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INTERNATIONAL

ORIGINAL ARTICLE

**Received:** 30.11.2025
**Accepted:** 15.12.2025
**Published:** 20.03.2026

**CITE THIS ARTICLE AS:**
Prendergast C., Delahunt R., Green E., Donlon E., Kavanagh E., Branewska J. et al.: Smartphone-Based Hearing Testing Versus Clinical Audiometry: A Comparative Study in Ear, Nose, and Throat Practice; Otolaryngol Pol 2026; 80 (2): 6–13; DOI: 10.5604/01.3001.0055.6407

**AUTHORS' CONTRIBUTION:**
**A.** Conceptualization
**B.** Data Curation
**C.** Formal Analysis
**D.** Funding Acquisition
**E.** Investigation
**F.** Methodology
**G.** Project Administration

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**COMPETING INTERESTS:**
The authors declare that they have no competing interests.

# Smartphone-Based Hearing Testing *Versus* Clinical Audiometry: A Comparative Study in Ear, Nose, and Throat Practice

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**ABSTRACT:**

**Introduction:** Hearing loss affects millions worldwide, yet access to timely audiometric testing remains limited. Mobile applications offer the potential for convenient, low-cost screening and monitoring outside the clinic.

**Aim:** This study evaluates the Mimi Hearing Test app, focusing on its diagnostic accuracy, reliability, and overall user experience compared with the clinical standard.

**Materials and methods:** Thirty adult patients from an otolaryngology clinic participated in this comparative study. Each underwent 2 assessments, a traditional pure-tone audiogram performed by an audiologist and a digital hearing test using the Mimi Hearing Test app. Participants then completed a questionnaire rating the app's usability, clarity of results, and suitability for at-home use.

**Results:** The study found a strong concordance between the pure tone average values obtained from the Mimi Hearing Test app and those from clinical audiometry, especially in participants with normal or moderate hearing loss. Discrepancies were noted in cases of profound and asymmetric hearing loss, where the app sometimes underestimated hearing thresholds. Patient feedback was generally positive, with a significant interest in regular at-home monitoring. Neutral or negative impressions were more common among older participants, highlighting the need for age-sensitive design and user support with digital health tools.

**Conclusions:** The Mimi Hearing Test app demonstrates strong potential as a screening and monitoring tool for individuals with mild-to-moderate hearing impairment. While it is not a substitute for formal clinical audiometry testing in complex cases, it serves as an effective complementary tool that can raise patient awareness, encourage self-monitoring, and support earlier interventions in hearing health.

**KEYWORDS:** audiometry, digital health tools, hearing loss, hearing test, mobile applications, patient satisfaction, telemedicine

**STRESZCZENIE:**

**Wprowadzenie:** Choć niedosłuch dotyka milionów ludzi na całym świecie, dostępność szybkich badań audiometrycznych pozostaje ograniczona. Aplikacje mobilne oferują możliwość prowadzenia wygodnych i niskokosztowych badań przesiewowych oraz monitorowania pacjentów poza kontekstem klinicznym.

**Cel:** Celem niniejszego badania było przeprowadzenie oceny aplikacji Mimi Hearing Test, ze zwróceniem szczególnej uwagi na jej dokładność diagnostyczną, niezawodność oraz ogólne doświadczenie użytkownika w porównaniu ze standardem klinicznym.

**Materiały i metody:** W badaniu porównawczym wzięło udział 30 dorosłych pacjentów kliniki otolaryngologicznej. Każdego pacjenta poddano 2 rodzajom badania: tradycyjnej audiometrii tonalnej wykonywanej przez audiologa oraz cyfrowemu

badaniu słuchu przy użyciu aplikacji Mimi Hearing Test. Po badaniu uczestnicy wypełniali kwestionariusz oceniający użyteczność, przejrzystość wyników i przydatność aplikacji do użytku domowego.

**Wyniki:** Stwierdzono wysoką zgodność między wartościami średnich tonalnych uzyskanymi z aplikacji Mimi Hearing Test a wartościami uzyskanymi w klinicznym badaniu audiometrycznym, szczególnie u uczestników z normalnym lub umiarkowanym ubytkiem słuchu. Rozbieżności odnotowano w przypadkach głębokiego i asymetrycznego ubytku słuchu, w których aplikacja niekiedy zaniżała progi słyszalności. Opinie pacjentów były ogólnie pozytywne, a zainteresowanie regularnym monitorowaniem słuchu w warunkach domowych było znaczne. Oceny neutralne lub negatywne częściej wyrażali uczestnicy starsi, co podkreśla potrzebę uwzględnienia wieku grupy docelowej w projektowaniu aplikacji i wsparcia użytkownika narzędzi e-zdrowotnych.

