Implementation components and factors that influence the provision of tele-audiology services for children and adults - a mixed-methods approach

Vidya Ramkumar (vidya.ramkumar@sriramachandra.edu.in)
Sri Ramachandra Institute of Higher Education and Research https://orcid.org/0000-0002-3590-6721

Varsha Shankar
Sri Ramachandra Institute of Higher Education and Research

Shuba Kumar
SAMARTH

Research Article

Keywords: Implementation, telepractice, audiology, qualitative, scoping review, semi-structured interviews, barriers, facilitators

Posted Date: June 16th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1640164/v2

Abstract

Background

Tele-audiology has accelerated with the rapid advancement in information and communication technology. There is a significant knowledge gap concerning the use of implementation science and factors influencing tele-audiology as a routine or long-term, sustained effort. This mixed-methods study aimed to identify implementation factors that influence the provision of tele-audiology services.

Method

We carried out a mixed-methods study comprising a scoping review and semi-structured interviews (SSI). Articles describing tele-audiology were included based on a set of inclusion and exclusion criteria.

Results

Data was extracted from 32 studies that were mapped to 21 projects in tele-audiology. The broad areas of focus identified in tele-audiology included the provision of hearing screening, diagnostic evaluation, a combination of diagnostic audiological with otorhinolaryngological evaluation, hearing aid fitting and programming, cochlear implant fitting and mapping, aural re/habilitation services and comprehensive audiological services. Provision of diagnostic and therapeutic services were predominantly carried out using synchronous/ real-time telepractice methods. Asynchronous methods were used predominantly for audiometric screening, video-otoscopy and tympanometry. The most commonly used model was the '*professional-facilitator-patient'* followed by the '*professional-patient'* model. Barriers to long-term sustainability included insufficient initial financial investment, lack of reimbursement policies, limited internet (speed and bandwidth), and lack of organisational policies and uniform laws. Successful implementation was reported to be aided by having a stable source of funding, a devoted team of professionals and technicians with defined roles and duties, and with methodical planning.

Conclusion

The scoping review, as well as the interviewees, represented tele-audiology implementation efforts in a wide range of countries that include low-middle income and high-income nations. Successful implementation was reported to be aided by having a stable source of funding, a devoted team of professionals and technicians with defined roles and duties, and with methodical planning. Sustained implementation occurred when the need and usefulness of tele-audiology were accepted by public sector policy-makers. However, a more accurate understanding of sustainability can be obtained by the use of implementation science and frameworks to guide tele-audiology services.

Contributions To Literature

- The current study identifies implementation components and factors that influenced tele-audiology services.
- The study findings represent tele-audiology implementation efforts in a wide range of countries that include low-middle income and high-income nations.
- Focus area of implementation efforts, method, model and barriers and facilitators of sustained telepractice implementation efforts have been summarized.
- Challenges in maintaining robust internet connections for the purpose of tele-audiological tests in remote/rural locations persist.
- Successful implementation was aided by sustained source of funding, a devoted team, a methodical plan including impact evaluations and acceptance by public sector policy-makers.

Introduction

Information and communication technology (ICT) has been used to provide and enhance healthcare services. With the constant progress and pervasiveness of technology in our daily lives over the last decade, there has been an increase in the use of ICT in health care service delivery. Due to its vast applications, it has been explored to promote prevention, enhance wellness and increase access to services which is otherwise limited. Certainly, the COVID-19 pandemic further accelerated the demand and use of telepractice[1].

Tele-audiology has been reported to be beneficial in screening, diagnosing and rehabilitation of ear and hearing disorders. The computerization of equipment and the boom in ICT was instrumental in the growth of telepractice applications in this discipline[2]. The benefits of tele-audiology include (a) cost-effectiveness, (b) increased accessibility to speciality services, and (c) the potential to overcome the shortage of professionals[3]. Despite the benefits of telepractice services, the long-term viability of these services is uncertain due to a dearth of implementation outcomes[4]. There is a major lack of information regarding the use of implementation science and the factors affecting the implementation of tele-audiology as a routine or long-term, sustained endeavour.

