LANGUAGE, TECHNOLOGY, AND SOCIAL MEDIA

ISSN: 3026-7196

Occupational Noise Exposure and Age as Predictors of Disabling Hearing Loss in Pakistan

Huma Hanif*, Ibtasam Thakur, Georgios P. Georgiou, and Paris Binos

To cite this article. H. Hanif, I. Thakur, G. P. Georgiou, and P. Binos, "Occupational Noise Exposure and Age as Predictors of Disabling Hearing Loss in Pakistan," *Lang. Technol. Soc. Media*, vol. 4, no. 1, pp. 54–69, 2026.
DOI: https://doi.org/ 10.70211/ltsm.3026-7196.275

OPEN ACCESS

Language, Technology, and Social Media Vol 4 No 1 (2026) https://doi.org/10.70211/ltsm.3026-7196.275

Check for updates

Research Article

Occupational Noise Exposure and Age as Predictors of Disabling Hearing Loss in Pakistan

Huma Hanif*, Ibtasam Thakur, Georgios P. Georgiou, and Paris Binos

Received: 27 August 2024	Revised: 28 October 2025	Accepted: 16 November 2025	Online: 17 November 2025

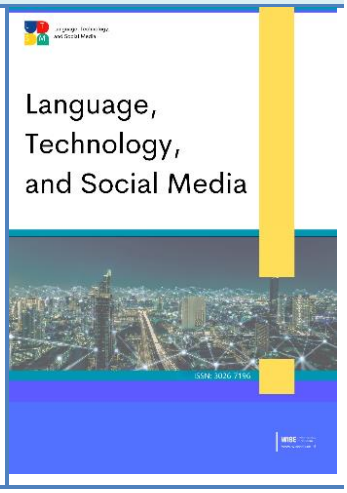
Abstract

This study aimed to assess the prevalence, severity, and functional impact of hearing loss (HL) in Rawalpindi and Islamabad, Pakistan. A total of 400 participants, aged 12 to 70 years, were enrolled in the study, and data were collected using pure-tone audiometry (PTA) and the Hearing Handicap Inventory for Adults (HHIA). The results indicated that 18% of participants had some form of HL, with 22% meeting the criteria for disabling HL (≥35 dB HL). The severity of HL ranged from mild to profound, with 55% of participants exhibiting no measurable HL. Sensorineural HL was the most common type (60%), followed by conductive (24%) and mixed (10%) types. Bivariate analysis revealed that older age (≥60 years) and occupational noise exposure were significantly associated with HL ≥35 dB HL. The multivariable logistic regression model confirmed that age and occupational noise exposure were independent predictors of HL. Furthermore, hearing aid users reported significantly lower HHIA scores, indicating reduced psychosocial burden compared to non-users. This study highlights the need for early detection, public health interventions, and increased access to hearing aids, particularly in rural areas. The findings also demonstrate the importance of occupational noise control and workplace interventions to reduce the risk of HL in high-noise environments. The study contributes to the understanding of HL in Pakistan, offering valuable insights for improving hearing care accessibility and policy development.

Keywords: Hearing Loss; Audiometry; Hearing Aid; Occupational Noise Exposure; Psychosocial Burden; Pakistan; Public Health; HHIA

Publisher's Note:

WISE Pendidikan Indonesia stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



INTRODUCTION

Hearing loss (HL) is a significant public health concern globally, affecting millions of individuals across diverse demographics. According to the World Health Organization (WHO), approximately 1.5 billion people are currently living with some degree of HL, and 430 million of them suffer from disabling HL [1], [2]. In this context, "disabling HL" follows the WHO epidemiological classification, which defines it as a hearing threshold of ≥ 35 dB HL in the better ear. This classification is intended for public-health reporting and does not imply a clinical or functional diagnosis of disability. It is also recognized that even mild or sub-threshold losses can have significant communicative and educational consequences, particularly among children and young adults. In Pakistan, the burden of HL is substantial, with an estimated 14.5 million people (6.9% of the population) affected [3], [4], [5]. Despite the considerable prevalence, early detection and intervention programs remain underdeveloped, particularly in rural areas [6], [7]. The lack of accessible hearing care services exacerbates the public health challenge, leading to negative outcomes for individuals with HL, such as reduced communication abilities, impaired social participation, and limited educational and employment opportunities.

In children, untreated HL can delay speech and language development, causing significant academic underachievement and psychological distress [8], [9]. For adults, HL leads to a reduction in productivity, social stigmatization, and an increased risk of mental health issues, including depression [10]. In older adults, untreated HL is associated with cognitive decline and social isolation, further impacting their overall quality of life [11], [12], [13]. Unfortunately, cost-effective interventions such as the universal newborn hearing screening (UNHS), vaccination, and affordable hearing aids are not widely available or utilized in Pakistan. Although UNHS has been successful in detecting congenital HL, it remains limited in identifying mild, low-frequency, progressive, and delayed-onset HL (DOHL). Without continued audiologic monitoring, such cases may remain undetected until developmental or educational problems emerge. Accordingly, global best practices now emphasize Early Hearing Detection and Intervention (EHDI) frameworks as recommended by the Joint Committee on Infant Hearing (JCIH), which advocate ongoing audiometric surveillance throughout childhood to ensure timely diagnosis and intervention. Moreover, social stigma around using hearing aids further reduces their uptake, despite their proven benefits for improving communication and psychosocial wellbeing [14], [15], [16].

Although several studies have explored hearing-related health issues in Pakistan, there remains a gap in comprehensive research that combines audiometric data with functional impairment assessments. Most of the existing research has either focused on children or industrial workers, while broader community-based studies are limited. For example, a study by Riaz et al. [17] found a prevalence of chronic otitis media exceeding 20% among schoolchildren in Rawalpindi, while Aliyeva and Sari [18] highlighted the role of occupational noise exposure in the development of HL among factory workers. However, there is limited research that simultaneously addresses the prevalence, severity, and functional impact of HL in a general population sample, especially one that includes both urban and rural residents.

This study aims to fill this gap by providing a comprehensive analysis of the prevalence, severity, and functional impact of HL in Rawalpindi, Pakistan, using both standardized audiometric assessments and self-report hearing handicap questionnaires. The goal is to identify significant risk factors for disabling HL and to provide evidence that can inform public health interventions. This research also contributes to the broader understanding of HL in low-resource settings and

demonstrates the emergency for integrating hearing care into national health systems to address the growing burden of HL.

