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IMPROVING HEARING AID ACCESS, USE AND OUTCOMES IN ADULTS

by

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A thesis submitted in fulfilment of the requirements for the degree

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Faculty of Humanities

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PLAGIARISM DECLARATION

Full name: Bopane Mothemela

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I declare that this thesis is my own original work. Where secondary material is used, it has been carefully acknowledged and referenced in accordance with university requirements.

I understand what plagiarism is and am aware of university policy and implications in this regard.

Bopane Mothemela March 2024

PUBLICATIONS AND RESEARCH OUTPUT

This thesis is based on the subsequent original articles:

Mothemela, B., Manchaiah, V., Mahomed-Asmail, F., Knoetze, M., & Swanepoel, D. W. (2023). Factors influencing hearing aid use, benefits, and satisfaction in adults: a systematic review of the past decade. *International Journal of Audiology*, 1-14.

Mothemela, B., Manchaiah, V., Mahomed-Asmail, F., Graham, M., & Swanepoel, D. W. (2023). Factors Associated with Hearing Aid Outcomes Including Social Networks, Self-Reported Mental Health, and Service Delivery Models. *American Journal of Audiology*, 32(4), 823-831.

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Research paper	Scientific conference
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Research paper	Scientific conference
Mothemela, B., Manchaiah, V., Mahomed-Asmail, F., Graham, M., & Swanepoel, D. W. (2023). Factors Associated with Hearing Aid Outcomes Including Social Networks, Self-Reported Mental Health, and Service Delivery Models. American Journal of Audiology, 32(4), 823-831.	• International Hearing Aid Conference (2022), Tahoe City, California, USA. • 58th South African ENT/SAAA Congress (2022), Johannesburg, South Africa. • 50th Annual Scientific and Technology Conference of the American Auditory Society (2023), Arizona, USA. • American Association of Audiologists 2023 +HearTECH Expo (2023) Seattle, USA. • European Federation of Audiology Societies Congress (2023), Sibenik, Croatia.

ABSTRACT

Title: IMPROVING HEARING AID ACCESS, USE AND OUTCOMES IN ADULTS

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Hearing loss affects over 1.5 billion people globally. Most individuals experiencing hearing loss can benefit from hearing aids. Despite the effectiveness of hearing aids, only a small proportion of those with hearing loss globally have access to these devices, and their use is often inadequate. This indicates complex factors influence hearing aid outcomes concerning use, benefit, and satisfaction. This study aimed to 1) explore and synthesise factors influencing hearing aid use, benefit, and satisfaction; 2) determine factors influencing hearing aid outcome; and 3) evaluate the feasibility of improving access to hearing aids through a community-based hearing aid fitting model for low-income communities.

For Study I, a systematic literature review was conducted to explore and synthesise evidence on factors influencing hearing aid use, benefit, and satisfaction. Studies published between 2010 and 2023 were identified using PRISMA guidelines from databases including Web of Science, Scopus, PubMed, EBSCOhost, CINAHL, and Academic Search Complete. The National Institute of Health Quality assessment tool and the Oxford Centre for Evidence-Based Medicine tool were used for quality assessment and grading of the level of evidence. Forty-five articles met the inclusion criteria and were included in the review; 101 significant factors influencing hearing aid use (n=47), benefit (n=17) and satisfaction (n=37) were identified. Positive determinants include hearing sensitivity, self-reported hearing difficulty, speech perception, attitude, and beliefs. Negative determinants include the prevalence of hearing aid problems, active neurological disorder and bothersome tinnitus. New factors, including social networks and service delivery models, were also identified.

Study II was a prospective cross-sectional study to identify and describe factors influencing hearing aid outcomes. An online survey was sent to hearing aid users in the United States of America (USA) through the Hearing Tracker website from October to November 2021. The survey included questions on demographics, audiological, general health, and social factors, as well as self-reported hearing aid outcomes. Regression models evaluated potential contributing factors of hearing aid outcomes on the IOI-HA. Three hundred ninety-eight hearing aid users completed the survey with an average age of 66.6 (13. SD) years, of which 59.3% were male. Positive contributing factors included the social network of people with hearing loss who use hearing aids, self-reported mental health, work situation, life quality, and hearing difficulty. Adverse contributing factors encompassed newly identified factors, which included social networks of people with hearing loss without hearing aids and service delivery models from a private or university clinic and big box retailers. These newly identified factors can inform public hearing health promotion and individualised audiological care to optimise hearing aid outcomes.

Study III assesses the feasibility of a community-based hearing aid fitting model for low-income communities facilitated by community health workers (CHWs). This study examines self-reported hearing aid outcomes among participants who experienced the hearing aid fitting process within a community-based model. In this study, 25 participants received bilateral GoPrime direct-to-consumer hearing aids from CHW working in a low-income community setting. Among the 25 participants fitted with bilateral GoPrime hearing aids, 30% were male, whereas 70% were female. The average four-frequency pure tone average was 55.3 (12.3 SD) and 56.6 (15.4 SD) for the left and right ears, respectively. Most participants reported positive hearing aid outcomes, including effective performance of the hearing aids in background noise. The total IOI-HA scores indicated above-average results in hearing aid use, benefits, and satisfaction.

This thesis comprehensively explored the multifaceted factors influencing hearing aid use, benefits, and satisfaction among individuals with hearing loss. This was achieved through a systematic literature review, a cross-sectional survey, and prospective evaluation of a community-based hearing aid fitting model. The findings of this project emphasise the importance of considering a broad spectrum of factors in audiological practice and public health strategies to optimise hearing aid outcomes. Future research should expand on these

insights, exploring the scalability of community-based models and refining personalised care strategies to meet the diverse needs of hearing aid users globally.

KEYWORDS

Hearing loss

Hearing aid

Outcomes

Use

Benefit

Satisfaction

Hearing healthcare

mHealth solutions

Systematic review

Community health workers (CHW)

ABBREVIATIONS

4FA	Four Frequency Average
ACHIEVE	Ageing and Cognitive Health Evaluation in Elders
AI	Artificial intelligence
APA	American Psychological Association
APHAB	Abbreviated Profile of Hearing Aid Benefit
BTE	Behind the Ear
CBR	Community-based rehabilitation
CBT	Cognitive behavioural therapy
CEBM	Centre for Evidence-Based Medicine
CHW	Community health workers
DTC	Direct to consumer
FDA	Food and Drug Administration
HCP	Hearing care professionals
HEARS	Hearing Equality through Accessible Research and Solutions
HL	Hearing loss
HRQoL	Health related quality of life
Hz	Hertz
IOI-HA	International Outcome Inventory for Hearing Aids
ITE	Included in the Ear
kHz	Kilohertz
LMIC	Low- and middle-income countries
MAE	Mean absolute error
mHealth	Mobile Health
NGO	Non-government organisation

NIH	National Institute of Health
OTC	Over-the-counter
PICOST	Population Intervention Comparison Outcome Study Design Timeline
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROM	Patient-reported outcome measures
PSAP	Personal sound amplification products
PTA	Pure-tone average
SADL	Satisfaction with Amplification in Daily Living
SRT	Speech recognition threshold
SWiM	Synthesis without meta-analysis
UN	United Nations
USA	United States of America
WHO	World Health Organization
WRS	Word recognition score

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CHAPTER 1: INTRODUCTION

1.1 Introduction

Hearing loss is a prevalent global health concern, affecting 1.5 billion people (World Health Organization [WHO], 2021). Among these, 1.16 billion experience mild hearing loss, 400 million experience moderate to severe hearing loss, and 30 million have profound hearing loss (Haile et al., 2021). Adults over 60 account for over 58% of moderate or more significant degrees of hearing loss (Haile et al., 2021), with the most common cause of hearing loss being ageing (WHO, 2021). Other contributors to hearing loss in the adult population include chronic diseases, otosclerosis, head trauma, ototoxic medication, loud noise, and genetic variations (WHO, 2021). The effect of untreated hearing loss on individuals is far-reaching, causing difficulties in communication, hearing, academic performance, productivity, increased odds of unemployment, life quality, and deficient general and mental health (Oliviera et al., 2015; Ferguson et al., 2019; Idstad & Engdahl, 2019; Mick et al., 2016). The global economic cost of untreated hearing loss exceeds USD 980 billion annually, attributed to healthcare, education, productivity losses, and societal costs (WHO, 2021).

1.2 Hearing loss prevention and management

Hearing loss can be prevented and treated through public health preventive measures and clinical interventions. Primary public health preventive measures are implemented before the onset of hearing loss and include education on ototoxicity prevention, promoting safe listening practices, and noise control in recreational and occupational settings (Daniel, 2007; Kraaijenga et al., 2016). Novel mHealth initiatives for primary public health prevention have been used and include using widely popular mobile communication platforms, such as text messages, WhatsApp messages, and voice recordings, to provide hearing healthcare education to patients (Swanepoel, 2023). Secondary prevention measures focuses on early detection and intervention and include measures such as hearing screening of those at risk of hearing loss, such as older adults, those using ototoxic medication, and those exposed to loud sound. These measures can be facilitated through new mHealth technologies, such as smartphone-based hearing screening audiometry (Swanepoel et al., 2014; Swanepoel, 2023).

Adult hearing screening and effective referral pathways are important strategies to ensure early identification and diagnosis of individuals with hearing loss. Tertiary prevention of hearing loss

focus on addressing already existing hearing loss and include measures such as hearing rehabilitation or management, aiming to minimise the effect of hearing loss on daily living and functioning (WHO, 2001; Swanepoel, 2023).

The most common approach to hearing rehabilitation is use of hearing technology, which includes effective options, such as hearing aids, cochlear implants, and implantable aids (Brodie & Smith, 2018). Conventional hearing aids are the most common treatment for various types of hearing loss (Ferguson et al., 2019). Patients who cannot benefit from conventional hearing aids can be considered for cochlear implants, electronically implanted devices, stimulating the auditory nerve (Brodie & Smith, 2018). Other implantable aids, such as bone conduction (active and non-surgical) devices are effective for conductive and mixed hearing loss (Briggs, 2019). Active middle ear implant systems (e.g. Vibrant Soundbrigde) are effective in patients with middle ear diseases and external ear malformations with conductive and mixed hearing loss (Briggs, 2019; Tisch, 2017). Additional approaches to rehabilitation include sign language, sensory substitution, speech reading, and alternative methods of communication such as manual signs, gestures and speech generating devices (WHO, 2021).

1.3 Hearing loss management with hearing aids

Globally, over four hundred million people diagnosed with hearing loss can be treated effectively with hearing aids (Fröschl, 2019). Compared to other hearing rehabilitative technologies, hearing aids are non-invasive, user-friendly, are indicated for various types and degrees of hearing loss, and are cost-effective (Joore et al., 2003). Studies reveal that hearing aids can improve communication, reduce depression, and enhance health and life quality (Tsimpida et al., 2022; Ferguson et al., 2019). In a recent large-scale randomised controlled trial called the Ageing and Cognitive Health Evaluation in Elders (ACHIEVE) conducted by Lin et al. (2023), it was demonstrated that hearing intervention involving hearing aid provision, related technology, and audiological counselling led to a 48% reduction in the decline of thinking and memory abilities over three years for those at risk for cognitive decline. Despite the proven effectiveness of hearing aids in improving hearing and health outcomes, hearing aids are still largely inaccessible to most people diagnosed with disabling hearing loss due to lack of workforce, awareness, provider gatekeeper, cost of audiology equipment and hearing aids (Orji et al., 2020).

According to recent statistics from the WHO (2021), over 91% of individuals with disabling hearing loss in low-income countries lack access to hearing aids. Globally, from the 457 million individuals who could benefit from hearing aids, only 44.7 million have access to them (Bisgaard et al., 2022). Contributing factors towards the inaccessibility of hearing aids include the high cost of hearing aids, which arise from profit mark-ups by manufacturers and professionals and burdensome regulation and bureaucracy (Blustein & Weinstein, 2016). These contributing factors emanate from the traditional centralised models of care, which are difficult to scale owing to the lack of human resources (e.g., audiologists) and expensive clinical equipment required to support evidence-based audiologic practices (Mulwafu et al., 2017; WHO, 2021; Goulios & Patuzzi, 2008).

Efforts have been made to improve access to hearing healthcare by exploring alternative approaches to the traditional centralised models of care. One of these approaches involves task-shifting to community health workers (CHW) and other hearing professionals such as audiology technicians, assistants and audiometrists. This strategy has been recently prioritised by the WHO to guide the shortage of hearing healthcare professionals (WHO, 2021; Chadha et al., 2018; Yousuf Hussein et al., 2018). Another promising approach, reducing dependence on involves over-the-counter hearing aids. The United States Food and Drug Administration (FDA) recently allowed the direct sale of these hearing aids to consumers with mild to moderate self-perceived hearing issues (Food and Drug Administration, 2022). These new developments, and the support of mHealth technologies, promote various service delivery models differing from traditional audiology best practices. Despite the validation and efficacy of multiple sets of hearing aid service delivery models, such as over-the-counter and community-based hearing care, there are still inadequate studies investigating the feasibility of these models' hearing aid provision in LMICs. The high prevalence of hearing loss and the substantial costs associated with untreated cases emphasise the importance of enhancing the accessibility of hearing aids and monitoring the outcomes for individuals fitted with these devices.

1.4 Factors influencing hearing aid outcomes

Evaluating patient outcomes is a method to assess the effectiveness of hearing aids in treating hearing loss. Recently, there has been a growing emphasis on measuring hearing aid outcomes among studies, clinicians, civil organisations, and hearing aid manufacturers, compelled by the increasing prevalence of hearing loss, the need to scale hearing aid provision and associated rehabilitative processes, and the cost of undiagnosed hearing loss (WHO, 2021).

Manufacturers may measure hearing aid outcomes to improve product quality, quality assurance, customer satisfaction, research and development, clinical validation, and regulatory compliance (Kates et al., 2018). Hearing aid outcomes are primarily based on health indicators, such as improved communication, decreased anxiety and depression, and better life quality, or are specifically related to hearing and hearing aids (Ferguson et al., 2019). Common measures of hearing aid outcomes include hearing aid use, benefit, and satisfaction. Clinically, these outcomes can be measured using objective criteria, such as data logging of hearing aid usage, behavioural measures, such as speech testing with and without hearing aids, or self-reported standardised measures, such as the International Outcome Inventory for Hearing Aids (IOI-HA). Factors, such as individual characteristics (e.g. hearing loss, personality) and the hearing aid itself (e.g.features, style, strength), can significantly influence hearing aid outcomes in the domains of use, benefit, and satisfaction.

One factor influencing hearing aid outcomes is the price, accounting for 4.2% of the hearing aid outcomes (Wang et al., 2021). Apart from the cost of hearing aid, other factors contribute significantly towards hearing aid outcomes. Assi et al. (2021) reported hearing aid usage of 27% among 5,146 participants diagnosed with hearing loss who were provided hearing aids freely through the United Kingdom National Health Service. Increasing the probability of hearing aid use is associated with several enabling factors. These include higher income, living alone (as opposed to living with family members other than a spouse), and having a regular source for general health care needs. Another recent study by Wang et al. (2021) identified audiological factors, such as word recognition score and daily hearing aid use, accounting for 17.1% and 8.1% of overall hearing aid outcomes measured through the IOI-HA, respectively.).

Studies aimed to synthesize existing evidence to identify factors influencing hearing aid usage, benefits, and satisfaction. For instance, a scoping review by Knudsen et al. (2010) identified 31 factors studied regarding four outcome domains, including help-seeking behaviour for hearing loss, hearing aid uptake, hearing aid use, and satisfaction from 39 peer-reviewed articles. Factors identified include personal elements (e.g., source of motivation, expectation, attitude), demographic characteristics (e.g., age, gender and external factors (e.g., cost, counselling)), and self-reported hearing problems as predictor variables for the four outcome domains. A systematic review by Ng and Loke (2015) identified five audiological factors (i.e., self-perceived hearing problems, severity of hearing loss, type of hearing aids, background noise acceptance, and insertion gain), and six non-audiological factors (i.e. expectation,

demographics, group consultation, support from spouses, self-perceived benefit, and hearing aid satisfaction) as determinants of hearing aid adoption and use. In clinical practice, the identified factors should considered to optimize hearing aid outcomes.

1.5 Research project rationale

This research evaluated factors contributing to patient hearing aid outcomes. There has been growing evidence of factors influencing hearing aid use, benefits, and satisfaction from recently published studies. Recent studies explore new factors influencing hearing aid use, benefits, and satisfaction in adults, such as mental health, service delivery model, and social networks, omitted in previous reviews (Knudsen et al., 2010; Ng & Loke, 2015). For instance, Giuliani (2021) indicated an adverse association among neurological disorders contributing to mental health and infrequent hearing aid use. Another recent study by Nixon et al. (2021) found a positive correlation between improved cognition and higher rates of hearing aid usage. Provided these new findings, an updated review is warranted, synthesising evidence on factors influencing hearing aid use, benefits, and satisfaction from studies in the past decade. Study I is an updated systematic review which synthesises evidence on factors of hearing aid use, benefits, and satisfaction on studies published in the past decade (2010 and 2023). This study is the latest systematic review that summarizes and consolidates evidence from the literature on factors, including recent ones, influencing hearing aid outcomes. Evidence on recent factors needs to be strengthened through further investigation. Study II is an exploratory survey study to extend existing evidence on newly identified factors, including self-reported mental health, social networks, and service delivery models. Strengthening evidence on recently identified factors (Study I) through an exploratory study (Study II) contributes to the broader refinement of evidence-based practice, enhance decision-makers' understanding, support strategic planning, and inform decision-making in audiology clinical practice.

Several studies investigated the feasibility of alternative scalable service delivery models, including community-based hearing care and over-the-counter hearing aids. For instance, Nieman et al. (2017) assessed the feasibility of a community-based hearing care intervention called Hearing Equality through Accessible Research and Solutions (HEARS). The study reveals that the HEARS intervention through personal sound amplification products (PSAPs) was well-received and practical for implementation; participants reported experiencing improvements in self-reported hearing handicap and communication difficulties after the intervention. A more recent study by Frisby et al. (2022) evaluated the feasibility of a community-based rehabilitation (CBR) model that delivered hearing aids to adults through CHW supported by mHealth technologies. The study demonstrates positive hearing aid

outcomes in 18 participants who received hearing aids through the CBR model implemented by CHW.

These positive findings were further supported by another recent feasibility randomised controlled trial conducted by Coco et al. (2023). The trial indicated improved hearing outcomes in the experimental group, where CHW facilitated the intervention compared to the control group facilitated by trained student facilitators. Study III of this research evaluated the feasibility of a community-based hearing aid fitting model for low-income communities facilitated by CHW. This study contributes to building evidence towards the feasibility of a community-based hearing aid fitting model through CHW, supported by mHealth technologies (Studts, 2022). Novel developments, such as over-the-counter hearing aids and the proposal of task-shifting to CHW, will be employed to assess their feasibility within LMICs (WHO, 2021; Chadha et al., 2018; Hussein et al., 2018; Stephenson, 2022).

CHAPTER 2: METHODOLOGY

2.1 Research aims

This study aimed to 1) synthesise evidence on factors influencing hearing aid use, benefits, and satisfaction; 2) explore recent factors influencing hearing aid outcome; and 3) evaluate the feasibility of improving access to hearing aids through a community-based hearing aid fitting model for low-income communities in the Khayelitsha, Western Cape, South Africa.

The three aims constituted a research project published or submitted as an article in accredited peer-reviewed journals. These three studies are summarised in Table 2.1 according to titles and objectives.

Table 2.1: Summary of studies according to titles and objectives

	Study I	Study II	Study III
Title	**Factors influencing hearing aid use, benefits, and satisfaction in adults: A systematic review of the past decade**	**Factors associated with hearing aid outcomes, including social networks, self-reported mental health and service delivery models**	**Hearing health care for adults in low-income communities using mHealth and hearing aid technologies: a feasibility study**
Objective	To examine audiological and non-audiological factors influencing hearing aid use, benefits, and satisfaction in adults based on the studies published during the last decade (2010 and 2023).	To identify and describe factors influencing hearing aid outcomes, including social networks, self-reported mental health and service delivery models.	To determine the feasibility of a community-based hearing aid fitting model for low-income communities in the Western Cape, South Africa, using low-cost in-the-ear digital hearing aids with three pre-set programmes facilitated by CHW.
Publication Status	Mothemela, B., Manchaiah, V., Mahomed-Asmail, F., Knoetze, M., & Swanepoel, D. W. (2023). Factors influencing hearing aid use, benefits, and satisfaction in adults: a systematic review of the past decade. International Journal of Audiology, 1-14.	Mothemela, B., Manchaiah, V., Mahomed-Asmail, F., Graham, M., & Swanepoel, D. W. (2023). Factors Associated with Hearing Aid Outcomes Including Social Networks, Self-Reported Mental Health, and Service Delivery Models. American Journal of Audiology, 32(4), 823-831.	Mothemela B., Frisby C., Mahomed-Asmail F., de Kock T., Moore, D., Manchaiah, V., Swanepoel., (2024). Hearing health care for adults in low-income communities using mHealth and hearing aid technologies: a feasibility study. In Press: Global Health Action.
Ethical Clearance	University of Pretoria, HUM009/0622 (Appendix A2)	University of Pretoria, **HUM009/0622** (Appendix A2 and Lamar University review boards **(IRB-FY21-248) (**Appendix B: Clearance from Lamar University (IRB-FY21-248)**)**	University of Pretoria, HUM011/0822 (Appendix A1)
Chapter in thesis	Chapter 3	Chapter 4	Chapter 5

2.2 Ethical consideration

Research ethics approval was received from the University of Pretoria Research Ethics Committee of the Faculty of Humanities (Appendix A1 and A2 and the Lamar University ethics review board (IRB-FY21-248, Appendix B: Clearance from Lamar University (IRB-FY21-248)). The research project theme encompassed improving access to hearing health care, a priority objective of the WHO and forms part of the United Nations Sustainable Development goals to reduce inequalities within the healthcare systems, ensure healthy lives, promote well-being, and sustainable and inclusive economic growth.

Study I was a systematic review including the non-direct involvement of participants. As such, ethical considerations only included plagiarism and data synthesis procedures solicited by adhering to the PRISMA and American Psychological Association (APA) referencing guidelines. Components of Study II and III of the research project included human participants. They were, therefore, conducted in compliance with the Declaration of Helsinki (2013) and the guidelines from the South African National Health Act (2013) to promote respect and protect the rights of participants. The World Medical Association Declaration of Helsinki (2013) comprises ethical principles, including privacy and confidentiality, informed consent, risks, and benefits, guiding medical and social research. The South African National Health Act (2013) comprises similar ethical principles as the Declaration of Helsinki but more specific to research conducted in South Africa.

2.2.1 Anonymity

For Study II, deidentified data were provided. Participant identities were kept anonymous and sensitive personal information, such as patient name and surname, was concealed from hearing tracker and involved research investigators.

2.2.2 Confidentiality

For Study III, participants' information was kept confidential. While capturing the results, a participant number was allocated to each participant's results. All data were analysed using the alphanumerical code assigned to each participant.

2.2.3 Protection from harm

There were no medical risks or discomforts associated with both studies. Participants were briefed on the procedure and provided consent before being included (Appendix C).

For Study II, the survey link led to a consent form that had to be signed electronically before the survey could be completed (Appendix C). The survey automatically ended if participants did not provide consent. For Study III, consent was signed by the community health care workers and participants with hearing loss before procedures were performed (Appendix C). Participants (both CHWs and individuals with hearing loss) could withdraw their participation at any time by contacting the primary investigator.

For Study II, participants were informed there would be no direct benefits to them by participating in the study but that the results may provide evidence on hearing aid access, use, benefits, and satisfaction; however, for Study III, the benefits included one free pair of bilateral Go prime hearing aids.

Study I: Factors influencing hearing aid use, benefits, and satisfaction in adults: A systematic review of the past decade

2.3 Research design

The first study employed a systematic review and included the reviewing of existing peer-reviewed articles on hearing aid use, benefits, and satisfaction. The systematic review protocol was registered on the International Prospective Register of Systematic Reviews (CRD42022298403).

2.4 Research procedures

Systematic literature searches were conducted through these databases: (i) Web of Science (ii) Scopus, (iii) PubMed, (iv) EBSCO host through CINAHL, and (v) Academic Search Complete.

The search was conducted using the following search terms: “hearing aid” or “hearing device” or “amplification” or hearing instrument” AND “use” or “usage” or “usage rate” or “non-use” or “rejection” or “refusal” or “utilization” or “benefit” or “advantage” or “gain” or “satisfaction” or “satisfy” or “contentment” or “fulfillment” or “success” or “outcome” or “post-fitting”. The searches were limited to English, peer-reviewed publications published between 2010 and 2023. The dates were chosen based on the last systematic review (Knudsen et al. 2010) on hearing aid outcomes which was conducted over a decade ago, A secondary literature search that includes manual search and reference checks from included articles was done during the process of writing the review to identify the latest or initially missed articles. Search results were exported to the Ryann systematic review software and reviewed based on the exclusion and inclusion criteria indicated in Table 2.2.

Table 2.2: Inclusion and exclusion criteria

Characteristics	Inclusion	Exclusion
Population	Adult hearing aid users (18 years or older)	Non-hearing aid users, Infant and children below the age of 18 years
Intervention	Amplification with digital air-conduction hearing aid (i.e., bilateral or unilateral).	Amplification with surgically implanted hearing devices (e.g., cochlear implant, bone-anchored hearing aid).

Control	Any comparator	None
Outcomes	▪ Self-reported outcomes (e.g., self-reported hearing aid use, hearing aid benefit and/or satisfaction) ▪ Behavioral measures such as speech recognition (word and sentence) in quiet and/or noise ▪ Objective assessments such as hearing aid data log	No outcomes reported
Study Design	Quantitative studies with any design published in peer-reviewed journals	Unpublished studies, non-peer-reviewed publications, thesis/dissertations, animal studies, systematic reviews and qualitative studies. Qualitative studies were excluded from this review to be in line with the previous reviews for comparative data.
Timing	Peer-reviewed articles from 2010 onwards	Peer- reviewed articles from 2009 and earlier.
Language	English only	Articles written in any other language other than English

2.4.1 Data charting and extraction

Results from the literature search were extracted to Rayyan software (https://www.rayyan.ai) for independent blinded eligibility screening. Study duplicates were identified and removed through the Rayyan software, followed by a screen of titles and abstracts with full texts inspected when required. Studies passing the initial screening were perused to determine eligibility independently by each of the two researchers; 29% of the conflicted decisions on the exclusion and inclusion of articles were recorded and resolved by the two researchers. Any disagreements between the two reviewers were resolved using a consensus approach through discussion with a third researcher. For each study, relevant data suggested by the PRISMA 2020 guidelines were extracted. Data extraction was conducted by the primary researcher on an Excel spreadsheet designed specifically for this review. A second researcher cross-checked 20% of randomly selected articles to ensure reliability and consistency. Descriptive data,

including country, population, sample size, study design, mean age, biological gender ratios, and information relevant to key outcomes, were extracted.