**Wnioski:** Aplikacja Mimi Hearing Test charakteryzuje się dużym potencjałem użyteczności jako narzędzie do badań przesiewowych oraz monitorowania osób z lekkim i umiarkowanym upośledzeniem słuchu. Choć w bardziej złożonych przypadkach aplikacja nie jest w stanie zastąpić formalnego klinicznego badania audiometrycznego, może być skutecznym narzędziem uzupełniającym, pomagającym w zwiększeniu świadomości pacjenta, zachęcającym do samokontroli i wspierającym wcześniejsze interwencje w zakresie zdrowia słuchu.

**SŁOWA KLUCZOWE:** aplikacje mobilne, audiometria, badanie słuchu, e-zdrowie, niedosłuch, satysfakcja pacjentów, telemedycyna

## ABBREVIATIONS

**App** – application
**EHT** – e-audiologia
**ENT** – ear, nose, and throat
**PTA** – pure tone average
**WHO** – World Health Organization
**YSHT** – Yuichi Sakashita

## INTRODUCTION

Hearing deficits are one of the most common health problems worldwide. According to the World Health Organization (WHO), approximately 1 in 10 people around the world suffer from disabling hearing loss, and that the annual economic burden of unaddressed hearing loss accounts for almost $1 trillion USD [1]. Early detection and intervention are therefore essential not only to address the reduced quality of life for the patient but also to minimize long--term healthcare costs. Evidence suggests that every euro invested in hearing care saves 10 euros in the long term [2].

In recent years, since the COVID pandemic, telemedicine has emerged as a way to increase accessibility and give patients more control over monitoring their own health. A reliable at-home hearing test could help identify hearing deficits earlier, particularly to populations with limited access to audiological services and could reduce healthcare costs by decreasing the need for clinical screening.

The Mimi Hearing Test app (Mimi Hearing Technologies GmbH, Germany) is a widely used mobile hearing-test application. Over four million hearing tests have been performed since launch. It measures hearing thresholds using a pure-tone audiometry procedure and provides results in under five minutes [3]. The app is available for iOS devices, and the official website lists supported headphone models which work best with the app, though one may use unsupported headphone models. Although originally marketed as a CE-certified Class I medical device, this certification was discontinued in the EU in May 2024. The developer maintains that the Mimi Hearing Test app is still committed to providing a "high-quality and user-friendly hearing test experience" [4].

Previous research has explored the accuracy of the Mimi Hearing Test app as compared to an audiogram conducted in an otolaryngological practice and concluded that the Mimi Hearing Test is reliable for identifying moderate hearing loss but lacks precision in detecting thresholds at low frequencies [5, 6]. However, existing studies have been limited to controlled environments, and few have assessed patient satisfaction, ease of use, or real-world suitability as a replacement to traditional audiometry testing.

## AIM

This article aims to evaluate the accuracy and practicality of the Mimi Hearing Test app when used by patients and to compare their experience with a standard audiogram conducted in a clinic. In addition to assessing threshold accuracy, we investigate factors that may influence test performance and usability, including age, gender, history of hearing loss and health status. This study will help determine whether at home hearing test applications such as the Mimi Hearing Test app may serve as a complement or a potential alternative to traditional audiometry.

## MATERIALS AND METHODS

### Study Design and Participants

This was a comparative study conducted at an Otolaryngology Clinic of a University Hospital. The study was conducted on a sample size (n = 30) consisting of randomly selected patients (14 males and 16 females) who had scheduled appointments at the clinic and met the inclusion criteria. Selection criteria included the following: (1) age 18 years or older; (2) capable of understanding and following the test instructions (Polish speaking, no language impairments); (3) normal hearing or any degree of sensorineural or conductive hearing loss. All participants provided voluntary and informed consent prior to their participation. An application was submitted to and approved by the bioethics committee to begin our investigations (Bioethics Committee, CM NCU KB 84/2025).

### Pre-Test Measurement

Prior to the use of the Mimi Hearing Test app, participants had their blood pressure measured and recorded to evaluate the level of stress experienced by the patient.

### Mimi Hearing Test app

The participant was seated in a quiet room, instructed and supervised by the research team. The app guided the user through its hearing test protocol using the supplied headphones.

### Post-Test Measurement

Immediately following the completion of the hearing test, the participant's blood pressure was measured once again to assess physiological indicators of stress.

### Questionnaire

The participant completed the survey on usability and satisfaction.

### Materials and Apparatus Clinical Audiometry

A calibrated Interacoustics AC40 clinical audiometer was used in a standardized soundproof booth. Air and bone conduction thresholds were measured according to standard clinical procedures.

A standard pure-tone audiogram was performed by a certified clinical audiologist. This included pure-tone audiometry, where both air and bone conduction thresholds were determined for each ear at frequencies of 125, 250, 500, 750, 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz. The evaluation also included speech audiometry and the Weber and Rinne tuning fork tests.

