

REVIEW ARTICLE

The Demand and Implementation of Automated Hearing Tests in Clinical and Non-Clinical Settings: A Literature Review

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ABSTRACT

Hearing loss is a growing global public health concern, and the demand for accessible hearing healthcare is increasing. Automated hearing tests have been introduced as a practical solution to address the limited number of audiologists and to expand access to timely hearing assessments. This literature review examines the demand for automated hearing tests and their application in both clinical and non-clinical settings. A structured search was conducted using Scopus, PubMed, and the Cochrane Library. The search identified five relevant studies conducted in non-clinical settings outside Malaysia and four studies conducted within Malaysia. The reviewed studies indicate that automated audiometry demonstrates good agreement and test-retest reliability with conventional manual audiometry in controlled clinical settings and improves accessibility for hearing screening in non-clinical environments, despite limitations related to environmental noise and specific populations. Overall, the findings indicate that automated audiometry has the potential to enhance accessibility to hearing assessments and reduce service gaps by complementing existing audiological resources in Malaysia.

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INTRODUCTION

According to the World Health Organization (WHO), a person is considered to have hearing loss if their hearing capacity is reduced and they are not able to hear as well as someone with normal hearing. "Normal" hearing typically refers to hearing thresholds of 20 dB or better in both ears [1].

The WHO further reports that more than 1.5 billion people, almost 20% of the global population, experience disabling hearing loss. Most of this cohort suffers from disabling hearing loss, totalling 1.16 billion individuals. The WHO estimates that 401 million individuals in Southeast Asia have varying degrees of hearing loss, with 109.4 million (5.5%) suffering from moderate to severe hearing impairment. By 2050, an estimated 666 million

Southeast Asian individuals will experience varying degrees of hearing loss [1]. The Malaysian Ministry of Health reports that the nationwide prevalence of hearing impairment among adults in Malaysia is 3.2%, making it the second most prevalent kind of disability among Malaysian adults, following visual impairment [2]. Occupational noise-induced hearing loss (NIHL) remains a major public health concern globally, including in Malaysia [3]. According to the Department of Occupational Safety and Health, in 2022, there were 7,413 cases, with more than two-thirds or 76.7 per cent of the total disease concentrated in the NIHL category, which accounted for 5,478 cases [4].

The consequences of neglected hearing loss can have a profoundly adverse impact on all facets of an individual's life, particularly when their communication needs are unmet. Auditory deprivation can diminish quality of life and impede access to verbal communication, perhaps increasing the risk of dementia and cognitive decline in later life [5,6].

The increasing prevalence of hearing loss surpasses the availability of audiologists providing hearing healthcare services [7]. The WHO (2021) stated that 93% of low-income and 76% of middle-income nations possess fewer than one audiologist per 1 million individuals for hearing healthcare services [1].

As healthcare professionals, audiologists play a central role in the diagnosis and management of hearing loss, while also contributing to raising awareness and improving community access to hearing healthcare services. A survey overseeing audiology services in 64 countries worldwide that 86% of respondents indicated insufficient audiologists were available to meet community needs and the increasing demand for hearing services in overcrowded clinics and remote areas, coupled with challenges in training more audiologists and issues related to remote living, highlights the problem of under-servicing [7,8].

As of 2023, Malaysia has over 800 qualified local audiologists employed in various public and private sectors, with 198 working in 48 government hospitals. The population of 34 million Malaysians indicates a ratio of one audiologist for every 42,500 individuals (1:42,500), a figure that is significantly inadequate compared to the anticipated requirement of one audiologist per 500 individuals (1:500) [9]. This shortage highlights the urgent need for innovative approaches, such as mobile health (mHealth) solutions, to expand the reach of hearing services and improve access, particularly in underserved communities. In addition, the occupational health doctor (OHD) is also involved in managing occupational noise-related hearing disorders, such as ensuring the audiometric testing conducted by an audiometric technician follows the procedures and legal requirements and interprets audiograms and diagnose hearing disorders accordingly [10].

The Ministry of Health (MOH) Malaysia has initiated and executed measures including teleaudiology, financial support for hearing health programs, community-based rehabilitation initiatives, and the training of additional audiologists to enhance access to hearing healthcare services, especially in rural and underserved regions [11-14]. These efforts reflect a broader shift toward mobile health (mHealth) solutions, which utilize mobile devices, wireless communication technologies, and applications to support health management and healthcare delivery. mHealth encompasses innovations such as automated audiometry and refers to tools that can enhance disease management, medication adherence, medical decision-making, medical education, and research [15]. By enabling patients to monitor and manage their health when access to healthcare providers is limited, mHealth helps bridge care gaps [16]. Additionally, mHealth applications provide education, guidance on treatment, and ongoing monitoring of patients' health status [17].

