

Evaluation Of Accuracy And Reliability Of Commercially Available Audiometry Applications For Assessment Of Hearing Acuity

Dr. Zainab Shahid*

Postgraduate Resident ENT Department, Combined Military Hospital (CMH), Lahore
Email: zainabadnan1612@gmail.com

Brig. Dr. Attique Ahmed

Consultant/HOD ENT Department, Combined Military Hospital (CMH), Lahore

Dr. Wajiha Asif

Postgraduate Resident ENT Department, Combined Military Hospital (CMH), Lahore

Dr. Riddah Sultan

Postgraduate Resident ENT Department, Combined Military Hospital (CMH), Lahore

Dr. Shahid Pervez

Postgraduate Resident ENT Department, Combined Military Hospital (CMH), Lahore

Abstract

Objectives: To determine diagnostic accuracy of audiometry mobile application to detect hearing loss keeping pure tone audiometry as gold standard.

Study Design: Prospective validation study.

Place and Duration of Study: “Combined Military Hospital, Lahore from July 2024 to December 2024”.

Methodology: Eighty nine patients who presented at ENT outdoor department with hearing difficulty were included in the study. Initial assessment for hearing loss was made using a commercially available android mobile phone application Hearing test pro ® version 2.4. After this patients underwent pure tone audiometry to diagnose hearing loss. Data was analyzed using SPSS v22.00.

Results: Median age was 54.00 (67.00 – 29.00) years. There were 64 (71.91%) males and 25 (38.09%) were females. Specificity, sensitivity, accuracy, negative predictive value and positive predictive value of audiometry application to diagnose hearing loss with pure

tone audiometry being the gold standard were 93.75%, 95.89%, 95.51%, 83.33% and 98.59%, respectively.

Conclusion: Commercially available audiometry applications are useful and reliable tools to detect presence of hearing loss.

Author Details

Keywords: Audiometry, Assistive Technology, Diagnostic Accuracy, Hearing Loss, Mobile Phone

Received on 20 Jan 2025

Accepted on 25 Mar 2025

Published on 31 Mar 2025

Corresponding E-mail & Author*:

Dr. Zainab Shahid*

Postgraduate Resident ENT Department, Combined Military Hospital (CMH), Lahore
Email: zainabadnan1612@gmail.com

Introduction

Hearing loss is a major concern of public health that affects millions worldwide and presents a multifaceted burden involving communication barriers, decreased social integration and economic costs.¹ According to estimates from the World Health Organization (WHO), over 1.5 billion people experience some degree of hearing impairment.² In Pakistan, hearing loss is a considerable but often overlooked health concern, impacting approximately 14.5 million people in Pakistan.³ There are several factors that contribute to these high burden of hearing loss including inappropriately treated ear infections, high rates of marital consanguinity, noise pollution, inadequate access to healthcare services, stigma surrounding hearing impairment, lack of public awareness and limited audiology services.^{4, 5} In addition, with the availability of treatment for major chronic morbidities, elderly population in Pakistan is also expected to rise in coming future which raises the possibility of increasing the societal burden of hearing loss even higher owing to direct association of hearing loss with advancing age.⁶

Pure-tone audiometry (PTA) is a key diagnostic tool that measures hearing thresholds at various frequencies and provides an audiogram, which helps classify hearing loss as conductive, sensorineural, or mixed as is the gold standard investigation.⁷ However, in modern world of assistive technology and artificial intelligence other easily accessible means of hearing assessment are available like commercially available audiometry mobile applications.⁸ These not only are cheaper but also not operator dependent giving them a logistic advantage. In addition, their results are reproducible at much shorter times compared to conventional hearing loss tests but the chances of results being inaccurate are also relatively higher in these automated audiometry applications.⁹

Since, Pakistan is still quite far behind in development as well as use of assistive technology in the field of healthcare and healthcare professionals themselves are still reluctant to adopt modern devices and rely on the conventional technology, not much regional research has been conducted in this regard. Additionally, PTA is mostly not available in the periphery hospitals where mobile application based audiometry can be very beneficial in screening patients for hearing loss. To address this, present study is being conducted with the aim to determine diagnostic accuracy of audiometry mobile application to detect hearing loss keeping PTA as gold standard.

METHODOLOGY

This prospective validation study was conducted at “Combined Military Hospital, Lahore from July 2024 to December 2024. Appropriate sample size was calculated using following formula:

For calculations, following assumptions were used; confidence level of 95%, absolute

$$n = \frac{z_{1-\alpha/2}^2 P(1-P)}{d^2}$$

precision of 8% and anticipated sensitivity of audiometry mobile application to detect hearing loss 82%.¹⁰ This gave a sample size of 89.