2.4.2 Quality assessment and determination of the level of evidence

The National Institute of Health (NIH) Quality Assessment Tool (National Institute of Health, 2021) was used to assess the quality of the studies included. The ratings 0-4 indicated inadequate quality, 5-10 indicated fair quality, and 11-14 indicated decent quality (Biagias et al., 2021). The level of evidence for included studies was determined using the Oxford Centre for Evidence-Based Medicine (CEBM) - Levels of Evidence tool, which classifies studies based on the research design. According to the CEBM tool, systematic reviews are categorised as high Level 1 evidence, whereas case-control studies are categorised as low Level 5 (less evidence). Quality assessment and level of evidence determination were conducted by a primary researcher, and a second reviewer cross-checked 20% of randomly selected articles.

2.4.3 Data synthesis

Owing to the high heterogeneity of included studies, quantitative synthesis of results was not feasible. The synthesis without meta-analysis (SWiM) reporting guidelines (Campbell et al., 2020) was used to summarise the study findings. Vote counting based on the direction of effect was selected as the synthesis method (Campbell et al., 2020). The synthesis was conducted through a full reading of the included articles and extracting identified factors from the primary reviewer. The results were reported as agreed on by research team members.

Study II: Factors associated with hearing aid outcomes, including social networks, self-reported mental health and service delivery models

2.5 Research design

A prospective cross-sectional survey design was employed to evaluate recent factors contributing to hearing aid use, benefits, and satisfaction. The study included 398 participants (hearing aid users) members of the Hearing Tracker website community (www.hearingtracker.com) who completed an online survey.

2.6 Participants

The study included 398 hearing aid users recruited using a convenience sample from the Hearing Tracker (www.hearingtracker.com) database. Hearing Tracker is a website providing comprehensive and up-to-date information about hearing instruments and services to consumers (Manchaiah et al., 2020). An email with the study invitation and a link to the survey was distributed to the Hearing Tracker membership database.

2.7 Study material and apparatus

An online survey was sent to Hearing Tracker members through the Qualtrics platform during October and November 2021. The survey contained questions on 1) demographic, 2) audiological variables; 3) self-reported hearing aid outcomes; 4) general health, 5) mental health and 6) social network information. Demographic items included age, gender, race, ethnicity, work situation, education level, household income and living arrangement. In this study, work situation refers to the participant's state of employment and comprises the subsequent employment status options; retired, out of work, and employed.

Audiological items included self-reported hearing difficulty, duration of hearing loss, duration before hearing aids were obtained after the patient noticed hearing problems, monaural or binaural fitting, hearing aid style (in the ear or behind the ear), hearing aid brand, and service delivery model. For the self-reported hearing aid benefit and satisfaction measure, the IOI-HA (Cox & Alexander, 2002) outcome tool was used. The IOI-HA comprises seven items scored using a 5-point Likert scale, with a score of five indicating the best result and a score of one

indicating the worst; therefore, a higher score on each question and the total score indicated a better outcome (Cox & Alexander, 2002).

General social networks were defined as the number of people in households, children, close friends and grandchildren. Social networks related to hearing loss and hearing aids are divided into two categories: (i) social networks of people with hearing loss and no hearing aids and (ii) social networks of people with hearing loss with hearing aids, indicating the number of known people with hearing loss with and without hearing aids, respectively. Mental health in this study represents the general status of self-reported mental well-being measured on a five point scale (i.e. excellent, very good, good, fair and poor)

2.8 Research procedures

The research co-supervisor, Prof. Vinaya Manchaiah, formulated an online survey through the Qualtrics platform and sent to the Hearing Tracker database during October and November 2021. Participation was voluntary, and deidentified responses were recorded on Qualtrics and, after that, analysed.

2.9 Data analysis

Survey data were extracted from the Qualtrics platform into Microsoft Excel. The data screening process included identifying (i) missing values and (ii) unconsented responses. These responses were excluded: participants who did not provide consent (n=23); participants with only an implantable device(s) (e.g., cochlear implants, bone-anchored hearing devices; n=3); participants without conventional hearing aids but used direct-to-consumer devices, such as PSAP (n=14). After eliminating participants with incomplete data, the remaining 398 participants were included in the data analysis. All statistical analyses were completed in SPSS (IBM Corporation, v 28, 2021).

Exploratory data analysis was conducted, with the results indicating a violation of the assumptions of normality, linearity, and homogeneity of variance for demographic variables. Seven ordinal regression models were constructed for each of the IOI-HA items—Item 1 to 7 (ordinal variables) and one quantile regression model was constructed for the IOI-HA total score (continuous variable) as the dependent variable. The independent (contributing factor) variables included demographic variables (i.e., age, gender, race, ethnicity, work situation, education level, living arrangement, household income), audiological variables (i.e., self-

reported hearing difficulty/without hearing aids, duration before hearing aid purchased, type of hearing aid service delivery model), social network variables (i.e., general social networks and social networks related to hearing loss and hearing aids), self-reported general health, self-reported mental health and life quality.

Study III: Hearing health care for adults in low-income communities using mHealth and hearing aid technologies: a feasibility study

2.10 Study design

This was a prospective feasibility study. Ethical approval was obtained from the University of Pretoria Humanities Ethics Board (Appendix A1 and Appendix A2).

2.11 Research context

Study III was conducted in Khayelitsha, Western Cape, South Africa. The Western Cape is one of nine provinces in South Africa. The Cape Town metropole has a population of 4,067,774 and is in the Southern Peninsula of the Western Cape (Statistics South Africa, 2020). Khayelitsha is 30 km from the City of Cape Town, with an estimated population of 391,749. Khayelitsha has 118,810 households, of which 44.6% are formal dwellings and 18.8% have no income at all (Stats SA, 2014). The study was conducted in collaboration with the hearX Foundation, a nonprofit organisation in South Africa. Following the task-shifting approach suggested by the WHO, CHW employed by the hearX Foundation conducted hearing screening, hearing testing, and hearing aid fittings, supervised by qualified audiologists, using mHealth solutions.

2.12 Participants

The participants were selected from 188 participants who received hearing screening conducted through mHealth solution (hearscreen^{TM}). Thirty participants who met inclusion criteria and consented to study procedures were fitted with bilateral GoPrime hearing aids (hearX Group, Pretoria, South Africa) by CHW. The inclusion criteria include: i) ≥18 years of age, iii) bilateral hearing loss (4FA PTA; 26 dB HL; no greater than 85dB HL owing to the max output of hearing aids), ii) have WhatsApp or receive SMSs (either themselves or a household member), iii) willing to be contacted for interviews.

2.13 Study apparatus and material

mHealth solutions used include HearScope^{TM}, hearTest^{TM} and the Go prime hearing aids, innovative solutions by the hearX Group, a medical technology company in Pretoria, South Africa. hearTest^{TM} is conventional pure tone audiometry which tests hearing at all frequencies up to 8 KHz. The HearScope^{TM} is a video otoscope with artificial intelligence (AI) imaging

used to inspect the outer ear to identify any ear disease (e.g., wax impaction, perforation, or ear infection) and to evaluate the patency of the ear canal to accommodate a hearing aid. GoPrime hearing aids are low-cost in-the-ear digital hearing aids with six channels, 12 bands, three pre-set programmes, noise reduction, feedback cancellation, memory recall function, adjustable volume, and rechargeable. The participants were orientated regarding user-operated controls (i.e. volume, program) and device maintenance.

2.14 Study procedures

The subsequent CBR service delivery model components included i) recruitment, ii) hearing assessment and hearing aid demonstration, iii) hearing aid fitting, and iv) 45 days follow-up and support were conducted. These components were conducted in collaboration with the hearX Foundation, a non-government organisation in the Western Cape, South Africa.

2.14.1 Recruitment phase

Community health workers conducted hearing testing on 188 adults with suspected self-reported hearing loss using a calibrated mHealth testing audiometer (hearTest TM, hearX Group, Pretoria, South Africa) in the community of Khayelitsha.

2.14.2 Hearing assessment and hearing aid demonstration

Smartphone otoscopy with AI imaging through the HearScope^{TM} (HearX Group, Pretoria, South Africa) was used to inspect the outer ear to identify any ear disease (e.g., wax impaction, perforation, or ear infection) and to evaluate the patency of the ear canal to accommodate a hearing aid. Identified ear diseases were referred to the local primary healthcare facility. Conventional audiometry through the hearTest^{TM} was used. This test requires that participants raise their hands or push a button on the smartphone each time they hear a tone, even when it becomes softer. Participants with confirmed hearing loss were offered an opportunity to experience listening through the GoPrime hearing aids on a program of their choice The hearing aids (hearX GoPrime) are low-cost in-the-ear digital hearing aids with six channels, 12 bands, three pre-set programmes, noise reduction, feedback cancellation, memory recall function, adjustable volume, and rechargeable. Hearing aid fitting

Thirty participants who met the inclusion criteria were fitted with bilateral GoPrime hearing aids on a programme of their choice. The participants were oriented regarding the user-operated

controls and device maintenance. The CHW facilitated the hearing aid fittings under the supervision of qualified audiologist researchers. Hearing aid follow-up and support

A 45-day mHealth support and acclimatisation programme was offered. Information regarding hearing health, device management, and use was accessible to the community members, such as SMS or WhatsApp messaging service. For follow-up, participants received three telephonic interviews on days 8, 20 and 43 after the hearing aid fitting. Participants received an in-person follow-up 45 days after the hearing aid fitting. Outcomes measures, including a four-week follow-up questionnaire and the International Outcome Inventory for Hearing Aids (IOI-HA) (Appendix F: Four-week follow-up questionnaire) (Cox & Alexander, 2002) translated in isiXhosa (local language of South Africa) were used to capture patients' perceptions, experiences, and challenges on mHealth hearing aid fitting and support programme. Data analysis

Raw data were exported to Microsoft Excel spreadsheets and the program Statistical Package for the Social Sciences (SPSS, v27. Chicago, Illinois). Descriptive statistics, including mean and standard deviations, were determined for participant age, gender, hearing loss, and the IOI-HA scores. Qualitative questions from the participant survey were analysed by the first author (BM) using inductive thematic analysis to determine emerging themes. For quality control, the second author (CF) reviewed the themes, and any discrepancies were resolved through a consensus approach.

CHAPTER 3: FACTORS INFLUENCING HEARING AID USE, BENEFITS, AND SATISFACTION IN ADULTS: A SYSTEMATIC REVIEW OF THE PAST DECADE

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3.1 Abstract

Objective: This systematic review examined the audiological and non-audiological factors that influence hearing aid use, benefit and satisfaction in adults based on studies published during the last decade (2010 and 2023).

Design: Studies were identified by using PRISMA guidelines for systematic searches on five platforms (Web of Science, Scopus, PubMed, EBSCOhost including CINAHL and Academic Search Complete). The National Institute of Health Quality assessment tool and the Oxford Centre for Evidence Based Medicine tool were used for quality assessment and grading of level of evidence.

Results: Forty-six articles were included in the review. A total of 101 significant factors influencing hearing aid use (n=47), benefit (n=17) and satisfaction (n=37) were identified. Clear determinants of hearing aid use, benefit and satisfaction included hearing sensitivity, self-reported hearing difficulty, speech perception, attitude and beliefs. Thirty-four cross-sectional studies in this review were graded level 4, 9 cohort studies rated level 3, and 3 randomized control trials rated level 2.

Conclusion: Factors associated with hearing aid outcomes identified in the past decade support previous evidence. New factors like social networks and service-delivery models, have also

been identified. These factors require further investigations through high quality studies to further strengthen existing evidence.

Keywords

Hearing aid, Hearing aid outcome, Hearing aid use, Hearing aid benefit, Hearing aid satisfaction, Systematic review.

3.2 Introduction

Most people with hearing loss (71.3%) are adults who present with a mild to moderate degree of hearing loss which can be managed successfully with hearing aids (World Health Organization, 2021). Hearing aids have been shown to be effective in improving hearing, communication, and quality of life (Ferguson et al., 2019). The effectiveness of hearing aids on the treatment of hearing loss can be evaluated by considering patient outcomes. These outcomes can be based on health indicators such as improvements in communication, decreased anxiety, depression, and improved quality of life or specifically based on hearing and/or hearing aids. Clinically it is common to measure patient outcomes in terms of hearing aid use, benefit and satisfaction. Moreover, these outcomes can be measured using objective (e.g., hearing aid use through data logging), behavioral (e.g., hearing aid benefit measures through speech testing with and without hearing aids) and/or self-reported (i.e., standardized measures such as International Outcome Inventory for Hearing Aids; IOI-HA) measures.

The three constructs of hearing aid outcomes (i.e., use, benefit and satisfaction) are closely related and have been well defined in the audiological literature (Humes, 1999). Hearing aid use refers to how many hours a day a hearing aid owner uses their hearing aid/s (Solheim et al., 2012) whereas hearing aid benefit is defined as improvements in hearing function and communication ability as a result of hearing aid performance (Cox & Alexander, 1992). Hearing aid satisfaction refers to positive emotional experience as a result of the user's evaluation of their hearing aid performance (Wong et al., 2003). While they can be defined separately, these constructs are related and influenced by one another. For instance, hearing aid use is a good indicator or factor of hearing aid performance. Houmoller et al. (2022) and Wang et al. (2021) revealed a positive association between daily hearing aid usage time and hearing aid benefit. Furthermore, Korkmaz et al. (2016), Singh et al. (2015) and Wang et al. (2021) showed a positive association between daily hearing aid use time and hearing aid satisfaction.

However, among those who use hearing aids, the amplification or gain provided by hearing aids does not guarantee satisfaction (Wong et al., 2003).

The above defined constructs or domains of hearing aid outcomes are largely influenced by various factors. This study defines factor(s) as a circumstance or element that influences the result of hearing aid outcomes (Brown, 2020). Efforts have been made by researchers to synthesise available evidence to identify different factors influencing hearing aid use, benefit and satisfaction. For example, a review of 39 peer-reviewed articles by Knudsen et al. (2010) identified 31 factors that were studied in relation to the four outcome domains of help-seeking behavior for hearing loss, hearing-aid uptake, hearing-aid use, and satisfaction. These factors can be grouped into categories of personal factors (e.g., source of motivation, expectation, attitude), demographic factors (e.g., age, sex) and external factors (e.g., cost, counseling), with self-reported hearing problem as a strong predictor variable for all the four outcome domains.

Another systematic review of 22 articles by Ng and Loke (2015) identified five audiological factors (i.e., self-perceived hearing problems, severity of hearing loss, type of hearing aids, background noise acceptance, and insertion gain) and six non-audiological factors (i.e. expectation, demographics, group consultation, support from significant others, self-perceived benefit, and hearing aid satisfaction) as determinants of hearing aid adoption and use. A recent systematic review focusing on a population of people living with dementia and age related hearing loss by Hooper et al. (2022) identified degree of hearing loss, hearing aid handling proficiency, positive experiential consequences, degree of hearing aid comfort or fit, person-environment interactions and social reinforcement as factors influencing hearing aid use within this community.

It is noteworthy that the first two reviews (Knudsen et al., 2010; Ng and Loke, 2015) were conducted over a decade ago. Moreover, these reviews identified most factors which were explored in a limited number of studies (e.g., cost, hearing aid features, fitting counseling, handling of hearing aids and satisfaction with hearing aids, income level and education). In addition, no conclusion was reached for several factors (e.g., source of motivation, attitudes towards hearing aids and counseling) due to mixed evidence. The most recent review by Hooper et al. (2022) focused only on a specific population of people living with dementia and age-related hearing loss, excluding young and middle-aged adults without dementia making the review limited in its extent.

During the last decade, several studies have been published that explore new factors influencing hearing aid use, benefit and satisfaction in adults. For example, mental health, service delivery model and social networks which were not included in the previous reviews. A study by Giuliani (2021) showed a negative association between neurological disorders that contribute to mental health and infrequent hearing aid use. Another recent study by Nixon et al. (2021) showed a positive association between better cognition and increased hearing aid use. These new studies that have examined a range of additional factors related to hearing aid outcomes that have been published in this decade warrant an updated review in this area. This systematic review, therefore, aims to examine audiological and non-audiological factors that influence hearing aid use, benefit and satisfaction in adults based on the studies published during the last decade (2010 and 2023).

3.3 Methods

3.2.1 Research design

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021) was used in conducting and reporting this review. The review protocol was registered on the International Prospective Register of Systematic Reviews (CRD42022298403). Ethical clearance was obtained from the University of Pretoria Humanities Research Ethics Committee (Appendix A1 and Appendix A2).

3.2.2 Search strategy

The following databases were utilized: (i) Web of Science (ii) Scopus, (iii) PubMed, (iv) EBSCOhost including CINAHL, and (v) Academic Search Complete. The search was conducted using the following search terms: “hearing aid” or “hearing device” or “amplification” or hearing instrument” AND “use” or “usage” or “usage rate” or “non-use” or “rejection” or “refusal” or “utilization” or “benefit” or “advantage” or “gain” or “satisfaction” or “satisfy” or “contentment” or “fulfillment” or “success” or “outcome” or “post-fitting”. The same strategy was used throughout all databases, with natural language used for PubMed. Two researchers (BM and MK) independently searched for relevant articles based on the inclusion criteria (see Table 3.1) which was developed using the Population Intervention Comparison Outcome Study Design Timeline (PICOST) criteria. A secondary literature search that includes

manual search and reference checks from included articles was done during the process of writing the review to identify the latest or initially missed articles.

Table 3.1: Inclusion and exclusion criteria

Characteristics	Inclusion	Exclusion
Population	Adult hearing aid users (18 years or older)	Non-hearing aid users, Infant and children below the age of 18 years
Intervention or Exposure	Amplification with digital air-conduction hearing aid (i.e., bilateral or unilateral).	Amplification with surgically implanted hearing devices (e.g., cochlear implant, bone-anchored hearing aid).
Control	Any comparator	None
Outcomes	▪ Self-reported outcomes (e.g., self-reported hearing aid use, hearing aid benefit and/or satisfaction) ▪ Behavioral measures such as speech recognition (word and sentence) in quiet and/or noise ▪ Objective assessments such as hearing aid data log	No outcomes reported
Study Design	Quantitative studies with any design published in peer-reviewed journals	Unpublished studies, non-peer-reviewed publications, thesis/dissertations, animal studies, systematic reviews and qualitative studies. Qualitative studies were excluded from this review to be in line with the previous reviews for comparative data.
Timing	Peer-reviewed articles from 2010 onwards	Peer-reviewed articles from 2009 and earlier.
Language	English only	Articles written in any other language other than English

3.2.3 Data charting and extraction

Results from the literature search were extracted to Rayyan software (https://www.rayyan.ai) for independent blinded eligibility screening. Study duplicates were identified and removed through the Rayyan software which was followed by a screen of titles and abstracts with full texts inspected when required. Studies passing the initial screening were read to determine eligibility independently by each of the two researchers (BM & MK). 29% of the conflicted decisions on the exclusion and inclusion of articles were recorded and resolved by the two researchers. Any disagreements between the two reviewers were resolved through discussion with a third researcher using a consensus approach (VM). For each study, relevant data suggested by the PRISMA 2020 guidelines were extracted. Data extraction was conducted by the primary researcher (BM) on an Excel spreadsheet designed specifically for the purpose of this review. A second researcher (MK) cross-checked 20% of randomly selected articles to ensure reliability and consistency. Descriptive data including country, population, sample size, study design, mean age, biological sex ratios as well as information relevant to key outcomes were extracted.

3.2.4 Quality assessment and determination of level of evidence

The National Institute of Health (NIH) Quality Assessment Tool (National Institute of Health, 2021) was used to assess the quality of the studies included. The ratings 0-4 indicated poor quality, 5-10 indicated fair quality and 11-14 indicated good quality (Biagias et al., 2021). The level of evidence for included studies was determined using the Oxford Centre for Evidence Based Medicine (CEBM) - Levels of Evidence tool, which classifies studies based on the research design. According to the CEBM tool, systematic reviews are categorized as high level 1 evidence while case control studies are categorized as low level 5 (less evidence). Both quality assessment and level of evidence determination were done by a primary researcher (BM) and a second reviewer (MK) cross-checked 20% of randomly selected articles.

3.2.5 Data synthesis

Due to the high heterogeneity of included studies, quantitative synthesis of results was not possible. Hence, the synthesis without meta-analysis (SWiM) reporting guidelines Campbell et al., 2020) was used to summarize the study findings. Vote counting based on the direction of effect or association was selected as the synthesis method (Campbell et al., 2020). The

synthesis was conducted through full reading of the included articles and extraction of identified factors by the primary reviewer (BM). The results were reported as agreed on by all members of the research team (MK, VM, FMA, and DS).

3.4 Results

3.4.1 Included studies

A total of 1,111 peer-reviewed articles were identified through the search process (see Figure 3.1). After removing 376 duplicate articles, the remaining 735 articles were screened. Of these, 660 were excluded based on abstract screening and the full text of the remaining 73 were reviewed to determine eligibility. A total of 46 articles, including those identified manually after the initial electronic search, were included in the review.

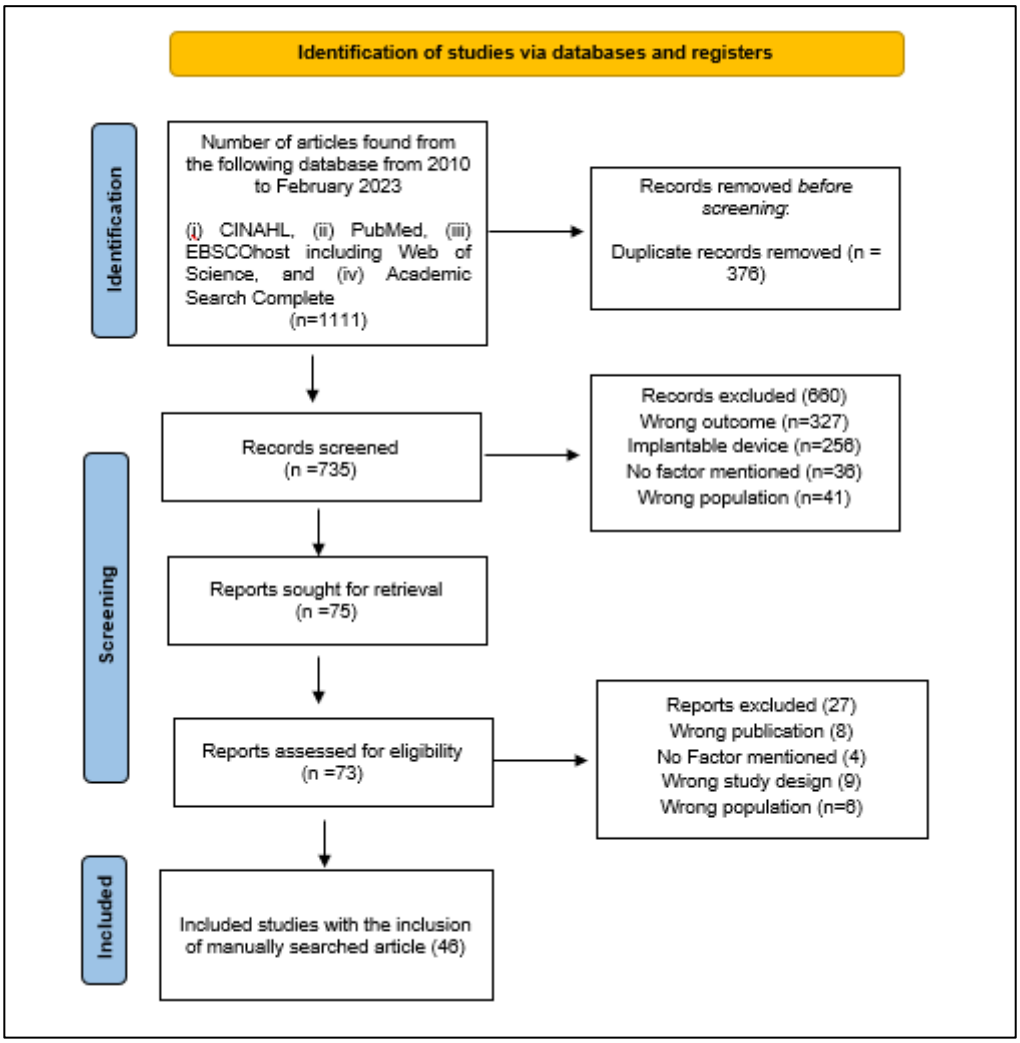

Figure 3.1: PRISMA flow diagram of the selection process

Study design varied between nine cohort studies (Bennett et al., 2020; Houmøller et al., 2021; Nixon et al., 2021), 34 cross sectional and three randomized control trials (Humes et al., 2017; Naylor et al., 2015). Sample sizes varied significantly across studies, ranging from 20 to 164 460 participants, with an average age of 67 years (ranging from 49 to 81). Most of the included studies used non-standardized questionnaires and/or patient-reported outcome measures (PROMs) as a data collection method (31/46), with two studies using telephonic interviews (Arnold et al., 2019; Kaplan-Neeman et al., 2012) and a single study using a structured interview (Fuentes-López et al., 2019). See Table 3.1. Studies used varied statistical analysis methods, including multivariate regression model (14/46), logistic regression model (10/46), correlations and linear regression model (11/46) and others (6/46).

3.4.2 Outcome measures

The International Outcome Inventory for Hearing Aids (IOI-HA) was most commonly used (14/46) PROM to evaluate hearing aid outcomes, followed by the Satisfaction with Amplification in Daily Living (SADL; 5/46) (Ferguson et al., 2016; Kaplan-Neeman et al., 2012; Singh et al., 2015 & Jilla et al., 2015) and the Abbreviated Profile of Hearing Aid Benefit (APHAB; 3/46) (Humes et al., 2017; Nixon et al., 2021; Tognola et al., 2019). Data-logging was used in eight studies as an outcome measure for hearing aid use (Giuliania, 2021; Houmøller et al., 2021; Staehelin et al., 2011).