Despite the emergence of automated hearing tests in Western countries to serve the demand for hearing healthcare services, their implementation in Asian countries, particularly in Malaysia, remains insufficiently researched. Malaysia is a relevant focus because hearing healthcare access is unevenly distributed, with services concentrated in urban regions and limited availability in rural and underserved populations. This aligns with national health priorities to enhance digital health adoption and supports the country's commitment to the Sustainable Development Goals (SDGs), particularly SDG 3 (Good Health and Well-being) and SDG 10 (Reduced Inequalities) [18]. Previous studies have demonstrated promising results for automated hearing tests, underscoring the importance of addressing critical issues such as background noise control and consistency between automated and manual hearing test results [8]. A survey of 43 Malaysian audiologists revealed that around 50% believed tele-audiology may enhance treatment quality and accessibility, with an increased willingness to embrace it if it improves care quality [13]. Thus, this narrative review aims to address the implementation of automated hearing tests worldwide and also emphasises the lack of research on automated hearing tests in Malaysia.

METHODOLOGY

A literature review search was conducted using multiple databases, including Scopus, PubMed, and Cochrane Library, to identify studies published between 2018 and 2023 that investigated validation, reliability, and potential advantages of automated pure-tone audiometry over traditional manual audiometry methods. The inclusion criteria were studies done in any country or region, articles written in English, and characterized in terms of participants, intervention(s), outcomes, and study design. A structured search was conducted using the keywords "automated hearing test," "self hearing test," and "pure tone audiometry," combined with the terms "clinical," "diagnostic," "non-clinical," "community," and "school." However, for the studies in Malaysia, no specific inclusion criteria were applied to the searching strategy due to the limited number of studies that had been conducted. Furthermore, grey literature searches through an internet web engine such as Google and Google Scholar were also conducted to identify any related publications.

AUTOMATED HEARING TEST

Automated hearing tests are increasingly recognized as part of mHealth technologies, offer a scalable and accessible solution for hearing screening and assessment. All hearing assessments begin by delivering sound to a subject at a regulated intensity and then employing various methodologies to assess sound detection. Sound detection is ascertained through behavioural responses or numerous physiological tests. Behavioural evaluations

are favoured as they confirm the integrity of the auditory response from the ear to the highest cortical areas [19]. Pure tone audiometry (PTA) is the gold standard for assessing hearing sensitivity and determining the presence and severity of hearing loss. It assesses frequencies critical for speech perception and can ascertain the degree, configuration, and type of hearing loss, providing sufficient detail to aid the healthcare team in identifying the aetiology and prognosis of the hearing loss and the most effective treatment approach [20].

Traditionally, an audiologist or a qualified operator performs the procedure manually using standardised methods in clinical settings. However, automated protocols have been available for several decades and are gaining popularity, mainly due to the recent COVID-19 pandemic and the expanding domain of teleaudiology [21]. In evaluating the implementation of automated audiometry, it is crucial to recognise that the techniques employed to obtain hearing thresholds are reliable and grounded in empirical data. Despite the existence of these automated pure-tone testing methods for a considerable duration, their application in diagnostic audiometry has been limited [22].

When individuals encounter the word automated audiometry, they envision a remarkable apparatus capable of autonomously and impeccably assessing an individual's hearing threshold. Automated audiometry refers to technologies that automate or self-administrate from the test initiation using similar methods utilised in PTA and conducted in various environments such as hearing health care, occupational health, and community settings [23,24].

Development of Automated Audiometry

While early developments in automated audiometry—such as the Bekesy audiometer introduced in 1947—laid the groundwork for self-administered hearing tests, the emphasis today is on clinically validated, software-driven systems that improve access and efficiency [22]. Contemporary PC-based audiometers with integrated microprocessors now enable automation in various settings, from hospitals to schools [22,25].

Several modern platforms have been developed and tested for clinical use. For instance, the KUDUwave, introduced by GeoAxon in 2008, integrates an audiometer within sound-attenuating headphones and can operate in both automatic and remote modes [27]. Similarly, systems like NIH Toolbox Hearing Test, Otogram, and OtoKiosk represent validated, portable solutions that support efficient hearing screening and diagnostic testing in both clinical and community settings. These technologies offer promising tools to address workforce shortages and improve accessibility to hearing healthcare [26-29].

Advantages and Challenges of Automated Audiometry

Automated audiometry has gained increasing attention as an alternative to traditional manual testing, particularly in efforts to expand hearing healthcare access. While this method offers several advantages in terms of cost, efficiency, and accessibility, it also presents challenges that must be considered in clinical application.