LITERATURE REVIEW

Global and National Prevalence of HL

HL remains a growing global public health concern, affecting hundreds of millions of individuals worldwide, as highlighted in recent international reports [19], [20], [21]. Pakistan is no exception, with tens of millions of cases reported [22], [23]. However, early diagnosis and intervention remain limited, particularly in rural areas where healthcare resources are scarce. Studies consistently show that the prevalence and impact of HL are increasing, leading to substantial challenges in communication, education, and overall quality of life [24], [25].

Risk Factors for HL

The risk factors for HL are multifaceted, including genetic predispositions, environmental exposures, and age-related changes. Many workers are routinely exposed to hazardous levels of noise in their workplaces. Such exposure is a significant contributor to HL in adults, particularly in industrial and transport sectors. Sheppard et al. [26] reported that workers exposed to high levels of occupational noise had a higher incidence of HL. Similarly, studies have shown that recurrent ear infections, particularly in childhood, are strong predictors of HL later in life [27], [28]. Furthermore, advancing age has been identified as a critical risk factor, with older adults experiencing a higher prevalence of disabling HL [29], [30], [31]. In addition, unsafe listening practices among adolescents and young adults, such as high-volume use of personal audio devices or frequent attendance at loud entertainment venues, have been shown to substantially increase the risk of hearing impairment in later life [32], [33], [34].

Functional Impact of HL

HL not only affects hearing but also has profound psychosocial and emotional impacts. The Hearing Handicap Inventory for Adults (HHIA) is a validated tool that assesses the functional impact of HL on individuals' lives, including social, emotional, and communication difficulties. Research has shown that individuals with HL experience increased social isolation, depression, and challenges in everyday communication [35], [36], [37]. The importance of providing hearing aids and other assistive technologies to mitigate these impacts has been well-documented in international studies [38]. However, the uptake of such devices remains low, especially in low- and middle-income countries (LMICs) like Pakistan, due to stigma, cost, and limited availability [30], [31].

The Role of Technology in Mitigating the Impact of HL

Technological advancements in hearing aids, cochlear implants, and speech processing technologies have significantly improved the lives of those with HL. Hearing aids, in particular, have been shown to improve communication abilities, reduce the functional impact of HL, and enhance the quality of life for individuals with disabling HL [32], [33]. Despite these advancements, the availability and usage of such technologies in LMICs are limited, primarily due to cost and lack of awareness. Research by Knoetze et al. [39] emphasized the barriers to hearing aid uptake in South Asia, suggesting that public health initiatives should focus on awareness, affordability, and accessibility of hearing technologies.

Gaps in the Literature and Study Rationale

While there has been significant research on the prevalence and risk factors for HL in Pakistan, there is a lack of comprehensive studies that combine both audiometric data and functional impact assessments. Most studies have either focused on specific populations such as children or workers, limiting the generalizability of the findings [35], [36]. This study aims to fill this gap by providing a broad community-based analysis of the prevalence, severity, and functional impact of HL in Rawalpindi, Pakistan. By incorporating both objective audiometric assessment and psychosocial measures, this research examines multiple risk factors simultaneously, offering a more complete understanding of HL in the general population.

METHODS

Study Design

This study employed a cross-sectional analytic design to assess the prevalence, correlates, and functional impact of HL in Rawalpindi, Pakistan. The cross-sectional design was chosen to provide a snapshot of the extent of HL in the population and to identify factors associated with disabling HL at a specific point in time. This approach is suitable for epidemiological studies aimed at understanding the distribution and determinants of health conditions within a defined population. The design also facilitates the collection of both quantitative audiometric data and self-reported functional data, offering a comprehensive understanding of HL's impact on the community.

Study Setting

The research was conducted between January and June 2024 in Rawalpindi and Islamabad, Pakistan. These cities were selected because they represent both urban and semi-urban settings in Pakistan, providing a diverse sample in terms of demographics, healthcare access, and environmental exposure to risk factors such as noise. Data were collected from multiple settings, including community health centers, secondary schools, and one tertiary Ear, Nose, and Throat (ENT) clinic, ensuring a wide representation of the general population and high-risk groups (e.g., schoolchildren and workers). To ensure representativeness, recruitment procedures were designed to achieve an approximately balanced distribution across age and gender groups. Participants were purposively enrolled to reflect a broad age range and near-equal gender proportions, with no overrepresentation of either males or females in any specific age group. Although stratified random sampling was not applied, age and gender distributions were continuously monitored during data collection to maintain demographic balance across study sites.

Participants

The study sample comprised 400 participants, with a mean age of 41.5 years (SD = 16.2), ranging from 12 to 70 years. Participants were recruited through a convenience sampling approach from community health centers, secondary schools, and one tertiary ENT clinic. The baseline demographic and clinical characteristics of the participants are summarized in Table 1. Because recruitment was based on voluntary participation across these diverse settings, the demographic distribution reflects natural availability within each site rather than a stratified sampling framework. However, efforts were made to maintain balance in age and gender representation during data collection to avoid bias toward any particular subgroup. In terms of risk factors, 21% of participants

reported exposure to occupational noise, 22.5% had a history of recurrent ear infections, and 18% had a family history of HL. Only 7% of participants were current hearing-aid users. These characteristics highlight the demographic and clinical diversity of the sample.

Table 1. Demographic Characteristics of Participants

Characteristic	Value
Age	Mean (*SD*) = 41.5 (16.2) years
Female	216 (54%)
Rural Residence	192 (48%)
Occupational Noise Exposure	84 (21%)
Recurrent Ear Infections	90 (22.5%)
Family History of HL	72 (18%)
Current Hearing-Aid User	28 (7%)

Ethical Considerations

The study was approved by the Institutional Review Board (IRB) of Lahore College for Women University. Although no specific file number was issued, the committee formally approved the study protocol prior to data collection. All participants provided written informed consent before participation, and parental consent was obtained for participants under the age of 18. The research adhered to the ethical guidelines set forth by the Declaration of Helsinki regarding participant rights, confidentiality, and data management.