Implementation science frameworks are important for contextualising and carefully designing the post-experimental or feasibility assessment phases of novel treatments (such as tele-audiology). A comprehensive implementation method assesses feasibility, stakeholder and organisational readiness. Implementation errors are the result of a lack of a systematic approach, which can waste a significant amount of time, human resources, and money. According to Campbell et al[5], implementation frameworks are not widely employed to guide the implementation of telepractice services in allied health sciences. There is a failure to utilise robust theoretical models that are accessible to understand telepractice implementation.

Systematic and scoping reviews have reported studies in tele-audiology[6–10]. The primary goal of these reviews has been to analyse evidence regarding telepractice applications in terms of treatments offered for ear and hearing disorders, as well as details about patient-site facilitators. The purpose of this mixed-methods study was to identify implementation components and factors that influenced tele-audiology services.

Method

Ethical clearance was obtained from the Institutional Ethics Committee (Reference Number: CSP/20/NOV/87/191) for this study.

Scoping Review

The Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews guidelines (PRISMA-ScR)[11] was used to develop the scoping review protocol (additional file 1). The Population-Context-Concept framework was used to formulate the eligibility criteria which included search terms, strategies, quality appraisal criteria and extraction methods. Search phrases were finalised after an initial pilot was carried out (additional file 2). An initial decision profile (additional file 3) was designed and created for systematic documentation of the selection of articles.

Six electronic databases (PubMed, Cochrane Library, Web of Science, Scopus, Google Scholar and ProQuest) were searched and the Rayyan QCRI software (Qatar Computing Research Institute, Doha, Qatar) was utilised for duplicate removal and article selection process. Two reviewers were involved during this entire process, and any disagreements between the two were discussed until a consensus was established.

Studies describing tele-audiology service provision (including screening, diagnostic, or rehabilitative services) to individuals of all age groups, for two or more years, based on prior research evidence were included. Quasi-experimental trials, and community or field trials were also considered. All telepractice modalities, including video conferencing, web-based, mobile applications, and remote computing, were considered. Only literature published in English between January 2010 and April 2021 was included.

Studies that compared in-person and telepractice measures, or reported validity of tests or tools but did not report long-term implementation were excluded. When full texts were not available after reasonable efforts, articles were excluded.

Analysis

The search results were summarised using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram. We extracted information on geographical distribution, the focus area of service delivery, method and model of tele-audiology service delivery. Barriers and facilitators were analysed and classified under five themes (*technical aspects, organisational aspects, patient*

perspectives, economical aspects, and ethical-legal aspects) which were identified from telemedicine implementation frameworks[4,12,13]. Some studies highlighted barriers and facilitators based on their experiences; otherwise, recommendations to improve overall implementation were provided. Recommendations for quality enhancement were regarded as facilitators, while recommendations for a fundamental necessity for tele-audiology that was not already available were regarded as barriers (additional file 4).

Semi-structured interviews (SSI)

Before the semi-structured interview, informed e-consent was obtained from the participants for the publication of interview details. The interview guides were developed based on the framework provided by the domains identified during the analysis of the scoping review. It was initially pilot-tested with one project implementer. A copy of the interview guide has been provided (additional file 5).

E-mails were sent to the primary and corresponding authors of the studies identified in the scoping review along with a link to an online consent form. When responses from the primary and corresponding authors were unavailable, other authors were contacted. In a couple of instances, the authors led the investigators to another team member. Reminders were provided for scheduling the interview regularly and the consent form remained available for three months.

Data collection

The SSIs were conducted at a mutually convenient time for six authors who expressed consent, using an encrypted online video-conferencing platform. Interviews were carried out between March and August 2021 with each interview lasting 30 to 45 minutes in English by investigators who had received training in conducting qualitative interviews.

Analysis

We conducted thematic analysis of verbatim transcription of all the audio and video recorded interviews using NVivo 12 software. Thematic analysis was carried out using a hybrid inductive-deductive approach[14,15]. After familiarisation with the transcripts, the authors coded two transcripts independently and updated the existing codebook by adding codes generated inductively from the interviews. Any coding differences were discussed and resolved. Upon fine-tuning the codebook, we organised the codes based on similarity and frequency, which aided in categorising codes. We analysed these categories for important patterns in the data that were relevant to our study objectives and compiled them under themes. Finally, we presented an explanation of our study findings, which were substantiated with quotes placed under the respective themes.

Results

The current scoping review identified 32 papers that satisfied the inclusion criteria in tele-audiology (Figure 1).