Automated PTA is advantageous due to its cost-effectiveness, as it reduces the duration of testing and decreases manpower requirements, thereby lowering overall operational costs [30]. These efficiencies make automated PTA suitable for large-scale hearing loss screening programmes and population-based studies, where time and financial resources must be optimised. Conversely, manually administered PTA is typically regarded as more trustworthy due to the operator's ability to tailor the approach to meet the patient's specific demands. This is particularly significant for populations that are more challenging to assess, such as elderly adults. Nonetheless, the operator may introduce bias in manual audiometry. Clinical expectations or time limitations may compel audiologists to diverge from established methods, thus affecting the test outcomes. Computerised automated processes can eliminate human error elements [31]. A significant benefit of automated audiometry is that the test can be self-administered or conducted by a general nurse, thus eliminating reliance on the availability of audiological competence, which is sometimes limited in various regions globally [30].

Automated audiometry can reduce the professional time needed to assess these patients and augment the time allocated for more complex cases, such as youngsters, some elderly individuals, and those with developmental disabilities. Validation studies of automated systems, such as AMTAS, have demonstrated comparable accuracy and reliability to conventional manual audiometry [32]. AMTAS testing was also significantly faster than PTA, reducing test time by an average of 3.03 minutes per person in clinical settings and 2.68 minutes in non-clinical settings [33]. Moreover, automated audiometry can reduce the expenses associated with test administration. Delivering accurate results allows audiologists to concentrate on interpreting outcomes, making referral decisions, and creating management strategies. This method is highly conducive to telemedicine, significantly enhancing service access [22]. Improving the efficiency of constrained specialists' time by automation significantly boosts efficacy in hearing healthcare [34].

Implementing automated audiometry may encounter problems, including assessing environmental noise's influence on test outcomes, documenting bone-conduction hearing thresholds, and ensuring the quality of automated audiometry results. Environmental noise is typically monitored using sound level meters or noise dosimeters, which apply frequency weightings

(A-weighted or C-weighted) to reflect human auditory sensitivity, particularly in the 500 Hz to 6 kHz range [10]. "Excessive noise" is defined as daily noise exposure exceeding 82 dB(A), a daily personal noise dose above 50%, a maximum sound pressure level exceeding 115 dB(A) at any time, or a peak sound pressure exceeding 140 dB(C), as regulated under Regulation 3 of the Occupational Safety and Health (Noise Exposure) Regulations 2019 [10]. Additional research is necessary to evaluate various computerised solutions and associated obstacles for automated audiometry [25].

While no automated audiometer can substitute for an audiologist, a device capable of yielding results comparable in accuracy to manual audiometry could significantly alleviate the demand for hearing health services. In addition, assert that audiology may enhance patient service through increased efficacy and efficiency by using existing technology in clinics, and they advocate for the utilisation of automation for its several benefits [22].

Automated Hearing Tests in Clinical Setting

The historical evolution from early electrical audiometers to contemporary automated audiometry highlights the necessity for ongoing investigation and validation [24]. A clinical setting refers to testing conducted in a healthcare facility, typically in a sound-treated or acoustically controlled room [35]. Automated audiometry requires precision and dependability validation before its extensive clinical application. Successful clinical validations, reliability assessments, and methodological approaches to automated audiometry in clinical environments have been documented. Validity is assessed by the precision and dependability of automated threshold audiometry compared to manual threshold audiometry [8]. Accuracy is the indirect measurement approach that compares two distinct techniques assessing the same variable, one of which serves as the gold standard [23]. Manual audiometry is the benchmark, whereas automated audiometry is the comparative approach for assessing auditory thresholds. Test-retest reliability denotes a test's capacity to yield consistent results when administered multiple times to people under the same settings [8].

Yu and colleagues from Canada studied otograms at the BCAL laboratory at a community hospital in Edmonton, Alberta [27]. The Otoqram is an automated, computer-assisted audiometer that enables patients to self-administer their pure-tone audiograms. It evaluates air and bone conduction thresholds and applies masking when necessary. Participants comprised individuals with normal conductive and sensorineural hearing loss. Both investigations demonstrate that air conduction thresholds are consistent across automated and manual audiometry. Nonetheless, variations in bone conduction thresholds were seen in intricate masking situations. Individuals with conductive and asymmetrical hearing

impairments provide assessment challenges due to the masking issue.

In 2023, Wiseman and his colleagues from the United States performed a validation study of the NIH Toolbox – Hearing Threshold Test (HTT), a tablet-based evaluation utilising consumer-grade headphones, on a clinical sample of children and adults with diverse hearing acuity levels [28]. The electroacoustic examination of the hearing assessment application and headphones revealed acoustic outputs that adhered to established conformity standards for hearing evaluation. The results indicated a strong correlation between thresholds obtained from the tablet-based evaluation and those from the clinical hearing assessment for children and adults across all frequencies and various levels of hearing acuity. The HTT also satisfied clinical test-retest reliability criteria. The study determined that the tablet-based hearing evaluation yields satisfactory hearing level estimations for children and adults without diagnostic audiometric assessment capabilities.