PTAs obtained from standard audiometric testing were compared with PTAs calculated from the Mimi Hearing Test app, stratified by level of hearing impairment as defined by WHO/European guidelines: normal hearing (PTA ≤ 20 dB HL), mild hearing loss (21 dB ≤ PTA < 35 dB HL), moderate hearing loss (35 dB ≤ PTA < 50 dB HL), moderately severe hearing loss (50 dB ≤ PTA < 65 dB HL), severe hearing loss (65 dB ≤ PTA < 80 dB HL), and profound hearing loss (PTA ≥ 80 dB HL).

### Mobile Application Testing

The Mimi Hearing Test app (Mimi Hearing Technologies GmbH, Germany, Version 6.6.0) was installed on an Apple iPad (8$^{th}$ generation). A single model of Bluetooth headphones (Sennheiser HD 350BT headphones, Sennheiser electronic GmbH & Co.KG, Germany) was used for all participants to ensure consistency.

### Questionnaire

A questionnaire was developed by the research team to evaluate user experience with the app. It included questions on a Likert scale regarding ease of use, clarity of instructions, and comfort, as well as open-ended questions about their willingness to use the app at home.

### Physiological Measurement

Blood pressure was measured immediately before and after the Mimi hearing test. This was included to assess whether the at-home test procedure generated stress or discomfort, as stress could influence test performance.

### Data Collection and Analysis

All collected data was anonymized using a coding system to protect patient privacy. The analysis was structured into two components: audiometric data and questionnaire data.

### Audiometric Data

For each ear, hearing thresholds (dB HL) from the clinical audiogram and the Mimi Hearing Test app were recorded at the same frequencies. A Pure Tone Average (PTA) was calculated for both data sources using the standard equation: $PTA = \frac{500Hz+1000Hz+2000Hz+4000Hz}{4}$.

The analysis included:

- Direct Pure Tone Audiometry Comparison – the PTA values from the Mimi Hearing Test app were compared against the clinical audiogram PTA to determine the app's accuracy.
- Pattern Analysis – a qualitative comparison of the audiogram configurations was performed to assess the Mimi Hearing Test app's ability to correctly identify the pattern of hearing loss and the symmetry between ears.
- Questionnaire Data – responses to the custom questionnaire were analyzed to evaluate patient experience and the likelihood of future use. Responses to Likert-scale questions (e.g. ease of use) were analyzed. Open-ended responses and specific questions were reviewed to find key themes such as usability, trust and willingness to adopt at home. Responses were further categorised by age group and degree of hearing loss to explore potential influencing factors.

## RESULTS

### Demographics of the whole cohort

The cohort consisted of 30 adult participants with a mean age of 51.9 years. The age range was 24–94 years. All 30 participants completed the entire study protocol which consisted of undertaking a traditional pure-tone audiogram and the Mimi hearing test. Of the 30 participants, 14 (46.7%) were female and 16 were male (53.3%).

Of the 30 participants, 26 (86.6%) were undergoing a standard audiogram based on their doctor's recommendation. Additionally, 3 (10%) of participants stated that they often have audiograms performed and 1 (3.3%) participant reported receiving an annual audiogram.

Fourteen of the 30 participants reported a medical history of hearing loss or prior hearing issues, while the remaining 16 participants identified as having no history of hearing problems.