Project mapping

A summary of the literature reviewed based on the scoping review's inclusion criteria was tabulated for analysis. The study code, study title, authors, countries, and focus area are all listed in Table 1a (additional file 6). Table 1b (additional file 6) describes the settings, participants, employees, and types of services.

Studies describing similar background content in the introduction, common implementation sites, broad objectives, and a contiguous group of investigators were mapped as a single project. This exercise was undertaken to make a realistic assessment of the implementation focus. Studies were considered independent projects when they could not be mapped under any other larger project. Twenty-one projects were identified based on this mapping exercise (Table 1) and each project was coded as P (project) and serial number, for ease of reference. The subsequent findings will be reported using these project codes

Geographical distribution of projects

Tele-audiology was implemented in 12 projects in the United States of America (USA); two projects in Australia; three projects in India; two projects in Canada; one project each from Poland and South Africa. Projects implemented in almost all the countries (P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P14, P16, P18, P19, P20) were delivered to overcome access barriers for individuals in rural areas and/or remote locations. However, in the US there were few projects (P11, P12, P13, P15, P17, P21) that provided tele-audiology services even to urban and semi-urban areas due to scheduling related issues (work, having other children to take care of, household responsibilities).

Focus area of service delivery

Tele-audiology was implemented in projects with a focus on ear and hearing screening, diagnostic audiological evaluations, a combination of diagnostic audiological with otorhinolaryngological evaluation, hearing aid fitting and programming, cochlear implant fitting and mapping as well as intervention services.

Mobile phone-based ear and hearing screening was carried out among school-aged children (P1). Telepractice was used to conduct diagnostic confirmation of hearing loss among infants in follow-up to hearing screening (P2; P3; P4; P5; P6). Tele-auditory brainstem response (ABR) and tele-distortion product otoacoustic emissions (DPOAEs) were performed in all these projects. Other diagnostic tests such as immittance including high-frequency tympanometry and middle ear muscle reflexes, and Auditory Steady-State Response (ASSR) were included only in a few projects (P2, P3).

Diagnostic audiological evaluation combined with otorhinolaryngological evaluation using telepractice was reported in four projects (P7, P8, P9, and P10). In these projects, basic ear (video-otoscopy) and

hearing testing (audiometry and tympanometry) was provided as a routine service to individuals of all age groups.

Remote hearing aid fitting, verification and programming (P11, P12) as well as remote cochlear implant switch-on and mapping (P14) were conducted for all age groups. One project focused on cochlear implant mapping for geriatric patients alone (P13). In the projects where remote cochlear implant switch-on and mapping were conducted (P13, P14), tests such as acoustic reflex threshold/neural response telemetry/ neural response imaging and e-stapedial reflex threshold was carried out through telepractice.

Telepractice was used for aural re/habilitation of both children and adults (P15, P16, P17, P18, and P19) to provide auditory-verbal therapy or some form of habilitation training to individuals with hearing loss.

Comprehensive audiological services to individuals of different age groups were provided with tests including audiometry, hearing aid fitting and programming, cochlear implant fitting and mapping in one project (P20). On the other hand, another project (P21) conducted only hearing screening and hearing aid reprogramming using telepractice, for adults. The diagnostic confirmation and hearing aid fitting was done in person.

Method of telepractice

Use of synchronous/real-time, asynchronous/ store and forward, or a combination/ hybrid method for providing tele-audiology services was identified from the scoping review.

In tele-audiology, the asynchronous method of service delivery was predominantly used for audiometric screening, video-otoscopy, and tympanometry (P1, P7, P8, P9, and P10). Client details, video-otoscopic images, and audiometric or tympanometric data were stored and forwarded to an audiologist or otolaryngologist for review. For tele-diagnostic evaluation of hearing among infants, synchronous methods (for both ABR and DPOAEs) or hybrid methods of synchronous (for ABR) and asynchronous (for DPOAEs) were used (P3, P4, P5, P6). In one project (P2) all diagnostic tests (video-otoscopy, middle ear analysis, DPOAEs, ABR and ASSR) were completed synchronously. Remote hearing aid fitting and programming (P11, P12, P20, and P21) and remote cochlear implant fitting and mapping (P13, P14), were conducted synchronously. In one project (P12), even real-ear probe measures were conducted synchronously. Aural habilitation services like Auditory Verbal Therapy (AVT) were provided synchronously (P15, P16, P17, P18, and P19).