Data Collection

Data were collected through a structured protocol, which involved two primary components: audiometric testing and functional assessment through questionnaires.

Audiometric Testing

Pure-tone thresholds at 0.5, 1, 2, and 4 kHz were obtained, and a four-frequency pure-tone average (PTA4) was calculated for each ear. PTA4 was conducted using a calibrated portable audiometer (ISO 8253-1 standards) to assess the air- and bone-conduction thresholds. A standard masking protocol was employed in cases where interaural differences exceeded 40 dB HL for air conduction or 15 dB HL for bone conduction, using narrowband noise as the masker in accordance with ISO 8253-1 (2010) recommendations. PTA is considered the gold standard for assessing HL and is widely used in epidemiological research on HL. Disabling HL was defined as a threshold greater than 35 dB in the better ear according to the World Health Organization (WHO) epidemiological classification for public-health reporting [37], [38]. This definition was applied for consistency with global prevalence studies and does not imply a clinical or functional diagnosis of disability. It is acknowledged that even slight or mild losses below this threshold can still exert significant communicative and educational impacts. This threshold was selected because it captures clinically significant HL that affects daily activities such as communication, education, and employment [38], [39], [40]. The severity of HL in the sample was categorized into the degrees outlined in Table 1, providing a comprehensive view of the distribution of HL severity.

Questionnaire and Functional Assessment

The HHIA was administered to assess the functional impact of HL on psychosocial well-being. It comprises a validated self-reported tool designed to measure both emotional and social effects of HL. This tool has been widely used in clinical and epidemiological studies and has been validated in the Pakistani context through the forward-backward technique to ensure cultural and linguistic relevance [41], [42]. The questionnaire was designed to collect key demographic and risk factor information, such as age, gender, type of employment, residence, education level, history of recurrent ear infections, and hearing aid use.

The HHIA scores were analyzed to assess the emotional and social effects of HL. In addition to the HHIA, the questionnaire gathered data on hearing aid use, as it is an important factor in reducing the perceived functional handicap caused by HL. Functional assessment in this study relied solely on the HHIA because speech audiometry was not feasible across community and school settings due to time and equipment constraints. Moreover, the HHIA has been validated as a reliable proxy measure of functional and psychosocial impact in large-scale epidemiological research.

Statistical Analysis

The data were analyzed using SPSS version 25, and the analysis consisted of several key steps to assess the relationships and patterns within the data. Because participants were recruited through a convenience sampling approach, the regression analyses were interpreted as exploratory and associative rather than inferential or predictive at the population level. The findings, therefore, reflect relationships observed within the sampled population and should not be generalized beyond the study context. Below is a detailed description of the analytical steps used.

Bivariable Analysis

Associations between categorical variables (i.e., age, occupational noise exposure, gender) were examined using chi-square tests (χ^2). For continuous variables, such as HHIA scores, an independent *t*-test was used to assess significant differences between groups, namely, hearing-aid users vs non-users with disabling HL. The significance level was set at $p < 0.05$, which is considered statistically significant.

Multivariable Logistic Regression

To identify independent predictors of disabling HL, a multivariable logistic regression model was employed. This model accounted for potential confounding factors such as age, gender, occupation, rural residence, and recurrent ear infections. The odds ratios (OR) with 95% confidence intervals (CIs) were calculated for each predictor to quantify their association with disabling HL. This regression analysis helped to determine which factors independently contribute to the likelihood of experiencing disabling HL, adjusting for other variables. An overview of the study's methodology is illustrated in Figure 1.

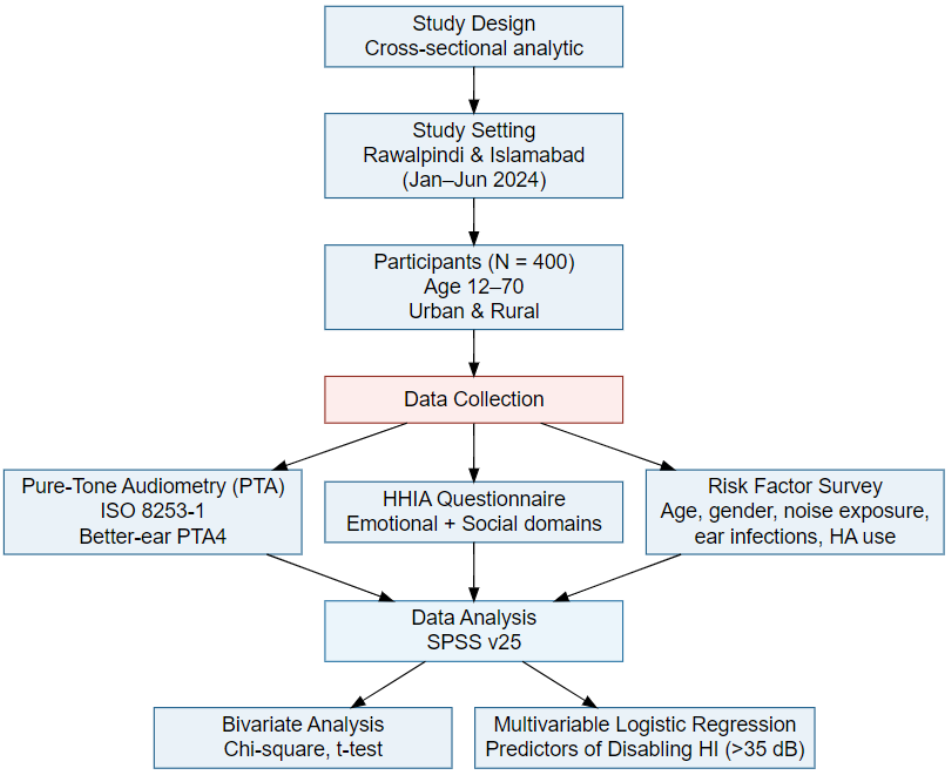


Figure 1. An overview of the study's methodology

RESULTS AND DISCUSSION

Prevalence of HL

The prevalence of HL among the study participants varied by severity, as shown in Table 2 and Figure 2. Of the 400 participants, 55% exhibited no measurable HL, 23% had mild HL, and 22% met the criteria for disabling HL (HL ≥ 35 dB HL). The severity distribution also revealed that 13.5% of participants had moderate to severe impairment, highlighting the substantial burden of HL across different levels of severity.