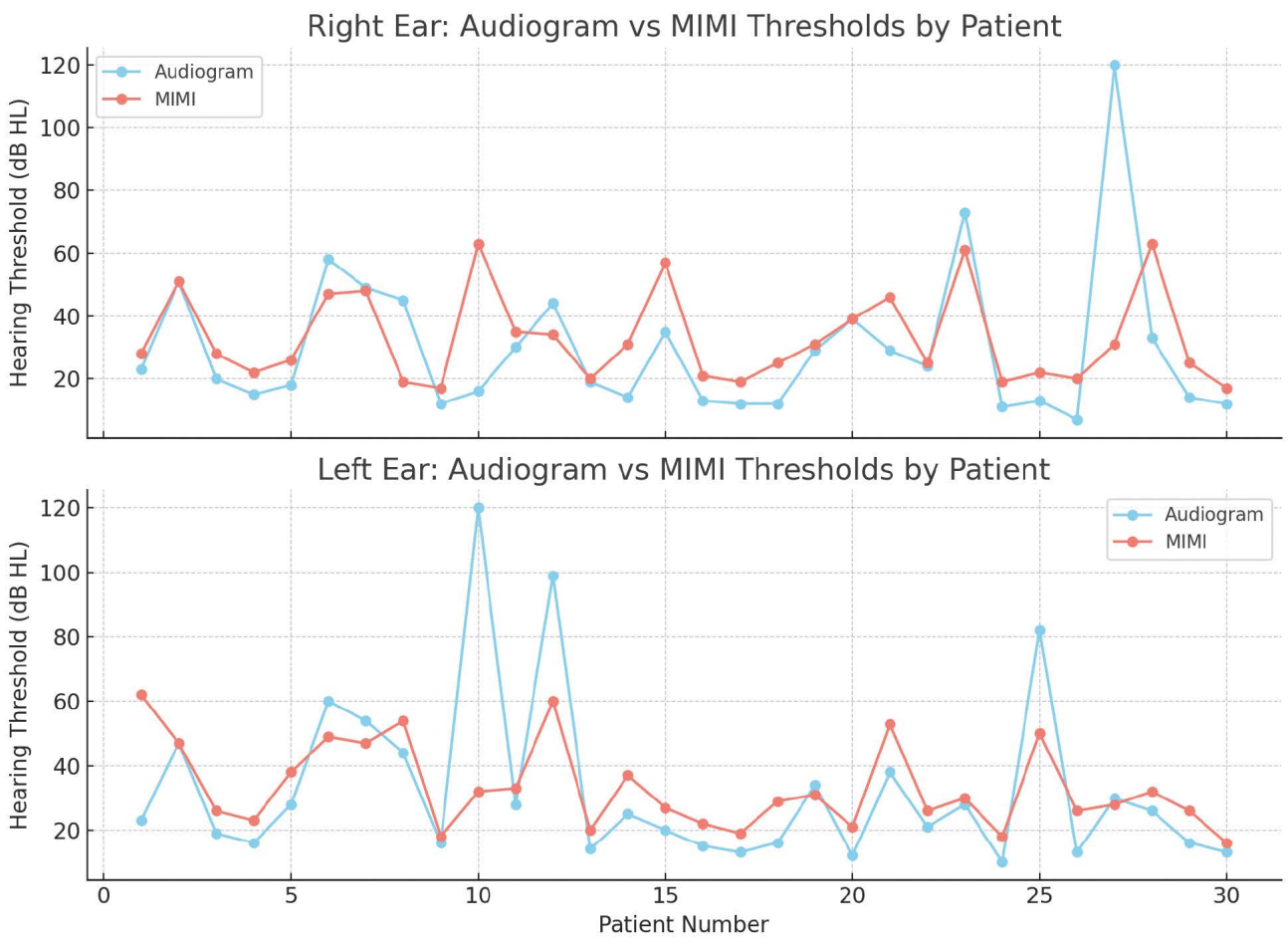


**Fig. 1.** Comparison of audiogram and Mimi Hearing Test app thresholds across patients.

Comparison of the hearing thresholds in studied patients, as measured in audiograms conducted in the otolaryngology clinic and the Mimi Hearing Test app, in the right and left ear respectively.

Participants with moderate to severe hearing loss also showed good alignment between the two methods. The comparison of audiogram and Mimi Hearing Test app thresholds across patients is shown in Fig. 1. However, in cases of profound hearing loss (PTA ≥ 80 dB HL) or asymmetric hearing loss, occasional discrepancies were observed, with the Mimi Hearing Test app sometimes underestimating hearing thresholds compared to standard audiometry. A comparison of the degree of hearing loss detected by the audiogram and the Mimi Hearing Test app is shown in Fig. 2., illustrating differences in classification across severity categories. Despite these few outliers, the application demonstrated clinically consistent PTA values across frequencies and hearing loss severities, supporting its potential utility for at-home hearing monitoring and screening purposes.

## Statistical Analysis

For each participant, the PTA obtained from the Mimi Hearing Test app was compared to the PTA derived from conventional audiometry for both the right and left ears. Mean PTA values, differences, and results of both parametric and non-parametric tests are summarized below, according to the Julius AI Data Analyst.

Right Ear: The mean audiometric PTA was approximately 29.5 dB HL, compared with a mean Mimi Hearing Test app PTA of 33.5 dB HL, giving an average difference of –3.96 dB (Audiogram – Mimi Hearing Test app). A paired t-test showed no statistically significant difference between the two methods ($t = -0.86$, $p = 0.39$). However, the Wilcoxon signed-rank test, which does not assume normal distribution, indicated a significant difference between paired results ($p = 0.027$).

Left Ear: The mean audiometric PTA was 30.3 dB HL, while the mean Mimi Hearing Test app PTA was 32.7 dB HL, producing an average difference of –2.38 dB. The paired t-test again revealed no significant difference ($t = -0.19$, $p = 0.85$), whereas the Wilcoxon signed-rank test identified a significant difference ($p = 0.037$).

Taken together, the paired *t*-tests suggest that, assuming normally distributed data, the two testing modalities provide comparable average results. Conversely, the non-parametric analysis suggests a small but consistent bias, with the Mimi Hearing Test app tending to report slightly higher hearing thresholds than the clinical audiogram. This minor systematic deviation may reflect the influence of non-normal data distribution or variability among participants with heterogeneous hearing profiles.