The same year, a validation study was conducted on the OtoKiosk automated audiometry system in quiet and low-level noise conditions, targeting individuals with normal and impaired hearing. Pure tone air conduction thresholds were recorded for each participant under three randomised conditions: standard audiometry, automated quiet, and automated testing in noise. The results indicated that the average changes between tests were minimal, and noise did not influence the thresholds assessed using OtoKiosk [29].

The majority of studies have determined that automated audiometry accurately measures hearing thresholds; however, validation data remain insufficient for (1) automated bone conduction audiometry, (2) automated audiometry in children and challenging populations, and (3) various types and severities of hearing loss [8]. Certain studies underscore the need to capture bone-conduction hearing thresholds, considering the potential for occlusion effects from the earphones and the necessity of assuring the quality of automated audiometry test results [25].

Automated Hearing Test in Non-Clinical Setting

This narrative review thoroughly examines automated audiometry, emphasising its validation, reliability, and possible benefits compared to conventional manual audiometry techniques. A non-clinical setting refers to environments outside formal healthcare institutions, such as community centres or homes, which may or may not meet standard acoustic conditions [29,36]. The capacity of automated hearing tests to yield precise results enhances the potential for audiologists to optimise their productivity, enabling them to devote additional time to other vital components of hearing health care. This may strengthen access to hearing services, especially in regions experiencing a deficiency of audiologists and

hearing healthcare practitioners. Nonetheless, despite the advantageous attributes of computerised hearing assessments, specific issues necessitate additional investigation. Environmental noise may affect the precision of test results, requiring stringent noise monitoring protocols to guarantee dependable outcomes. This analysis highlights the revolutionary potential of automated audiometry in enhancing global hearing health services and meeting the needs of underserved communities. **Table 1** and **Figure 1** encapsulate recent research employing automated hearing assessments in non-clinical environments.

Comparison of Automated Hearing Tests in Clinical and Non-Clinical Settings

Automated audiometry is applied in both clinical and non-clinical environments, with each setting serving distinct purposes and populations. In clinical settings, testing is typically conducted in sound-treated or acoustically controlled rooms within healthcare facilities, and is administered by audiologists or trained clinicians. These tests often include both air and bone conduction assessments, with accuracy validated against conventional pure-tone audiometry (PTA) and high test-retest reliability. Clinical automated testing is particularly valuable for diagnostic evaluations, complex cases, and

populations requiring precise threshold measurements. While clinical implementation may involve higher costs and specialist time, the reliability and comprehensive nature of the results are significant advantages.



Fig. 1: Hearing assessment using AMTAS in non-clinical settings

Table 1: Summary of the recent studies on automated hearing test in non-clinical settings.

Studies	Validation of a-PTA	Test-Retest Reliability of a-PTA	Effect of Environmental noise	Client's Satisfaction	Community approach
Authors	Govender & Mars [37]	Bastianelli et.al. [27]	Bean et. al. [29]	Yeo et. al. [38]	Mealings et. al. [39]
Year	2018	2019	2021	2023	2020
Population	50 school aged children (6 - 13 y/o)	40 adults (23 - 56 y/o)	26 adults (47 - 76 y/o)	100 adults (21-78 y/o)	Children (4-14 y/o)
Intervention	Air and bone conduction thresholds	Pure-tone AC threshold	AC hearing threshold (Hughson-Westlake) with noise ~35 dBA	Diagnostic hearing threshold (Hughson-Westlake) & feedback questionnaire	Hearing thresholds at 1 & 4k Hz
Comparator	Conventional vs a-PTA	Internal reliability within same automated hearing test	Automated audiometry in quiet, and in noise	Conventional vs automated hearing test	Conventional vs automated hearing test
Outcome	Within 10 db mean difference between conventional and a-PTA	Mean difference was 0 (SD = 2.1) left ear, and 0.1 (SD = 1.1) right ear	Noise did not affect thresholds measured with OtoKiosk.	85% of the participants indicated that the machine was easy to use	88% of thresholds show acceptable threshold differences of ≤ 5 dB
Application/ Tool	KUDUwave 5000	SHOEBOX™ Audiometry	OtoKiosk	Automated Method for Testing Auditory Sensitivity (AMTAS)	AutoAud
Study Limitation	Variability in bone conduction results, children's slower or inconsistent responses, and discomfort with testing equipment may affect the accuracy and generalisability of automated audiometry outcomes.	Limitations include potential learning effects, the lack of ambient noise measurement, restricted testing to English word lists, and evaluation in primarily quiet clinical environments, which may affect the generalizability of the findings to other settings and populations.	This study was limited to four frequencies, adult participants aged 47–76 years, and testing in a sound-attenuating booth, which may not reflect performance in pediatric, geriatric, or more distracting clinical settings.	This study was limited by background noise levels, minor discrepancies in hearing profiles between AMTAS and manual PTA, and issues with device usability that may affect result accuracy.	The study was limited by potential language barriers for children whose first language is not English and by reliance on clinician-administered tests as the gold standard, which themselves may be influenced by child compliance and examiner skill.
Suggestion	Automated audiometry protocols should incorporate adjustments for children's response time, ongoing encouragement, and proper equipment setup to enhance reliability and accuracy.	Future studies should evaluate the tablet audiometer in diverse patient populations, clinical scenarios, and language contexts, including bone conduction and speech reception threshold testing, to enhance its generalizability and clinical applicability.	Future studies should evaluate the OtoKiosk automated audiometry system across a wider range of test frequencies, age groups, and real-world clinical environments to confirm its accuracy and generalizability	Future studies should address ambient noise control, consistency of hearing profiles, and software enhancements to optimize the accuracy and feasibility of AMTAS in diverse clinical settings	Future research should continue to validate self-administered hearing tests, including language-independent versions, and improve the sensitivity of speech-in-noise components for more accurate detection in children from diverse linguistic backgrounds.