Table 2. Prevalence and Degree of HL (Better Ear, PTA4)

Degree of HL (dB HL)	n (%)
None (<20)	220 (55%)
Mild (20–34.9)	92 (23%)
Moderate (35–49.9)	54 (13.5%)
Moderately Severe (50–64.9)	18 (4.5%)
Severe (65–79.9)	10 (2.5%)
Profound (≥80)	6 (1.5%)
Disabling HL (>35)	88 (22%)

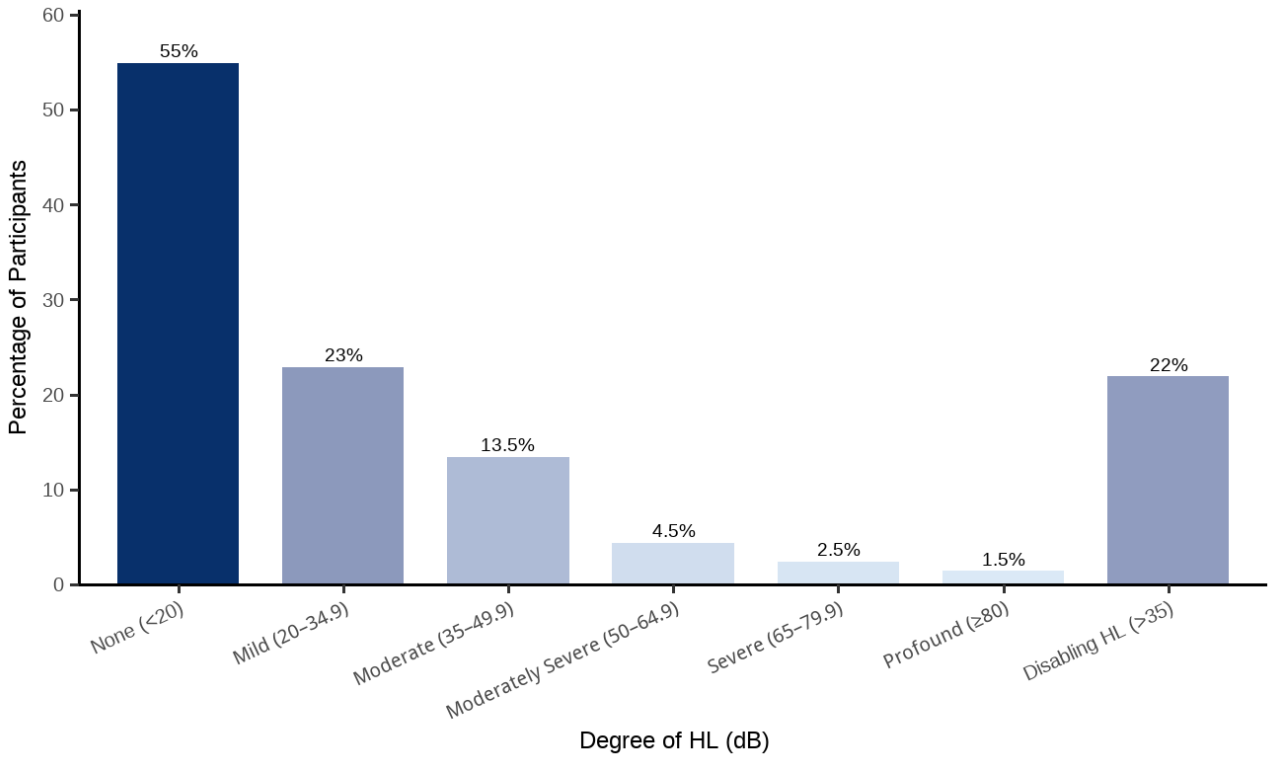


Figure 2. Prevalence and Degree of HL (Better Ear, PTA4)

Type of HL

Among participants with measurable HL, sensorineural HL (SNHL) was the most common type, affecting 60% of participants. This was followed by conductive HL (24%) and mixed types (10%). The remaining 6% of participants showed an indeterminate HL type, as shown in Table 3.

Table 3. Type of HL by Tympanometric Pattern (n=400)

Type of HL	n (%)
Conductive	96 (24%)
Sensorineural	240 (60%)
Mixed	40 (10%)
Indeterminate	24 (6%)

Bivariate Analysis of Risk Factors for Disabling HL

Bivariate analysis using chi-square tests (χ^2) revealed significant associations between age and occupational noise exposure with the prevalence of disabling HL. Specifically, older adults (⩾60 years) had a significantly higher prevalence of disabling HL (36%) compared to younger adults (18%). Occupational noise exposure was also associated with a higher prevalence of disabling HL (32% vs. 20%) (see Table 4).

Table 4. Bivariate χ^2 Associations with Disabling HL

Variable	Group Comparison	Disabling HL (%)	χ^2 (df)	*p*-value
Age	≥60 vs. <60	36% vs. 18%	17.8 (1)	<0.001

Variable	Group Comparison	Disabling HL (%)	χ^2 (df)	*p*-value
Occupational Noise Exposure	Exposed vs. Not Exposed	32% vs. 20%	6.4 (1)	0.012
Gender	Male vs. Female	25% vs. 19%	3.7 (1)	0.054

Multivariable Logistic Regression Results

The multivariable logistic regression model identified age and occupational noise exposure as independent predictors of disabling HL. As shown in Table 5, each ten-year increase in age was associated with a 38% higher likelihood of disabling HL (adjusted odds ratio [aOR] = 1.38, 95% CI: 1.18–1.61, $p < 0.001$). Similarly, participants exposed to occupational noise had 1.58 times higher odds of experiencing disabling HL compared to those without such exposure (aOR = 1.58, 95% CI: 1.01–2.50, $p = 0.046$). Other variables, including recurrent ear infections, male gender, and rural residence, were not statistically significant predictors after adjustment for confounders, although recurrent ear infections showed a positive trend (aOR = 1.60, 95% CI: 0.96–2.65, $p = 0.072$). These results indicate that both increasing age and exposure to occupational noise are key independent risk factors for disabling HL in the studied population. The results are shown in Table 5.