Model of telepractice service delivery

When an e-helper/telepractice assistant/ support staff supported patient care, it was categorised as "*professional-facilitator-patient*" model; when the professional delivered the service directly to the patient without intermediary personnel, it was categorised as '*professional-patient*' model; and '*professional-professional*' model involved a second audiologist or any other professional at the patient site.

In tele-audiology, irrespective of test procedures, the ‘professional-facilitator-patient’ model was used whenever services were provided to remote rural areas. In this case, a trained e-Helper/telepractice assistant/community-based health worker served as a facilitator for telepractice (P1, P2, P3, P4, P5, P6, P8, P9, P10, P11, P12, and P20) and their roles were defined in the project. This was the most commonly used model of telepractice service delivery. The ‘professional-patient’ model was predominantly used for services provided through video-conferencing such as AVT and habilitation of individuals with hearing loss (P15, P16, P17, P18, P19, and P21). The ‘professional-professional’ model was used for fitting cochlear implants (P13, P14) when both audiological and otorhinolaryngology services were provided (P7). The professional at the patient’s end was an audiologist with no specialised training in cochlear implant aural rehabilitation, while the professional who provided services via telepractice was specialised in this area (P13). In one project (P14), a speech therapist was the professional available at the patient end to facilitate the telefitting of cochlear implants. Otolaryngology consultations were supported at the patient end by a variety of professionals including audiologists, physicians, public health nurses, dentists, and physician assistants, as a part of a routine telemedicine clinic (P7).

Implementation Barriers and Facilitators

Out of the identified projects in tele-audiology, 14 projects (P1, P2, P3, P4, P5, P7, P9, P10, P11, P13, P14, P18, P19 and P20) reported service delivery to be ongoing or routine. The rest, even though long-term, were still in the research phase.

Tele-audiology services were implemented in a more sustained manner in hearing screening programs for infants. For example, follow-up diagnostic evaluations were conducted using telepractice in the USA and Canada (P2, P3, P4, P5), ear and hearing screening among school children was conducted in the USA (P1) and diagnostic audiological with otorhinolaryngological evaluation for adults was conducted in the USA and in India (P7, P9, P10). The Veterans hospitals in the USA have implemented remote hearing-aid fitting and programming as well as cochlear implant fitting and mapping as a routine service (P11, P13, and P20). Another effort is the National Network of Teleaudiology in Poland for cochlear implant switch-on and mapping (P14). Aural rehabilitation has also been implemented in a sustained manner in both the USA and Australia (P18, P19).

The factors that influenced implementation positively (facilitators) and negatively (barriers) are reported based on the combined results of the scoping review and thematic analysis of SSI**.** The combined data could be identified under three domains: *patient/ caregiver related aspects, organisational aspects, and ethical-legal aspects.* The quotes are summarized in table 2 under the respective overarching themes.

Patient/ caregiver related aspects

Parents were hesitant to adopt tele-audiology in the beginning as they were apprehensive about the child's ability to build rapport with the therapist. In such a case, they were given a choice of a combined approach of in-person and telepractice sessions until they felt comfortable and confident (P5, P19) or visiting in-person for the sessions till they wanted to explore telepractice sessions (P15, P18). The

families were provided with the opportunity to meet the therapist and participate in a practice video conference session before the commencement of telepractice sessions. Such a mindful approach was found to help address patient apprehensions (refer to quote 1). Parents also became ambassadors of the program when they saw the value in it (refer to quote 2).

Patients' or caregivers' perceptions and understanding of the advantages of tele-audiology service delivery was a key facilitator (P5, P7, P8, P14, P15, P19, and P20) (refer to quote 3). Continuous and ongoing engagement with communities in a culturally safe manner and building awareness regarding the service enhanced acceptance (P1, P8) (refer to quotes 4 and 5). Reduced travel cost associated with tele-audiology services was perceived as facilitatory for implementing such services (P12, P14). Real-time presence of the professional, technical team and support staff and reassurance by them, facilitated the acceptance of tele-audiology by patients/ caregivers (P15, P18, P19, and P20). Patient's acceptance of technology use in ear and hearing care improved when visual images of tests conducted (image of tympanic membrane) were provided (refer to quote 6). Acceptance was also conditional to the absence of any direct cost to the patient (refer to quote 7) or in case of subsidised service (refer to quote 8). Patients felt secure when data security, privacy and confidentiality were protected (P5, P16).