3.4.3 Factors influencing hearing aid use

Twenty audiological and 37 non-audiological factors reported across studies on hearing aid use are illustrated in Table 3.3 and Table 3.4, respectively. Among the studied factors, 46 were found to be significant determinants (i.e., positive or negative relation to hearing aid outcome) and 10 were not significant determinants (i.e., neutral association) of hearing aid use. Figure 3.2 represents the number of significant factors (either negatively or positively associated with hearing aid outcomes) per category.

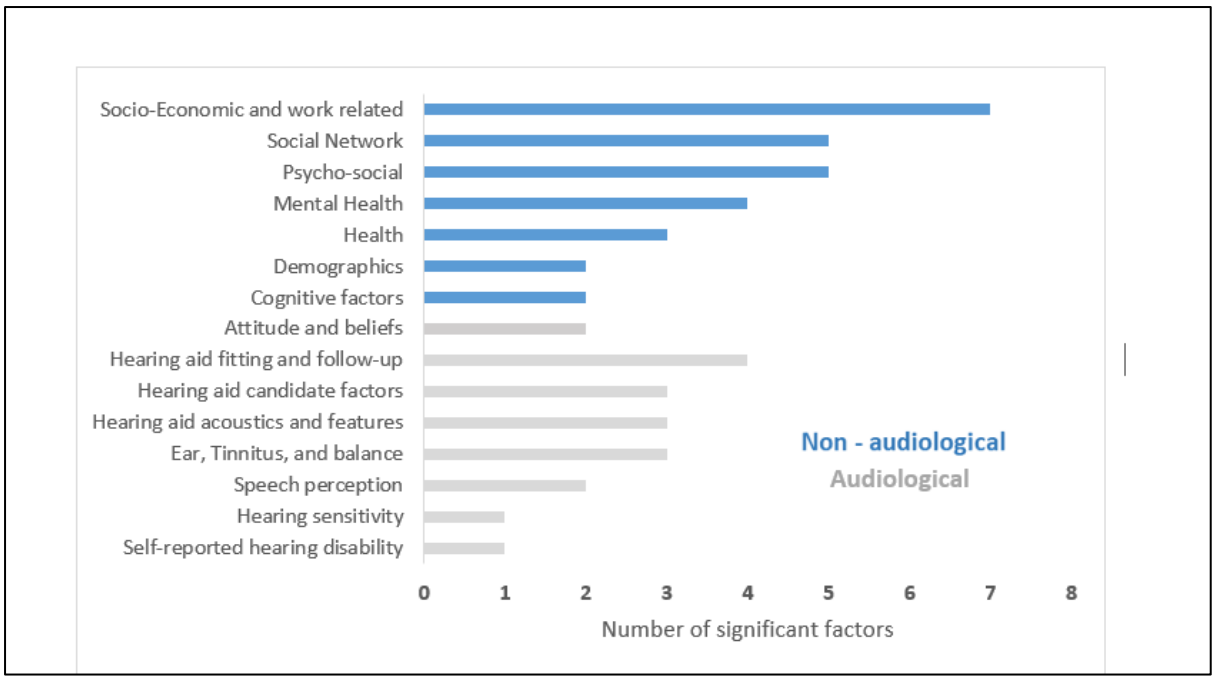

Figure 3.2: Number of significant factors identified within studies that influence hearing use for each category of audiological and non-audiological factors

3.4.4 Audiological factors influencing hearing aid use

Audiological factors within the categories of hearing sensitivity, speech perception, self-reported hearing difficulty, ear problems, tinnitus and balance problems were shown to be significantly associated with hearing aid use (Figure 3.2 & Table 3.2). Measures of hearing loss severity including pure-tone average (PTA) (Aazh et al., 2015; Arnold et al., 2019; Fuentes-López et al., 2017; Helvik et al., 2016; Ho et al., 2018), hearing loss asymmetry (Houmøller et al., 2021) and self-reported hearing difficulty (Helvik et al., 2016;, Meyer et al., 2014; Klyn et al., 2020) were shown to be positively associated with increased hearing aid use. Hearing aid users with higher speech perception abilities measured through self-reported speech perception ability, word recognition score (WRS) and speech recognition threshold (SRT) were shown to use hearing aids more frequently (Dwarakanath & Manjula, 2020b; Jorbonyan et al., 2022; Houmøller et al., 2021; Wang et al., 2021; Wu et al., 2019). Additionally, hearing aid users who presented with bothersome tinnitus, tympanic membrane perforation and balance problems were shown to be frequent hearing aid users (Giuliania, 2021; Houmøller et al., 2021; Moon et al., 2015).

Several factors in categories of hearing aid acoustics and features, candidate factors, fitting and follow-up were significantly associated with use (see Figure 3.2). Within these categories,

increasing hearing aid use was positively associated with digital versus analog hearing aids, conducting real-ear insertion gain measures, using more expensive hearing aids (Jorbonyan et al., 2022; Hickson et al., 2014; Wang et al., 2021), people who adopt a diagnostic narrative on hearing aid fitting procedures (Naylor et al., 2015) and with better hearing aid handling skills (Nixon et al., 2021). Increasing prevalence/number of hearing aid problems was a negative predictor of hearing aid use (Bennett et al., 2020). Other factors such as hearing aid satisfaction and benefit and bilateral hearing aid fittings had mixed results of positive and no significant associations with hearing aid use respectively (Aazh et al., 2015; Jorbonyan et al., 2022; Staehelin et al., 2011; Wang et al., 2021). Three studies reported different results of a neutral link between these factors and hearing aid use (Ho et al., 2018; Jilla et al., 2015; Wu et al., 2019).

Table 3.2: Audiological factors influencing hearing aid use

Factor	Number of Studies	Positive	Negative	No association
Hearing sensitivity				
Pure Tone Average (PTA)	13	10	-	3
Slope of the audiogram	1	-	-	1
Hearing loss Asymmetry	1	1	-	-
Speech perception				
WRS	2	2	-	-
SRT	1	1	-	-
Speech perception ability	2	2	-	-
Self-reported hearing disability				
Non-standardized self-reported hearing disability	5	4	-	1
Ear, Tinnitus, and balance				
Bothersome Tinnitus	3	3	-	-
TM perforation	2	2	-	-
Balance problems	1	1	-	-
Hearing aid acoustics and features				
Prevalence of hearing aid problems	1	-	1	-
Insertion gain	1	1	-	-
Price of Hearing aid	1	1	-	-
Digital hearing aids (compared to analog)	1	1	-	-
Hearing aid candidate factors				
Satisfaction and benefit with hearing aids.	3	2	-	1
First fitting age	1			1
Narratives on hearing aid fitting	1	1(D)	-	1(I)
Hearing aid handling skills	2	2	-	-
Previous hearing aid experience	1	-	-	1
Hearing aid fitting and follow-up				
Type of hearing aid fitting (bilateral versus unilateral)	6	3	-	3
Motivational Interviewing	1	1	-	-

Note: D=Prefer Group D (D=diagnostic narrative) I= prefer Group I (Interactive Group)

3.4.5 Non-audiological factors influencing hearing aid use

Several non-audiological factors were identified with positive and negative associations with hearing aid use across categories including demographics, social networks, psycho-social, mental health, cognitive factors, attitudes and beliefs, and socio-economic and work-related factors (Figure 3.2 & Table 3.3). A positive association was reported between men living with spouses and hearing aid use (Helvik et al., 2016). Three different studies showed mixed associations between female and male biological sex and increased and decreased hearing aid use (Houmøller et al., 2021; Klyn et al., 2020; Jorbonyan et al., 2022). In contradiction, one study shows a positive association between being male and hearing aid use (Staehelin et al., 2011). Race effects included a negative association between being non-Hispanic and hearing aid use and a positive association between being Hispanic and hearing aid use (Klyn et al., 2020; Sawyer et al., 2019).

Support from other people (Hickson et al., 2014), family time (Nixon et al., 2021), personality (Dwarakanath & Manjula, 2020a), perceived need (Arnold et al., 2019), accepted need (Solheim et al., 2012), cognition (Nixon et al., 2021), working memory (Dwarakanath & Manjula, 2020b; Nixon et al., 2021) were shown to have a positive influence on hearing aid use. Additionally, positive attitude towards hearing loss (Dwarakanath & Manjula, 2020a), positive attitude towards hearing aids and beliefs (Saunders et al., 2016) and motivation (Houmøller et al., 2021) were shown to be positive determinants of frequent hearing aid use. Adult hearing aid users with neurological disorders which contribute to mental health were shown to be infrequent hearing aid users in a single study (Giuliania, 2021).

Education (Helvik et al., 2016), healthy coping skills in work life (Laakso et al., 2022), knowledge (Fuentes-López et al., 2017), self-reported health status (Fuentes-López et al., 2019), and subjective health literacy (Klyn et al., 2020) which were all reported to be positive determinants of frequent hearing aid use. Income was shown to have mixed results, with two studies (Fuentes-López et al., 2017; Moon et al., 2015) showing a non-significant association and a single study (Fuentes-López et al., 2019) showing a positive association. Additionally, vision impairments and hearing aid use showed varied results, with myopia being negatively associated with hearing aid use whereas astigmatism was positively associated with hearing aid use (Moon et al., 2015). Having medical aid/subsidy or insurance was positively associated with hearing aid use (Moon et al., 2015).

Table 3.3: Non-audiological factors affecting hearing aid use

Factor	Number of studies	Positive	Negative	No Association
Demographics				
Age	15	3	8	4
Biological sex	9	3	2	4
Ethnicity	4		2 (black)	2
Race	4	3 (white	1 (black)	-
Marital Status	1	-	-	1
Living Arrangements	1	1 (MLS)	-	1 (WLS)
Living status (rural/urban)	1	1	-	-
Place of Residency	2	2	-	-
Social Network				
Social Support from others	2	2	-	-
Family time	1	1	-	-
Number of House Members	1	-	-	1
Psycho-social				
Personality	3	3	-	-
Perceived Need for of the hearing aid	1	1	-	-
Self-Efficacy	3	1	-	2
Accepted need	1	1	-	-
Social assessment and consciousness	1	-	-	1
Mental health				
Active Neurological disorders	1	-	1	-
Depressive mood	1	-	-	1
Amount of stress in life	1	1	-	-
Cognitive factors				
Working Memory	1	1	-	-
Cognition	1	1	-	-
Attitude and Beliefs				
Attitude	4	3	-	1
Beliefs	1	1	-	-
Motivation	1	1	-	-
Socio-Economic and work related				

Factor	Number of studies	Positive	Negative	No Association
Occupation and employment	2	1	-	1
Income	5	3	-	2
Knowledge	1	1	-	-
Education	7	7	-	-
Coping in work li fe	1	1	-	-
Socio-economic status	1	-		1-
Social activities	1	-	-	1
Health				
Myopia	1	-	1	-
Astigmatism	1	1	-	-
Self-reported General Health Status	4	2	1	1
Health Literacy	2	1 (SHL)	-	1 (OHL)
Hospitalization	1	-	-	1
Medical aid and financial support	2	2	-	-

Note: MLS= Male Living with Spouse; WLS= Women living with spouse; SHL =Subjective Health Literacy, OHL = Objective health literacy. Social assessment = view on how people think about them) Consciousness (of their hearing loss and hearing aids)

3.4.6 Factors influencing hearing aid benefit

Thirteen audiological factors (Table 3.4) and 10 non-audiological factors (Table 3.5) influencing hearing aid benefit were identified. Seventeen factors were found to be significant determinants of hearing aid benefit (17/23). Significant results will be discussed below while non-significant factors can be found in Table 3.5 and Table 3.6. Significant audiological and non-audiological factors are shown in Figure 3.3.

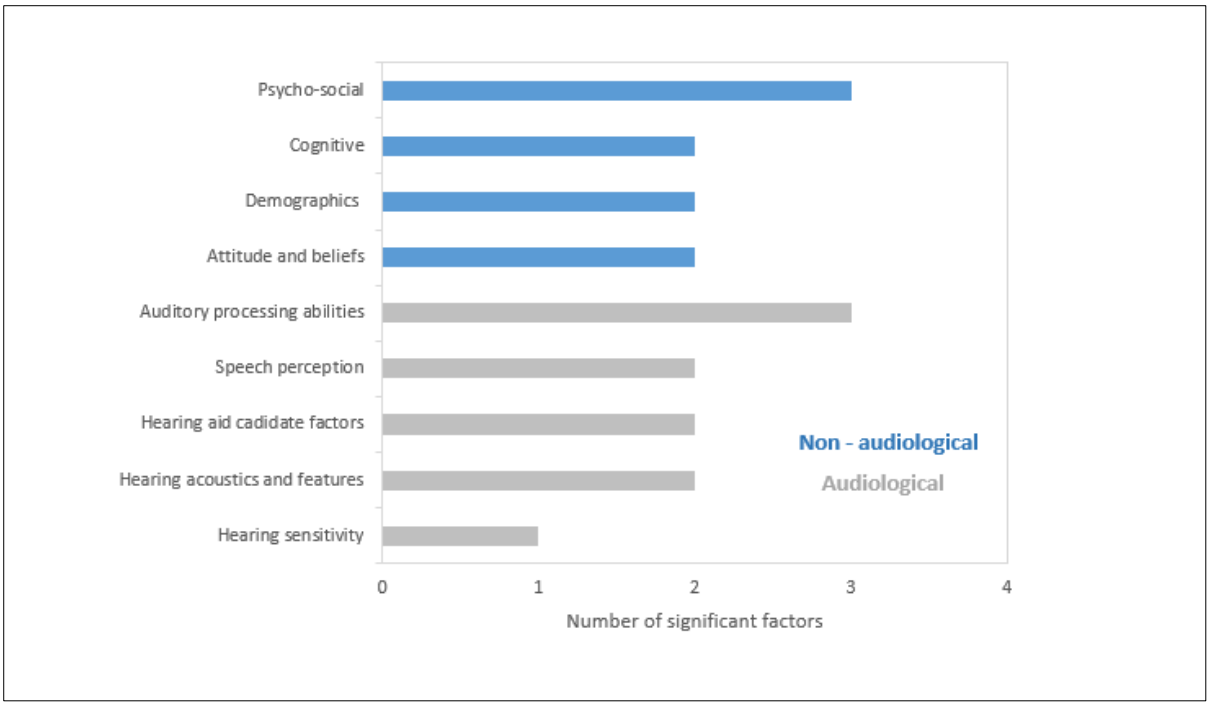

Figure 3.3: Number of significant factors identified within studies that influence hearing aid benefit for each category of audiological and Non-audiological factors

3.4.7 Audiological factors influencing hearing aid benefit

Hearing loss severity measured through PTA was shown to have mixed results of positive (Houmøller et al., 2021; Meister et al., 2015; Nixon et al., 2021) and negative associations with hearing aid benefit (Tognola et al., 2019; Wang et al., 2021). Hearing loss asymmetry was reported to be a negative determinant of hearing aid benefit (Houmøller et al., 2021). Better speech perception ability measured through a self-reported questionnaire, WRS and SRT were shown to be positively associated with increased hearing aid benefit (Dwarakanath & Manjula, 2020b; Houmøller et al., 2021; Wang et al., 2021; Wu et al., 2019). Difficulties in auditory processing abilities including auditory closure and binaural integration were shown to have a negative association with hearing aid benefit (Chinnaraj et al., 2022). Individuals with bothersome tinnitus were shown to have less hearing aid benefit (Houmøller et al., 2021). Hearing aid acoustics and hearing aid related factors such as prevalence/number of hearing aid problems and cost of hearing aids were shown to have a negative and positive influence on hearing aid benefit, respectively (Bennett et al., 2020; Wang et al., 2021). Hearing aid candidate factors such as daily hearing aid usage time (Houmøller et al., 2021; Wang et al., 2021) and adoption of a diagnostic narrative on hearing aid fitting by hearing healthcare professionals (Naylor et al., 2015) were shown to be positive determinants of hearing aid benefit.

Table 3.4: Audiological factors affecting hearing aid benefit

Factor	Number of studies	Positive	Negative	No association
Hearing Sensitivity				
Pure Tone Average (PTA)	6	3	2	1
Asymmetry	1	-	-	1
Speech perception				
WRS	2	2	-	-
SRT	1	1	-	-
Speech Perception Ability	1	1	-	-
Auditory processing abilities				
Temporal processing	1	-	-	1
Auditory closure	1	-	-	1
Binaural Interaction	1	-	-	1
Auditory closure	1	-	1	-
Binaural integration	1	-	1	-
Ear, Tinnitus and Balance				
Tinnitus	1	-	-	1
Hearing aid acoustic and features				
Prevalence of Hearing aid problems	1	-	1	-
Price of Hearing aid	1	1	-	-
Hearing aid candidate factors				
Daily use time	2	2	-	-
First fitting age	1	-	-	1
Narratives on hearing aid fitting appointments	1	1 (I)	-	1(D)

Note: D=Prefer Group D (D=diagnostic narrative) I= prefer Group I (Interactive Group)

3.4.8 Non-audiological Factors Influencing Hearing Aid Benefit

Older age was shown to have positive (Meister et al., 2015) and negative (Tognola et al., 2019; Wang et al., 2021) associations with hearing aid benefit. In terms of biological sex, female hearing aid users reported improved hearing aid benefit compared to males (Houmøller et al.,

2021), whereas a study by Narne et al. (2016) showed more hearing aid benefit among male hearing users. Personality (Dwarakanath & Manjula, 2020a), readiness to improve hearing, expectations (Dwarakanath & Manjula, 2020a; Ferguson et al., 2016), cognition (Meister et al., 2015; Nixon et al., 2021; Tognola et al., 2019), working memory (Dwarakanath & Manjula, 2020b), attitude towards hearing loss and hearing aids (Dwarakanath & Manjula, 2020a; Nixon et al., 2021; Saunders et al., 2016) and motivation (Dwarakanath & Manjula, 2020a; Houmøller et al., 2021; Nixon et al., 2021; Saunders et al., 2016) were shown to be positive determinants of hearing aid benefit.

Table 3.5: Non-audiological factors affecting hearing aid benefit

Factor	Number of studies	Positive	Negative	No association
Demographics				
Age	4	1	2	1
Biological sex	2	2	-	-
Psycho-social				
Personality	2	2	-	-
Self-Efficacy	1	-	-	1
Expectations	1	1	-	-
Readiness to improve hearing	1	1	-	-
Cognitive factors				
Cognition	3	3	-	-
Working Memory	2	1	-	1
Attitude and Beliefs				
Attitude	4	4	-	-
Motivation	1	1	-	-

3.4.9 Factors influencing hearing aid satisfaction

Forty-five factors influencing hearing aid satisfaction were investigated in 17 studies. Among all studied factors, 37 factors (see Table 3.6 and Table 3.7) were found to be significant

determinants (37/45) of hearing aid satisfaction whereas eight factors were shown to have no significant association with hearing aid benefit (8/45). The number of significant factors per category is shown in Figure 3.4.

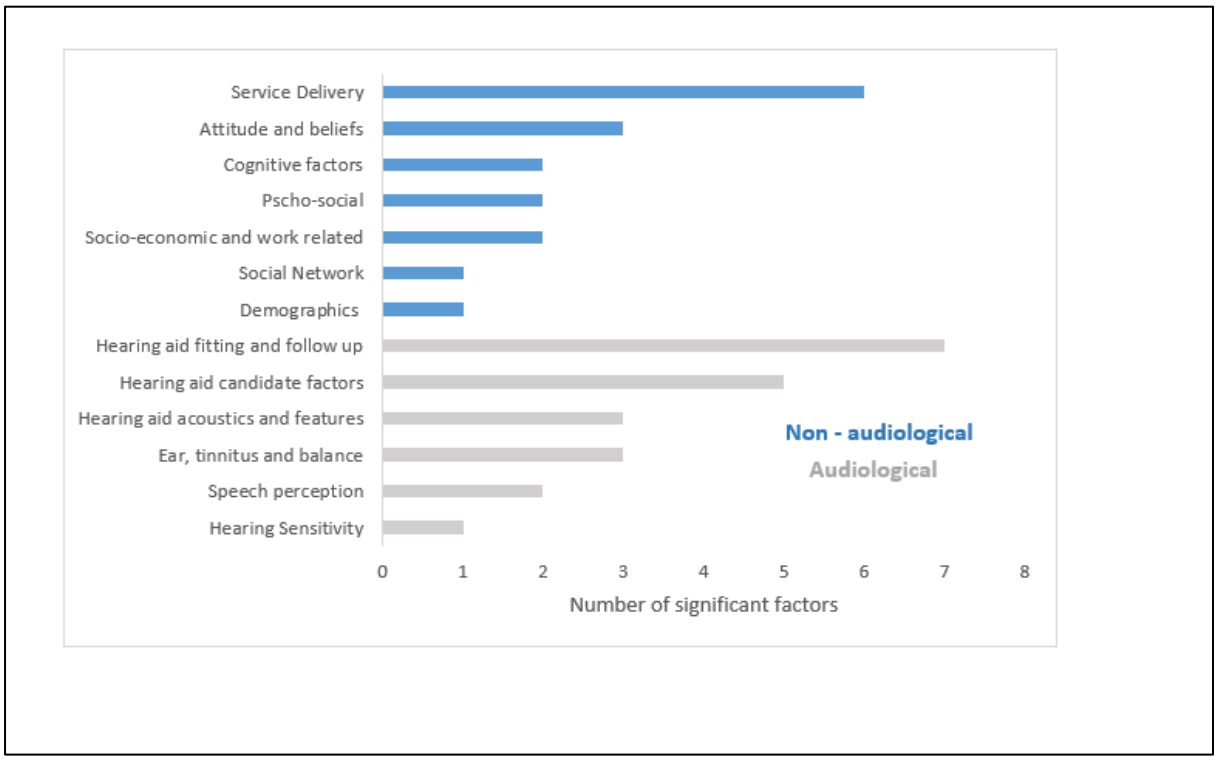

Figure 3.4: Number of significant factors identified within studies that influence hearing aid satisfaction for each category of audiological and non-audiological factors

3.4.10 Audiological factors influencing hearing aid satisfaction

Studies reporting an association between PTA and hearing aid satisfaction had mixed evidence of positive (Houmøller et al., 2021; Korkmaz et al., 2016; Meister et al., 2015) and negative associations with hearing aid satisfaction (Kaplan-Neeman et al., 2012; Turan et al., 2019; Wang et al., 2021). Hearing loss asymmetry was shown to be a negative determinant of hearing aid satisfaction (Houmøller et al., 2021). Hearing ability with hearing aids was shown to have a positive association with hearing aid satisfaction (Meyer et al., 2014). Speech perception ability measured through a self-reported questionnaire, WRS, and SRT were shown to be a positive determinant of hearing aid satisfaction (Houmøller et al., 2021; Wang et al., 2021; Wu et al., 2019). Additionally, bothersome tinnitus was shown to be negatively associated with hearing aid satisfaction (Houmøller et al., 2021).

Factors within categories of hearing aid acoustics and hearing aid related factors such as hearing aid candidacy and hearing aid fitting and follow up included In the Ear (ITE) vs Behind the Ear (BTE), price of hearing aid (Wang et al., 2021), hearing aid product performance and features (Bisgaard & Ruf, 2017), adoption of diagnostic narrative on hearing aid fitting procedure by hearing healthcare professionals (Naylor et al., 2015), daily hearing aid use (Gurjit et al., 2015; Houmøller et al., 2021; Kaplan-Neeman et al., 2012; Korkmaz et al., 2016; Wang et al., 2021), hearing aid handling skills (Kemker et al., 2012), regular hearing aid follow-up (Kim et al., 2022) and bilateral hearing aid fitting (Kaplan-Neeman et al., 2012; Turan et al., 2019; Wang et al., 2021) were shown to be positive determinants of hearing aid satisfaction. Prevalence of hearing aid problems and lack of hearing aid comfort were shown to have a negative association with hearing aid satisfaction in 2 studies (Bennett et al., 2020; Meyer et al., 2014).

Table 3.6: Audiological factors influencing hearing aid satisfaction

Factor	Number of Studies	Positive	Negative	No association
Hearing Sensitivity				
Pure Tone Average	9	3	3	3
Asymmetry	1	-	1	-
Hearing ability with hearing aids	1	1	-	-
Speech perception				
WRS	2	2	-	-
SRS	1	1	-	-
Speech Perception Ability	1	1	-	-
Ear, Tinnitus and balance				
Tinnitus	1	-	1	-
Hearing aid acoustics and features				
ITE vs BTE hearing aid	1	1	-	-
Digital Technology	1	-	-	1
Hearing aid comfort	1	-	1	-
Hearing aid appearance	1	1	-	-
Price of hearing aid	2	2	-	-

Factor	Number of Studies	Positive	Negative	No association
Prevalence of hearing aid problems	2	-	2	-
Product performance	1	1	-	-
Product features	1	1	-	-
Hearing aid candidate factors				
Duration of hearing aids	1	-	-	1
Hearing ability with hearing aids	1	1	-	-
Site of hearing aid wear	1	-	-	1
First fitting age	1	1	-	-
Narratives on hearing aid fitting appointments	1	1 (D)	-	1 (I)
Hearing aid usage	6	6	-	-
Experience with hearing aid use	2	-	-	2
Hearing aid handling skills	1	1	-	-
Hearing aid fitting and follow up				
Type of Hearing Aid Fitting (bil versus Uni)	6	5	-	1
Regular hearing aid follow up	1	1	-	-

Note: D=Prefer Group D (D=diagnostic narrative) I= prefer Group I (Interactive Group); WRS: Word Recognition Score; SRS: Speech Recognition Score.

3.4.11 Non-audiological factors influencing hearing aid satisfaction

Older age was shown to have mixed results of positive (Meister et al., 2015) and negative associations with hearing aid satisfaction (Kaplan-Neeman et al., 2012; Korkmaz et al., 2016; Laakso et al., 2022; Tognola et al., 2019; Turan et al., 2019; Wang et al., 2021). In terms of biological sex, Houmøller et al. (2021) reported a positive association between female and hearing aid satisfaction. Narne et al. (2016) and (Korkmaz et al., 2016) revealed a negative association between male sex and hearing aid satisfaction.