Table 5. Multivariable Logistic Regression Results (Outcome: Disabling HL)

Predictor	Adjusted Odds Ratio (aOR)	95% CI	*p*-value
Age (per 10 years)	1.38	1.18–1.61	<0.001
Occupational Noise Exposure	1.58	1.01–2.50	0.046
Recurrent Ear Infections	1.60	0.96–2.65	0.072
Male Gender	1.34	0.88–2.05	0.142
Rural Residence	1.22	0.76–1.95	0.420

Functional Impact of HL and Hearing Aid Use

The HHIA was used to assess the psychosocial burden of HL. Based on the result of the *t*-test, participants who used hearing aids reported significantly lower HHIA scores compared to non-users with disabling HL, indicating a reduction in the functional impact of their HL (see Table 6). The mean HHIA score for hearing aid users was 40.5 ($SD = 17.6$), compared to 55.8 ($SD = 15.9$) for non-users.

Table 6. Comparison of HHIA Scores by Hearing Aid Use

Group	HHIA Mean Score (SD)	Mean Difference	95% CI	*p*-value
Hearing-Aid Users	40.5 (17.6)	−15.3	−21.8 to −8.8	<0.001
Non-users with Disabling HL	55.8 (15.9)			

Discussion

The findings of this study confirm that HL is a significant public health concern in Pakistan, with a prevalence of 22% of participants meeting the criteria for disabling HL. This is in line with global

studies indicating that HL is one of the most prevalent sensory impairments, which significantly impacts communication, social participation, and overall well-being [1], [19], [43]. The study highlights the burden of HL in both urban and rural populations, reinforcing the need for targeted public health interventions and better access to hearing care services, especially in underdeveloped regions. A critical finding in this study is the strong association between age and disabling HL. Participants aged 60 years or older exhibited nearly double the prevalence of disabling HL compared to younger adults. This result is consistent with a large body of literature showing that age-related HL is a major contributor to HL in older adults, as the auditory system undergoes degenerative changes over time [14], [32], [45], [46], [47]. In Pakistan, where access to hearing care services is often limited, particularly in rural areas, older adults face compounded challenges in managing HL. The lack of early intervention and limited access to assistive technologies such as hearing aids exacerbate the issue, making age a significant determinant of disabling HL. This finding calls for urgent age-targeted interventions, including early screening programs and rehabilitative services such as hearing aids, to mitigate the growing burden of HL among older populations.

Occupational noise exposure also emerged as a significant risk factor for disabling HL in this study. Workers exposed to high levels of noise in industries such as manufacturing and transportation were found to have a significantly higher prevalence of HL compared to non-exposed workers. This finding is consistent with previous research by Wang et al. [48] and Aliyeva and Sari [18], which has shown a strong correlation between occupational noise exposure and the development of HL. The WHO has highlighted the need for noise control regulations in the workplace, as noise-induced HL is a preventable condition with appropriate safeguards [7]. In Pakistan, where industrial growth is accelerating, the implementation of occupational safety measures, including routine hearing screenings and noise protection, is essential to reduce the prevalence of workplace-related HL. One of the most compelling findings of this study is the protective effect of hearing aids on the functional impact of HL. Participants who used hearing aids reported significantly lower HHIA scores, reflecting a reduced psychosocial burden. This is consistent with global research demonstrating that hearing aids improve communication, reduce social isolation, and enhance quality of life for individuals with HL [8], [9]. However, the study found that only 7% of participants were current hearing aid users, highlighting a significant accessibility gap in the population. Barriers such as cost, stigma, and lack of awareness about the benefits of hearing aids continue to impede their widespread adoption in Pakistan. This is a crucial finding, as it indicates the need for public health campaigns that educate the public about the benefits of hearing aids and work towards making these technologies more affordable and accessible, particularly in rural areas.

The findings also suggest that digital media technologies can play a vital role in improving access to hearing care. Telemedicine, online consultations, and e-health platforms can provide more widespread access to hearing assessments and interventions, especially in areas with limited healthcare infrastructure [49]. Mobile apps for noise monitoring, online hearing aid fittings, and HL education could significantly improve awareness and accessibility. As the world becomes more digital, media technology can bridge the gap in healthcare delivery and offer accessible solutions for managing HL. The intersection of media technology and linguistic accessibility is crucial, particularly in countries like Pakistan, where traditional healthcare systems are strained.

This work also adds significant novelty to the existing body of research by integrating audiometric assessments with subjective functional assessments, using both PTA and the HHIA questionnaire. While previous studies in Pakistan have focused primarily on audiometric data or specific population subsets such as children or industrial workers [20], [46], this study combines both objective measurements of HL and self-reported functional data, providing a more comprehensive view of the impact of HL. By incorporating both physical and psychosocial dimensions of HL, the study highlights the multifaceted nature of HL and its effects on everyday life, which is a perspective often overlooked in previous research. Furthermore, this research emphasizes the importance of hearing aids not just as a medical tool but as a key component of social inclusion and communication accessibility. The role of hearing aids and other assistive technologies in enhancing linguistic accessibility in digital spaces is a critical area for future exploration, especially as the world becomes increasingly reliant on digital communication platforms.

CONCLUSION

This study provides a comprehensive evaluation of HL in Pakistan, highlighting its significant prevalence, severity, and functional impact. The findings underscore the crucial need for targeted public health interventions to address the rising burden of HL, especially in rural areas and among older adults. The study also identifies age and occupational noise exposure as critical predictors of disabling HL, both of which should be prioritized in future healthcare and policy interventions. The study's integration of audiometric testing with functional assessments, using both PTA and the HHIA, represents a significant contribution to understanding the multidimensional impact of HL. The results demonstrate the protective effect of hearing aids in mitigating the psychosocial burden of HL, reinforcing the importance of increasing access to assistive technologies in Pakistan, particularly in rural and underserved areas.

Despite the positive findings, the study highlights a critically low rate of hearing aid use, which continues to limit efforts to reduce the functional and psychosocial burden of HL. Addressing this gap requires coordinated public health initiatives that increase awareness, lower financial barriers, and reduce the social stigma associated with hearing aids. To achieve lasting impact, future research should adopt longitudinal designs to evaluate the long-term benefits of hearing aids and other rehabilitative interventions. Moreover, integrating digital health technologies into hearing care could enhance accessibility, particularly for underserved rural populations. Bridging the digital divide and promoting linguistic accessibility through technology-enabled solutions would allow individuals with HL to participate more fully in both social and digital spheres. Overall, this study contributes valuable evidence for improving hearing care delivery in Pakistan and offers insights applicable to other low- and middle-income contexts. Its holistic approach linking clinical, functional, and technological dimensions underscores the potential for policy and innovation to create more inclusive and effective hearing healthcare systems.