In contrast, non-clinical settings, such as community centres, schools, or home environments, provide greater accessibility and convenience, especially in underserved or remote regions. Testing in these settings is often self-administered or supervised by trained assistants rather than audiologists, and focuses primarily on air conduction thresholds. Although environmental factors such as background noise can affect accuracy, non-clinical automated audiometry offers faster testing, lower operational costs, and scalability for population-level screening. Both environments demonstrate complementary roles: clinical settings prioritise diagnostic precision, whereas non-clinical applications enhance accessibility and early detection, collectively contributing to more efficient and equitable hearing healthcare delivery. The summary of these comparisons is shown in **Table II**.

Table II: Comparison of Automated Hearing Tests in Clinical and Non-Clinical Settings

Aspect	Clinical Setting	Non-Clinical Setting
Purpose	Diagnostic assessment, validation of thresholds	Screening, early detection, population-level monitoring
Setting	Healthcare facilities, sound-treated/acoustically controlled rooms	Schools, community centres, and homes may have uncontrolled acoustic conditions
Administrator	Audiologists or trained clinicians	Trained assistants or self-administered by participants
Test Type	Air and bone conduction; validated against manual PTA	Primarily air conduction; limited bone conduction assessment
Accuracy	High, validated, and reliable	Moderate to high; influenced by environment and user familiarity
Cost and Time	Moderate; requires specialist time	Lower; faster testing, reduced specialist involvement
Accessibility	Limited by clinic locations and specialist availability	High; can reach remote or underserved populations
Advantages	Precision, reliability, tailored testing	Scalability, accessibility, reduced specialist time, and convenience
Limitations	Requires trained personnel, equipment cost, scheduling	Environmental noise sensitivity, limited bone conduction, and less controlled test environment

Automated Hearing Tests in Malaysia

In Malaysia, efforts to integrate automated hearing screening tools have led to the development of locally relevant technologies to address limitations in accessibility and standardisation. One such initiative is the automated hearing screening kit (auto-kit) developed specifically for the Malaysian context by Gan and colleagues. To ensure compliance, Gan and team developed an automated hearing screening kit (auto-kit) with real-time noise level monitoring [40]. The auto-kit includes a laptop, 24-bit sound card, headphones, microphone, and ANSI-calibrated graphical user interface. The auto-kit can provide 500, 1000, 2000, and 4000 Hz test tones at 25- or 40-dB HL screening cut-off levels. Clinical results at the 40 dB HL screening threshold showed 92.5% sensitivity and 75.0% specificity for the auto-kit. The 500 Hz test tone is not used in hearing screening; thus, the auto-kit testing method can omit it. Eliminating the 500 Hz test tone increased the auto-kit's specificity from 75.0% to

92.3%, suggesting it might be used for hearing screening. This study's restrictions include the auto-kit's expensive TDH-49 headphones for screening with an octave band sound level meter.