Non-audiological factors within categories of social network, socio-economic, work, and psycho-social had significant associations with hearing aid satisfaction. Social support (Gurjit et al., 2015), education (Korkmaz et al., 2016), self-efficacy, expectation (Kelly-Campbell & McMillan, 2015), readiness to improve hearing (Ferguson et al., 2016) and openness (Gurjit et al., 2015) were shown to have a positive association with hearing aid satisfaction in 3 studies (Dwarakanath & Manjula, 2020a; Ferguson et al., 2016; Kelly-Campbell & McMillan, 2015). Neuroticism was shown to have a negative association with hearing aid satisfaction (Gurjit et al., 2015). Non-audiological factors such as cognition (Meister et al., 2015; Nixon et al., 2021; Tognola et al., 2019), working memory (Dwarakanath & Manjula, 2020b), attitude (Dwarakanath & Manjula, 2020a; Nixon et al., 2021; Saunders et al., 2016), motivation (Houmøller et al., 2021) and confidence in healthcare practitioner (Gurjit et al., 2015) were shown to be positive determinants of hearing aid satisfaction. Additionally, Humes et al. (2017) reported a positive effect between audiology best practice service delivery model as compared to direct-to-consumer model and hearing aid satisfaction.

Table 3.7: Non- Audiological factors influencing hearing aid satisfaction

Factor	Number of Studies	Positive	Negative	No association
Demographics				
Age	12	2	7	3
Biological sex	4	2 (both)	1 (male)	1
Living status (rural/urban)	1	-	-	1
Quality of life measures	1	-	-	1
Social Network				
Social Support	1	1	-	-
Socio-Economic and work related				
Employment status	2	-	-	2
Education status	2	2	-	-
Psycho-social				
Personality	1	1	-	-
Self-Efficacy	2	1	-	1
Expectations	1	1	-	-
Readiness to improve hearing	1	1	-	-
Openness	1	1	-	-
Neuroticism	1	-	1	-
Cognitive factors				
Cognition	3	3	-	-
Working Memory	1	1	-	-
Attitude and Beliefs				
Attitude	3	3	-	-
Motivation	1	1	-	-
Service delivery				
Hearing healthcare practitioner	1	1	-	-
Service Delivery Model	1	1(AB)	-	-
Service Provision	1	1	-	-

Note: AB = Audiology best practice

3.4.12 Assessment of quality and level of evidence

The NIH Quality Assessment Tool was used to assess the quality of the studies included. Of the 46 included, 43 had a rating between 5-10, indicating fair quality (43/46) while 3 were rated between 11-14, indicating good quality (3/46). The studies included in this review were evaluated using the Oxford CEBM Levels of Evidence scale. Under this tool, studies are graded into 5 levels of evidence (1–5). 34 cross-sectional studies included in this review were graded as level 4 (34/46), 9 cohort studies rated as level 3 (9/46) and 3 randomized control trials rated as level 2 (3/46).

3.4.13 Discussion

This systematic review identified significant audiological and non-audiological factors influencing hearing aid use (46 factors), benefit (17 factors) and satisfaction (37 factors) from literature published during the last decade. Due to the high number of factors identified for each outcome variable, the discussion focuses on the prominent predictors across all three outcomes, those not reported in previous reviews, and factors with mixed or inconclusive results.

3.4.14 Audiological Factors Influencing Hearing Aid Use, Benefit and Satisfaction

The most reported audiological factor influencing hearing aid use, benefit and satisfaction is the degree of hearing loss measured as PTA, demonstrating a clear positive association with hearing aid use and mixed inconclusive associations with benefit and satisfaction. For the outcome dimension of hearing aid use, a systematic review by Ng and Loke (2015) reported results of a clear positive association while a review of literature by Knudsen et al. (2010) showed contrasting results of non-significant associations with hearing aid use. For the hearing aid dimension of satisfaction, Knudsen et al. (2010) showed similar mixed inconclusive results of positive and negative associations with hearing aid satisfaction.

Other audiological factors, which form part of the audiological profile including hearing loss asymmetry (Houmøller et al., 2021), speech perception ability (Wang et al., 2021; Wu et al., 2019), bothersome tinnitus (Houmøller et al., 2021) and tympanic membrane perforation (Moon et al., 2015), have limited evidence across hearing aid outcome dimensions of use, benefit and satisfaction. Some of these factors are important potential influencers of improved hearing aid outcomes. For instance, higher speech perception ability measured through SRT,

WRS and self-reported questionnaire was positively associated with improved hearing aid use, benefit and satisfaction, placing an emphasis on the inclusion of speech assessments to inform benefit and satisfaction with hearing aids (Davidson et al., 2021).

Recent audiological factors related to the hearing aid across hearing aid use, benefit and satisfaction not reported in previous reviews include bothersome tinnitus, narratives or perspectives of the hearing aid fitting process and prevalence of hearing aid problems. These recent factors are much more related to hearing aid features such as tinnitus management programs, mobile and virtual troubleshooting support. For instance, a scoping review by Jacquemin et al. (2021) showed that hearing aids could provide tinnitus relief. This explains the frequent use and improved satisfaction among hearing aid users with bothersome tinnitus (Lee et al., 2022). Another example is with the introduction of virtual forms of hearing aid support for hearing aid users such as multimedia educational programs, mobile applications and virtual access to hearing healthcare professionals as part of improved hearing aid related support features (Ross, 2020). This hearing aid support irrespective of the method used has been shown to facilitate the journey through hearing aid adaptation and address the prevalence of hearing aid problems for users, improving use and benefit (Ferguson et al., 2016).

Another recent factor is the patient narrative effect on the hearing aid fitting procedure. The study by Naylor et al. (2015) showed that patients who had a positive interactive narrative on the hearing aid fitting procedure reported improved hearing aid outcomes in terms of use, benefit and satisfaction as compared to those who were provided with a contrasting narrative (i.e., diagnostic). In this study, the hearing aid fitting process of a diagnostic narrative or character required that the participants should be passive, their opinions not sought, and the expert makes diagnostic measurements of their hearing and fits the hearing aid according to the audiogram. The interactive hearing aid fitting process was designed in a way that the participants should feel that they were involved in creating their own settings for the hearing aids (Naylor et al., 2015). The possible underlying factors in improved hearing aid outcomes include confidence in the hearing health care professional (Singh et al., 2015) and indicated the importance of hearing health care professionals in the management of hearing loss throughout the whole journey.

3.4.15 Non-audiological factors influencing hearing aid use, benefit and satisfaction

Age is a commonly explored demographic predictor of hearing aid outcome domains with mixed inconclusive results regarding hearing aid use, benefit and satisfaction. In contrast, a systematic review by Ng and Loke (2015) showed a clear positive association between the hearing aid outcome dimension of frequent hearing aid use and older age. Additionally, Knudsen et al. (2010) showed no significant association between age and hearing aid use. In comparison to mixed inconclusive results found by this study, Ng and Loke (2015) and Knudsen et al. (2010) showed clear results of positive and non-association with hearing aid use respectively. Biological sex is another prominently reported demographic predictor with mixed results of no association, positive association and negative association for hearing aid use and satisfaction. Knudsen et al. (2010) and Ng and Loke (2015) showed different results of a non-significant association and a clear female positive association with hearing aid use, respectively.

Apart from demographic factors, several other non-audiological factors within the patient's communication settings were found to be contributors towards hearing aid outcomes. For all studied hearing aid outcomes, this includes factors such as working memory and personality which were shown to have positive associations with improved hearing aid use, benefit and satisfaction. Knudsen et al. (2010) showed contrasting results of a non-significant association between personality and hearing aid use; but similar results of a positive association between the personal image subscale of SADL and four personality traits of neuroticism, extraversion, agreeableness and consciousness. Recent non-audiological factors identified to contribute to hearing aid outcomes include social networks in the form of social support, neurological disorders which contribute to mental health and service delivery of audiology best practice and direct to consumer showed varying associations with hearing aid use and satisfaction. These factors have been explored in limited studies and have not been included in previous reviews (Knudsen et al., 2010; Ng & Loke, 2015). These recent factors, along with overall non-audiological factors within the patient's communication setting, should be considered in clinical practice, promoting individualized care to optimize hearing aid outcomes.

Non-audiological factors in Knudsen et al. (2010), such as pre-fitting attitudes towards hearing aids, motivation and pre-fitting attitude towards own hearing loss, were also studied in the past decade, strengthening the evidence for their associations with hearing aid satisfaction. Pre-fitting attitudes towards hearing aids, motivation and pre-fitting attitudes towards hearing loss

showed positive associations with hearing aid satisfaction as reported by Knudsen et al. (2010). In this review, attitude towards hearing loss and hearing aids as well as motivation were reported to have a positive association with improved hearing aid satisfaction. The new and emerging evidence requires further exploration through studies of higher quality and higher level of evidence.

3.5 Future research

Some factors reported in this review (e.g., mental health, service delivery model) are recent and were not captured by previous reviews (Knudsen et al., 2010; Ng and Loke, 2015). There are also mixed inconclusive results on several factors (e.g., hearing sensitivity, age) and limited evidence for other factors (e.g., cost of hearing aid). This review therefore identifies the areas that require further investigations for these recently identified factors and those with mixed inconclusive results and limited evidence. Additionally, this review shows a need for studies of higher quality and higher level of evidence, which should be the focus in future studies in this area. Other factors which were not reported in this review (e.g., stigma, tele-audiology) should be evaluated on how they influence hearing aid outcomes of use, benefit and satisfaction.

Vote counting based on the direction of effect or association was the synthesis method employed for data analysis in this systematic review. This data synthesis method looks only at the direction of the association between the factors and hearing aid outcomes in the included studies (Campbell et al., 2020). As such, it has certain limitations, as it fails to consider the statistical magnitude of the association for each factor and its impact on hearing aid outcomes (Borenstien et al., 2009). Furthermore, this method does not adequately account for the statistical power of studies based on their sample size and timing of outcome assessment. As much as the above-mentioned limitations are acknowledged, it is important to note that this review could not account fully as it is not a meta-analysis study. Future research should take these limitations into consideration and explore alternative data synthesis methods, such as meta-analysis of effect estimates for homogenous studies, which incorporate crucial factors such as the magnitude of the association or effect.

3.6 Conclusion

Identified factors consistent with previous reviews include self-reported hearing difficulty, cost of hearing aid and its maintenance for hearing aid use, and PTA, hearing aid appearance, age, pre-fitting expectations, satisfaction with the practitioner, self-motivation, pre-fitting attitudes towards hearing aids for hearing aid satisfaction. Recent factors influencing hearing use, benefit and satisfaction, which were not captured by previous reviews, include speech perception ability, bothersome tinnitus, neurological disorders that contribute to mental health, prevalence of hearing aid problems, narratives on hearing aid fitting procedures, service delivery model and social networks. These identified factors need further investigations through studies of high quality and high level of evidence to strengthen evidence on their influence on hearing aid outcomes. In clinical practice, the identified predictors of hearing aid use, benefit and satisfaction should be considered to optimize hearing aid outcomes.

CHAPTER 4: FACTORS ASSOCIATED WITH HEARING AID OUTCOMES INCLUDING SOCIAL NETWORKS, SELF-REPORTED MENTAL HEALTH AND SERVICE DELIVERY MODELS

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4.1 Abstract

Background: Factors influencing hearing aid outcomes such as hearing sensitivity, age and gender have been widely studied with factors such as social networks, mental health and service delivery models not being readily investigated.

Purpose: This study aimed to identify and describe factors that influence hearing aid outcomes including social networks, self-reported mental health and service delivery models.

Methods: A prospective cross-sectional online survey was sent to hearing aid users recruited through an online platform (www.hearingtracker.com) between October and November 2021. The survey contained questions on patient demographics, audiological, general health and social factors, and self-reported hearing aid outcomes using the International Outcome Inventory for Hearing Aids (IOI-HA). Regression models evaluated potential contributing factors of hearing aid outcomes on the IOI-HA.

Results: 398 hearing aid users completed the survey with an average age of 66.6 (13. SD) years of which 59.3% were male. Positive contributing factors of hearing aid outcomes (IOI-HA total score) were social network of people with hearing loss with hearing aids (p<0.010; 0.03 Exp B [0.01, 0.1 95% CI]), self-reported mental health (p< 0.05; 0.6 Exp B [0.01, 1.2 95% CI]),

work situation (p<.001, 1.9 Exp B [0.7, 2.8 95% CI]), quality of life (p<.005; 1.2 Exp B [0.3, 1.1 95% CI]) and self-reported hearing difficulty (p<.02; 0.8 Exp B [0.2, 1.5 95% CI]). Negative contributing factors of hearing aid outcomes included social networks of people with hearing loss without hearing aids (p<.001; -0.1 Exp B [-0.3, 0.1 95% CI]) and service delivery model of private or university clinic compared to big box retailers (p<.003; Exp B [-2.6, 0.5 95% CI]).

Conclusion: Novel factors including social network of persons with hearing loss who use hearing aids, self-reported mental health, service delivery model and work situation are significant contributors to hearing aid outcomes. These newly identified factors can inform public hearing health promotion and individualized audiological care to optimize hearing aid outcomes. Future investigations should further consider and explore these factors to strengthen evidence on their relationship with hearing aid outcomes.

Keywords

Hearing loss, Hearing aid, Outcomes, Use, Benefit, Satisfaction

4.2 Introduction

Hearing loss affects more than 1.5 billion people globally of which 430 million can benefit from appropriate intervention (World Health Organization, 2021). In the US more than 30 million persons have bilateral hearing loss and could benefit from amplification (Lin et al., 2011). Hearing aids are the most common treatment with demonstrated effectiveness for improved hearing and communication (Ferguson et al., 2019). Apart from improvement in hearing and communication, hearing aids have been shown to reduce the psychological impact of hearing loss on individuals diagnosed with hearing loss including decreased depression (Tsimpida et al., 2022). Additionally, studies have shown that individuals with hearing loss who use hearing aids experience improved quality of life and report better overall health status, even those with mild losses (Ferguson et al., 2019). A systematic review with meta-analysis by Chisolm et al. (2007) also confirmed the benefits of hearing aids in improving health related quality of life (HRQoL) through limiting the effect of hearing loss on psychological, social, and emotional well-being of hearing aid users.

Ensuring optimal hearing aid outcomes is increasingly important to researchers, clinicians, civil organizations, and hearing aid manufacturers. Influenced by the increasing prevalence of

hearing loss, costs of unaddressed hearing loss and the required public health investment to improve access to hearing health care, the importance of supporting optimal hearing aid outcomes is a health priority (World Health Organization, 2021). Additionally, hearing aid outcomes have been measured to demonstrate the efficacy of treatment, provide evidence for third-party payment, carry out cost-benefit analyses, and justify resource allocation (Saunders et al., 2005). Clinically, hearing aid outcomes can be measured using objective (e.g., hearing aid use through data logging), behavioral (e.g., hearing aid benefit measures through speech testing with and without hearing aids) and/or self-reported measures (i.e., standardized patient-reported outcome measures [PROMs]). These objective and behavioral outcome measures quantify the results of the intervention, while self-assessment tools focus on the quantification of behavior in the psychological system including benefit and satisfaction (Bray & Nilsson, 2002). Self-reported measures of hearing aid outcomes such as benefit and satisfaction are positively associated with hearing aid use; indicating an increasing use of hearing aids by those benefiting from and satisfied with hearing aids (Gurjit et al., 2015; Houmøller et al., 2021; Wang et al., 2021).

Hearing aid outcome measures of use, benefit and satisfaction are included in widely used standardized PROMs such as Abbreviated Profile of Hearing Aid Benefit (APHAB), Satisfaction with Daily Amplification (SADL) and the International Outcome Inventory for Hearing Aids (IOI-HA). The IOI-HA is a widely used self-reported scale of hearing aid outcomes (Cox & Alexander, 2002) which consists of seven questions (Cox & Alexander, 2002; Cox et al., 2003). Apart from advantages such as ease of use and time efficiency; the IOI-HA scale covers a wide range of hearing aid outcome indicators through its items covering seven domains including 1) Daily use; 2) Benefit; 3) Residual activity limitations; 4) Satisfaction; 5) Residual participation restrictions; 6) Impact on others and 7) Quality of life.

Several studies have examined audiological factors influencing hearing aid outcomes, focusing mostly on hearing aid use, benefit and satisfaction (e.g., Aazh et al., 2015; Arnold et al., 2019; Wu et al., 2019). In a cross-sectional study of 1653 hearing aid users by Hickson et al. (2010), hearing aid attributes of fit/comfort, clarity of tone and sound, and comfort with loud sounds were identified as determinants of outcomes measured on the IOI-HA. More recently, a cross-sectional study of 235 hearing aid users by Wang et al. (2021) identified audiological factors such as word recognition score and daily hearing aid use which accounts for 17.1% and 8.1% of variability in hearing aid outcomes, respectively and non-audiological factors such as the

price of the hearing aid and age which accounts 4.2% and 1.6% of variability in the hearing aid outcomes, respectively.

Established contributing factors of hearing aid use, benefit and satisfaction include factors like the hearing loss severity which have been reported to have mixed associations of negative, positive and no association with the hearing aid outcomes (Arnold et al., 2019; Tognola et al., 2019; Meyer et al., 2014). Other factors like higher word recognition score (WRS) have been positively associated with improved hearing aid use, benefit and satisfaction (Houmøller et al., 2021). Non-audiological factors are also associated with outcomes. For example, higher purchase price of hearing aids has been positively associated with hearing aid outcomes and more hearing aid problems are negatively associated with hearing aid outcomes (Wang et al., 2021; Bennett et al., 2020).

More recently, studies have looked at new factors that have not been investigated previously. For example, Giuliania (2021) showed that an active neurological disorder that contributes to mental health is a negative determinant of hearing aid use. Another recent clinical trial by Humes et al. (2017) demonstrated that service delivery models including audiology best practices and direct-to-consumer models did not show any significant differences in hearing aid satisfaction. These recent studies highlight the importance of investigating unexamined factors that are potential contributors to hearing aid outcomes. The current study therefore aimed to extend existing evidence on factors influencing hearing aid outcomes by investigating factors such as social networks, self-reported mental health and service delivery models that have limited or no evidence to date.

4.3 Methodology

4.3.1 Study design

The study used a prospective cross-sectional survey design as part of a larger survey aimed at examining the language used by hearing aid users in describing their experiences (Swanepoel et al., 2022). Ethical approval (Appendix B: Clearance from Lamar University (IRB-FY21-248)) and Appendix A1 and Appendix A2 (Ethical clearance from the University of Pretoria) were obtained. All participants completed an informed consent form (Appendix C) before completing the online survey.

4.3.2 Participants

The study includes 398 hearing aid users recruited using a convenience sample from the Hearing Tracker (www.hearingtracker.com) database. Hearing Tracker is a website that provides comprehensive and up-to-date information about hearing instruments and services to consumers (Manchaiah et al., 2020). Participants from the Hearing Tracker community are hearing aid users who have signed up to receive up-to-date information on hearing instruments on the hearing tracker platform. Any interested hearing aid user based in the United States of America may join the Hearing Tracker community. An email with the study invitation and a link to the survey was sent out to the Hearing Tracker membership database. The link was sent to groups of hearing aid users who are active on the Hearing Tracker platform. A reminder email was sent a week later to the potential participants. To confirm that they are hearing aid users, the survey (supplementary material 1) had an item confirming the nature of their hearing aid fitting (i.e., unilateral and bilateral). This study excluded hearing aid users who are not part of the Hearing Tracker community, contributing to potential sample bias and limitations in generalizing the study results.

4.3.3 Survey

An online survey was sent to Hearing Tracker members via the Qualtrics platform during October and November 2021. The survey contained questions on 1) demographic 2) audiological variables; 3) self-reported hearing aid outcomes; 4) general health, 5) self-reported mental health and 6) social network information. Demographic items included age, gender, race, ethnicity, work situation, education level, household income and living arrangement. In this study, work situation refers to the participant's current state of employment and consists of the following employment status options; retired, out of work and employed.

Audiological items included self-reported hearing difficulty, duration of hearing loss, duration before hearing aids were obtained after the patient started noticing hearing problems, monaural or binaural fitting, hearing aid style (in the ear or behind the ear), hearing aid brand, and service delivery model. For the self-reported hearing aid benefit and satisfaction measure, the IOI-HA (Cox & Alexander, 2002) outcome tool was used. The IOI-HA consists of seven items which were scored using a 5-point Likert scale, with a score of five indicating the best result and a score of one indicating the worst. Thus, a higher score on each question as well as on the total score is indicative of a better outcome (Cox & Alexander, 2002).

General social networks were defined as the number of people in households, children, close friends and grandchildren. Social network related to hearing loss and hearing aids which was divided into two categories, (i) social networks of people with hearing loss and no hearing aids and (ii) social networks of people with hearing loss with hearing aids, indicating the number of known people with hearing loss with and without hearing aids, respectively. Self-reported mental health in the context of this study represents the general status of self-reported mental well-being.

4.3.4 Data analysis

Survey data were extracted from the Qualtrics platform into Microsoft Excel. The data screening process included identifying (i) missing values and (ii) unconsented responses. The following responses were excluded: participants who did not provide consent (n=23); participants who had only an implantable device(s) (e.g., cochlear implants, bone anchored hearing devices; n=3); participants who did not have the conventional type of hearing aids but used direct-to-consumer devices such as Personal Sound Amplification Products (PSAP) (n=14). After the elimination of participants who had incomplete data, the remaining 398 participants were included in the data analysis. All statistical analyses were completed in SPSS (IBM Corporation, v 28).

Assumption testing was conducted, with the results indicating a violation of the assumptions of normality, linearity and homogeneity of variance for some demographic variables. As such, seven ordinal regression models were built for each of the IOI-HA items, item 1 to 7 (ordinal variables) and one quantile regression model was built for the IOI-HA total score (continuous variable) as the dependent variable. The independent (contributing factor) variables included demographic variables (i.e., age, gender, race, ethnicity, work situation, education level, living arrangement, household income), audiological variables (i.e., self-reported hearing difficulty, duration before hearing aid purchased, type of hearing aid service delivery model), social network variables (i.e., general social networks and social networks related to hearing loss and hearing aids), self-reported general health, self-reported mental health and quality of life.

To explore how well a model fits, the final model (i.e., the model with only significant contributing factors) was compared to the null model. For ordinal regression models, the omnibus test uses a likelihood ratio Chi-square test (χ^2) to compare the final model against the thresholds-only model with a p-value less than 0.05 indicating a statistically significant

improvement. For models IOI-HA1 to IOI-HA7, the results were as follows: χ^2 values =34.418, 49.650, 81.786, 58.600, 93.540, 52.357, and 47.333 with all p-values < 0.001. For quantile regression models, the model quality is assessed by comparing the mean absolute error (MAE) of the final model to that of the intercept-only model (Appendix E: Supplementary tables). A lower MAE shows improvement, and for this study, there was a 6.26% reduction in error as the MAE lowered from 3.357 to 3.148 from the intercept-only model to the final model. It should be noted that some practitioners interpret the pseudo R^2 to determine the quality of quantile regression models; however, this was not done for this study since researchers (Gomez-Cravioto et al., 2022; Kurzawa & Lira, 2015) have pointed out that pseudo R^2 values cannot be interpreted as R^2 values from classical linear regression and, accordingly, we considered the percentage reduction of the MAE to assess model quality.

4.4 Results

4.4.1 Demographics of the study sample

398 hearing aid users completed the survey with an average age of 66.7 (13 SD) years. On average, participants had hearing loss for 24 (18.6 SD) years and spent 6.9 (11.3 SD) years before the purchase of hearing aids. Most participants were male (59.3%) and white (87.7%) (Table 4.1). The average number of general social networks participants had was 12 (SD 8.2) people. Participants on average reported knowing 3.5 (SD 6.9) people with hearing loss with no hearing aids and 9 (SD 18) people with hearing loss with hearing aids.

Table 4.1: Demographic variables of study participants (n=398)

Continuous variables	Mean	SD
Age	66.6	13. 0
HL duration (in yrs)	24.0	18.6
Duration before HA (in yrs)	6.9	11.3
General social networks	12.0	8.2
Social network (related to HL and HA)	3.5	6.9
Social networks (HL no HA)	9. 0	18. 0
Social Networks (HL with HA)		

Categorical variables	N	%
Gender		
Female	162	40.7%
Male	236	59.3%
Race		
Other	49	12.3%

Continuous variables	Mean	SD
White	349	87.7%
Ethnicity		
Non-Hispanic or Latino	382	96.0%
Hispanic or Latino	16	4.0%
Work Situation		
Retired	247	62.1%
Out of work	18	4.5%
Employed	133	33.4%
Education level		
University degree	298	74.9%
Some college but not degree	78	19.6%
High school or less	22	5.5%
Household Income		
$150,000 or more	74	18.6%
$100,000-$149,000	102	25.6%
$50,000-$99,999	139	34.9%
$25,000-$49,999	57	14.3%
Under $25,000	26	6.5%
Living arrangement		
On my own	67	16.8%
With spouse/partner	274	68.8%
With my family or with a friend	57	14.3%

4.4.2 Contributing factors of hearing aid outcomes

Self-reported hearing difficulty, self-reported mental health, quality of life and social networks (with HL and HA) were significant positive contributing factors of IOI-HA total score (Table 5.2; 8. IOI-HA total score). The *service delivery model* and *social network for HL and no HA* were significant negative contributing factors of IOI-HA total score (Table 5.2; 8. IOI-HA total score). With regards to *service delivery model*, participants who received hearing health care services from a private clinic or university obtained an IOI-HA total score that was 1.573 less on average than participants who received hearing health care services through the service delivery model of warehouse (e.g., big box retailers such as Costco).

Quality of life was shown to be a positive contributing factor throughout most IOI-HA items. Higher *self-reported hearing difficulty* was shown to be a negative contributing factor of IOI-HA items. Furthermore, *service delivery model* had varying results across IOI-HA items. For hearing aid use (IOI-HA item 1), benefit (IOI-HA item 2), and satisfaction (IOI-HA 4); factors such as *quality of life, service delivery model, self-reported hearing difficulty, work situation*

and social networks (HL no HA) were significant contributing factors. Work situation was a negative contributing factor of hearing aid benefit and satisfaction indicating that those who were employed had reduced hearing aid benefit and satisfaction. Larger *social networks (HL with HAs*) were shown to be a positive contributing factor of hearing aid benefit and satisfaction. Unique factors such as *self-reported mental health* was only positively associated with quality of life (IOI-HA item 7) and the IOI-HA total score.