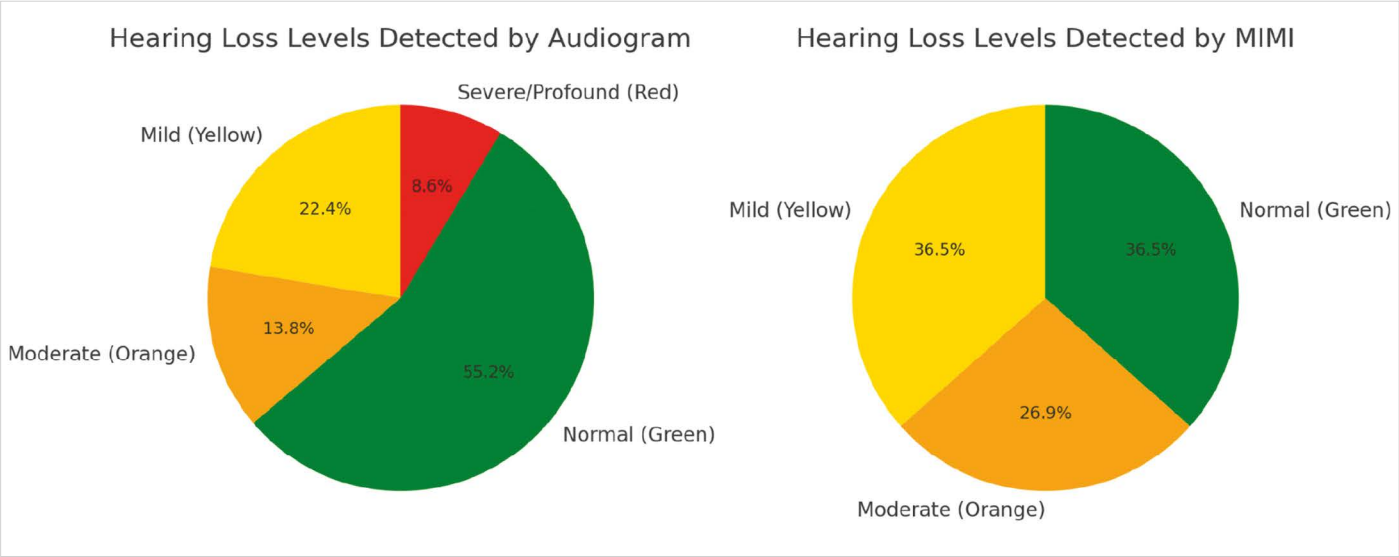


**Fig. 2.** Comparison of hearing loss levels detected by the audiogram and the Mimi Hearing Test app.

Comparison of the degree of hearing loss in studied patients according to audiograms and the Mimi Hearing Test app respectively. The PTA values derived from Mimi Hearing Test app represented normal hearing and mild and moderate degrees of hearing loss, whereas the PTA values derived from the audiogram were indicative of normal hearing as well as mild, moderate and severe degrees of hearing loss.

## Visual Analysis

Boxplots (Fig. 3.) demonstrate a mild upward skew in Mimi Hearing Test app-derived PTA values relative to audiometric measurements, supporting the finding that the app slightly overestimates hearing thresholds. The Bland–Altman plot (Fig. 4.) further illustrates agreement between the two methods, showing a mean bias of only a few decibels, consistent with good overall concordance. Nonetheless, the wide scatter of individual differences indicates that, while the methods align well at the group level, notable variability may occur for individual patients.

## Pure tone average stratified by level of hearing loss

Across the cohort, results from the Mimi Hearing Test app showed good agreement with conventional audiometric testing at all levels of hearing loss, with only minor discrepancies observed in cases of asymmetric or profound impairment. In particular, individuals with normal hearing or mild hearing loss demonstrated closely aligned PTAs between the two methods, whereas in patients with profound loss, the Mimi Hearing Test app occasionally underestimated thresholds relative to audiometry. Overall, no systematic bias was observed, and the Mimi Hearing Test app appeared to provide clinically comparable PTA values across degrees of hearing impairment.

## Participant satisfaction with Mimi Hearing Test application

Twenty-six of the patients (86.7%) included in this study stated that the Mimi Hearing Test app was easy to use. The remaining 4 patients (13.3%) found the app neutral in ease of use of the app. No patients (0%) said the app was difficult to use. The four patients who did not answer that the Mimi Hearing Test app was easy to use are older than the mean age of participants in this study. The rest of the data indicates that most patients had an easy experience using the app.

93.3% of patients (n = 28) indicated that the results of the audiogram from the Mimi Hearing Test app were clear and easy to interpret. Two patients (6.7%) of patients disagreed with this on the questionnaire.