Participation in tele-audiology sessions by other family members, who otherwise would not be able to do so, was further reassuring in some instances (P15, P19). However, program implementers felt that the assessment of a patient's suitability for tele-audiology was crucial and it was important to clearly communicate to the patient when telepractice might not be the best option (refer to quote 9). Setting appropriate expectations for the patient and ensuring clear communication prior to telepractice service delivery can enable acceptance (refer to quote 10).

Organisational aspects

Continued support from the organisation is crucial for sustainable telepractice service delivery. Adoption of new service delivery requires change and this change needs to be supported and driven by the leadership with a vision for sustainability (refer to quote 11). Organisations see value in telepractice because of their threefold advantage: teaching, research and service delivery (refer to quote 12).

Funding

Higher initial capital investment to set up tele-audiology service delivery and the need for specialised equipment to support such practice was reported as a barrier to implementation (P6, P12, P15, and P20) and was only possible with adequate funding (refer to quote 13). When there was a pause or temporary issue with the release of funds, it adversely affected service delivery (refer to quote 14). Even though tele-audiology has gained popularity and preference in the pandemic, it was not adequately supported financially by organisations in the past for routine service delivery (refer to quote 15). Multiple sources of funding including scientific grants, organisational funding, and charitable donations were required to ensure continuity of service (P19, P20) (refer to quote 16). On some occasions, lack of insurance reimbursement for tele-audiology services was a barrier (P11) (refer to quote 17).

When long-term cost outcomes or cost benefits of tele-audiology were evaluated they found it to be a beneficial alternative from a societal perspective (P10, P15). Considerable efforts were taken to establish and self-sustain billable tele-audiology service delivery and these were very few (P21) (refer to quote 18).

Administration

The lack of interlinking support structures across administrative health authorities is detrimental to sustainability (P5). Assessing needs, availability of internal resources, financial planning and a service delivery model that is flexible and adaptable to change was considered useful (P9, P20) (refer to quote 19). Systematic pre-implementation feasibility, test runs and validation of functional requirements were also other useful components of sustainable implementation (P9, P5, and P18). Formulating a Memorandum of Understanding (MOU) and a Telehealth Service Agreement (TSA) before implementation was reported to be facilitatory (P5, P11). Integrated electronic health records were also recommended to ease telehealth service implementation (P7, P20).

Limited or non-availability of professionals and technicians trained in tele-audiology service delivery was reported to be a major barrier (P15). Retention of personnel employed in tele-audiology service delivery was a challenge as it was perceived to be labour-intensive (refer to quote 20). The uniqueness of telepractice draws personnel to work in such services; however, continuity is supported by monetary benefit, opportunities for career development and positive outcomes of services (refer to quote 21). Hesitancy among service providers to adopt tele-audiology was another challenge (refer to quote 22). This could be due to a fear of change, and/or lack of training and expertise in telepractice service delivery which could affect long-term implementation.

In providing remote care, establishing a local “point of contact” who is dedicated and committed to assisting telepractice service delivery was beneficial (refer to quote 23). Having a liaison from the community helped minimise and overcome cultural barriers (refer to quote 24).

A dedicated team including professionals, and administrative and technical support staff was considered pertinent (P6, P19) (refer to quote 25). Reliable patient outcomes were associated with team-building, coordination and streamlined communication between all collaborators involved in telepractice service delivery (P5, P11, and P13) (refer to quote 26). Further, defining the roles and responsibilities of e-helper/ telepractice assistants with systematic culture-sensitive training was considered useful (P7, P20) (refer to quote 27).

Equipment and infrastructure:

Devices with a simple user interface, minimal skill requirement, display in local language and adequate battery back-up were essential to support remote community-based tele-audiology services (refer to quote 28).

Poor internet bandwidth compromised service delivery in rural areas (P10, P15, P17) (refer to quote 29) and the use of undersea cables and broadband connections were regarded as more reliable (P5, P19)

(refer to quote 30). High quality dedicated video conferencing equipment was a quality enhancer in tele-audiology service delivery (P14, P19, P20). In rural areas where issues in connectivity were expected, the store and forward method of tele-audiology was found beneficial (refer to quote 31).