Table 4.2: Significant contributing factors (p<0.05) of hearing aid outcomes based on the ordinal regression models for IOI-HA 1-7 and a quantile regression model for IOI-HA total score

IOI-HA Item	Significant contributing factors	*P*-value	Exp B (95% CI)
1 Daily use (1)	Quality of life (+)	0.001	1.9 (1.3, 2.7)
	Hearing loss duration (+)	0.001	1.9 (1.3, 2.7)
	Self-reported hearing difficultly (-)	0.036	0.6 (0.4, 0.9)
	Uni-Bil hearing aid fitting (-)	0.049	2.4 (0.9, 5.9)
2. Benefit (2)	Service delivery (+)	0.003	1.8 (1.2, 2.7)
	Quality of life (+)	<0.001	1.6 (1.3, 2.2)
	Work Situation (-)	<0.001	0.4 (0.3, 0.7)
	Social networks (HL no HA) (-)	0.002	0.95 (0.9, 1.0)
	Social networks (HL with HA) (+)	0.001	1.02 (1.01, 1.04)
3. Residual activity limitations (3)	Social networks (HL no HA) (-)	0.004	0.95 (0.9, 1.0)
	Social Networks (HL with HA) (+)	0.032	1.008 (1.0, 1.013)
	Self-reported hearing difficulty (-)	<0.001	2.1 (1.6, 2.7)
	Service delivery model (-)	0.044	1.5 (1.0, 2.2)
	Age (-)	0.010	0.98 (0.96, 0.1.0)
	Mental Health (-)	0.009	1.3 (1.0, 1.6)
	Race (-)	0.047	1.9 (1.0, 3.4)
	Living Arrangement	0.037	0.5 (0.2, 0.6)
4. Satisfaction (4)	Quality of life (+)	<0.001	1.9 (1.4, 2.5)
	Social Networks (HL with HA) (+)	0.028	1.015 (1.002, 1.028)
	Social Network (HL no HA) (-)	0.003	0.96 (0.93, 1.0)
	Self-reported hearing difficulty (-)	0.014	0.7 (0.5, 0.9)
	Service Delivery Model 2(-)	0.001	2.1 (1.3, 3.3)
	Work Situation (-)	0.001	0.5 (0.3, 0.7)
	Race (-)	0.006	0.4 (0.2, 0.8)
5. Residual participation restriction (5)	Living arrangement (+)	0.006	0.4 (0.2, 0.5)
	Ethnicity (+)	0.003	0.2 (0.1, 0.6)
	Social networks (HL no HA) (+)	0.009	0.9 (0.9, 0.9)
	Self-Reported hearing difficulty (-)	<0.001	1.9 (1.5, 2.5)
	Service delivery model 2 (-)	<0.001	1.9 (1.3, 2.7)
	Quality of life (-)	<0.001	1.9 (1.5, 2.5)
6. Impact on others (6)	Self-reported hearing difficulty (+)	<0.001	1.8 (1.4, 2.3)

IOI-HA Item	Significant contributing factors	*P*-value	Exp B (95% CI)
	Quality of life (+)	<0.001	1.8 (1.4, 2.4)
	Ethnicity (+)	0.004	0.2 (0.1, 0.6)
	Social Networks (HL no HA) (+)	0.009	0.97 (0.95, 1.0)
7. Quality of life (7)	Mental Health (+)	0.005	1.4 (1.1, 1.6)
	Quality of life (+)	<0.001	1.9 (1.3, 2.5)
	Work Situation (-)	0.012	0.6 (0.4, 0.9)
8. IOI-HA Total	Social Network (HL and HAs) (+)	0.010	0.03 (0.01-0.1)
	Social Networks HL no HA (-)	<0.001	0.1 (-0.2, -0.02)
	Mental Health (+)	0.05	0.6 (0.01, 1.2)
	Service Delivery Model (-)	0.001	-1.6 (-2.7, -0.7)
	Quality of Life (+)	0.005	1.2 (0.3, 1.1)
	Work Situation (+)	0.001	1.9 (0.7, 2.8)
	Self-reported hearing difficulty (+)	0.02	0.8 (0.2-1.5)

4.5 Discussion

Several additional contributing factors of hearing aid outcomes were identified in this study. In terms of *social networks*, knowing more people with hearing loss that use hearing aids was positively associated with improved hearing aid outcomes. Conversely, knowing more people with hearing loss not using hearing aids was associated with poorer hearing aid outcomes. These findings highlight the advantage of a larger social network of persons with hearing loss owning hearing aids. Such advantages include access to knowledge from peers about first-hand experiences on hearing aids, knowledge on optimizing hearing aid use, assistance in the selection of effective hearing aids, the reduction of stigma and improved attitude towards hearing loss and hearing aids (Ruusuvuori et al., 2021). A study by Chundu et al. (2020) investigated the social representations of people with hearing loss using the social representation theory (SRT) and identified negative connotations of perceptions and attitudes towards hearing aids among people with hearing loss. In another study, Chundu et al. (2021) examined social representations of hearing aids which showed that appearance and design are one of the most common aspects people recall when they think about hearing aids. These findings highlight the importance of addressing stigma and negative attitudes towards hearing aids by people with hearing loss to improve hearing aid outcomes. These can be promoted through education on hearing aid technology and increased exposure to people with hearing loss using hearing aids to promote shared values and beliefs (Chundu et al., 2020).

Despite the increasing prevalence of mental health problems or diagnoses, such as depression in the global population (Nochaiwong et al., 2021), the impact of mental health difficulties on hearing aid outcomes has not been widely investigated. In this study, *self-reported mental*

health was found to be not associated with hearing aid use (IOI-HA item 1) but better *self-reported mental health* was positively associated with improved overall hearing aid outcomes (IOI-HA total). For hearing aid use (IOI-HA item 1), a cohort study of 666 hearing aid users by Dawes et al. (2015) showed similar results of a non-significant association between mental health and hearing aid use. Contrastingly, a study of 93 people with hearing loss by Stark and Hickson (2004) demonstrated a positive relationship between mental health measured through the Short Form 36 (SF-36) survey and hearing aid use. The current existing literature on mental health is focused on the outcome of hearing aid use, indicating a need for further exploration on other measures of hearing aid outcomes, including the overall hearing aid outcomes (IOI-HA total). The relationship between self-reported mental health and overall hearing aid outcomes (IOI-HA-total) highlights the importance of considering patient's mental health in the management of hearing loss through the use of hearing aids and appropriate rehabilitative supports.

In terms of *service delivery model*, patients receiving hearing aids through big box stores (e.g., retailers such as Costco) and third-party payers demonstrated significantly better hearing aid outcomes compared to those receiving hearing aids through private practice or university clinics. One randomized double-blind placebo-controlled trial by Humes et al. (2017) compared different service delivery models including audiology best practice and a lower cost direct to consumer (DTC) model. Humes et al. (2017) did not find significant differences in overall hearing aid outcomes but did find significantly lower levels of satisfaction and likelihood to purchase for the DTC group. Additionally, the purchase price of the hearing aid did not have a significant effect on the hearing aid outcomes in the study by Humes and colleagues (2017). Their findings also demonstrated that the purchase price of hearing aid did however negatively affect the decision to retain the hearing aids, with 85% of those who decided not to retain their hearing aids in the typical audiology best practice model.

The current study and Humes et al. (2017) compare different set of service delivery models, indicating a need for studies comparing hearing aid outcomes on service delivery models in private clinics, university clinics and big box retailers. Unlike Humes et al. (2017), this study did not consider the moderating effect of hearing aid purchase price on hearing aid outcomes and the decision to retain hearing aids for the selected service delivery models. Although the direct effect of cost was not formally investigated, our findings may be partly related to cost-

benefit expectations as hearing aids obtained through big box stores and third-party payers generally have lower cost when compared to private practice and university clinics.

Generally, *quality of life* was shown to be a positive factor for improved hearing aid outcomes. A consumer survey by Picou (2020) showed similar results whereby a high quality of life was shown to contribute towards higher levels of hearing aid satisfaction. Although demonstrated to contribute to most IOI-HA items, quality of life has typically been studied as an outcome of hearing aid use as opposed to a contributing factor of hearing aid outcomes. For example, a study by Kochkin (2011) showed hearing aid use as a positive determinant of improved quality of life. A systematic review by Brodie et al. (2018) showed that all forms of audiology rehabilitation including hearing aids, cochlear implants and bone anchored hearing devices improve quality of life. Nevertheless, it is not surprising to see that those with better quality of life are likely to benefit and be more satisfied with their hearing aids.

Work situation measured as the participant's current state of employment (consisting of options including retired, out of work and employed) was explored in the present study whereby working/being employed was a positive determinant of hearing aid outcomes as opposed to not working. Factors that may contribute towards the improved hearing aid outcomes for employed hearing aid users include income (Fuentes-López et al., 2019), affordability for hearing aids and hearing aid maintenance (Blustein & Weinstein, 2016), and improved quality of life associated with being employed (Carlier et al., 2013). These results contrast with those reported by Meyer et al. (2014) and Korkmaz et al. (2016) where being employed, or employment status had no influence or effect on hearing aid outcomes.

Severity of *self-reported hearing difficulty* was shown to be a positive contributing factor of improved hearing aid outcomes. Other studies such as Helvik et al. (2016), Hickson et al. (2010) and Klyn et al. (2020) confirm the positive association between self-reported hearing difficulty measured through non-standardized questionnaires and hearing aid outcomes. Self-reported hearing difficulty is an expression of the patient's experience with hearing loss in daily living and may be influenced by impacts of hearing loss experienced by a patient such as communication difficulties, stress and anxiety (Kim et al., 2017). A combination of self-reported hearing difficulty and other clinical measures of hearing sensitivity such as the PTA is important in quantifying hearing loss/difficulty used in the prescription of hearing aid treatment.

4.6 Limitations

Although self-reported hearing difficulty measures some form of hearing sensitivity, the gold standard in the measurement of hearing sensitivity is pure tone audiometry (Kiely et al., 2012) was not available in this study. The influence of hearing sensitivity has been demonstrated to influence IOI-HA outcomes (Aazh et al., 2015; Houmoller et al., 2022; Staehelin et al., 2011; Wang et al., 2021). It is also noteworthy that the use of other clinical measures of hearing aid outcomes such as objective (e.g., hearing aid use through datalogging) and behavioral (e.g., hearing aid benefit measures through speech testing with and without hearing aids) measures were not used. Another limitation of this study is in using a single survey question as a measure of general self-reported mental health. Apart from limitations related to study measures, the main limitation of this study is the potential sampling bias as a result of the recruitment method utilized, whereby only hearing aid users who were subscribed to the hearing tracker website were invited to partake in the study. As a result, there may be noticeable differences between the study sample and the general population in terms of demographic factors such as age, race, education, and income which could limit the generalization of the study results to the general population.

4.7 Conclusion

Factors including social network of persons with hearing loss using hearing aids, mental health and service delivery model have been identified as important factors that predict hearing aid outcomes, as measured by the IOI-HA, in this study. As an exploratory study, future investigations should further consider and explore these factors to strengthen evidence on their relationship with hearing aid outcomes. These newly identified factors can support public hearing health promotion and individualized audiological care to optimize hearing aid outcomes.

CHAPTER 5: COMMUNITY-BASED HEARING AID FITTING MODEL FOR ADULTS IN LOW-INCOME COMMUNITIES FACILITATED BY COMMUNITY HEALTH WORKERS: A FEASIBILITY STUDY

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5.1 Abstract

Objective: To determine the feasibility and outcomes of a community-based hearing aid fitting model designed for low-income communities facilitated by community health workers (CHW).

Method: Using Bowen's framework, feasibility was evaluated according to service delivery and patient outcomes. A total of 25 (six male) participants were fitted with bilateral GoPrime preset, over-the-counter (OTC) hearing aids by CHW in Khayelitsha, a low-income community in Cape Town, South Africa. Benefit and satisfaction were measured using the International Outcome Inventory for Hearing Aids (IOI-HA). An open-ended survey used to obtain their perceptions on the impact of the hearing aids on communication, the mHealth program, and willingness to purchase the hearing aids was analyzed using inductive thematic analysis.

Results: Pure Tone Average across participants was 57.3 dB HL (11.5 SD) in the left ear and 54 dB HL (14.2 SD) in the right ear. The majority of participants self-reported positive outcomes while using hearing aids, including good hearing in background noise. IOI-HA showed above standardized average scores of 3.91 for daily use, 4.46 for benefit, and 4.58 for satisfaction. 92% of participants reported the hearing aids as extremely helpful, with 87.5% recommending hearing aids for others with hearing loss. Additionally, participants reported positive experiences with the mHealth support program and described the program as clear and helpful.

Conclusion: The community-based hearing aid fitting model is feasible and demonstrated positive hearing aid outcomes in a low-income community. This approach, supported by

mHealth technologies and CHW, presents a promising solution to address the hearing care gap in low- and middle-income countries (LMICs).

Keywords

Hearing loss, Hearing aids, Community health workers, mHealth, Low- and middle-income countries

5.2 Background

Hearing loss affects more than 1.5 billion people globally (World Health Organization, 2021). Over four hundred million of these individuals could benefit from intervention with hearing aids (Fröschl, 2019). Although shown to be effective in the treatment of hearing loss (Ferguson et al., 2019), hearing aids are inaccessible to most people with hearing loss (Orji et al., 2020). Globally, only about 10% of those who could benefit from hearing aids make use of hearing aids (Bisgaard et al., 2022; World Health Organization, 2021). Major barriers contributing to the inaccessibility of hearing healthcare emanate from a lack of trained professional workforces, centralized models of hearing care, and the cost of traditional clinical equipment (Mulwafu et al., 2017; World Health Organization, 2021; Goulios and Patuzzi, 2008; Swanepoel, 2023). Even if some elements of care are available (e.g., hearing assessment), hearing aids are often unaffordable (McPherson, 2011; Sinha et al., 2020). Factors such as limited availability of hearing aid manufacturers, regulation, bureaucracy, and high-profit markups contribute to the high cost of hearing aids in LMICs (Blustein & Weinstein, 2016).

Recently, different approaches to hearing healthcare have been suggested and prioritized to improve access to hearing healthcare (Swanepoel, 2023; Nieman et al., 2022). These approaches include task-shifting, recommended by the World Health Organization (WHO), where trained community healthcare workers (CHW) are utilized to address the shortage of hearing healthcare professionals (Eubank et al., 2022; World Health Organization, 2021; Chadha et al., 2018; Yousuf Hussein et al., 2018). Availability of audiologists varies across regions, based on income level, according to WHO (2013), with only 5.2% of low-income countries and 27.7% of LMICs reporting more than one audiologist per 1 million people. Latest evidence on the shortage of audiologists has recently been reported by Kamenov et al. (2021), showing that a majority of countries in the sub-Saharan region of Africa have less than one hearing healthcare professional per million people. In contrast, most European countries have more than 50 times as many audiologists.

Employment of CHW in the provision of hearing healthcare services, supported by mHealth technologies, promotes a variety of service delivery models that could improve access compared to traditional audiological best practice. The feasibility of these alternative service delivery models has been studied by Nieman et al. (2017). They assessed the feasibility of Hearing Health Equity through Accessible Research and Solutions (HEARS). This was a community-based intervention involving screening, provision of personal sound amplification

products (PSAPs), and communication education. The HEARS intervention was accepted by the community and found to be feasible for implementation. Participants self-reported improvements in hearing and communication following intervention. In a follow-up randomized controlled study of the HEARS intervention by Nieman et al. (2022), an intervention group was led by CHW and provided with low-cost PSAPs and instructions on both the device and effective communication strategies. A waitlist control group was included, receiving the intervention only after reaching the 3-month trial endpoint. Twelve-month post-intervention data were collected for both groups, with results indicating significant improvements in self-perceived communication measured by changes in the Hearing Handicap Inventory for the Elderly–Screening Version score (HHIE-S) within the intervention group.

The feasibility of an adult community-based rehabilitation (CBR) model, providing self-programmed hearing aids, CHW support, and mHealth technologies, was evaluated in a recent study by Frisby et al. (2022). The mHealth technologies included a smartphone-based video otoscope equipped with artificial intelligence (AI) image classification and automated in-situ pure-tone audiometry (at frequencies of 0.5, 1, 2, and 4 kHz) facilitated by Lexie Lumen hearing aids (hearX Group, South Africa). The study demonstrated positive hearing aid outcomes measured through the IOI-HA. Frisby et al. (2023) also evaluated the feasibility of an mHealth acclimatization and support program using qualitative open-ended measures. The participants described the program as helpful, supportive, informative, sufficient, and clear at 45 days and six months follow-up. A recent feasibility randomized controlled trial conducted by Coco et al. (2023) found improved listening self-efficacy measured through the Self Efficacy for Situational Communication Management Questionnaire in the experimental group, facilitated by CHW, compared to the control group, facilitated by trained student facilitators. These studies demonstrate the feasibility and efficacy of CHW-based service delivery models.

In addition to these models, the feasibility of other decentralized approaches to hearing healthcare has been explored. One decentralized approach to hearing healthcare is over-the-counter (OTC) hearing aids, which have recently been approved for sale directly to consumers in the United States by the Food and Drug Administration (FDA) (Stevenson, 2022). A double-blind, placebo-controlled randomized trial by Humes et al. (2017) compared hearing aid outcomes between participants fitted through current audiology best practice or OTC hearing aids. The study found no significant differences in overall hearing aid outcomes between

participants in each group. Similarly, a study by Swanepoel et al. (2023) showed similar self-reported hearing aid outcomes (measured through IOI-HA) for participants using OTC hearing aids and those prescribed by hearing care professionals (HCP). HCP clients reported significantly longer hours of daily use, while OTC hearing aid users reported significantly less difficulty hearing in situations where they most wanted to hear better.

Despite growth in research interest in hearing aid service delivery models focused on community-based or consumer-based hearing care, there are limited implementation and feasibility studies on these service delivery models within LMICs. Bowen et al. (2009) proposed a rigorous framework for assessing feasibility study design, outlining key areas of focus, sample outcomes, and suggested sample designs. Following that framework, this study examined the feasibility of a community-based hearing aid fitting model through CHW supported by mHealth technologies. Additionally, this study describes self-reported outcomes among participants fitted with hearing aids within this community-based model.

5.3 Method

5.3.1 Study design

The Bowen framework provides guidance for designing feasibility studies with consideration for eight focus areas, including acceptability, demand, implementation, practicality, adaptation, integration, expansion, and limited-efficacy testing (Bowen et al., 2009). Among these, this study sought to address the components of the feasibility of the community-based hearing aid fitting model, including acceptability, demand, practicality and adaptability. Cross-sectional surveys were employed to evaluate the feasibility of the model through patient outcomes. These surveys aimed to capture the patients' self-reported outcomes and views of the model, considering the Bowen Framework focus areas. Institutional review board approval was obtained from the University of Pretoria Humanities Ethics Board (Appendix A1 and Appendix A2).

5.3.2 Participants

Three CHW with four years' experience in providing hearing healthcare services in low-income communities were recruited to recruit participants and conduct hearing screenings, assessments, hearing aid fittings, and follow-up. These CHW are employed by a South African-based non-government organization (NGO), the hearX Foundation, which provides access to

hearing healthcare services in low-income communities. One qualified audiologist, the program manager from the Foundation, provided supervision and guidance to the CHW when necessary. The CHW provided hearing healthcare services from hearing testing to hearing aid fitting and follow-ups in Khayelitsha, Western Cape, South Africa. Khayelitsha is a low-income community in Western Cape, with an estimated population of about 400,000, living in 120,000 households of which 45% are formal dwellings (Statistics South Africa, 2022). Participants from this community were sampled through convenience sampling, where adults (18 years and above) with self-suspected hearing loss were recruited through self-report and community referral.

5.3.3 Study apparatus and materials

For audiometric testing, an automated smartphone-based audiometer, the hearTest™ (hearX Group, South Africa) application, recognized for its effectiveness in diagnostic testing (Corona et al., 2020), was used with headphones. A smartphone-based video-otoscope with AI imaging capabilities, the HearScope™ (hearX Group, South Africa) was used to examine the ear. In-the-ear OTC hearing aids (GoPrime™, Group, South Africa) were used to fit eligible community members. These hearing aids are rechargeable, offer six channels, 12 bands, three pre-set programs, noise reduction, feedback cancellation, a memory recall function, adjustable volume and cost less than $100. Outcome measures, including the isiXhosa translated International Outcome Inventory for Hearing Aids (IOI-HA) (Frisby et al., 2022) and a four-week follow-up survey (Appendix F: Four-week follow-up questionnaire), were used to evaluate participant outcomes with hearing aids. The four-week follow-up survey contained open-ended questions on the impact of the hearing aids on communication, the mHealth program, and willingness to purchase the hearing aids. The mHealth program comprises of compiled messages containing information on hearing health, device management and use which are distributed through whatsapp and text messages.

5.3.4 Study procedures

The following CBR service delivery model components included 1) recruitment, 2) hearing assessment and hearing aid demonstration, 3) hearing aid fitting, and 4) follow-up and support. Several recommended best practices for community-delivered hearing healthcare, as outlined by Suen et al. (2019), were incorporated in the implementation of this study. These included the use of trained and experienced CHW, the integration of mHealth technologies, ongoing

education facilitated by the mHealth support program, and the provision of referrals to the onsite nurse for the management of ear diseases.

5.3.4.1 Recruitment phase

Community health workers identified 188 adults with suspected self-reported hearing loss through self-report and community referrals. Written consent was obtained to conduct hearing assessments to identify and diagnose hearing loss.

5.3.4.2 Hearing assessment and hearing aid demonstration

Smartphone video-otoscopy was conducted by CHWs. The hearScope™ was used to inspect the outer ear for disease (e.g., wax impaction, perforation, or ear infection). Images were classified by AI algorithms and uploaded to cloud storage. Where ear diseases were identified, individuals were referred to an onsite nurse.

Smartphone-based audiometry, the hearTest™ (hearX Group, South Africa), was used to evaluate hearing sensitivity in octave steps between 125 Hz and 8000 Hz. Participants were asked to raise their hand or push a button on the smartphone every time they heard a tone, even if it was soft. Participants with confirmed hearing loss (26 to 85 dB HL) were offered an opportunity to experience listening through the hearing aids on a program of their choice.

5.3.4.3 Hearing aid fitting

Twenty-five participants who met the inclusion criteria were fitted bilaterally by CHWs with hearing aids on a set program of their choice that they felt was most comfortable. Inclusion criteria included: a) ≥18 years of age, b) bilateral hearing loss (4FA PTA; 26 to 85 dB HL), c) have access to the smartphone application WhatsApp, or SMSs (either themselves or a household member), and d) willing to be contacted for interviews. The participants were orientated regarding user-operated controls and device maintenance. The CHWs facilitated the hearing aid fittings.

5.3.4.4 Follow-up and support

A mHealth program was offered for 30 days to participants fitted with the hearing aids in the form of 14 WhatsApp or text messages sent on certain scheduled days (day 1,2,4,5,8,10,12,1517,19,22,24,26,27). Information regarding hearing health, device

management and use was provided in a manner accessible to the community members, such as SMS or WhatsApp messaging service. Participants received an in-person follow-up with the CHW 30 days after the hearing aid fitting. Outcome measures, including the IsiXhosa translated IOI-HA and a non-standardized hearing aid outcome survey (Appendix D: Survey), were administered to the participants 30 weeks post-fitting.

Figure 5.1: Illustration of the hearing aid service-delivery model

5.3.5 Data analysis

Raw data were exported to Microsoft Excel spreadsheets and the program Statistical Package for the Social Sciences (SPSS, v27. Chicago, Illinois). Descriptive statistics, including mean and standard deviations, were determined for participant age, gender, degree of hearing loss, and the IOI-HA scores. Qualitative questions from the survey were analyzed by the first author (BM) using inductive thematic analysis to determine emerging themes. For quality control, the second author (CF) reviewed the themes, and any discrepancies were resolved through discussion.

5.4 Results

5.4.1 Participant characteristics

Of the 25 participants fitted with hearing aids, 24 attended 30 days follow-up appointment. One participant withdrew from the study due to personal unforeseen circumstances. Participant demographics are shown in Table 5.1.

Table 5.1: Participant demographics and hearing thresholds for those fitted with hearing aids (25)

Demographic variable	Adults fitted with hearing aids (n=25)
Age	76.5 (9.2 SD)
Gender	19 Female; 6 Male
PTA left	57.3 (11.5 SD)
PTA right	54.0 (14.2 SD)
Degree of hearing loss	
Mild (25–40 dB HL)	2 (8 %)
Moderate (41–60 dB HL)	15 (60%)
Moderately severe (61–80 dB HL)	7 (28%)
Severe (81+ dB HL)	1 (4%)

5.4.2 Self-reported hearing aid outcomes

Seventeen (70%) of the participants were wearing their hearing aids upon arrival for the follow-up visit. 25% of participants reported wearing their hearing aids always, while 58% reported wearing them often. 92% of participants reported that they found their hearing aids extremely helpful, and 87.5% mentioned that they would "definitely recommend" the hearing aids. With the IOI-HA, participants obtained a score of 3.91 out of 5 for daily hearing aid use. Furthermore, the average scores for items including hearing aid benefit and satisfaction were 4.46 and 4.58 out of 5, respectively. The total IOI-HA score obtained is 32.08, indicating above average hearing aid outcomes (Table 5.2). These results are above the statistical norms of 3.73 for hearing aid use, 3.39 for hearing aid benefit, and 3.20 for satisfaction, with an average IOI-HA score of 24.17 (Cox et al., 2003). Overall, participants obtained positive above average hearing aid outcomes measured through the IOI-HA.

Table 5.2: Hearing aid outcome results measured through the IOI-HA

IOI-HA Item	Mean (SD)	Median (1-5)
1. **Daily Use**	3.91 *(0.64)*	4
2. **Benefit**	4.46 *(0.76)*	4
3. **Residual activity limitation**	4.75 *(0.59)*	5
4. **Satisfaction**	4.58 *(0.76)*	5
5. **Residual participation restrictions**	4.83 *(0.47)*	5
6. **Impact on others**	4.96 *(0.20)*	5
7. **Quality of life**	4.58 *(0.58)*	4
Total	**32.08 (0.33)**	**32**

Regarding hearing aid functionality, all participants reported average, good, and very good performance in various contexts, including background noise, without background noise, and while watching TV or listening to the radio (Figure 5.2).