A private Malaysian university's Physiology Laboratory study compared audiometric results to an internet-based hearing screening exam to measure adult hearing status [41]. This research used PTA, two online speech-in-noise tests, Internet Test 1 (MED-EL's HearCom Digit Triplet Test) and Internet Test 2 (NHS's Speech in Noise Test). The study found a strong correlation between audiograms and internet-based hearing tests and significant differences in associated parameters examined by a complete questionnaire. The research showed that an online hearing test can determine hearing status, and the findings are essential for applications and further study. An internet-based hearing evaluation cannot replace a clinical pure-tone audiogram but can test a large population for auditory competence.

Hatta et al. (2024) conducted the latest preliminary study on translating, adapting, and integrating the Automated Method for Testing Auditory Sensitivity (AMTAS) instructional video into Malay [7]. For instructional integrity, verbatim translation ensured word-for-word accuracy. Integrating translated material into AMTAS improved guidance for Malaysian users. The process included movie transcription, Malay translation, and linguistic expert review. The Malay instructional video increased user comfort and reaction precision by increasing accessibility. This effort addresses the linguistic barrier to auditory evaluations and enhances the usefulness of AMTAS in Malaysia. In conclusion, the translated video can enhance hearing evaluations, particularly in rural and underserved areas, thereby promoting audiology services nationwide. In the expansion of this study, they had conducted a study to investigate the validation, reliability, and usability of AMTAS [33]. They concluded that the AMTAS is a valid and reliable approach for measuring hearing status in the Malaysian population, demonstrating high user satisfaction.

Limitations of the Review

This review acknowledges that the use of a narrative approach may limit the comprehensiveness of evidence mapping, particularly given the growing diversity of studies examining automated hearing tests in Malaysia and comparable settings. A scoping review would have enabled a more systematic exploration of the available literature, identification of research gaps, and classification of emerging themes—an approach recommended when the evidence base is broad and heterogeneous [42]. However, the current study intentionally employed a narrative synthesis to provide an initial overview of trends and challenges in automated hearing assessments in Malaysia. Future research adopting a scoping review methodology

is therefore warranted to offer a more detailed and structured mapping of existing evidence.

CONCLUSION

The rising demand for hearing healthcare services in Malaysia, together with the limited number of audiologists, underscores the importance of exploring innovative approaches such as automated audiometry. This review summarises the development of automated audiometry, outlines its advantages and challenges, describes its application in both clinical and non-clinical settings, and highlights its emerging implementation in Malaysia.

Internationally, automated audiometry has been increasingly adopted for screening and diagnostic purposes due to its efficiency, scalability, and ability to support service delivery in settings with limited specialist availability. In Malaysia, however, research and implementation remain at an early stage, with studies demonstrating promising potential but indicating the need for further validation to ensure accuracy and reliability across diverse user groups and clinical conditions.

Moving forward, more local research, feasibility testing, and pilot implementation studies are required to refine automated testing protocols, strengthen validity and reliability evidence, and evaluate performance in real-world environments. Expanding the use of automated audiometry—particularly in underserved and remote areas—may contribute meaningfully to improving hearing healthcare accessibility. As technological advancements continue, automated audiometry is likely to play an increasingly supportive role in complementing, rather than replacing, conventional audiological practice in Malaysia.