Inclusion criteria: Patients aged over 18 years, both males and females, presenting at outdoor ENT department with complaint of hearing difficulty were included in the study.

Exclusion criteria: Patients who had evidence/history of hereditary hearing loss, ongoing therapy with ototoxic drugs, history anatomical anomaly of ear, ongoing ear infection and pregnant women were excluded from the study.

Patients were selected by using non-probability purposive sampling. A detailed interview was conducted with the patient and baseline characteristics of the patients including age and gender were documented. Initial assessment for hearing loss was made using a commercially available android mobile phone application Hearing test pro ® version 2.4 (a paid and automated audiometry application available on the Google ® application store). Hearing assessment was performed in a quiet room and the status of hearing loss by this assessment was documented. After this all the patients underwent PTA to make definitive diagnosis of hearing loss. Hearing loss by both the methods was defined as “air conduction thresholds checked at frequencies of 500Hz, 1000Hz, 2000Hz and 3000Hz to be more than 20 dB”. Based on the assessment by both methods, cases were identified as “true positive (TP)” defined as patients having hearing loss both on audiometry application and PTA, “true negatives (TN)” defined as patients having no hearing loss both on audiometry application and PTA, “false positives (FP)” defined as patients having hearing loss on audiometry application but not on PTA and “false negatives (FN)” defined as patients not having hearing loss on audiometry application but present on PTA.

Statistical analysis of collected data was performed by using Statistical package for Social Sciences version 22.00. Normality of data was checked by Shapiro-Wilk test. Age was not distributed normally and was represented using median interquartile range (IQR). Qualitative data was represented by using percentage and frequency. 2x2 contingency table was drawn based on which specificity, sensitivity, accuracy, negative predictive value (NPV) and positive predictive value (PPV) were calculated.

RESULTS

In this study, 89 patients were included. Median age was 54.00 (67.00 – 29.00) years. Frequency of patients aged 18-30 years were 3 (3.37%), 31-50 years were 25 (28.09%), 51-60 years were 41 (46.07%) and > 60 years were 20 (22.47%). There were 64 (71.91%) males and 25 (38.09%) were females. These baseline characteristics are given below in Table-I:

Table-I: Baseline characteristics (n = 89)

Parameter	Median (IQR); n (%)
Median age	54.00 (67.00 – 29.00) years
Age groups	
18-30 years	3 (3.37%)
31-50 years	25 (28.09%)
51-60 years	41 (46.07%)
> 60 years	20 (22.47%)
Gender	
Male	64 (71.91%)
Female	25 (38.09%)

Frequency of patients who were found to have hearing loss by assessment through commercially available android mobile phone application Hearing test pro ® version 2.4 was 71 (79.78%) while frequency of patients who were diagnosed to have hearing loss based on PTA assessment was 73 (82.02%). A total of 70 (78.65%) patients were found to have hearing loss both on audiometry application and PTA [TP] while those with hearing loss on audiometry application but not on PTA was 1 (1.12%) [FP]. Similarly, patients who did not have hearing loss on audiometry application but had

on PTA were 3 (3.37%) [FN] while those who neither had hearing loss on audiometry application nor on PTA were 15 (16.85%) [TN]. Based on these following 2 x 2 contingency table was drawn, Table-II:

Table-II: 2x2 Contingency table of TP, TN, FP and FN cases (n = 89)

	Hearing loss on PTA	No hearing loss on PTA
Hearing loss on audiometry application	70 (TP)	1 (FP)
No hearing loss on audiometry application	3 (FN)	15 (TN)

Based on the formulas, it was found that “specificity (SP), sensitivity (SN), accuracy, negative predictive value (NPV) and positive predictive value (PPV)” of audiometry application to diagnose hearing loss with PTA being the gold standard were 93.75%, 95.89%, 95.51%, 83.33% and 98.59%, respectively. This is tabulated below in Table-III:

Table-III: Diagnostic parameters of audiometry application in diagnosis of hearing loss with PTA as gold standard (n = 89)

Specificity (TN/FP+TN) x 100	93.75%
Sensitivity (TP/TP+FN) x 100	95.89%
Accuracy (TP+TN/TP+TN+FP+FN) x 100	95.51%
NPV (TN/FN+TN) x 100	83.33%
PPV (TP/TP+FP) x 100	98.59%

DISCUSSION

With the global advancement in technology in all works of life, assistive technology has become a major part in the field of medicine.^{11,12} Advanced diagnostics, robotic surgical procedures and complex problem solving through artificial intelligence is continuously being integrated in the conventional healthcare practices.^{13,14} However, in Pakistan, integration process of technology in healthcare is still years behind compared to the developed world due to lack of financial resources, skilled manpower and reluctance to replace conventional practices by healthcare professionals themselves.¹⁵ One such assistive technology is audiometry mobile phone applications for assessment of hearing loss which was the focus of present study.