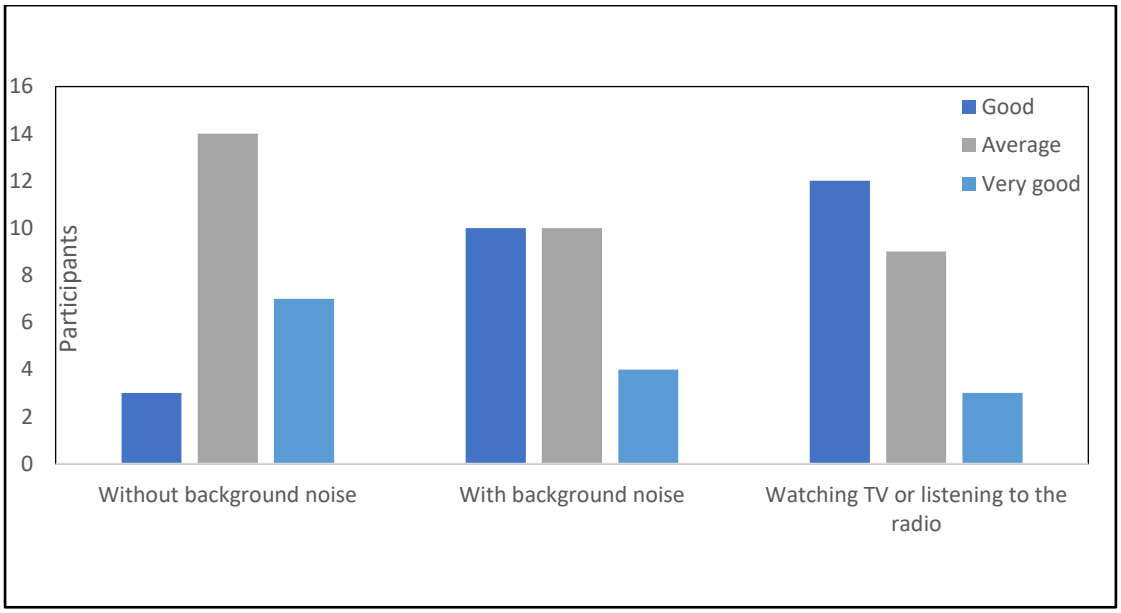

Figure 5.2: Hearing aid functioning in selected contexts (n=24)

In terms of hearing aid handling and care, the majority of participants reported that it was easy or that they could perform handling tasks comfortably. These included putting the devices on, inserting them into the ears, adjusting the volume, and cleaning (Figure 5.3).

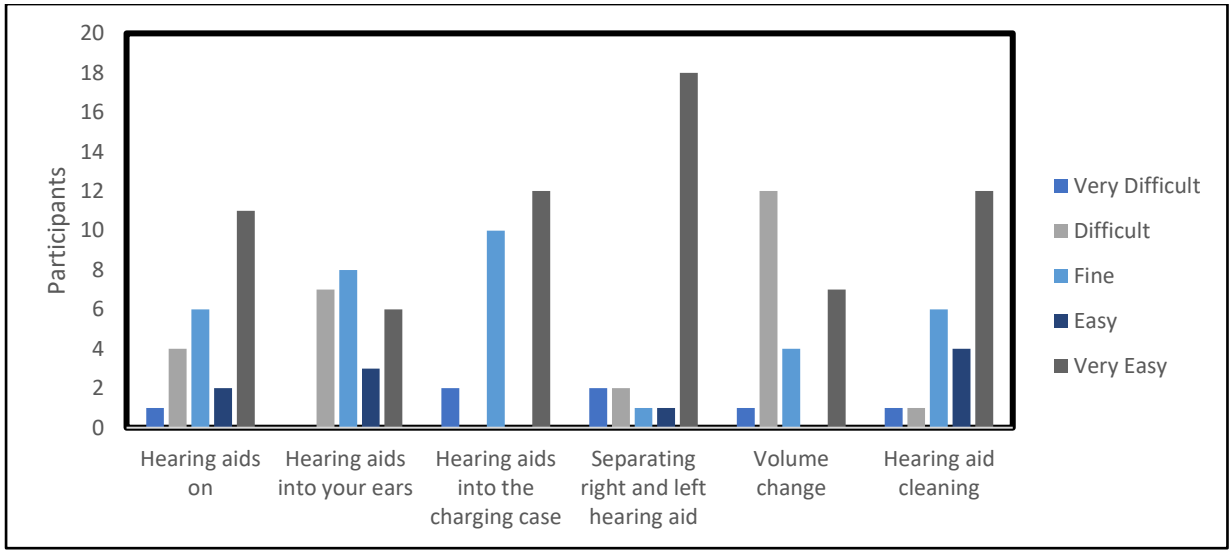

Figure 5.3: Hearing aid handling and care

5.4.3 Qualitative self-reported outcomes

In the thematic analysis of the open-ended qualitative questions, participants mentioned seven themes with hearing aid benefits, with improved hearing, communication, and social life mentioned on more than twenty occurrences (Table 5.3). Additionally, participants reported positive changes in their communication, lack of stigma associated with their hearing aid use and positive impact of family on hearing aid use.

Table 5.3: Qualitative thematic analysis themes, number of occurrences and example quotes

Theme (occurrences)	Example quotes
Improved hearing, communication and social interaction *(20)*	"She can hear better" "Yes, because they said to her now, they cannot gossip about her because she now hears"
Reduced dependency on others *(5)*	"No need for someone to help her explain everything, especially at the club"
Positive impact on social life and Family *(13)*	"She is happy now that she can hear better and communicate well with people" "The family is happy"
Gratitude and appreciation *(9)*	"It really helped me a lot because he can hear better and enjoy life happily and freely" "100% my family is happy"
Perception and recognition of Change *(9)*	"They see a big difference when she wears them; she hears better" "He does not see any changes to people now"
Positive treatment and acceptance *(13)*	"It changed my life very much because before I was avoiding conversation, now I can talk to people freely without fear" "They treat him good, with no problem"

Theme (occurrences)	Example quotes
Lack of stigma *(4)*	"No, because no one notices, and she is not ashamed of what people will say"

Participants reported that the mHealth support program was useful, with the following themes including (i) the useful role of WhatsApp for communication, (ii) learning and knowledge enhancement and (iii) assistance and support appearing in high number of occurrences during inductive thematic analysis. Some strengths of the support program mentioned were that the messages received were clear and easy to understand. Suggestions for the mHealth program improvement included the incorporation of additional information and an increased use of IsiXhosa in the messages. Despite these recommendations, overall, participants expressed satisfaction and gratitude for the support program.

5.4.4 Affordability and willingness to pay

Regarding affordability and cost, all participants indicated willingness to pay monthly installments ranging from 2.6 to 10.5 USD (R50 to R200) for the hearing aids. The most frequently mentioned installment amount for the hearing aids is 10.5 USD (R200). However, 16.7% of participants mentioned that they cannot afford to pay any amount for hearing aids due to income constraints and other financial commitments. In terms of income, all participants included in the project were receiving only an old-age social grant, which is less than 131.1 USD (R2500) per month.

5.5 Discussion

The current study evaluated a CHW-led, community-based hearing aid fitting model within the Bowen feasibility framework. Several key insights were revealed. The high satisfaction levels among participants not only underscore the acceptability of the model but also reflect its responsiveness to user needs in low-income settings. The notable demand for the service is evident from participants finding their hearing aids extremely helpful and their willingness to recommend them, indicating a vital need in these communities. The successful implementation of the program, as planned, highlights its practicality and adaptability to resource-limited environments. Furthermore, the integration of a mHealth support program was instrumental in enhancing participants' knowledge and self-confidence in handling hearing aids, thereby fostering greater independence and engagement with the technology. These findings not only align with Bowen's framework but also contribute to a deeper understanding of implementing

healthcare innovations in low-income settings, offering valuable insights for future policy and practice.

Our study supports the findings of Frisby et al. (2022), which demonstrated the acceptability, practicality, and feasibility of a similar CBR model within the same low-income community. The CBR service delivery model offered advantages, including flexibility and mobility of hearing healthcare services. While both studies employed CHWs, it is worth noting that Frisby et al. (2022) utilized more expensive, advanced behind-the-ear, self-fitting OTC hearing aids (Lexie Lumen) as opposed to the preset-based OTC hearing aids employed in the current study. In comparison to the programmable hearing aids, the hearing devices used in this study are bud-style in-ear devices, more affordable (500 USD less), and require no programming before fitting. Despite being less advanced and more affordable, these devices yielded similar positive self-reported hearing aid outcomes compared to Frisby et al. (2022). Additionally, a feasibility study by Nieman et al. (2017) on a community-based hearing care intervention (HEARS program) reported high acceptability among participants, with 93% reporting benefits and 100% recommending the intervention. Although Nieman et al. (2017) and our study were facilitated by CHWs, it is important to note that Nieman et al. (2017) provided PSAPs while our study used preset-based OTC hearing aids. The difference between the PSAPs used in Nieman et al. (2017) and the hearing aids used in this study include that the PSAPs lack programming and other features like noise reduction or feedback cancellation.

The successful implementation of the CHW-based hearing healthcare provision model, as demonstrated in our study, illustrates the potential to replicate and scale hearing healthcare services in other low-income communities. Similar feasibility has been observed in other low-income communities, including India and Bangladesh. In India, a study conducted by Emmerson et al. (2013) demonstrated the effectiveness of trained CHWs in identifying disabling hearing loss and providing programmable mini behind-the-ear hearing aids. Consistent with our study, the outcome results reported by Emmerson et al. (2013) measured through the Abbreviated Profile of Hearing Aid Benefit (APHAB) indicated improvements and benefits in communication during daily activities. In Bangladesh, a randomized control trial conducted by Borg et al. (2017) revealed similar positive performance measured through the IOI-HA between participants fitted with pocket model hearing aids through a community-based approach compared to center-based approach. These studies support our findings, which

revealed the feasibility and efficacy of CHWs facilitated hearing healthcare provision models in low-income communities.

Our study revealed positive hearing aid outcomes measured through self-report questionnaires. For instance, the total IOI-HA score obtained was 30.2, with average scores of 3.7, 3.8, and 4.2 for hearing aid use, benefit, and satisfaction, respectively. On average, the results closely resemble those reported by Frisby et al. (2023), wherein a total IOI-HA score of 32.1 was attained, accompanied by average scores of 4.4, 4.6, and 4.6 for hearing aid, benefit, and satisfaction, respectively. While the difference in total mean IOI-HA scores was minor (0.32), the variations in scores for hearing aid use, benefit, and satisfaction were significant. A potential contributing factor to the superior outcomes observed in Frisby et al. (2023) could be the use of more advanced programmable self-fitting OTC hearing aids. Additionally, the performance of hearing aids in various settings, such as background noise, noise-free environments, and during activities like watching TV or listening to music was reported by Frisby et al. (2023) to be above average. In another recent study by Nieman et al. (2022), significant improvements in self-perceived communication function were observed in participants who received low-cost amplification devices (PSAPs) and instructions from CHWs compared to a waitlist control group.

Some of the recommended best practices of community-delivered hearing healthcare were adopted during the implementation of this study. These included the use of already trained and experienced CHWs, the use of mHealth technologies, continuous education through the mHealth support program, and referrals to the onsite nurse for ear disease management. These recommendations are in line with a study bv Suen et al. (2019) which first proposed some best practices to ensure success of community delivered hearing healthcare. These practices included competency-based training of CHWs, supervision by an audiologist or ENT surgeon, continuing education, a clearly defined scope for all members involved, adoption of existing policies on the provision of hearing healthcare, the use of technology, and the tracking of costs.

The mHealth support program significantly improved participants' abilities to maintain and care for their hearing aids, with the majority finding these tasks easy to perform. These positive findings complement those from Frisby et al. (2023), which demonstrated the feasibility and effectiveness of an mHealth support program in enhancing hearing aid acclimatization, as well as care and handling. While both studies report positive findings, and were implemented in the form of WhatsApp and text messages, differences existed in the frequency and duration of the

support program. Frisby et al. (2023) employed a 45-day period with 20 messages sent whereas, in our study, fewer (14) messages were sent over a shorter (30-day) period.

The successful implementation of the CHW-based hearing aid model demonstrated in this study highlights the potential for replicating and scaling CHW-provided hearing healthcare services in low-income communities. While the feasibility of such models has been established, it is crucial to address their sustainability. This includes the ongoing promotion of innovative, affordable hearing products, such as GoPrime hearing aids. In addition to their affordability, these devices are also easy to maintain and use in LMICs as evidenced, for example, by their being rechargable. We also successfully developed a sustainable installment payment model to cover both project and hearing aid costs. The demand for such an innovative payment arrangement was demonstrated in most participants' willingness to pay monthly installments despite their low income. Integrating these innovative models into Primary Health Care Systems could make the scaling of hearing healthcare services a reality that is more affordable for stakeholders, including governments and charity organizations.

5.6 Limitations

Despite the demonstrated feasibility in improving hearing aid outcomes, this study presents several limitations. The primary limitation was the relatively small sample size, comprising only 25 participants, and the consequent possibility of sampling bias. This study was purely observational, lacking control groups for comparison. The outcomes were not assessed over the long term, limiting our understanding of the sustained evaluation of the CHW interventions. Evaluation was purely reliant on self-reported hearing aid outcomes, excluding objective and behavioral measures such as aided speech in noise and in-ear measures. Finally, there were no matching pre- and post outcome measures to evaluate individual differences in outcome measures post hearing aid intervention.

5.7 Conclusion

The community-based hearing aid fitting model, facilitated by CHWs in low-income communities was demonstrated to be feasible. Successful implementation may be due to several critical practices, including CHW training, the integration of mHealth technology, and audiologist supervision. While this model has proven feasible in improving hearing aid outcomes, it is important to conduct further research in a variety of other low-income settings to assess the scalability of the model. Comparative and cost effectiveness studies should be conducted to evaluate its success in relation to more traditional hearing aid fitting models.

CHAPTER 6: DISCUSSION AND CONCLUSION

This chapter provides a summary and context for the results obtained in Studies I-III. It explores the clinical implications, strengths, and limitations, and offers recommendations for future research arising from the study.

6.1 Summary of study findings

The study aimed to achieve three objectives: 1) synthesise evidence on factors influencing hearing aid use, benefits, and satisfaction; 2) explore recent factors influencing hearing aid outcome; and 3) evaluate the feasibility of improving access to hearing aids through a community-based hearing aid fitting model for low-income communities in the Western Cape. This research was divided into three studies. In the first study, an examination and compilation of data from research conducted between 2010 and 2023 identified 101 distinct and critical factors affecting the use (n=47), benefit (n=17), and satisfaction (n=37) of hearing aids. Positive influencers that led to improved use, benefits, and satisfaction from hearing aids included factors such as hearing sensitivity, reported hearing issues, speech recognition, and personal attitudes and beliefs. Conversely, negative influencers that diminished the effectiveness and satisfaction of hearing aid use involved issues, such as hearing aid complications, existing neurological disorders, and significant tinnitus.

The second study emphasised and discussed recent factors affecting hearing aid outcomes through a cross-sectional survey distributed to users on the Hearing Tracker platform. Factors, such as having a social network people with hearing loss with hearing aids, good mental health, employment status, quality of life, and increased levels of self-reported hearing difficulty positively influenced hearing aid outcomes. Conversely, factors that negatively affected hearing aid outcomes included a lack of social networks of people with hearing loss using hearing aids, and the type of service model (where private clinics and universities resulted in poorer outcomes as compared to large retailers).

The third study evaluated the effectiveness of a community-based approach to fitting hearing aids in a low-income community, led by Community Health Workers. This assessment focused on the participants' reported experiences with the hearing aid fitting process under this model. On average, the degree of hearing loss was moderate, making these individuals reasonable audiometric candidates for the over-the-counter hearing aids. Most participants reported

favourable outcomes from using the hearing aids, including satisfactory performance in noisy environments. The IOI-HA scores were above the standard average, with 3.91 for daily usage, 4.46 for benefits, and 4.58 for satisfaction, indicating positive experiences. Furthermore, 92% found the hearing aids to be beneficial, and 87.5% would recommend their use.

6.2 Clinical implications

Several clinical implications emerged from this research project which are explored under two primary themes: (1) enhancing hearing aid outcomes and (2) expanding the reach of scalable hearing healthcare services within low-income communities. The first theme explores three key areas influencing hearing aid outcomes: the function of audiologists and hearing healthcare practitioners, the effect of patient-related factors, and manufacturers' contributions regarding development of the devices.

6.2.1 Enhancing hearing aid outcomes: The role of audiologists and hearing healthcare practitioners

Studies I and II clarify factors beyond hearing loss and hearing aid technology affecting patients hearing aid outcomes. Most identified factors are non-audiological and are more likely to be disregarded during standard audiology consultations because these consultations typically focus on audiology-related issues. A more comprehensive approach should be followed during clinical audiology consultations to avoid overlooking these factors including those identified in this research (Naughton, 2018). A person-centred approach is one such example, it recognises the whole individual, including their personality, life history, and social structure, to establish a shared understanding of their hearing loss, treatment goals, and any obstacles to achieving treatment and well-being (Naughton, 2018). It includes interactive communication between the hearing healthcare professional and the patient, allowing for identifying factors that should be considered to optimise hearing aid outcomes and support informed counselling and management of expectations. The person-centred approach aligns with the principles of the WHO's Classification of Functioning framework (WHO-ICF), which promotes the consideration of patient factors; audiological and non-audiological identified in Study I and II in the treatment of hearing loss (WHO, 2001).

In clinical audiology practice, benefits of a broad consideration of factors identified in Study I and II through a person-centred approach support the improvement of clinical understanding

of patient individual preferences, and the promotion of shared goal setting and decision-making in the treatment of hearing loss (Boisvert et al., 2017). This broad clinical understanding of the patient allows for customised hearing loss treatment to meet the unique needs of each patient (Granberg & Skagerstrand, 2022). Compared to generalised forms of treatment, the customised hearing loss treatment approach offers several advantages. These advantages include improved treatment adherence and improved hearing aid outcomes of use, benefit, and satisfaction (Naughton, 2018).

Clinical interventions to enhance these hearing aid outcomes can be formulated by broadly considering audiological and non-audiological factors identified in Study I and II. For instance, one clinical intervention to enhance hearing aid outcomes through consideration of patient mental health could involve strengthening the referral relationships among audiologists and counsellors, psychologists, or psychiatrists (Manchaiah et al., 2020). Establishing more robust connections between audiologists and mental health professionals can help to support the psychological well-being of patients with hearing loss, which will enhance hearing aid outcomes (Manchaiah, 2020). Another example of a clinical intervention to improve identified factors, including hearing aid follow-up and social support, entails implementing virtual support for hearing aid users (Ross, 2020). This could include multimedia educational programmes, mobile applications, and virtual access to hearing healthcare professionals (Ross, 2020). Such virtual forms of hearing aid support have demonstrated their efficacy in assisting individuals in adapting to hearing aids and in directing common hearing aid-related concerns improving the usage and benefits of hearing aids (Ferguson et al., 2016).

6.2.2 Enhancing hearing aid outcomes: The influence of the patient factor

One approach to incorporate factors influencing hearing aid outcomes is through patient education or information counselling, which is a strategy for promoting adherence to hearing loss treatment and enhancing hearing aid outcomes (Oosthuizen et al., 2022). Patient education should encompass audiological and non-audiological factors observed as barriers or facilitators towards optimal hearing aid outcomes. For instance, elaborating on the advantage of a larger social network of persons with HL owning hearing aids may present benefits. These benefits include access to knowledge from firsthand experiences on hearing aids, knowledge on optimising hearing aid use, and assistance in selecting effective hearing aids to promote better hearing aid outcomes (Ruusuvuori et al., 2021). Additional facilitative factors include family time, attitude, personality, education, income, and motivation. These factors can be

emphasised, enhanced, and promoted among those to whom they apply to improve hearing aid outcomes.

Factors that are barriers to improved hearing aid outcomes identified in Study I and II, such as the prevalence of hearing aid problems, bothersome tinnitus, medical aid and finance, should be considered. Patient education may still be pivotal in equipping patients with the knowledge to mitigate the effect of these barriers and optimise hearing aid outcomes (Oosthuizen et al., 2022). For instance, bothersome tinnitus can be effectively addressed through patient education, informational counselling, and cognitive behavioural therapy (CBT). Regarding financial constraints or the high costs associated with hearing aids, directing these challenges may require involving additional stakeholders, including policymakers or third-party funders. Patients may be presented with alternative and more affordable options for hearing loss treatment, such as over-the-counter hearing aids (Stevenson, 2022).

6.2.3 Enhancing hearing aid outcomes: Manufacturer and development considerations

Certain factors identified in Study I and I as barriers to improved hearing aid outcomes can be considered and addressed from a development and manufacturing level. Examples of such factors which can be addressed at this level include tinnitus management through incorporating tinnitus-management application features (Lee et al., 2022; Jacquemin et al., 2021). Another factor includes support introduced through mobile applications for hearing aid users (e.g. MyPhonak) (Ross, 2020). Integrating measures by manufacturers can offer various advantages, including product enhancement, ensuring quality standards, enhancing customer satisfaction, supporting research and development, validating clinical effectiveness, and adherence to regulatory requirements (Kates et al., 2018). Provided the ongoing evolution of the hearing aid industry, introducing more innovative solutions to remediate factors can be anticipated (Popelka & Moore, 2016). This could involve AI advancements to improve speech comprehension while optimising speech intelligibility in diverse communication contexts while in the aided condition.

Table 6.1: Summary of factors influencing hearing aid outcomes and clinical intervention considerations across the audiologist, patient, and manufacturers, or development levels

	Factor	Clinical intervention
Audiologist	Hearing loss and appropriate treatment measures	Appropriate intervention for hearing loss e.g., cochlear implantation for moderate, severe and profound hearing loss (Brodie & Smith, 2018; Fröschl, 2019).
	Word Recognition	Central auditory assessments should be considered for patients with lower WRS in higher intensities or with amplification to detect and manage any other forms of auditory deficiencies beyond hearing loss (Grant et al., 2022).
	Bothersome Tinnitus	• Activation of hearing aid tinnitus features • Inclusion of other forms of tinnitus audiological management, such as Cognitive Behavioural Therapy (Langguth et al., 2013).
	Hearing aid features.	Activation of hearing aid features, such as background noise programme and feedback manager (Kerckhoff et al., 2008).
	Prevalence of hearing aid problems.	• Comprehensive hearing aid orientation • Continuous follow-up and support (Ross, 2020).
Manufacturer	Digital Technology	Innovation, improvement in research and design on signal processing and use of AI (Popelka & Moore, 2016)
	Hearing aid features (Hearing aid appearance, digital vs analogue and insertion gain)	Continuous research and development to improve hearing aid performance, look, comfort, technology, and use (Popelka & Moore, 2016).
	Hearing aid support	Virtual mobile-based hearing aid support applications (Ross, 2020)
	Price of hearing aid	Introduction of low-cost and/or community-driven service delivery models with affordable hearing aid options (Stevenson, 2022)
Patient	Family Support.	Promotion of family-centred care and integrating of family in the hearing loss management plan (Ekberg et al., 2020).
	Social Support including Social Networks and family time)	Promotion of focus groups and networking among individuals diagnosed with hearing loss (National Academies of Sciences, Engineering, and Medicine, 2016).
	Attitude, Beliefs and Motivation	Education and informational counselling to shape patient perspectives on hearing loss and hearing aid use (National Academies of Sciences, Engineering, and Medicine, 2016).
	Hearing aid acoustics and features.	Improved customised programming and use of recent technology to improve speech comprehension and communication.

6.3 Improving access to scalable hearing healthcare services in low-income communities

Study III validates the practicality of a community-based hearing aid fitting model in LMICs, demonstrating its potential to decentralise and broaden service reach into traditionally underserved regions (Swanepoel, 2023). One major implication is that this approach enhances service accessibility while also introducing innovative clinical practices, including the training of CHW, redefining the professional extent between CHW and audiologists, and fostering a more collaborative healthcare environment (Suen et al., 2019; Coco et al., 2022). Furthermore, this model enables audiologists to place more focus on complex audiological clinical procedures other than hearing aid fitting, such as cochlear implantation, vestibular assessment and management, and aural rehabilitation (Coco et al., 2022). This shift of focus places a need of transformation in audiology practices, which historically depended on hearing aid sales for revenue (Coco et al., 2022). While this may constitute financial challenges to some audiology private practices, it concurrently compels market competition and affordability, benefitting end-users by reducing costs (Coco et al., 2022).

Another major implication of this model includes the use of mHealth technologies in the provision of hearing healthcare services. mHealth technologies present as a cost-effective solution to traditional service delivery barriers, such as audiologist scarcity and expensive clinical equipment (Mulwafu et al., 2017; WHO, 2021; Windmill & Freeman, 2013). This reduces hearing healthcare costs and aligns with global health efforts to provide affordable hearing care options. The community-based model echoes the principles of the United Nations Sustainable Development Goals by mitigating economic disparities caused by hearing loss and encouraging sustainable economic growth (Goal 8). This model promotes healthy hearing to improve the quality of life for individuals with hearing loss (Goal 3) while reducing inequalities caused by hearing loss and within health systems (Goal 10). By directing these goals, the model not only contributes to ending poverty and promoting health but also supports broader efforts to create fair and prosperous societies globally.

6.3.1 Study strengths

Study I presents the most recent systematic review that effectively synthesised evidence spanning the past decade regarding the determinants of hearing aid use, benefits, and satisfaction. This allowed the examination of evidence sourced from global peer-reviewed

journals, rendering its findings applicable and relevant on a global scale. Furthermore, this study was conducted in adherence to PRISMA guidelines. The most critical stages of the systematic review, such as inclusion and exclusion criteria, and data extraction, were conducted and cross-checked by two researchers. Furthermore, quality control measures involved the NIH quality assessment tool and the Oxford CEBM to assess the quality of studies and the level of evidence.

Study II was conducted in the United States—which is one of the first countries to legalise the sale of OTC hearing aids (Stevenson, 2022), presenting the novelty of this study in the global space. Aside from the advantage of context, Study II employed a validated standardised outcome measure: the IOI-HA to assess hearing aid outcomes. This measure is widely recognised and used for its ability to evaluate crucial constructs, such as hearing aid use, benefit, and satisfaction. Additionally, a large sample of participants from real-world data was obtained and used to develop specific regression models between diverse factors and the hearing aid outcomes.

The strength of Study III remains in employing a widely used standardised strategy for measuring hearing aid outcomes (IOI-HA) and adopting the Bowen feasibility framework in conducting the feasibility study. The study adhered to guidelines recommending best practices for community-delivered hearing healthcare (Suen et al., 2019). These practices included employing trained and experienced CHW, integrating mHealth technologies, providing ongoing education through the mHealth support programme, and facilitating referrals.