REFERENCES

- World report on hearing. Geneva: World Health Organization; 2021. <https://www.who.int/publications/i/item/9789240020481>
- Rifin HM, Sui WK, Ratnam KK, Lourdes TG, Kuay LK, Riyadzi MR, Saminathan TA, Zain SH, Hafizah S, Zulkipli DS, Nasaruddin NH. NATIONAL HEALTH AND MORBIDITY SURVEY 2023.
- Mutthumanickam G, Supramanian RK, Lim YC. Prevalence and Factors Associated With Occupational Noise-Induced Hearing Loss Among Palm Oil Mill Workers in Selangor, Malaysia. *Cureus*. 2024 Aug 3;16(8).
- Jabatan Perangkaan Malaysia. STATISTIK KEMALANGAN DAN PENYAKIT PEKERJAAN NEGARA 2022 [Internet]. 2023 Sep. Available from: https://www.dosm.gov.my/uploads/content-downloads/file_20231003080659.pdf
- Haile LM, Kamenov K, Briant PS, Orji AU, Steinmetz JD, Abdoli A, Abdollahi M, Abu-Gharbieh E, Afshin A, Ahmed H, Rashid TA. Hearing loss prevalence and years lived with disability, 1990–2019: findings from the Global Burden of Disease Study 2019. *The Lancet*. 2021 Mar 13;397(10278):996-1009.
- Livingston G, Huntley J, Sommerlad A, Ames D, Ballard C, Banerjee S, Brayne C, Burns A, Cohen-Mansfield J, Cooper C, Costafreda SG. Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. *The lancet*. 2020 Aug 8;396(10248):413-46.
- Hatta NHM, Rashid MFN, Zakaria MN, Wan Mohamad WN. Translation, adaptation, and integration of the Automated Method for Testing Auditory Sensitivity (AMTAS) instructional video in Malay. *Semarak Int J Public Health Prim Care*. 2024;2(1):December
- Mahomed F, Swanepoel DW, Eikelboom RH, Soer M. Validity of automated threshold audiometry: a systematic review and meta-analysis. *Ear and hearing*. 2022 Feb 21.
- Bernama. “Health Ministry aims to enhance access to audiology services”. *Malay Mail*, 28 Oct 2023.
- Department of Occupational Safety and Health Malaysia. Industry Code Of Practice For Management Of Occupational Noise Exposure And Hearing Conservation. 2019.
- Rashid MF, Maamor N, Yen CF, Kar QT. Development of Teleaudiology Service in Special Education Service Centre in Malaysia: Lessons Learned. *Journal of Advanced Research in Applied Sciences and Engineering Technology*. 2024;34(1):289-98.
- Quar TK, Maamor N, Chong FY, Rashid MF. Validation and reliability of teleaudiology approach among deaf or hard of hearing school age children in Malaysia: A preliminary study. *Speech, Language and Hearing*. 2024 Oct 30:1-1.
- Rashid MF, Quar TK, Chong FY, Maamor N. Are we ready for teleaudiology?: data from Malaysia. *Speech, Language and Hearing*. 2020 Jul 2;23(3):146-57.
- Romli M, Timmer BH, Dawes P. Hearing care services for adults with hearing loss in Malaysia: a scoping review. *International Journal of Audiology*. 2024 Oct 1;63(10):753-60.
- Hajesmaeel-Gohari S, Khordastan F, Fatehi F, Samzadeh H, Bahaadinbeigy K. The most used questionnaires for evaluating satisfaction, usability, acceptance, and quality outcomes of mobile health. *BMC Medical Informatics and Decision Making*. 2022 Jan 27;22(1):22.
- Kao CK, Liebovitz DM. Consumer mobile health apps: current state, barriers, and future directions. *Pm&r*. 2017 May 1;9(5):S106-15.
- Mustafa N, Safii NS, Jaffar A, Sani NS, Mohamad MI, Abd Rahman AH, Sidik SM. Malay version of the mHealth app usability questionnaire (M-MAUQ): translation, adaptation, and validation study. *JMIR mHealth and uHealth*. 2021 Feb 4;9(2):e24457.