Capitalising on available resources (patient's own devices, pre-existing infrastructure) facilitated seamless implementation (refer to quotes 32 and 33). Contrary to popular belief, digital proficiency was not reported to be a significant barrier, as it was felt that a supporting mechanism can be created (refer to quote 34).

Ethical-Legal Aspects

Lack of acts, laws, malpractice liability and credentialing issues were some of the reported barriers (P11). In certain countries where state licensing was essential, unique licensing policies to deliver telepractice services across states was required (refer to quote 35). Some of these legislative policies gained popularity only after the COVID-19 pandemic and program implementers felt that these changes need to be made permanent (refer to quote 36).

Discussion

This mixed-methods study allowed us to explore tele-audiology services in the context of sustained implementation. While the scoping review helped identify the key components involved in implementing tele-audiology service, the semi-structured interviews helped to delve deeper into the barriers and facilitators of such an implementation.

We found that tele-audiology was predominantly implemented in remote/rural locations to overcome practical challenges associated with receiving in-person services. The most common application of tele-audiology was for diagnostic testing with ABR or OAE in infant hearing screening programs. This was done to reduce the loss to follow-up especially when hearing screening was conducted in primary health care clinics or rural communities[19, 20, 22, 23].

Aural re/habilitation for hearing loss was the next most common application, where only simple video-conferencing software was required. Remote hearing aid fitting and programming was minimally explored, possibly due to the limited availability of supportive features in products of a wider price range[7].

There is a definite preference for using synchronous methods for conducting diagnostic tests or fitting hearing devices when audiologists' real-time judgement is more crucial[48]. Whenever screening was done or images could be captured (like video-otoscopy or tympanometry), asynchronous methods were used. Also, in such tests, real-time assessments by the professional were not critical for test completion. It was possible to provide telepractice services, such as aural re/habilitation, at homes using simple real-time videoconferencing which did not mandate specialised skills[49]. In these cases, patient preparation was necessary and the parent/caregiver acted as a facilitator.

The patients/ beneficiaries and the providers are primary end-users in tele-audiology services and their perceived demand and acceptance seems key for sustainable tele-audiology implementation. Also key is the provider's willingness and comfort in adapting their services using technology[50].

Long-term sustained implementation of tele-audiology within organisational structures necessitates supportive organisational policies that recognise it as an important component of service delivery[51]. This will impact various organisational aspects including the availability of human resources, collaborations and effective planning. The findings of the current study indicate that better administrative convergence is required between health authorities for implementation of tele-audiology services.

Internet access is a basic prerequisite for tele-audiology. The internet's speed and bandwidth affect various aspects of tele-audiology implementation, including test selection, technique and model of service delivery[52]. The use of broadband connectivity and undersea cables was reported to be useful by implementers, yet there seems to be a continued challenge in maintaining robust connections for the purpose of tele-audiological tests in remote/rural locations[53].

Several countries introduced technical guidelines and changes in legislative policies for telepractice only during the COVID-19 pandemic[54]. But supportive mechanisms such as integrated electronic health records are still not widely available at a national level[55].

In the current study, tele-audiology services provided as a part of comprehensive multi-speciality telehealth services were reported only in two projects (P1, P7). Impact evaluations of such implementations are likely to inform the value of capitalising on common infrastructure and shared human resources. Even though tele-audiology services were initiated through research grants, several of them were able to integrate these services into public-funded programs. This suggests that sustained implementation occurred when the need and usefulness of tele-audiology were accepted by public sector policy-makers. Also, if research projects include economic evaluation, then this can in turn inform the allocation of funds by organisations to support sustained implementation[56].

Many tele-audiology studies did not follow the standard principles of implementation science in reporting outcomes. Therefore, we did not use the Standards for Reporting Implementation Studies (StaRI)[57], but instead operationally defined implementation for the purpose of this study. Also, during the literature search, we found several articles that described tele-audiology services, yet it was not possible to infer if services were implemented on an ongoing basis from the information available in the article. Therefore, such studies could not be included. The strength of the current study lies in the representation of tele-audiology implementation efforts in a wide range of countries that include low-middle income (India and South Africa) and high-income (USA, Canada, Australia and Poland) nations. We found that the implementation factors reported in both High-Income Countries (HICs) and Low-Middle Income Countries (LMICs) were similar, except with respect to insurance coverage for tele-practice, and the availability of electronic or digital health records which emerged in the context of HICs and not LMICs. Therefore, we believe that the findings of this study will be useful to program implementers from different regions.