In present study, average age of the patients who were found to have hearing loss was 54 years with majority of the patients having age ranging from 51 to 60 years. This finding correlates with the findings of previous literature reporting that hearing loss is much more prevalent among older people as compared to the younger population.¹⁶

¹⁷ Major mechanism that contributes to hearing loss with advancing age is the inability to clear the metabolic toxins produced in the body. This impairs the body’s ability to repair the tissue damage resulting in irreversible cochlear tissue damage.¹⁸ It was also observed that majority of victims of hearing loss were males which is coherent with the findings reported in previous literature showing a significant male predominance in this regard.^{19,20} This male predominance can be attributed to the

higher exposure of men in the community to the damaging noise pollution due to their predominant social role in the community.²⁰

In terms of diagnostic ability, it was found that “specificity, sensitivity, accuracy, NPV and PPV” of audiometry application to diagnose hearing loss with PTA being the gold standard were 93.75%, 95.89%, 95.51%, 83.33% and 98.59%, respectively. Compared to this, Dutta et al.¹⁰ reported the specificity of audiometry application to diagnose hearing loss was 95% which was similar to present study but the reported sensitivity was only 82% which was much lower as compared to present study. In another study conducted by Gupta et al.²¹ with similar aim, sensitivity value (96%) was comparable to current study but the reported specificity was much lower at only 82%. Similar trend compared to present study was observed by Swami et al.²² who found automated audiometry application’s diagnostic parameters at 95%, 98%, 78.57% and 98.65%. In one study, specificity of audiometry application for detecting hearing loss was reported only 60% but the sensitivity was 100%.²³ In one study these values were found to be 76% and 92% making application based audiometry a more sensitive rather than a specific tool to detect hearing loss.

Present study shows that automated audiometry mobile phone application proves to be a highly specific and sensitive toll to detect hearing loss compared with the conventional gold standard, i.e., PTA. This shows that integration of mobile phone based assistive technology in the clinical practice for detecting hearing loss is need of the hour. Limited sample size, single study center and lack of assessment of younger population were few limitations of study.

CONCLUSION

Mobile phone based audiometry application is a useful diagnostic tool to detect hearing loss in community with high degree of specificity as well as sensitivity reported at 93.75% and 95.89%.

CONFLICT OF INTEREST

None.

ACKNOWLEDGEMENTS

None.

AUTHORS CONTRIBUTIONS

None.

REFERENCES

- Pennino F, Di Lillo M, Sorrentino M, Fiorilla C, Parisi A, Mirizzi PD, et al. Understanding hearing health: a cross-sectional study of determinants in a metropolitan area. *Healthcare (Basel)*. 2023 Aug 10;11(16):2253. <https://doi.org/10.3390/healthcare11162253>.
- Wasano K, Nakagawa T, Ogawa K. Prevalence of hearing impairment by age: 2nd to 10th decades of life. *Biomedicines*. 2022;10(6):1431. <https://doi.org/10.3390/biomedicines10061431>.
- Shadab M, Abbasi AA, Ejaz A, Ben-Mahmoud A, Gupta V, Kim HG, et al. Autosomal recessive non-syndromic hearing loss genes in Pakistan during the previous three decades. *J Cell Mol Med*. 2024;28(8):e18119. <https://doi.org/10.1111/jcmm.18119>.
- GBD 2019 Hearing Loss Collaborators. Hearing loss prevalence and years lived with disability, 1990-2019: findings from the Global Burden of Disease Study 2019. *Lancet*. 2021;397(10278):996-1009. [https://doi.org/10.1016/S0140-6736\(21\)00516-X](https://doi.org/10.1016/S0140-6736(21)00516-X).