73.3% of patients (n = 22) included in this study expressed that they would be comfortable using a smartphone app, such as the Mimi Hearing Test app, for future hearing tests instead of visiting an ENT clinic; 23.3% of patients (n = 7) stated that they would not be comfortable with this; 3.3% of patients (n = 1) responded that they had no opinion on this issue. Only one of the patients who expressed a lack of comfort using a smartphone app for future hearing tests disclosed a reason for this. They stated that the cabin used for the official audiogram testing is better insulated than the examination room that the Mimi hearing tests were conducted in. The other six patients did not give a reason, so we are unable to draw any conclusions on why they felt this way.

73.3% of patients (n = 22) stated that they feel more confident about their hearing after having both an audiogram performed at an ENT clinic and with a smartphone, while 26.7% of patients (n = 8) stated that they did not feel this way.

86.7% of patients (n = 26) disclosed that they would consider regularly using an audiogram app on their smartphone to monitor their hearing health; 13.3% of patients (n = 4) stated that they would not consider using an app. Each of these 4 patients indicated issues with using the app. One of these patients found the ease of app usage to be neutral (not easy) and indicated that they would not be comfortable using a smartphone app for future hearing tests instead of visiting an ENT clinic. Another of these patients also stated that they would not be comfortable using a smartphone app for future hearing tests instead of visiting an ENT clinic. The third patient who would not consider using the Mimi Hearing Test app to monitor hearing at home, informed us that they did not find the results of the Mimi Hearing Test app audiogram clear and easy

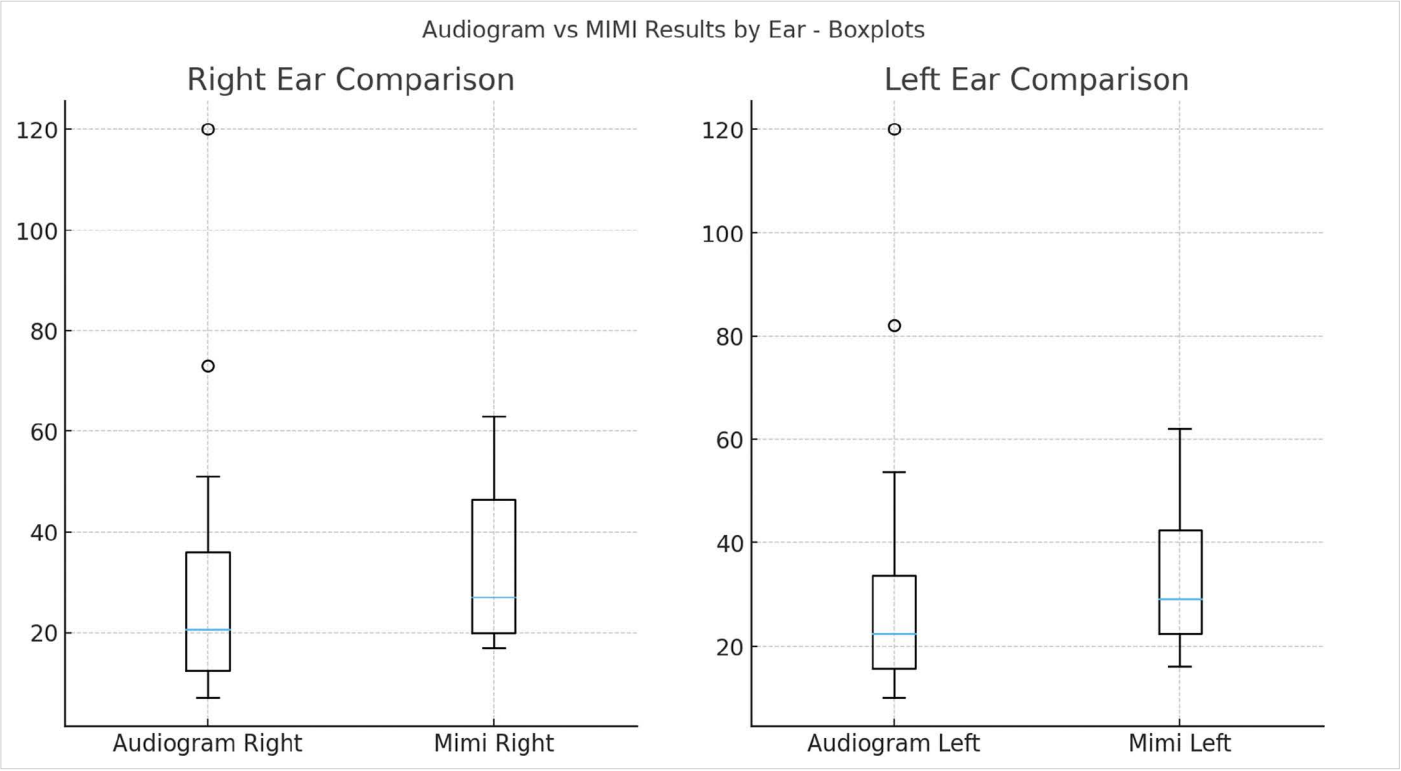


**Fig. 3.** Comparison of the results of the audiogram and the Mimi Hearing Test app by ear using box plots.

In both the right and left ears, there are slightly elevated Mimi Hearing Test app-derived PTA values as compared to the PTA values derived from the audiogram in the otolaryngology clinic.

to interpret and stated that they would not be comfortable using a smartphone app for future hearing tests instead of visiting an ENT clinic. The final patient in this group also did not find the results clear and easy to interpret.