LIMITATIONS

This study has several limitations. The cross-sectional design limits the ability to establish causal relationships between risk factors and disabling HL. Longitudinal studies would be necessary to track the progression of HL over time and assess the long-term effects of interventions. Additionally, the use of self-reported data for variables such as occupational noise exposure,

hearing aid use, and history of recurrent ear infections introduces the potential for recall bias. Future research could benefit from objective measures such as noise dosimeters or medical records. The generalizability of the findings is another limitation, as the sample was restricted to participants from Rawalpindi and Islamabad, which may not reflect the experiences of individuals in other regions of Pakistan. A broader, more geographically diverse sample would enhance the applicability of the results. Moreover, while PTA is a gold standard for assessing HL, it does not fully capture the functional impact of HL in real-world settings. Future studies should incorporate additional assessments, such as speech audiometry, to better understand the day-to-day challenges faced by individuals with HL. Lastly, this study did not account for potential confounding factors such as socioeconomic status or access to healthcare, which could influence both the prevalence and management of HL. Further research should explore how these factors impact the accessibility and effectiveness of interventions like hearing aids.

AUTHOR INFORMATION

Corresponding Author

Huma Hanif – Lahore College for Women University, Lahore (Pakistan);
orcid.org/0000-0003-0235-4462
Email: humahanif11@outlook.com

Authors

Huma Hanif – Lahore College for Women University, Lahore (Pakistan);
orcid.org/0000-0003-0235-4462
Ibtasam Thakur – Lahore College for Women University, Lahore (Pakistan);
orcid.org/0009-0002-6175-0625
Georgios P. Georgiou – University of Nicosia (Cyprus);
orcid.org/0000-0002-7192-2649
Paris Binos – Cyprus University of Technology (Cyprus);
orcid.org/0000-0003-3850-1866

AUTHOR CONTRIBUTION

The study was conceptualized and designed by H.H., who led the data collection process, performed the statistical analysis, and drafted the initial manuscript. I.T. contributed to the study design, coordinated data collection, and assisted with the interpretation of audiometric and HHIA results, as well as critically revising the manuscript for intellectual content. G.P.G. provided expert guidance on the study design and statistical methods, particularly in the multivariable logistic regression model, and played a key role in revising and finalizing the manuscript in detail. P.B. contributed to the conceptual framing and refinement of the discussion, reviewed the manuscript for linguistic and theoretical clarity, and provided critical editorial feedback during the final revision process.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DECLARATION OF USE OF AI IN SCIENTIFIC WRITING

The authors used Napkin.ai during the preparation of this work to create graphics and diagrams. After utilizing the tool, the authors thoroughly reviewed and edited the content as necessary and assumed full responsibility for the publication's content.

REFERENCES

[1] B. O. Olusanya, A. C. Davis, and H. J. Hoffman, "Hearing loss grades and the International classification of functioning, disability and health," *Bull. World Health Organ.*, vol. 97, no. 10, pp. 725-728, Oct. 2019. https://doi.org/10.2471/BLT.19.230367

[2] C. S. Brown, S. D. Emmett, S. K. Robler, and D. L. Tucci, "Global Hearing Loss Prevention," *Otolaryngol. Clin. North Am.*, vol. 51, no. 3, pp. 575-592, Jun. 2018. https://doi.org/10.1016/j.otc.2018.01.006

[3] R. Hussain and R. Kabir, "Knowledge and discriminatory attitudes towards HLV/AIDS among the women of reproductive age group of Pakistan using the Multiple Indicator Cluster Survey (MICS)," *Glob. Heal. J.*, vol. 8, no. 2, pp. 74-82, Jun. 2024. https://doi.org/10.1016/j.glohj.2024.05.004

[4] M. Aizaz, F. A. Abbas, A. Abbas, S. Tabassum, and E. I. Obeagu, "Alarming rise in HLV cases in Pakistan: Challenges and future recommendations at hand," *Heal. Sci. Reports*, vol. 6, no. 8, Aug. 2023. https://doi.org/10.1002/hsr2.1450

[5] A. Zubair, M. Ali, R. Munir, and M. B. Hossain, "Assessment of HLV Infection in HLV Patients Admitted to Pakistan Institute of Medical Sciences, Islamabad, Pakistan," *AIDS Res. Treat.*, vol. 2025, no. 1, Jan. 2025. https://doi.org/10.1155/arat/5549074

[6] F. Z. Muhammed, K. Yamaguchi, K. N. Handayani, and A. Hagishima, "Affordable Housing in Developing Regions: A Systematic Review of Materials, Methods and Critical Success Factors with Case Insights," *Buildings*, vol. 15, no. 22, p. 4015, Nov. 2025. https://doi.org/10.3390/buildings15224015

[7] E. Eze, R. Gleasure, and C. Heavin, "Worlds apart: a socio-material exploration of mHealth in rural areas of developing countries," *Inf. Technol. People*, vol. 35, no. 8, pp. 99-141, Dec. 2022. https://doi.org/10.1108/ITP-04-2020-0228

[8] W. H. K. Liang, L. W. E. Gn, Y. C. D. Tan, and G. H. Tan, "Speech and language delay in children: a practical framework for primary care physicians," *Singapore Med. J.*, vol. 64, no. 12, pp. 745-750, Dec. 2023. https://doi.org/10.4103/singaporemedj.SMJ-2022-051

[9] P. Tatsiopoulou, G.-N. Porfyri, E. Bonti, and I. Diakogiannis, "Priorities in the Interdisciplinary Approach of Specific Learning Disorders (SLD) in Children with Type I Diabetes Mellitus (T1DM). From Theory to Practice," *Brain Sci.*, vol. 11, no. 1, p. 4, Dec. 2020. https://doi.org/10.3390/brainsci11010004