- Naz S. Molecular genetic landscape of hereditary hearing loss in Pakistan. *Hum Genet.* 2022 1;141(3-4):633-648. <https://doi.org/10.1007/s00439-021-02320-0>.
- Yang W, Zhao X, Chai R, Fan J. Progress on mechanisms of age-related hearing loss. *Front Neurosci.* 2023;17:1253574. <https://doi.org/10.3389/fnins.2023.1253574>.
- Oremule B, Abbas J, Saunders G, Kluk K, Isba R, Bate S, et al Mobile audiometry for hearing threshold assessment: A systematic review and meta-analysis. *Clin Otolaryngol.* 2024;49(1):74-86. <https://doi.org/10.1111/coa.14107>.
- Davis L, Hwa TP, Eliades SJ, Bigelow DC, Ruckenstein MJ, Brant JA. Pure tone audiometry as assessed by a commercially-available mobile phone application compared to formal audiometry. *Am J Otolaryngol.* 2022;43(5):103552. <https://doi.org/10.1016/j.amjoto.2022.103552>.
- Lee SY, Seo HW, Jung SM, Lee SH, Chung JH. Assessing the accuracy and reliability of application-based audiometry for hearing evaluation. *Sci Rep.* 2024;14(1):7359. <https://doi.org/10.1038/s41598-024-57944-9>.
- Dutta A, Khan S, Akhtar Z. Use of mobile phone based hearing app Hear WHO for self detection of hearing loss. *J ENT Surg Res.* 2023;1(1):1-4. <https://www.opastpublishers.com/open-access-articles/use-of-mobile-phone-based-hearing-app-hear-who-for-self-detection-of-hearing-loss.pdf>.
- Bayramzadeh S, Aghaei P. Technology integration in complex healthcare environments: A systematic literature review. *Appl Ergon.* 2021;92:103351. <https://doi.org/10.1016/j.apergo.2020.103351>.
- Dang VA, Vu Khanh Q, Nguyen VH, Nguyen T, Nguyen DC. Intelligent healthcare: integration of emerging technologies and internet of things for humanity. *Sensors (Basel).* 2023;23(9):4200. <https://doi.org/10.3390/s23094200>.
- Chatterjee S, Das S, Ganguly K, Mandal D. Advancements in robotic surgery: innovations, challenges and future prospects. *J Robot Surg.* 2024;18(1):28. <https://doi.org/10.1007/s11701-023-01801-w>.
- Bindra S, Jain R. Artificial intelligence in medical science: a review. *Ir J Med Sci.* 2024;193(3):1419-1429. <https://doi.org/10.1007/s11845-023-03570-9>.
- Malik M, Kazi AF, Hussain A. Adoption of health technologies for effective health information system: Need of the hour for Pakistan. *PLoS One.* 2021;16(10):e0258081. <https://doi.org/10.1371/journal.pone.0258081>.
- Didczuneit-Sandhop B, Józwiak K, Jolie M, Holdys J, Hauptmann M. Hearing loss among elderly people and access to hearing aids: a cross-sectional study from a rural area in Germany. *Eur Arch Otorhinolaryngol.* 2021;278(12):5093-5098. <https://doi.org/10.1007/s00405-021-06799-1>.
- Brotto D, Benvegnù F, Colombo A, de Filippis C, Martini A, Favaretto N. Age-related changes in auditory perception. Hearing loss in the elderly: aging ear or aging brain? *Aging Clin Exp Res.* 2023;35(11):2349-2354. <https://doi.org/10.1007/s40520-023-02570-0>.
- Yang W, Zhao X, Chai R, Fan J. Progress on mechanisms of age-related hearing loss. *Front Neurosci.* 2023;17:1253574. <https://doi.org/10.3389/fnins.2023.1253574>.
- Park YH. Do women have better hearing than men? *Clin Exp Otorhinolaryngol.* 2021;14(1):1-2. <https://doi.org/10.21053/ceo.2020.02418>.
- Villavisanis DF, Berson ER, Lauer AM, Cosetti MK, Schrode KM. Sex-based differences in hearing loss: perspectives from non-clinical research to clinical outcomes. *Otol Neurotol.* 2020;41(3):290-298. <https://doi.org/10.1097/MAO.0000000000002507>.
- Gupta DK, Pati S, Singh S, et al. Efficacy of android based mobile device as a screening tool for hearing loss in quiet and noisy environments. *J Evol Med Dent Sci.* 2019;8(32):2577-2581. [HTTPS://DOI.ORG/10.14260/jemds/2019/561](https://doi.org/10.14260/jemds/2019/561).

- Swami H, Bhargava A, Sabarigirish K, Arvind BM. A comparative study of smartphone based app with free field hearing for possible use as a screening test. *Int J Otorhinolaryngol Head Neck Surg.* 2017;3(3):710-714. <https://doi.org/10.18203/issn.2454-5929.ijohns20173052>.
- Abu-Ghanem S, Handzel O, Ness L, Ben-Artzi-Blima M, Fait-Ghelbendorf K, Himmelfarb M. Smartphone-based audiometric test for screening hearing loss in the elderly. *Eur Arch Otorhinolaryngol.* 2016;273(2):333-339. <https://doi.org/10.1007/s00405-015-3533-9>.
- Li LYJ, Wang SY, Wu CJ, Tsai CY, Wu TF, Lin YS. Screening for hearing impairment in older adults by smartphone-based audiometry, self-perception, HHIE screening questionnaire, and free-field voice test: comparative evaluation of the screening accuracy with standard pure-tone audiometry. *JMIR Mhealth Uhealth.* 2020;8(10):e17213. <https://doi.org/10.2196/17213>.