## DISCUSSION

The findings of this study demonstrate that the Mimi Hearing Test app is largely consistent with audiometric outcomes of standard clinical audiometry across a broad range of hearing thresholds. Overall, the Mimi Hearing Test app demonstrated strong concordance with conventional audiometry across all degrees of hearing loss, with no evidence of systematic over- or underestimation of PTAs. For participants with normal hearing (PTA ≤ 20 dB HL) and mild hearing loss (PTA 21–34 dB HL), PTAs measured by the Mimi Hearing Test app closely matched those from standard testing, indicating reliable estimation in these categories. This aligns with the reports of Yesantharao et al. [5] suggesting that phone-based hearing tests can approximate hearing in a reliable manner. Perhaps most significantly the Mimi Hearing Test app showed reliable results in patients presenting with normal to moderate hearing loss, however discrepancies were found in profound or asymmetric hearing impairments. This suggests that while mobile applications cannot fully substitute the gold standard of audiometry in complex or severe cases, there is a potential use for screening and routine monitoring purposes.

The patient feedback of this study is an important data set. It showed a high level of patient satisfaction. The vast majority of patients said the application was easy to use, and most reported the results were clear and easily understood. As there is such a small number of patients with difficulty interpreting the results displayed by the app, the issue could be due to age-related factors. A notable minority of older participants expressed neutral or negative impressions on its ease of use. The mean age of all patients assessed was 51.9 years old, and the range was 24–94 years old. These patient demographics may indicate that the patients who found the app 'neutral' to use may have issues with using modern technology in general, not just with the Mimi Hearing Test app. Older patients represent the majority of patients undergoing audiological testing [7], and so this highlights the importance of health technology and increasing accessibility to a wide age range, especially due to the prevalence of hearing loss due to old age.

There are a vast number of benefits of at-homing hearing testing. Apps such as the Mimi Hearing Test app can give patients the opportunity to monitor the changes in their hearing before regular appointments with their doctors. It may be of particular benefit in nursing homes and long-term care facilities where appointments with specialist physicians can be complicated and difficult to organize and attend. Other at-home hearing testing apps, such as e-audiologia (EHT) and Yuichi Sakashita (YSHT), have been shown to have benefits for use by patients in a wide variety of settings, including nursing homes and emergency departments [8].

At-home hearing tests can also have an important role in occupational medicine. For people working in loud and disruptive environments, such as construction workers, accessibility to hearing tests that can be performed regularly at their convenience can help to reduce