Conclusion

The current mixed-methods study identified implementation factors that influence the provision of tele-audiology services. The scoping review, as well as the interviewees, represented tele-audiology implementation efforts in a wide range of countries that include low-middle income (India and South Africa) and high-income (USA, Canada, Australia and Poland) nations.

Challenges in maintaining robust connections for the purpose of tele-audiological tests in remote/rural locations persist. Successful implementation was reported to be aided by having a stable source of funding, a devoted team of professionals and technicians with defined roles and duties, and with methodical planning. Impact evaluations of such implementations are likely to inform the value of capitalising on common infrastructure and shared human resources, which is currently limited. Sustained implementation occurred when the need and usefulness of tele-audiology were accepted by public sector policy-makers. However, a more accurate understanding of sustainability can be obtained by the use of implementation science and frameworks to guide tele-audiology services.

Abbreviations

Information and Communication Technology - ICT

Preferred Reporting Items for Systematic Reviews and Meta-Analyses - PRISMA

United States of America - USA

Distortion Product Otoacoustic Emissions - DPOAEs

Auditory Brainstem Response - ABR

Auditory Steady-State Response - ASSR

Memorandum of Understanding - MOU

Telehealth Service Agreement - TSA

Standards for Reporting Implementation Studies - StaRI

High-Income Countries - HICs

Low-Middle Income Countries - LMICs

Declarations

Ethics approval: Ethical clearance was obtained from the Institutional Ethics Committee (Reference Number: CSP/20/NOV/87/191) for this study.

Informed consent: Informed consent with 'No objections' to publish the data were obtained from all interview participants prior to the interviews.

Data availability statement: The data underlying this study consists of transcripts of the qualitative interviews that identify the participants and cannot be sufficiently de-identified. To ensure confidentiality and data protection, we have only included relevant excerpts from the interviews with 'no objections' from the participants. Any specific qualitative data set underlying this study can be made available on request to the corresponding author. We will only provide the transcripts to researchers/those that provide a proposal of how the data will be used by them. The corresponding author will ensure to remove identifiers from the particular data set and obtain 'no objections' from the participants before sharing the same.

Extended data:

Open Science Framework: Implementation components and factors that influence the provision of tele-audiology services for children and adults - a mixed-methods approach

DOI: https://doi.org/10.17605/OSF.IO/KXTS6

This project contains the following extended data:

- PRISMA Scoping Review Checklist
- Search terms used for the article selection
- Initial Decision Profile
- Barriers and facilitators reported in tele-audiology projects
- A copy of the interview guide
- Table 1a and 1b: Summary of articles identified in tele-audiology

Competing interests: No competing interests were disclosed.

Funding: This work was supported by the Wellcome Trust DBT India Alliance [A/CPHI/19/1/504614]. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Author Contribution:

VR conceptualized the research topic, both VR and VS were involved in data curation, formal analysis, investigation, finalizing methodology, original draft preparation and reviewing & editing. VR was also integral in supervision, visualisation and acquisition of funding, resources and software. Both authors read and approved the final manuscript.

Acknowledgements: We would like to thank all the researchers who consented to participate in the interviews sharing their valuable time for furthering the understanding in this area of research.

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Tables

Table 1: Summary of project mapping in tele-audiology

Focus area	Country	Project	Project code
Hearing Screening	United States of America	Emmett et al[16]	P1
		Emmett et al[17]	
		Robler et al[18]	
Diagnostic audiological evaluation	United States of America	Dharmar et al[19]	P2
		Stuart[20]	P3
	Canada	Campbell and Hyde[21]	P4
		Hatton et al[22]	P5
	India	Ramkumar et al[23]	P6
		Ramkumar et al[24]	
Diagnostic audiological with otorhinolaryngological evaluation	United States of America	Hofstetter et al[25]	P7
		Kokesh, Ferguson and Patricoski[26]	
	Australia	Smith et al[27]	P8
		Smith et al[28]	
		Smith et al[29]	
	India	Gupta et al[30]	P9
		Ravi et al[31]	P10
Hearing aid fitting and programming	United States of America	Dennis, Gladden and Noe[32]	P11
		Novak et al[33]	P12
Cochlear implant fitting and mapping	United States of America	Luryi et al[34]	P13
	Poland	Skarżyński et al[35]	P14
		Skarżyński et al[36]	
Aural re/habilitation	United States of America	Houston[37]	P15
		Blaiser et al[38]	