[10] A. Javed et al., "Reducing the stigma of mental health disorders with a focus on low- and middle-income countries," *Asian J. Psychiatr.*, vol. 58, p. 102601, Apr. 2021. https://doi.org/10.1016/j.ajp.2021.102601

[11] K. Hreha, R. Samper-Ternent, H. E. Whitson, L. P. Downer, J. S. West, and B. Downer, "The Association of Vision and Hearing loss on Cognitive Function and Loneliness: Evidence From the Mexican Health and Aging Study," *J. Aging Health*, vol. 37, no. 5-6, pp. 337-346, Jun. 2025. https://doi.org/10.1177/08982643241247583

[12] E. Uğur, B. Uludag, Ç. Aydın, T. A. Gilik, and B. O. Konukseven, "Evaluation of the effect of hearing loss on cognitive-vestibular functions in the geriatric population," *Egypt. J. Otolaryngol.*, vol. 40, no. 1, p. 97, Sep. 2024. https://doi.org/10.1186/s43163-024-00656-8

[13] H. G. Saber, F. N. Fatouh, A. Askoura, G. O. Wassif, and E. R. Mohamed, "Cognitive function and psychological well-being in older adults with sensorineural hearing loss: An Egyptian

perspective," *Clin. Epidemiol. Glob. Heal.*, vol. 33, p. 102008, May 2025. https://doi.org/10.1016/j.cegh.2025.102008
[14] C. Frisby, V. Manchaiah, N. Dawood, C. Nieman, and D. W. Swanepoel, "Hearing loss and hearing aid stigma in low- and middle-income settings: a scoping review," *Disabil. Rehabil.*, pp. 1-18, Aug. 2025. https://doi.org/10.1080/09638288.2025.2540506
[15] K. Khoza-Shangase and T.-J. Munyembate, "Patient Experiences with Hearing Aids in South African Public Healthcare," *J. Otorhinolaryngol. Hear. Balanc. Med.*, vol. 6, no. 1, p. 8, May 2025. https://doi.org/10.3390/ohbm6010008
[16] N. Scarinci et al., "How do adults with hearing loss, family members, and hearing care professionals respond to the stigma of hearing loss and hearing aids?," *Int. J. Audiol.*, vol. 64, no. sup1, Apr. 2025. https://doi.org/10.1080/14992027.2024.2406885
[17] N. Riaz, M. Ajmal, and M. S. Khan, "Frequency of otitis media with effusion among children aged 1-5 years presenting to immunization center of tertiary care hospitals, Rawalpindi," *World J. Otorhinolaryngol. - Head Neck Surg.*, vol. 8, no. 4, pp. 315-320, Dec. 2022. https://doi.org/10.1016/j.wjorl.2021.03.002
[18] A. Aliyeva and E. Sari, "Role of occupational factors in noise-ınduced hearing loss: a single-center real-world data study," *Egypt. J. Otolaryngol.*, vol. 41, no. 1, p. 43, Mar. 2025. https://doi.org/10.1186/s43163-025-00790-x
[19] M. Aldè, U. Ambrosetti, S. Barozzi, and S. Aldè, "The Ongoing Challenges of Hearing Loss: Stigma, Socio-Cultural Differences, and Accessibility Barriers," *Audiol. Res.*, vol. 15, no. 3, p. 46, Apr. 2025. https://doi.org/10.3390/audiolres15030046
[20] K. Wasano, T. Nakagawa, and K. Ogawa, "Prevalence of Hearing loss by Age: 2nd to 10th Decades of Life," *Biomedicines*, vol. 10, no. 6, p. 1431, Jun. 2022. https://doi.org/10.3390/biomedicines10061431
[21] A. Bhamjee, T. le Roux, K. Schlemmer, M. A. Graham, and F. Mahomed-Asmail, "Audiologists' Perceptions of Hearing Healthcare Resources and Services in South Africa's Public Healthcare System," *Heal. Serv. Insights*, vol. 15, Jan. 2022. https://doi.org/10.1177/11786329221135424
[22] S. Akhtar, J. A. Nasir, T. Abbas, and A. Sarwar, "Diabetes in Pakistan: A systematic review and meta-analysis," *Pakistan J. Med. Sci.*, vol. 35, no. 4, Jul. 2019. https://doi.org/10.12669/pjms.35.4.194
[23] U. Saleem, N. Aslam, R. Siddique, S. Iqbal, and M. Manan, "Hepatitis C virus: Its prevalence, risk factors and genotype distribution in Pakistan," *Eur. J. Inflamm.*, vol. 20, Sep. 2022. https://doi.org/10.1177/1721727X221144391
[24] D. E. Paping, J. L. Vroegop, H. El Marroun, R. J. Baatenburg de Jong, and M. P. van der Schroeff, "The association of sociodemographic factors and risk behavior with unsafe use of personal listening devices in adolescents," *Int. J. Environ. Health Res.*, vol. 33, no. 7, pp. 700–709, Jul. 2023. https://doi.org/10.1080/09603123.2022.2047901
[25] N. Diviani, S. Chadha, M. O. Arunda, and S. Rubinelli, "Attitudes towards Safe Listening Measures in Entertainment Venues: Results from an International Survey among Young Venue-Goers," *Int. J. Environ. Res. Public Health*, vol. 18, no. 23, p. 12860, Dec. 2021. https://doi.org/10.3390/ijerph182312860
[26] A. Sheppard, M. Ralli, A. Gilardi, and R. Salvi, "Occupational Noise: Auditory and Non-Auditory Consequences," *Int. J. Environ. Res. Public Health*, vol. 17, no. 23, p. 8963, Dec. 2020. https://doi.org/10.3390/ijerph17238963
[27] S. F. Ahmed et al., "Deep learning modelling techniques: current progress, applications, advantages, and challenges," *Artif. Intell. Rev.*, vol. 56, no. 11, pp. 13521-13617, Nov. 2023. https://doi.org/10.1007/s10462-023-10466-8
[28] A. E. Arısoy, E. S. Arısoy, N. Bayar Muluk, C. Cingi, and A. G. Correa, Eds., *Hearing Loss in Congenital, Neonatal and Childhood Infections*. in *Comprehensive ENT*. Cham: Springer International Publishing, 2023. https://doi.org/10.1007/978-3-031-38495-0