6.3.2 Limitations

Study I presents certain limitations that warrant consideration. For instance, the data synthesis method known as vote counting, which assesses only the direction of the association between factors and hearing aid outcomes, was employed (Campbell et al., 2020). This data synthesis method involves inherent limitations, primarily because it solely examines the direction of the association without considering the statistical magnitude of each factor's effect on hearing aid outcomes (Borenstein et al., 2009). It fails to adequately account for the statistical power of studies based on factors such as sample size and the timing of outcome assessments. Additionally, this study lack calculated interrater reliability values (Copen's Kappa) to measure the consistency and reliability of the agreement between the researchers.

The primary limitation of Study II stems from sampling bias resulting from the recruitment method employed. Specifically, the study exclusively invited hearing aid users subscribed to the Hearing Tracker website to participate. This approach could introduce noticeable disparities between the study sample and the broader population, particularly concerning demographic factors, such as age, race, education, and income. The generalisability of the study findings to the wider population may be restricted. Additional clinical measures of hearing aid outcomes are omitted, such as objective assessments and behavioural evaluations. Other limitations of this study include the lack of power analysis or provision of statistical significance values set for the analyses or for model building and the lack of application of a family-wide error rate to account for multiple comparisons.

The primary constraint of Study III lies in the relatively small sample size and sampling bias, comprising only 25 participants. Additionally, the study was purely observational, lacking control groups for comparison. Furthermore, the outcomes were not assessed over the long-term, limiting an understanding of the sustained evaluation of the CHW interventions.

6.3.3 Recommendations for future work

Methodological constraints in Study I, involving the use of vote counting, fail to account for the statistical significance and influence of each factor on hearing aid outcomes (Borenstien et al., 2009). Future research should consider these limitations and explore alternative data synthesis methods. These methods include meta-analysis of effect estimates, which incorporate crucial factors, such as the magnitude of the association or effect.

This research induced additional questions requiring further investigation. For instance, identifying recent factors (in Study I and II) and mixed inconclusive results warrants further exploration to strengthen the evidence on how such factors (e.g. mental health, social networks and prevalence of hearing aid problems) influence hearing aid outcomes. Other factors not reported in Study I and II (e.g., stigma and tele-audiology) should be evaluated to understand how they influence hearing aid outcomes. Study I indicated a need for higher quality studies and a higher level of evidence, which should be the focus of future research.

Regarding Study III, the methodological constraints—such as a small sample size, sampling bias, absence of control groups for comparison, and lack of long-term outcome evaluation—emphasise the necessity for future research to direct these limitations in feasibility studies

related to community CHW-based hearing aid fitting. Replicating the CHW-based hearing aid fitting model in other low-income settings would enhance the evidential support. Additionally, newer feasibility studies should be longitudinal to enable the study of patient outcomes over time.

6.4 Conclusion

This study explored the multifaceted factors influencing hearing aid use, benefits, and satisfaction among individuals with hearing loss. This was achieved through a systematic literature review, a cross-sectional survey, and a prospective evaluation of a community-based hearing aid fitting model. The findings of this project emphasise the importance of considering a broad spectrum of factors in audiological practice and public health strategies to facilitate access to hearing interventions and optimise hearing aid outcomes. Furthermore, the community-based model shown in Study III demonstrates the promise of improving access and scalability of hearing healthcare services within low-income communities. Although shown to be feasible in low-income communities, this model needs to be replicated in other low-income communities to strengthen evidence. Future research should expand on other factors apart from access that influence hearing aid outcomes to refine personalised care strategies to meet the diverse needs of hearing aid users globally.

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APPENDICES

Appendix A1: Ethical clearance: University of Pretoria Faculty of Humanities Research Ethics Committee (HUM011/0822)

Faculty of Humanities
Fakulteit Geesteswetenskappe
Lefapha la Bomotho

05 December 2022

Dear Prof DCDW Swanepoel

Project Title:	Hearing care for adults in low-income communities using mHealth and hearing aid technologies
Researcher:	Prof DCDW Swanepoel
Supervisor(s):	
Department:	Speech Language Pathology and Audiology
Reference number:	02606623 (HUM011/0822)
Degree:	Staff Research / Non Degree

I have pleasure in informing you that the above application was **approved** by the Research Ethics Committee on 05 December 2022. Please note that before research can commence all other approvals must have been received.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. Should the actual research depart significantly from the proposed research, it will be necessary to apply for a new research approval and ethical clearance.

We wish you success with the project.

Sincerely,

Prof Karen Harris
Chair: Research Ethics Committee
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail: tracey.andrew@up.ac.za

Appendix A2: Ethical clearance: University of Pretoria Faculty of Humanities Research Ethics Committee (HUM009/0622)

Faculty of Humanities
Fakulteit Geesteswetenskappe
Lefapha la Bomotho

Humanities 100

22 July 2022

Dear Mr BG Mothemela`

Project Title:	Factors predicting hearing aid use, benefit and satisfaction
Researcher:	Mr BG Mothemela`
Supervisor(s):	Prof DCDW Swanepoel
Department:	Speech Language Pathology and Audiology
Reference number:	13182006 (HUM009/0622)
Degree:	Doctoral

Thank you for the application that was submitted for ethical consideration.

The Research Ethics Committee notes that this is a literature-based study and no human subjects are involved. The application has been **approved** on 22 July 2022 with the assumption that the document(s) are in the public domain. Data collection may therefore commence, along these guidelines.

Please note that this approval is based on the assumption that the research will be carried out along the lines laid out in the proposal. However, should the actual research depart significantly from the proposed research, a new research proposal and application for ethical clearance will have to be submitted for approval.

We wish you success with the project.

Sincerely,

Prof Karen Harris
Chair: Research Ethics Committee
Faculty of Humanities
UNIVERSITY OF PRETORIA
e-mail: tracey.andrew@up.ac.za

Appendix B: Clearance from Lamar University (IRB-FY21-248)

[EXTERNAL] IRB-FY21-248 - Initial: Initial - Exempt - Approved

do-not-reply@cayuse.com <do-not-reply@cayuse.com>
Fri 7/23/2021 3:40 PM
To: Vinaya Manchaiah <vmanchaiah@lamar.edu>

RESEARCH & SPONSORED PROGRAMS ADMINISTRATION
LAMAR UNIVERSITY

Jul 23, 2021 3:40:40 PM CDT

Vinaya Channapatna Manchaiah

Re: Exempt - Initial - IRB-FY21-248 Hearing aid experiances

Dear Dr. Vinaya Channapatna Manchaiah

Lamar University's Institutional Review Board (IRB) for Human Research Participants Protection has completed its review of your submission and has deemed your study to be exempt from further IRB review.

Category 2.(i). Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording).
The information obtained is recorded by the investigator in such a manner that the identity of the human subjects cannot readily be ascertained, directly or through identifiers linked to the subjects.

As a research investigator, please be aware of the following:

- You will immediately report to the IRB via LU Cayuse any injuries or other unanticipated problems involving risks.
- You acknowledge and accept your responsibility for protecting the rights and welfare of human research participants and for complying with all parts of 45 CFR Part 46, the LU IRB Policy and Procedures.
- You will ensure that legally effective informed consent is obtained and documented if necessary. If written consent is required, the consent form must be signed by the participant or the participant's legally authorized representative. A copy is to be given to the person signing the form and a copy is to be kept for your file.
- Any proposed changes, including changes to your survey, hard copy or in Qualtrics, from previously approved IRB applications must be submitted to the Office of Research and Sponsored Programs via LU Cayuse. The proposed changes cannot be initiated without IRB review and approval.

Once your study is complete, please login to Cayuse and close your study.

Good luck with your research endeavors.

Sincerely,
Lamar University Human Subjects Review Board

ALERT This email originated outside Lamar University. Do not click links, open attachments, or respond unless you validate the sender and know the content is safe.

Appendix C: Consent form

INVITATION TO RECEIVE HEARING AIDS

The hearX Foundation, in partnership with the hearX Group and the University of Pretoria, will be providing a hearing service in the communities. Many people suffer from hearing loss. This project aims to identify community members with hearing loss, demonstrate the potential benefit of hearing aids, and fit adults with suitable hearing loss with hearing aids.

What will I need to do if I agree to receive the hearing aids?

One of the tests done at the previous hearing check will need **to** be confirmed before the hearing aids can be fit. This test will be non-invasive, without charge, and results will be made available to you. All testing should take about 30 minutes to complete. Should you agree, the following procedures will be followed:

- Questionnaire about your hearing (5 minutes)

Before you are fitted with hearing aids, you will be asked a few questions about your hearing and how you feel about hearing aids.

- Looking in your ear with a camera [Video-otoscopy] (5 minutes)

For this test, you will be required to be seated upright while your ear canal is visually inspected using an otoscope (ear-light).

- Hearing aid fitting (20 minutes)

The hearing aids will be set to a program suitable for your results. After that, you will be taught how to use and look after your hearing aids. You will receive phone calls on days 8, 20, and 43 to answer some questions. You will need to have a follow-up visit 4 weeks and 6 months after the hearing aid fitting, where you will be asked to complete two questionnaires. You will receive WhatsApp messages or SMSs during the 4 weeks to help you learn more about your hearing aids.

Are there any risks or benefits for me if I participate in this study?

Participants will not be exposed to any risk or experience any discomfort during this hearing aid fitting. Participants can keep their hearing aids once the project has been completed. Information obtained from this study will assist in increasing the effectiveness of smartphone technologies in hearing loss detection, support, and intervention. Participants will also be referred to follow-up services when and where necessary.

What are your rights as a participant?

Your participation in this project is entirely voluntary. You may decline to participate or stop at any time during the examination. This will not affect any current services you are receiving. You can consent if you wish to have your results used as part of any potential research based on this service. You can

decline to have your results included in any potential research based on this service without affecting any current services you are receiving. You can provide your contact details should you be interested in participating in potential future research. You can decline participation in potential future research or request that your contact details be removed without affecting any current services you are receiving.

COVID-19 Protocols

The hearing screeners will bring in hand sanitiser, and all participants, hearing screeners, and researchers will be required to sanitize their hands frequently. All equipment will be sanitized before and after each participant's tests. If the participant, hearing screeners, or researcher feels unwell on the day scheduled for testing, the testing will be postponed to a later date.

Confidentiality

All your information will be kept confidential. Once your results have been captured, a number will be allocated to your results. All data will be analysed using the alphanumerical code assigned to you. Your name will not appear on any documents.

Should you consent to have your results used for research purposes, research articles in scientific journals will not include any information that could identify you. All the data collection sheets from this project will be stored for a period of 15 years in both hard copies and scanned electronic versions.

Before agreeing to participate, you should fully understand what is involved. Please do not hesitate to ask your hearing screener if you have any questions that this letter does not fully explain. Alternatively, you can contact us at info@hearxfoundation.org or send a please call me to 068 192 2413 (Mbekweni) or 084 393 0717 (Khayelitsha).

Appendix D: Survey

Survey

Demographic and hearing aid related information

How old are you (in years)?

Please indicate your gender:

- ○ Male
- ○ Female
- ○ Non-binary (or gender neutral)

Do you have any difficulty with your hearing (without hearing aids)?

- ○ No, I always hear everything
- ○ Yes, sometimes I do not hear what is being said
- ○ Yes, I regularly do not hear what is being said
- ○ Yes, I almost never hear what is being said

How long have you had hearing loss? Provide your answer inyears.

Do you own a hearing aid for your:

- ○ Right Ear
- ○ Left Ear
- ○ Both Ears

From the time you first learned you had a hearing problem how long did you wait before purchasing your first hearing aids?

Please provide your answer as a numerical value (e.g., 1, 3, 15).

- ○ Year(s)
- ○ Month(s)

What type of hearing aid do you use?

- ○ In-the-ear (ITE) hearing aids (Hearing aid sits completely/entirely in the ear)

- ○ Behind-the-ear (BTE) hearing aids (Hearing aid has 2 parts: One part, the mold, sits in the ear and the other part, the hearing aid, sits behind the ear)

Which brand of hearing aid do you currently use?

- ○ Kirkland
- ○ Oticon
- ○ Phonak
- ○ ReSound
- ○ Signia / Siemens
- ○ Starkey
- ○ Unitron Widex
- ○ Other, please specify

Hearing aid benefit/satisfaction

Think about how much you used your present hearing aid(s) over the past two weeks. On an average day, how many hours did you use the hearing aid(s)?

- ○ None
- ○ Less than 1 hour a day 1 to 4 hours a day
- ○ 4 to 8 hours a day
- ○ More than 8 hours a day

Think about the situation where you most wanted to hear better, before you got your present hearing aid(s). Over the past two weeks, how much has the hearing aid helped in that situation?

- ○ Helped not at all
- ○ Helped slightly
- ○ Helped moderately
- ○ Helped quite a lot
- ○ Helped very much

Think again about the situation where you most wanted to hear better. When you use your present hearing aid(s), how much difficulty do you STILL have in that situation?

- ○ Very much difficulty
- ○ Quite a lot of difficulty
- ○ Moderate difficulty
- ○ Slight difficulty

- ○ No difficulty

Considering everything, do you think your present hearing aid(s) is worth the trouble?

- ○ Not at all worth it
- ○ Slightly worth it
- ○ Moderately worth it
- ○ Quite a lot worth it
- ○ Very much worth it

Over the past two weeks, with your present hearing aid(s), how much have your hearing difficulties affected the things you can do?

- ○ Affected very much
- ○ Affected quite a lot
- ○ Affected moderately
- ○ Affected slightly
- ○ Affected not at all

Over the past two weeks, with your present hearing aid(s), how much do you think other people were bothered by your hearing difficulties?

- ○ Bothered very much
- ○ Bothered quite a lot
- ○ Bothered moderately
- ○ Bothered slightly
- ○ Bothered not at all

Considering everything, how much has your present hearing aid(s) changed your enjoyment of life?

- ○ Worse
- ○ No change
- ○ Slightly better
- ○ Quite a lot better
- ○ Very much better

General health and well-being & social network

In general, would you say your health is:

- ○ Excellent
- ○ Very good
- ○ Good
- ○ Fair
- ○ Poor

In general, would you say your mental health is:

- ○ Excellent
- ○ Very good
- ○ Good
- ○ Fair
- ○ Poor

How would you rate your quality of life?

- ○ Very poor
- ○ Poor
- ○ Neither poor nor good
- ○ Good
- ○ Very good

Social Networks

For the following questions (questions 5 to 10), please provide your answer as a numerical value (e.g., 1, 3, 15).

How many people live in your household?

How many children do you have?

How many grandchildren do you have?

How many people do you know that you would call a close friend?

How many people do you know that have hearing loss but who do not have hearing aids?

How many people do you know that have hearing loss and have/wear hearing aids?

Additional demographic information

Which of the following options best describes your work situation?

- ○ Employed or homemaker
- ○ Out of work or looking for work
- ○ Student
- ○ Unable to work
- ○ Retired

What is the highest level of schooling (education) you have completed?

- ○ Less than high school
- ○ High school
- ○ Some college but not degree
- ○ A university degree

Please select one of the following options that describe your living arrangement/ situation:

- ○ I live with my family
- ○ I live with my spouse/partner I live with a friend

- ○ I live on my own

What is your ethnicity?

- ○ Hispanic or Latino
- ○ Non-Hispanic or Latino

What is your race?

- ○ American
- ○ Indian
- ○ Alaska Native, Asian
- ○ Black or African American
- ○ Native Hawaiian
- ○ Other Pacific Islander
- ○ White
- ○ More than One Race

What is your pre-tax household income, approximately?

- ○ Under $25,000
- ○ $25,000 to $49,999
- ○ $50,000 to $99,999
- ○ $100,000 to $149,000
- ○ $150,000 or more

In a typical week, how much time do you spend in total on moderate and vigorous physical activities where your heartbeat increases and you breathe faster (e.g., brisk walking, cycling, heavy gardening, running, recreational sport):

- ○ Less than ½ an hour (30 minutes)
- ○ ½ an hour to 1½ hours (30-90 minutes)
- ○ 1½ - 2½ hours (90-150 minutes)
- ○ 2½ - 5 hours (150-300 minutes)
- ○ More than 5 hours (more than 300 minutes)

How did you purchase your current hearing aids?

- ○ From a hearing clinic (private or university)
- ○ Discount Warehouse (Costco, Sams, etc.)
- ○ Internet / Online
- ○ Pharmacy Hearing Center (CVS)
- ○ A hearing professional came to my residence
- ○ Other, please specify:

Appendix E: Supplementary tables

Supplementary table 1: Mean absolute error for the model

Model:	Description of model:	MAE of model:	% reduction in error:
Null model	The null model is the model without any predictors	3.357016	
Full model	This is the full model with all predictors included (whether they are statistically significant or not)	3.083914626	8.14%
Final model	Model with only significant predictors using stepwise regression	3.147459596	6.24%

Supplementary table 2: Predictor model when different significant predictors have been removed

Predictor removed from the final model	MAE	Pseudo R-square	% model fit lost
Self-reported hearing diff	3.3779	0.01742	-7.32%
Mental health	3.16377	0.103113	-0.52%
QoL	3.233238	0.083419	-2.73%
People_HL no HA	3.184702	0.097179	-1.18%
People_HL with HA	3.19	0.095677	-1.35%
[Where purchased / service delivery model]	3.222992	0.086324	-2.40%
[Work situation]	3.283546	0.044867	-4.32%

Supplementary Table 3: Audiological factors influencing hearing aid use with references

Category and Factors	Number of Studies	Positive	Negative	No Association	References
Hearing sensitivity					
Pure Tone Average (PTA)	13	+,+,+,+,+,+,+,+,+,+		0,0,0	Arnold et al (2019); Aazh et al (2015); Fuentes-Lopez et al (2017); Helvik et al (2016); Ho et al (2018); Houmoller et al (2022); Il Joon et al (2015); Nixon et al (2021); Staehelin et al (2011); Wang et al (2021); Wu et al (2019); Laakso et al (2022); Jorbonyan et al (2022)
Slope of the audiogram	1	+			Aazh et al (2015)
Hearing loss Asymmetry	1	+			Houmoller et al (2022)
Speech perception					
WRS	2	+,+			Houmoller et al (2022); Wang et al (2021)
SRT	1	+			Wu et al (2019)
Self-reported Speech perception ability	2	+, +			Dwarakanath (2020); Jorbonyan et al (2022)
Self-reported hearing disability					
Non-standardized self-reported hearing disability	5	+,+,+,+		0	Fuentes-Lopez et al (2019); Helvik et al (2016); Hickson et al (2022); Klyn et al (2020); Sawyer et al. (2019)
Ear, Tinnitus, and balance problems					
Bothersome Tinnitus	3	+,+,+			Giuliania & Nicholas (2021); Houmoller et al (2022); Il Joon et al (2015)
Tympanic membrane perforation	2	+, +			Il Joon et al (2015); Sawyer et al (2019)
Balance problems	1	+			Il Joon et al (2015)
Hearing aid acoustics and features					
Prevalence of hearing aid problems	1		-		Bennett et al (2020)
Insertion gain	1	+			Hickson et al (2022)
Price of Hearing aid	1	+			Wang et al (2021)
Digital vs Analog hearing aids	1	+			Jorbonyan et al (2022)

Category and Factors	Number of Studies	Positive	Negative	No Association	References
Hearing sensitivity					
Hearing aid candidate factors					
Satisfaction and benefit with hearing aids.	3	+, +		0	Staehelin et al (2011); Jilla et al (2020); Jorbonyan et al (2022)
First Fitting Age	1			0	Wu et al (2019)
Narratives on hearing aid fitting	1	+			Naylor et al (2015)
Hearing Aid Handling skills	2	+, + (HIOC)			Nixon et al (2021), Kemker et al (2012)
Previous hearing aid experience	1			0	Jorbonyan et al (2022)
Hearing aid fitting and follow-up					
Type of Hearing Aid Fitting (bil versus Uni)	6	+, +, +		0,0,0	Aazh et al (2015); Ho et al (2018); Staehelin et al (2011); Wang et al (2021); Wu et al (2019); Jorbonyan et al (2022)
Motivational Interviewing	1	+			Aazh (2016)

Note: D=Prefer Group D (D=diagnostic narrative) I= prefer Group I (Interactive Group). Note: "+" indicates a positive association between the factor and the outcome, "–" a negative association, "0" no association.

Supplementary Table 4: Non-audiological factors affecting hearing aid use with references

Category and Factors	Number of studies	Positive	Negative	No association	References
Demographics					
Age	14	+ , +,+	-, -,-, -, -, -, - (working age)	0,0,0,0	Aazh et al (2015); Fuentes-López et al (2017);Fuentes-López et al (2019); Ho et al, (2018); Il Joon et al (2015); Klyn et al (2020); Solheim et al (2012); Wang et al (2021); Wu et al (2019); Laakso et al (2022); Sawyer et al (2019); Jorbonyan et al (2022)
Biological sex	9	+(Female), + (male),+	-(male), - (Female)	0,0,0,0	Fuentes-López et al (2019); Helvik et al (2016);Ho et al (2018); Klyn (2020); Solheim et al (2012); Staehelin et al (2011); Houmøller et al (2022); Jorbonyan et al (2022);
Ethnicity	4		-(black & indian),-	0,0	Ho et al (2018); Klyn et al (2020); Taylor et al (2023); Yi et al (2022)
Race	4	+,+,+ (white race)	-(black race)		Klynn et al (2020), Sawyer et al (2019); Yi et al (2022); Taylor et al (2021).
Marital Status	1			0	Solheim et al (2012)
Living Arrangements	1	+ (men living with spouses)		0 (women)	Helvik et al (2016)
Living status	1	+			Fuentes-López et al (2017)
Place of Residency	2	+, + (urban)			Arnold et al (2019); Yi et al (2022)
Social Network					
Social Support from others	2	+, +			Hickson et al (2014); Jorbonyan et al (2022)
Family time	1	+			Nixon et al (2021)
Number of House Members	1			0	Il Joon et al (2015)
Psycho-social					
Personality	3	+, +, + (extrovert)			Dwarakanath (2020); Jorbonyan et al (2022); Dwarakanath & Manjula (2022)
Perceived Need for of the hearing aid	1	+			Arnold et al (2019);
Self-Efficacy	3	+		0,0	Ferguson et al (2016); Jilla et al (2016); Jorbonyan et al (2022)
Accepted need	1	+			Solheim et al (2012)
Social assessment and consciousness	1			0	Solheim et al (2012)

Category and Factors	Number of studies	Positive	Negative	No association	References
Demographics					
Mental health					
Active Neurological disorders	1		-		Giuliania et al (2021)
Depressive mood	1			0	Il Joon et al (2015)
Amount of stress in life	1			0	Il Joon et al (2015)
Cognitive factors					
Working Memory	1	+			Dwarakanath (2020)
Cognition	1	+			Nixon et al (2021)
Attitude and Beliefs					
Attitude	4	+ (HL), +, +		0 (HA)	Dwarakanath (2020); Hickson et al (2014); Saunders et al (2016); Dwarakanath & Manjula (2022)
Beliefs	1	+			Saunders et al (2016)
Motivation	1	+			Houmøller et al (2022)
Socio-Economic and work related					
Occupation and employment	2	+		0	Il Joon et al (2015); Jorbonyan et al (2022)
Income	5	+,+,+		0,0	Fuentes-López et al (2017); Fuentes-López et al (2019); Moon et al (2015); Sawyer et al (2019); Bainbridge & Ramachandran (2014)
Knowledge	1	+(about the Auge programme)			Fuentes-López et al (2017);
Education	7	+,+,+, +, +,+,+			Fuentes-López et al (2019); Helvik et al (2016); Moon et al (2015); Jorbonyan et al (2022); Yi et al (2022); Sawyer (2019); Bainbridge & Ramachandran (2014).
Coping in work life	1	+			Laakso et al (2022)
Socio-economic status	1			0	Sawyer et al (2019)
Social activities	1			0	Sawyer et al (2019)

Category and Factors	Number of studies	Positive	Negative	No association	References
Demographics					
Health					
Myopia	1	-			Il Joon et al (2015)
Astigmatism	1	+			Il Joon et al (2015)
Self-reported general Health Status	4	+, +	-	0	Fuentes-López et al (2019); Il Joon et al (2015); Sawyer et al (2019); Jorbonyan et al (2022)
Health Literacy	2	+ SHL		0 (OHL)	Klynn et al (2020)
Hospitalization	1			0	Thai et al (2022)
Medical aid and financial support	2	+,+			Yi et al (2022); Bainbridge and Ramachandran (2014)

Note: MLS= Male Living with Spouse; WLS= Women living with spouse; SHL =Subjective Health Literacy, OHL = Objective health literacy. Social assessment = view on how people think about them) Consciousness (of their hearing loss and hearing aids). Note: "+" indicates a positive association between the factor and the outcome, "–" a negative association, "0" no association.

Supplementary Table 5: Audiological factors affecting hearing aid benefit with references

Categories and Factors	Number of studies	Positive	Negative	No association	References
Hearing Sensitivity					
Pure Tone Average (PTA)	6	+,+,+	-, -	0	Houmoller et al (2022); Meister et al (2015); Nixon et al (2021); Tognola et al (2019) Wang et al (2021); Wu et al (2019)
Asymmetry	1		-		Houmoller et al (2022)
Speech perception					
WRS	2	+,+			Houmoller et al (2022); Wang et al (2021);
SRT	1	+			Wu et al (2019)
Self-reported Speech Perception Ability	1	+			Dwarakanath et al (2020)
Auditory Processing abilities					
Temporal processing	1			0	Chinnaraj et al. (2022)
Auditory closure	1			0	Chinnaraj et al. (2022)
Binaural Interaction	1			0	Chinnaraj et al. (2022)
Auditory closure	1		-		Chinnaraj et al. (2022)
Binaural integration	1		-		Chinnaraj et al. (2022)
Ear, Tinnitus and Balance problems					
Bothersome Tinnitus	1		-		Houmoller et al (2022)
Hearing aid acoustic and features					
Prevalence of Hearing aid problems	1		-		Bennett et al (2020)
Price of Hearing aid	1	+			Wang et al (2021)
Hearing aid candidate factors					
Daily Use time	2	+,+			Wang et al (2021), Houmoller et al (2022)
First Fitting age	1			0	Wu et al (2019)
Narratives on hearing aid fitting appointments	1	+(I)			Naylor et al (2015)

Note: D=Prefer Group D (D=diagnostic narrative) I= prefer Group I (Interactive Group). Note: "+" indicates a positive association between the factor and the outcome, "–" a negative association, "0" no association.

