages when users exceed recommended maximum sound intensity (WHO, 2015, 2025b).

The findings should be interpreted cautiously with regard to generalizability. Because participants were recruited from a single running community in Bandung, the results may not represent runners from other communities, locations, or exercise backgrounds. Future studies should recruit larger and more diverse populations and use longitudinal designs, standardized pure-tone audiometry in controlled environments to confirm screening-based findings, and objective measurements of PLD exposure. Such approaches would improve the ability to evaluate temporal and dose-response relationships between PLD exposure and hearing outcomes (Le Prell et al., 2022; Mui et al., 2025; Yesantharao et al., 2022).

CONCLUSION

This cross-sectional study described PLD-use patterns and ScreenOut hearing-screening results among 64 runners recruited by convenience sampling. ScreenOut classified 42 participants (65.6%) as normal and 22 (34.4%) as abnormal at the application-specific 35-dB screening cutoff. The exploratory logistic-regression analysis found no statistically significant association between abnormal ScreenOut results and either PLD use for >60 minutes or self-reported volume >60% of device maximum. PLD type was described separately, with earbuds being the most common device type, but device-specific inferential associations could not be reliably estimated in the available sample.

These findings do not establish a causal relationship between PLD use and hearing impairment and should not be interpreted as an estimate of hearing-loss prevalence. Interpretation is limited by the non-probability sampling approach, unmeasured ambient noise during screening, lack of independent verification of ScreenOut output in the study hardware, self-reported PLD volume, and the absence of full adjustment for potential confounders. Larger studies using objective acoustic-exposure measurements, controlled screening conditions, diagnostic pure-tone audiometry, and adequately powered multivariable analyses are warranted to further evaluate the relationship between PLD use and hearing outcomes among runners.

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