[29] M. Chen, Y. Tao, Z. Lin, S. Li, W. He, and L. Zhang, "Risk Factors Associated with Falls in Hospitalized Older Adults Patients," *Gerontol. Geriatr. Med.*, vol. 10, Jan. 2024. https://doi.org/10.1177/23337214241302711
[30] S. Horgan et al., "Optimizing Older Adult Mental Health in Support of Healthy Ageing: A Pluralistic Framework to Inform Transformative Change across Community and Healthcare Domains," *Int. J. Environ. Res. Public Health*, vol. 21, no. 6, p. 664, May 2024. https://doi.org/10.3390/ijerph21060664
[31] A. Kupferberg and G. Hasler, "The social cost of depression: Investigating the impact of impaired social emotion regulation, social cognition, and interpersonal behavior on social functioning," *J. Affect. Disord. Reports*, vol. 14, p. 100631, Dec. 2023. https://doi.org/10.1016/j.jadr.2023.100631
[32] D. W. Sherman et al., "A Systematic Review of the Relationship between Social Isolation and Physical Health in Adults," *Healthcare*, vol. 12, no. 11, p. 1135, Jun. 2024. https://doi.org/10.3390/healthcare12111135
[33] L. Brandt, S. Liu, C. Heim, and A. Heinz, "The effects of social isolation stress and discrimination on mental health," *Transl. Psychiatry*, vol. 12, no. 1, p. 398, Sep. 2022. https://doi.org/10.1038/s41398-022-02178-4
[34] M. C. Pinzón-Díaz et al., "Technologies and Auditory Rehabilitation Beyond Hearing Aids: An Exploratory Systematic Review," *Audiol. Res.*, vol. 15, no. 4, p. 80, Jul. 2025. https://doi.org/10.3390/audiolres15040080
[35] S. Akhtar, F. Rabbani, J. Nafis, A. Siddiqui, and Z. Merali, "A qualitative study assessing acceptability and appropriateness of a technology-assisted mental health intervention by community frontline workers: mPareshan implementation research in rural Pakistan," *BMC Psychiatry*, vol. 25, no. 1, p. 16, Jan. 2025. https://doi.org/10.1186/s12888-024-06459-8
[36] M. Saleem et al., "A Digital Tool (Technology-Assisted Problem Management Plus) for Lay Health Workers to Address Common Mental Health Disorders: Co-production and Usability Study in Pakistan," *JMIR Form. Res.*, vol. 9, p. e59414, Jan. 2025. https://doi.org/10.2196/59414
[37] P. Morvan, J. Buisson-Savin, C. Boiteux, E. Bailly-Masson, M. Buhl, and H. Thai-Van, "Factors in the Effective Use of Hearing Aids among Subjects with Age-Related Hearing Loss: A Systematic Review," *J. Clin. Med.*, vol. 13, no. 14, p. 4027, Jul. 2024. https://doi.org/10.3390/jcm13144027
[38] L. Petrocchi-Bartal, K. Khoza-Shangase, and A. Kanji, "Early Intervention for Children with Hearing loss in the South African Context: A Narrative Review of Legislative and Policy Frameworks," *Disabilities*, vol. 5, no. 2, p. 52, May 2025. https://doi.org/10.3390/disabilities5020052
[39] M. Knoetze, V. Manchaiah, B. Mothemela, and D. W. Swanepoel, "Factors Influencing Hearing Help-Seeking and Hearing Aid Uptake in Adults: A Systematic Review of the Past Decade," *Trends Hear.*, vol. 27, Jan. 2023. https://doi.org/10.1177/23312165231157255
[40] P. Glavič, Ed., *Feature Papers to Celebrate the Inaugural Issue of Standards.* MDPI, 2024. https://doi.org/10.3390/books978-3-7258-0704-8
[41] W. A. Mustafa and H. Alquran, Eds., *Medical Data Processing and Analysis*. MDPI, 2025. https://doi.org/10.3390/books978-3-7258-3504-1
[42] L. E. Humes, "The World Health Organization's hearing-impairment grading system: an evaluation for unaided communication in age-related hearing loss," *Int. J. Audiol.*, vol. 58, no. 1, pp. 12-20, Jan. 2019. https://doi.org/10.1080/14992027.2018.1518598
[43] H. Göthberg et al., "Prevalence of hearing loss and need for aural rehabilitation in 85-year-olds: a birth cohort comparison, almost three decades apart," *Int. J. Audiol.*, vol. 60, no. 7, pp. 539-548, Jul. 2021. https://doi.org/10.1080/14992027.2020.1734878

[44] B. Engdahl and L. Aarhus, "Prevalence and predictors of self-reported hearing aid use and benefit in Norway: the HUNT study," *BMC Public Health*, vol. 24, no. 1, p. 474, Feb. 2024. https://doi.org/10.1186/s12889-024-17852-z
[45] T. Z. H. binti T. Zam Zam, A. A. A. Dzulkarnain, S. Rahmat, and M. Jusoh, "Translation, Adaptation and Cross-Cultural Validation of Hearing Handicap Inventory for Adult in Malay Language," *J. Audiol. Otol.*, vol. 23, no. 3, pp. 129-134, Jul. 2019. https://doi.org/10.7874/jao.2018.00395
[46] N. Ismail, A. Shalaby, R. Behairy, H. Khodary, and M. Ashraf, "The developed Arabic version of the Hearing Handicap Inventory for the Elderly," *Egypt. J. Otolaryngol.*, vol. 36, no. 1, p. 4, Dec. 2020. https://doi.org/10.1186/s43163-020-00004-6
[47] M. Gillis, "Hearing loss is associated with delayed neural responses to continuous speech," *Eur. J. Neurosci.*, vol. 55, no. 6, pp. 1671-1690, 2022. https://doi.org/10.1111/ejn.15644
[48] Y. Wang et al., "Associations Between Occupational Noise Exposure, Aging, and Gender and Hearing Loss: A Cross-Sectional Study in China," *Audiol. Res.*, vol. 15, no. 4, p. 91, Jul. 2025. https://doi.org/10.3390/audiolres15040091
[49] G. P. Georgiou, "Transforming Speech-Language Pathology with AI: Opportunities, Challenges, and Ethical Guidelines," Healthcare, vol. 13, no. 19, p. 2460, Sep. 2025. https://doi.org/10.3390/healthcare13192460