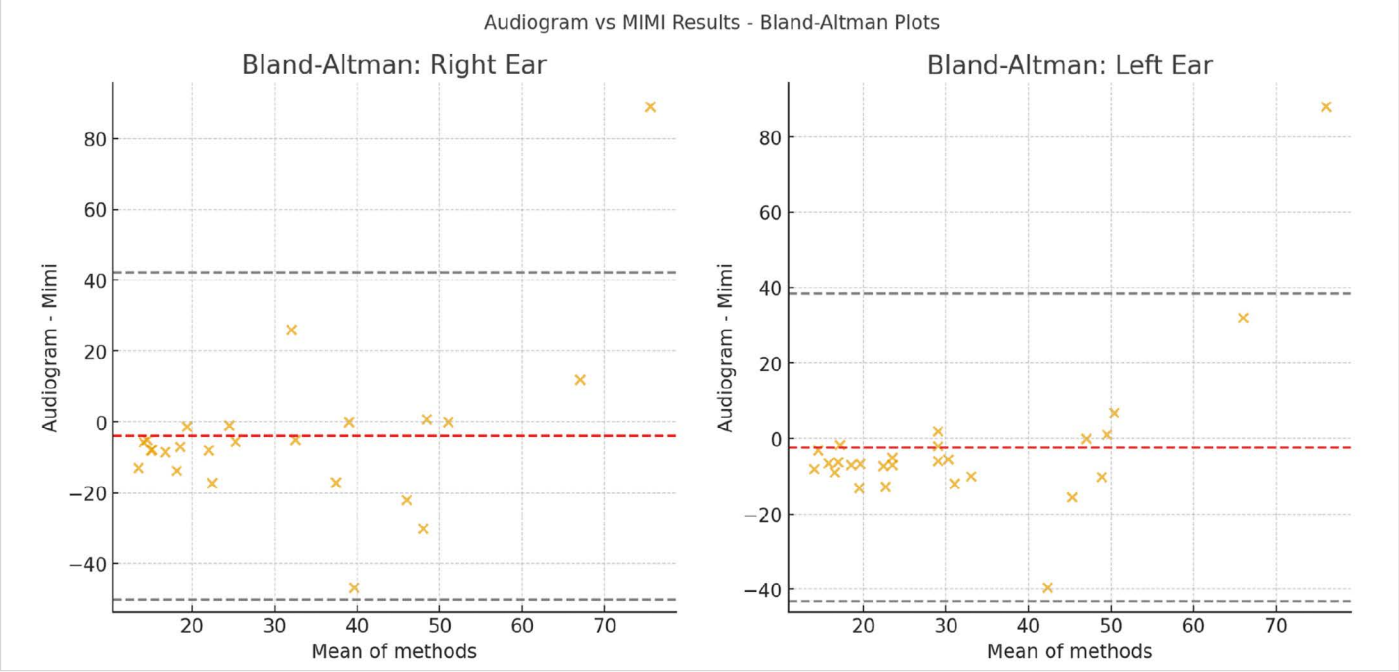


**Fig. 4.** Bland-Altman Plots showing good overall concordance of results between audiogram and Mimi Hearing Test app, in the right and left ears, respectively.

the risk of noise-induced hearing loss. This can also help to raise awareness about the importance of hearing protective devices in the workplace. A study by Leshchinsky [9] assessed the impact of annual audiograms on employees' awareness of noise-induced hearing loss and the importance of hearing protection devices. They concluded that individuals with noise-induced hearing loss may experience increased morbidity due to hearing loss, tinnitus, or speech discrimination difficulties. This highlights the importance of regular, accessible hearing tests to prevent hearing loss in younger patients. Applications such as the Mimi Hearing Test app are well--suited to circumstances like this.

From a clinical aspect, most participants would consider using the Mimi hearing test at home. This highlights the potential role of applications in telemedicine. For patients who face difficulties in attending clinics at home testing may provide an alternative for early detection and ongoing monitoring of hearing. However, some participants claimed they preferred more traditional methods, specifically, they would be more comfortable in a specific testing environment and clinic-based testing. These concerns reflect that app-based testing could be used in a complementary action to more traditional methods, rather than replace them altogether.

This study also showed that most patients would feel more confident in using a hearing test app. Such processes of health stewardship could enhance patient awareness which could lead to earlier intervention potentially reducing hospital burdens for patient lists.

However, a small number of participants remained unconvinced of the reliability of the app-based results. This potentially necessitates patient education on the app use, or a clearer data visualization.

There are a few limitations present in the study. Firstly, the sample size was relatively small (n = 30), and all came from a single otolaryngology clinic. Secondly, the study only used a single headphone model. Given the wide variety of headphones on the market, further studies comparing the accuracy of different models may provide different results. Thirdly, whilst efforts were made to reduce environmental noise, the testing was not conducted in fully soundproof conditions. This may have affected the results when compared to a controlled audiometric test. However, this environment was chosen to simulate the conditions a person could replicate in their own home. Despite these limitations, the findings above contribute to the growing knowledge and evidence that mobile hearing tests can provide informative and clear clinical data for patients. In addition to generally positive patient feedback, the widespread use of at-home hearing apps could significantly contribute to improving patients' awareness and education of their hearing health.

Overall, these results indicate that the Mimi Hearing Test app provides PTA values that closely approximate those obtained from standard audiometry. The lack of significance in the parametric tests supports the app's validity as a screening and monitoring tool for general use, particularly in cases of normal to moderate hearing loss. The significant Wilcoxon results and broad individual variability observed in the Bland–Altman plot, however, suggest that caution is warranted when interpreting individual results, especially in cases of asymmetric or profound hearing impairment. These findings highlight the app's potential as a complementary tool to clinical audiometry, rather than a replacement.

## CONCLUSIONS

This study aimed to investigate if the Mimi Hearing Test app could be used as a tool for screening and monitoring hearing health, either as a complement or a potential alternative to traditional audiometry. The application demonstrated strong concordance with standard clinical audiometry across varying

levels of hearing loss, particularly in cases of normal to moderately severe impairment.

Mobile applications such as the Mimi Hearing Test app have the potential to become valuable, user-friendly, and cost-effective tools options for hearing screening and longitudinal monitoring. With technology becoming increasingly widespread, self-assessment with hearing test applications could play a crucial role in preventing hearing loss in the younger population. Wider adoption and continued refinement of app-based hearing tests also have the potential to play a meaningful role in addressing the global burden of untreated hearing loss and tackling long waiting times for hospital assessment. Hearing apps help to educate patients and raise awareness, and contribute to their understanding of hearing health.

## DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this work the author(s) used Julius AI Data Analyst for interpretation and clarification of the data from the Mimi Hearing Test app. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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