18. Planning Division Ministry of Health Malaysia, editor. Health in the Sustainable Development Goals and Universal Health Coverage: Progress Report for Malaysia 2016 – 2019 & Seminar proceedings [Internet]. Planning Division Ministry of Health Malaysia; 2020 Aug. Available from: https://www.moh.gov.my/moh/resources/Penerbitan/Laporan/Umum/SDG_REPORT_FINAL_OCT2021.pdf
19. Katz J, Chasin M, English KM, Hood LJ, Tillery KL. Handbook of Clinical Audiology. 7th ed. Wolters Kluwer Health; 2015.
20. Musiek FE, Shinn J, Chermak GD, Bamiou DE. Perspectives on the Pure-Tone Audiogram. *J Am Acad Audiol*. 2017;28(7):655-671. <https://doi.org/10.3766/jaaa.16061>
21. Eikelboom RH, Swanepoel DW, Manchaiah V, Sandaram R, Marschark M, Ronald V, et al. International survey of audiologists during the COVID-19 pandemic: use of and attitudes to telehealth. *Int J Audiol*. 2022;61(4):283-292. <https://doi.org/10.1080/14992027.2021.1957160>
22. Margolis RH, Morgan DE. Automated pure-tone audiometry: an analysis of capacity, need, and benefit. *Am J Audiol*. 2008;17(2):109-113. [https://doi.org/10.1044/1059-0889\(2008/07-0047\)](https://doi.org/10.1044/1059-0889(2008/07-0047))
23. Wasmann JW, Pragt L, Eikelboom R, Swanepoel W. Digital approaches to automated and machine learning assessments of hearing: Scoping review. *J Med Internet Res*. 2022;24(2):e32581. <https://doi.org/10.2196/32581>
24. Eikelboom RH, Swanepoel deW, Motakef S, Upson GS. Clinical validation of the AMTAS automated audiometer. *Int J Audiol*. 2013;52(5):342-349 <https://doi.org/10.3109/14992027.2013.769065>
25. Shojaeemend H, Ayatollahi H. Automated audiometry: A review of the implementation and evaluation methods. *Healthc Inform Res*. 2018;24(4):263–275. <https://doi.org/10.4258/hir.2018.24.4.263>
26. Storey K, Mucoz K, Nelson L, Larsen J, White K. Ambient noise impact on accuracy of automated hearing assessment. *Int J Audiol*. 2014;53(10):730-736. <https://doi.org/10.3109/14992027.2014.920110>
27. Bastianelli M, Mark AE, McAfee A, et al. Adult validation of a self-administered tablet audiometer. *J Otolaryngol Head Neck Surg*. 2019;48:59. <https://doi.org/10.1186/s40463-019-0385-0>
28. Wiseman K, Slotkin J, Spratford M, Haggerty A, Heusinkvelt M, Weintraub S, Gershon R, McCreery R. Validation of a tablet-based assessment of auditory sensitivity for researchers. *Behav Res Methods*. 2023 Sep;55(6):2838–2852. <https://doi.org/10.3758/s13428-022-01933-1>
29. Bean BN, Roberts RA, Picou EM, Angley GP, Edwards AJ. Automated audiometry in quiet and simulated exam room noise for listeners with normal hearing and impaired hearing. *J Am Acad Audiol*. 2022 Jan;33(1):6–13. <https://doi.org/10.1055/s-0041-1728778>
30. Hoff M, Guthberg H, Tengstrand T, Rosenhall U, Skoog I, Sadeghi A. Accuracy of automated pure-tone audiometry in population-based samples of older adults. *Int J Audiol*. 2023;63(8):622–630. <https://doi.org/10.1080/14992027.2023.2220909>
31. Margolis RH, Wilson RH, Popelka GR, Eikelboom RH, Swanepoel deW, Saly GL. Distribution characteristics of air-bone gaps: Evidence of bias in manual audiometry. *Ear Hear*. 2016;37(2):177–188. <https://doi.org/10.1097/AUD.0000000000000246>
32. Hatta NH, Mohamad WN, Zakaria MN, Rashid MF. Validity, Reliability, and Usability of the Automated Method for Testing Auditory Sensitivity With Malay Instructional Video Among Malaysian Population. *Journal of Audiology & Otology*. 2025 Oct 20;29(4):265.
33. Hatta NH. Investigating the validation, reliability and usability of automated method for testing auditory sensitivity (AMTAS) with malay instructional video in clinical and non-clinical settings (Doctoral dissertation).
34. Swanepoel D, Clark JL. Hearing healthcare in remote or resource-constrained environments. *The Journal of Laryngology & Otology*. 2019 Jan;133(1):11-7.
35. Sidiras C, Nielsen J, Suresen CB, Schmidt JH, Pedersen RG, Pedersen ER. Ambient noise in candidate rooms for user-operated audiometry. *Healthcare (Basel)*. 2023;11(6):889. <https://doi.org/10.3390/healthcare11060889>
36. Serpanos YC, Hobbs M, Nunez K, Gambino L, Butler J. Adapting audiology procedures during the pandemic: validity and efficacy of testing outside a sound booth. *Am J Audiol*. 2022;31(1):91–100. https://doi.org/10.1044/2021_AJA-21-00108
37. Govender SM, Mars M. Assessing the efficacy of asynchronous telehealth-based hearing screening and diagnostic services using automated audiometry in a rural South African school. *South African Journal of Communication Disorders*. 2018;65(1):1-9.
38. Yeo Kai Hui H, Chua Wei De K, Kamath SH, Lee SL. A pilot study to validate AMTAS in a specialist outpatient clinic at a public restructured hospital in Singapore. *Proceedings of Singapore Healthcare*. 2023 Jan 23;32:20101058231154667.
39. Mealings K, Harkus S, Flesher B, Meyer A, Chung K, Dillon H. Detection of hearing problems in Aboriginal and Torres strait islander children: a comparison between clinician-administered and self-administrated hearing tests. *International journal of audiology*. 2020 Jun 2;59(6):455-63.
40. Gan KB, Azeez D, Umat C, Ali MA, Wahab NA, Mukari SZ. Development of a computer-based automated pure tone hearing screening device: a preliminary clinical trial. *Biomed Tech (Berl)*. 2012;57(5):323-332. <https://doi.org/10.1515/bmt-2011-0086>
41. Nyein C, Deborah S, Dhana Lekshmi UM, Kumari U. Comparison of audiometric findings with internet-

- based hearing screening tests and the relationship with other associated factors in adults. *Acta Sci Med Sci.* 2020;4:103-113. <http://dx.doi.org/10.31080/ASMS.2020.04.0802>
42. Kastner M, Tricco AC, Soobiah C, Lillie E, Perrier L, Horsley T, Welch V, Cogo E, Antony J, Straus SE. What is the most appropriate knowledge synthesis method to conduct a review? Protocol for a scoping review. *BMC medical research methodology.* 2012 Aug 3;12(1):114.