Supplementary Table 6: Non-audiological factors affecting hearing aid benefit with references

Categories and Factors	Number of Studies	Positive	Negative	No Association	References
Demographics					
Age	4	+	-,-	0	Meister et al (2015); Tognola et al (2019), Wang et al (2021); Wu et al (2019)
Gender	2	+(Female), +(male)			Houmøller et al (2022); Narne et al (2016)
Psycho-social					
Personality	2	+,+ (extrovert)			Dwarakanath et al (2020); Dwarakanath & Manjula (2022)
Self-Efficacy	1			0	Ferguson et al (2016)
Expectations	1	+			Ferguson et al (2016)
Readiness to improve hearing	1	+			Ferguson et al (2016)
Cognitive factors					
Cognition	3	+,+,+			Meister et al (2015); Nixon et al (2021); Tognola et al(2019)
Working Memory	2	+		0	Dwarakanath et al (2020); Chinnaraj et al. (2022)
Attitude and Beliefs					
Attitude	4	+ (HL), +, +, +			Dwarakanath et al (2020); Saunders et al (2016); Nixon et al (2021); Dwarakanath & Manjula (2022)
Motivation	1	+			Houmøller et al (2022)

Note: AB = Audiology best practice; CD= Direct to consumer. Note: "+" indicates a positive association between the factor and the outcome, "–" a negative association, "0" no association.

Table 7: Audiological factors influencing hearing aid satisfaction with references

Categories and Factors	Number of Studies	Positive	Negative	No Association	Reference
Hearing Sensitivity					
Pure Tone Average	9	+, +, +	-,-,-	0,0,0	Houmoller et al (2022); Kaplan-Neeman et al (2012); Korkmaz et al (2016); Meister et al (2015); Wang et al (2021); Wu et al (2019); Meyer et al (2014); Turan et al (2019); Laakso et al (2022)
Asymmetry	1			-	Houmoller et al (2022)
Hearing ability with hearing aids	1	+			Meyer et al (2014)
Speech perception					
WRS	2	+,+			Houmoller et al (2022); Wang et al (2021)
SRT	1	+			Wu et al (2019)
Speech Perception Ability	1	+			Dwarakanath et al (2020)
Ear, Tinnitus and balance problems					
Bothersome Tinnitus	1	-			Houmoller et al (2022)
Hearing aid acoustics and features					
ITE vs BTE hearing aid	1	+			Wang et al (2021)
Digital Technology	1			0	Kaplan-Neeman et al (2012),
Hearing aid comfort	1		-		Meyer et al (2014)
Hearing aid appearance	1	+			Meyer et al (2014)
Price of hearing aid	2	+, +			Wang et al (2021); Kim et al (2022)
Prevalence of hearing aid problems	2		-,-		Bennett et al (2020); Meyer et al (2014)
Product performance	1	+			Bisgaard & Ruf (2017)
Product features	1	+			Bisgaard & Ruf (2017)
Hearing aid Candidate factors					
Duration of Hearing aids	1			0	Kaplan-Neeman et al (2012),
Hearing ability with hearing aids	1	+			Meyer et al (2014)

Site of hearing aid wear	1			0	Korkmaz et al (2016)
First Fitting age	1			0	Wu et al (2019)
Narratives on hearing aid fitting appointments	1	+(D)			Naylor et al (2015)
Hearing Aid Usage	6	+,+,+,+,+, +			Houmoller et al (2022), Kaplan-Neeman et al (2012), Korkmaz et al (2016); Singh et al (2015); Wang et al (2021); Kim et al. (2022)
Experience with hearing aid use	2			0,0	Singh et al (2015); Meyer et al (2014)
Hearing aid Handling skills	1	+ (HIOC)			Kemker et al (2012)
Hearing aid fitting and follow up					
Type of Hearing Aid Fitting (bil versus Uni)	6	+, +, +,+, +		0	Kaplan-Neeman et al (2012); Wang et al (2021); Wu et al (2019); Turan et al (2019); Bisgaard & Ruf (2017), Kim et al. (2022)
Regular hearing aid follow up	1	+			Kim et al. (2022)

Note: D=Prefer Group D (D=diagnostic narrative) I= prefer Group I (Interactive Group). Note: "+" indicates a positive association between the factor and the outcome, "–" a negative association, "0" no association.

Supplementary Table 8: Non- Audiological factors influencing hearing aid satisfaction with references

Categories and Factors	Number of Studies	Positive	Negative	No Association	References
Demographics					
Age	12	+, + (working age)	-,-,-,-,-,-,-	0,0,0	Meister et al (2015); Tognola et al (2019), Wang et al (2021); Wu et al (2019); Kaplan-Neeman et al (2012); Korkmaz et al (2016); Singh et al (2015); Meyer et al (2014); Turan et al (2019); Laakso et al (2022); Kim et al (2022)
Gender	4	+(Female), -(male), (+male)		0	Houmøller et al (2022); Narne et al (2016); Korkmaz et al (2016); Meyer et al (2014)
Living status	1			0	Meyer et al (2014)
Quality of life measures	1			0	Singh et al (2015)
Social Network					
Social Support	1	+			Singh et al (2015)
Socio-Economic and work related					
Employment status	2			0,0	Korkmaz et al (2016); Meyer et al (2014)
Education status	2	+, +			Korkmaz et al (2016): Kim et al (2022)
Psycho-social					
Personality	1	+			Dwarakanath et al (2020)
Self-Efficacy	2	+		0	Ferguson et al (2016); Kelly-Campbell et al (2015)
Expectations	1	+			Ferguson et al (2016)
Readiness to improve hearing	1	+			Ferguson et al (2016)
Openness	1	+			Singh et al (2015)
Neuroticism	1		-		Singh et al (2015)
Cognitive factors					
Cognition	3	+,+,+			Meister et al (2015); Nixon et al (2021); Tognola et al (2019)
Working Memory	1	+			Dwarakanath et al (2020)

Attitude and Beliefs					
Attitude	3	+ (HL), +, +			Dwarakanath et al (2020); Saunders et al (2016); Nixon et al (2021)
Motivation	1	+			Houmøller et al., (2021)
Service delivery					
Hearing healthcare practitioner	1	+			Singh et al (2015)
Service Delivery Model	1	+ (CD had a slightly lower satisfaction that AB)			Humes et al (2017)
Service Provision	1	+			Bisgaard & Ruf (2017)

Note: AB = Audiology best practice; CD= Direct to consumer. Note: "+" indicates a positive association between the factor and the outcome, "–" a negative association, "0" no association.

CONSENT TO RECEIVE HEARING AIDS

I, _____, hereby consent to:

	I consent to receive the hearing aids.
	I consent that my results be used anonymously for any possible research publications on this project.
	I consent that my contact details be stored and that I can be contacted for any potential future services or research.
	I consent that photos be taken during the hearing aid fitting and follow-up visits.

I have read or been explained the content of the consent letter verbally. I understood the consent letter and have been allowed to ask questions, and I am satisfied that they have been answered satisfactorily. I understand that I can keep the hearing aids once the project is complete. I know I may withdraw from the project should I wish to do so. I understand that every effort will be made to ensure that I am not harmed while receiving the hearing check.

Signature: _____ **Date:** _____

Phone number: _____

Hearing Aid Serial numbers:

Left: _____

Right: _____

Appendix F: Four-week follow-up questionnaire

Participant number:	
Date:	
Field worker number:	

General comments: E.g., Were they wearing the hearing aid when you arrived, and what program were the hearing aids on?

_____

_____

_____

_____

1. Please indicate your agreement with the following statement: "The hearing aids have improved my hearing".

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
❑	❑	❑	❑	❑

2. How well did the hearing aids work when you were having a conversation without background noise?

Very Poor	Poor	Average	Good	Very Good
❑	❑	❑	❑	❑

3. How well did the hearing aids work when you were having a conversation, and there was background noise?

Very Poor	Poor	Average	Good	Very Good
❑	❑	❑	❑	❑

4. How well did the hearing aids work when watching TV or listening to the radio?

Very Poor	Poor	Average	Good	Very Good
❑	❑	❑	❑	❑

5. Would you recommend these hearing aids to your friends and family if they had hearing loss?

Definitely not recommend	Not recommend	Neutral	Would recommend	Definitely recommend
❑	❑	❑	❑	❑

6. How easy or difficult is it to put these hearing aids on?

Very difficult	Difficult	Fine	Easy	Very easy
❑	❑	❑	❑	❑

7. Have you already replaced the domes of your hearing aid?

	Yes
	No

8. If you had to replace the dome, how easy was it to replace?

Very difficult	Difficult	Fine	Easy	Very easy
❑	❑	❑	❑	❑

9. How easy did you find putting the hearing aids into your ears?

Very difficult	Difficult	Fine	Easy	Very easy
❑	❑	❑	❑	❑

10. How easy did you find putting the hearing aids into the charging case correctly?

Very difficult	Difficult	Fine	Easy	Very easy
❑	❑	❑	❑	❑

11. How easy was it to see the difference between your right and left hearing aid?

Very difficult	Difficult	Fine	Easy	Very easy
❑	❑	❑	❑	❑

12. How did you find changing the volume of your hearing aids?

Very difficult	Difficult	Fine	Easy	Very easy
❑	❑	❑	❑	❑

13. How did you find changing the programs of your hearing aids?

Very difficult	Difficult	Fine	Easy	Very easy
❑	❑	❑	❑	❑

14. How comfortable was it to wear hearing aids in your ears?

Very uncomfortable	Uncomfortable	Fine	Comfortable	Very uncomfortable
❑	❑	❑	❑	❑

15. How helpful has the hearing aid support program you received on the phone been for you?

Not helpful	Help a little	Not sure	Helpful	Very helpful
❑	❑	❑	❑	❑

16. The information I received via Whatsapp/SMS after receiving my hearing aid was helpful.

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
❑	❑	❑	❑	❑

17. Did you require assistance in performing any of the above-mentioned hearing aid tasks (10-17)?

	Yes
	No

18. If yes, which area did you require assistance?

	Changing the volume
	Changing the program
	Charging the hearing aids or hearing case
	Changing the domes
	Putting the hearing aids in your ears
	Cleaning the hearing aids.
	Changing the wax guard

19. Do you have any concerns about wearing your hearing aids?

	Yes
	No

If yes above, can you please share what your concerns are?

_____

_____

_____

20. Did people treat you differently after you started wearing a hearing aid?

_____

_____

_____

21. Do you feel like WhatsApp/SMS information was sufficient to support you in using your hearing aids?

_____

_____

_____

22. What information do you think is lacking from the WhatsApp/SMS information?

_____

_____

_____

23. Did you ever go back and reread the messages or relisten to the voice notes to remind you how to use your hearing aid? If yes, which one?

_____

_____

_____

24. Was the information in WhatsApp/ SMS easy to understand?

_____

_____

_____

25. Were there times during the day that you did not wear your hearing aid? Why?

_____

_____

_____

_____

_____

_____

26. Do you have any questions about how to use or look after your hearing aid that the messages did not answer?

27. Any recommendations to improve the support program?

28. You can keep your hearing aids free of charge, but how much would you be willing to spend if you had to pay for a hearing aid?

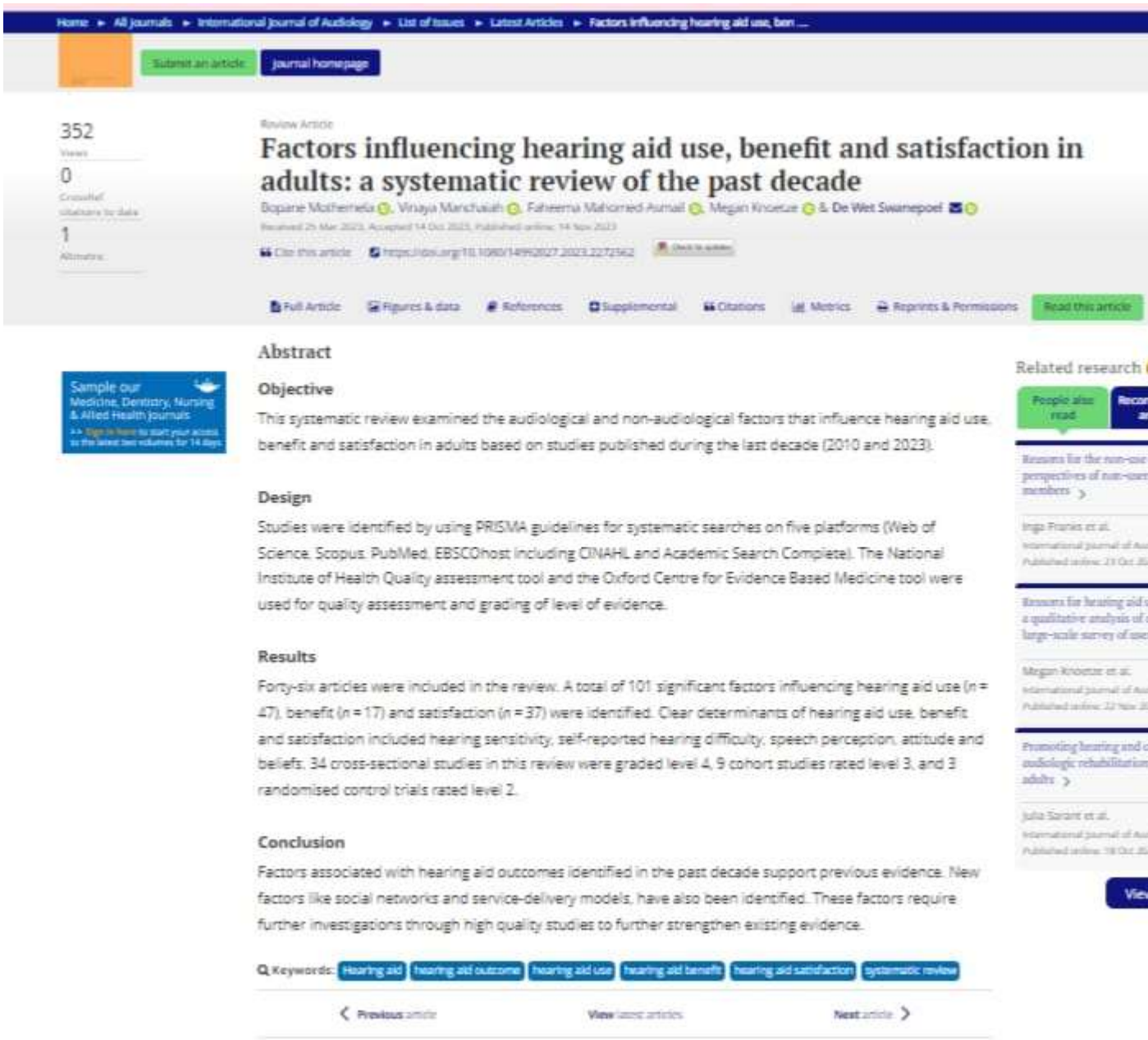
29. In what ways has using your hearing aids affected your life?

30. Have your family, friends, or colleagues noticed a difference since you started wearing hearing aids?

1.

31. Were there any situations where your hearing aids did not help?

Appendix G: International Journal of Audiology publication (Chapter 3)



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Review Article

Factors influencing hearing aid use, benefit and satisfaction in adults: a systematic review of the past decade

Bopane Motlhenke, Vinaya Manchaiah, Faheema Mahomed-Asmail, Megan Knoetze & De Wet Swanepoel

Received 25 Mar 2023, Accepted 14 Oct 2023, Published online: 14 Nov 2023

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Abstract

Objective

This systematic review examined the audiological and non-audiological factors that influence hearing aid use, benefit and satisfaction in adults based on studies published during the last decade (2010 and 2023).

Design

Studies were identified by using PRISMA guidelines for systematic searches on five platforms (Web of Science, Scopus, PubMed, EBSCOhost including CINAHL and Academic Search Complete). The National Institute of Health Quality assessment tool and the Oxford Centre for Evidence Based Medicine tool were used for quality assessment and grading of level of evidence.

Results

Forty-six articles were included in the review. A total of 101 significant factors influencing hearing aid use (*n* = 47), benefit (*n* = 17) and satisfaction (*n* = 37) were identified. Clear determinants of hearing aid use, benefit and satisfaction included hearing sensitivity, self-reported hearing difficulty, speech perception, attitude and beliefs. 34 cross-sectional studies in this review were graded level 4, 9 cohort studies rated level 3, and 3 randomised control trials rated level 2.

Conclusion

Factors associated with hearing aid outcomes identified in the past decade support previous evidence. New factors like social networks and service-delivery models, have also been identified. These factors require further investigations through high quality studies to further strengthen existing evidence.

Keywords: Hearing aid | hearing aid outcome | hearing aid use | hearing aid benefit | hearing aid satisfaction | systematic review

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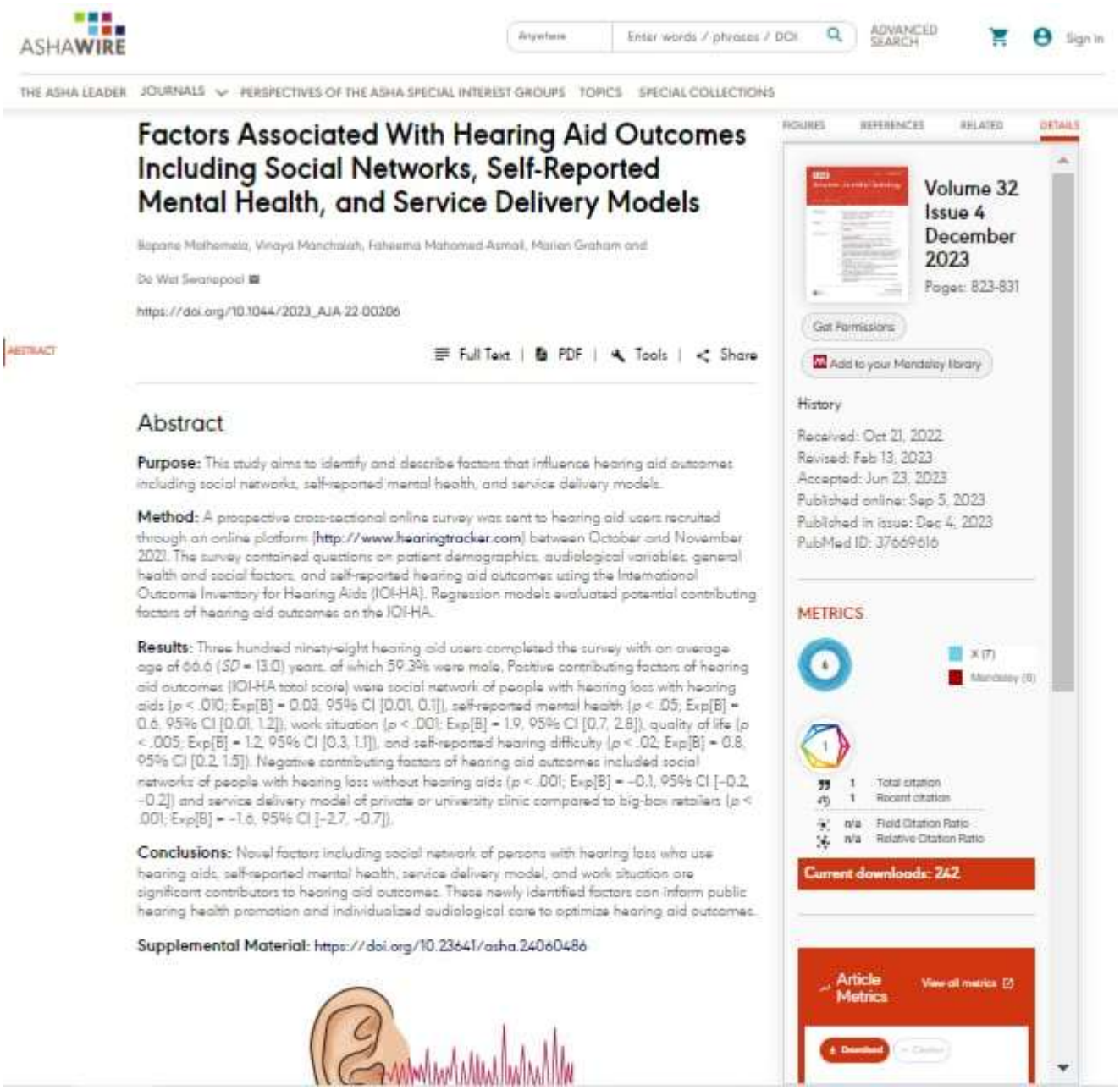
Appendix H: American Journal of Audiology (Chapter 4)



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Factors Associated With Hearing Aid Outcomes Including Social Networks, Self-Reported Mental Health, and Service Delivery Models

Bopane Mothomela, Vinaya Manchaiah, Faheema Mahomed-Asmail, Marlien Graham and

De Wet Swanepoel

https://doi.org/10.1044/2023_AJA-22-00206

ABSTRACT

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Abstract

Purpose: This study aims to identify and describe factors that influence hearing aid outcomes including social networks, self-reported mental health, and service delivery models.

Method: A prospective cross-sectional online survey was sent to hearing aid users recruited through an online platform (http://www.hearingtracker.com) between October and November 2021. The survey contained questions on patient demographics, audiological variables, general health and social factors, and self-reported hearing aid outcomes using the International Outcome Inventory for Hearing Aids (IOI-HA). Regression models evaluated potential contributing factors of hearing aid outcomes on the IOI-HA.

Results: Three hundred ninety-eight hearing aid users completed the survey with an average age of 66.6 (*SD* = 13.0) years, of which 59.3% were male. Positive contributing factors of hearing aid outcomes (IOI-HA total score) were social network of people with hearing loss with hearing aids ($p < .010$; Exp[B] = 0.03, 95% CI [0.01, 0.1]), self-reported mental health ($p < .05$; Exp[B] = 0.6, 95% CI [0.01, 1.2]), work situation ($p < .001$; Exp[B] = 1.9, 95% CI [0.7, 2.8]), quality of life ($p < .005$; Exp[B] = 1.2, 95% CI [0.3, 1.1]), and self-reported hearing difficulty ($p < .02$; Exp[B] = 0.8, 95% CI [0.2, 1.5]). Negative contributing factors of hearing aid outcomes included social networks of people with hearing loss without hearing aids ($p < .001$; Exp[B] = −0.1, 95% CI [−0.2, −0.2]) and service delivery model of private or university clinic compared to big-box retailers ($p < .001$; Exp[B] = −1.6, 95% CI [−2.7, −0.7]).

Conclusions: Novel factors including social network of persons with hearing loss who use hearing aids, self-reported mental health, service delivery model, and work situation are significant contributors to hearing aid outcomes. These newly identified factors can inform public hearing health promotion and individualized audiological care to optimize hearing aid outcomes.

Supplemental Material: https://doi.org/10.23641/asha.24060486

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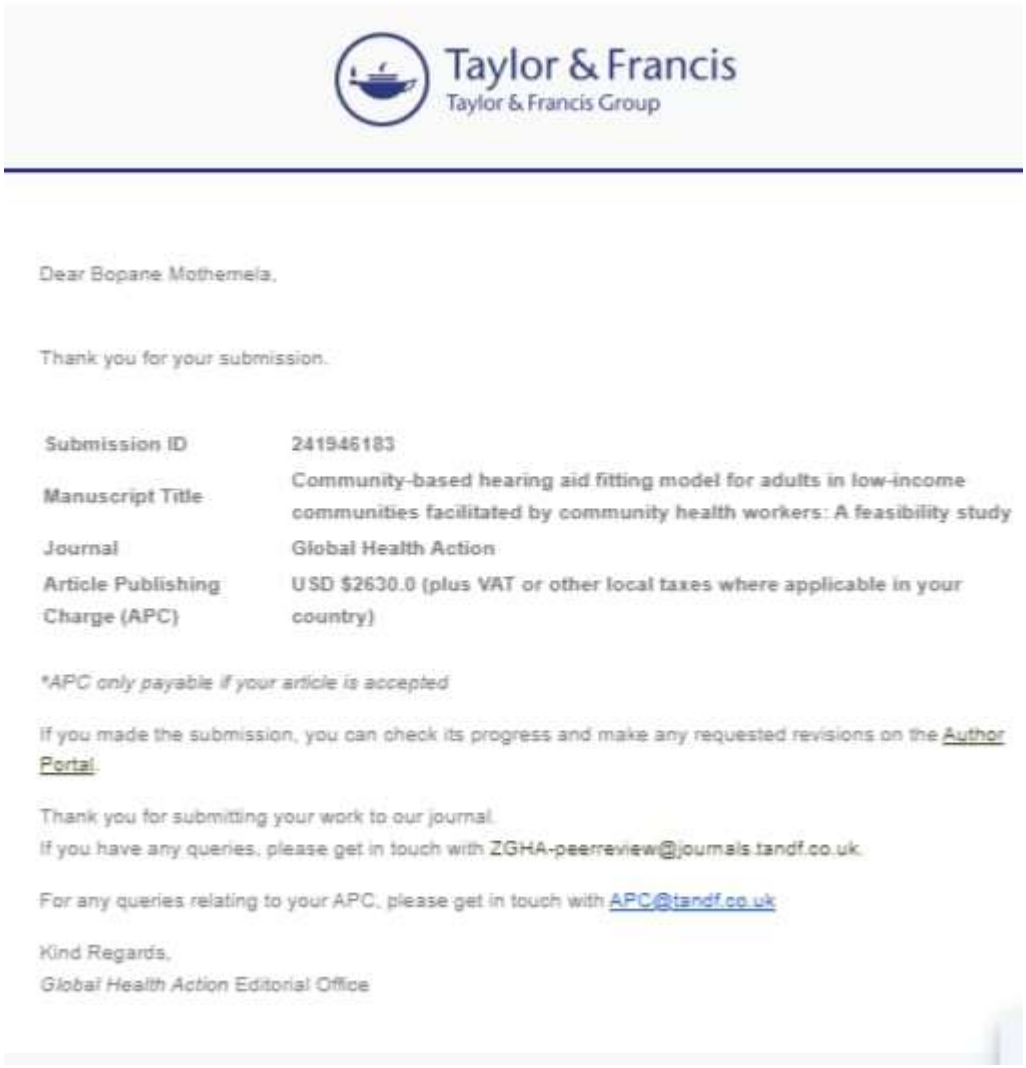
Appendix I: Taylor & Francis publication (Chapter 5)



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Appendix K: TurnItIn report