		Houston and Stredler-Brown[39]	
		Broekelmann[40]	P16
		Lalios[41]	P17
		Galvan, Case and Todd Houston[42]	P18
	Australia	McCarthy, Muñoz and White[43]	P19
		McCarthy[44]	
		McCarthy[45]	
Comprehensive audiological services	United States of America	Gladden, Beck and Chandler[46]	P20
	South Africa	Ratanjee-Vanmali, Swanepoel and Laplante-Lévesque[47]	P21

Table 2: Reference quotes from the semi-structured interviews

Patient/ caregiver related aspects	
1.	85% *(of the patients)* reported that they were very satisfied. Around 12% reported that they were satisfied. Some of them were not satisfied, but when we analyzed (*patient perspectives)* deeper, we found that this was reported only at the beginning. They wanted to have the first session on-site, at the centre, which we did. Then we found that the satisfaction level was over 95%. • Project implementer of an ongoing telepractice service delivery program in Poland
2.	Parents were the best ambassadors of the idea when they saw that the results from the rehabilitation service were the best. So they were convinced of the method. • Project implementer of a community-based telepractice service delivery program in India
3.	We have some testimony of parents saying, “This is awesome and it's motivational and it's informational. And I love that I didn't have to take my kid to *abc (referring to a distant location)* and get evaluated, then travel back and then travel down for surgery and travel back; I love that I could use this technology. I didn't have to travel or leave my community and my child is getting quick care and being seen.” And so we had a lot of positive reception around the technology in terms of the trial. Also, when we asked parents, “Do you want to be present for this follow-up?”. The idea was to try and make it very quick and not make it a scheduled appointment - not pull parents out of work to get it done. Like they've referred and then they got to the clinic and they got seen within a five-minute appointment. And so we had a lot of parents who said, “Yes, do it because it's hard for me. I got multiple kids at home or I'm working. And so that really helps me to make sure my kid gets seen.” • Project implementer of an ongoing telepractice service delivery program in the US
4.	We felt it was essential to really capture narratives of the experience that we were investigating from community members and various stakeholders. One of the strengths of the trial was that we built a stakeholder group right away. There were multiple stakeholders on the ground, including individuals like myself who have served the region for a long time and who have become trusted members of that region. We interviewed teachers, special education teachers, school, administrators, hospital administrators, and community health workers, who are basically the on-the-ground eyes and ears in local community clinics - Parents and children, youth, elders in the community…… And so for us, that's been really helpful. We've also been working with the school district on the healthcare system to better refine the collaboration that's kind of required, to get this implemented without the research arm pushing it forward. • Project implementer of an ongoing telepractice service delivery program in the US
5.	People were initially saying no. Then, initially, we did a lot of awareness activities. Wherever we planned to start the screening, for one week we put up posters, banners, and awareness activities. We went to the community and started with community dramas, for awareness, because nobody was ready to get screenings done. There were new dramas and other community activities done. There were 10- 20 days of awareness campaigns done so that they *(patients)* get convinced about getting the screening done because that behaviour has to be changed. The people over there need to understand what we are trying to do and what

	benefit they would get out of it. Then, we initiated these screenings door-to-door. Some people agreed based on that and more people followed. That's when screening happened. • Project implementer of a community-based telepractice service delivery program in India
6.	So the people are seeing the mobile phone screen. So they want to know what their tympanic membrane looks like. So everybody began to say, "sir, please do it for me". Maybe in future, we can have visual feedback or a video about hearing and oral hygiene. • Project implementer of an ongoing community-based telepractice service delivery program in South India
7.	We know that some of what we've done is not translatable to the general United States or even globally, but the *def (referring to the program)* is really a unique entity in that, healthcare is something that they are provided because their land has become part of the United States. So they receive *def* resources, and they had that as part of a single-payer system. So there was no cost to the parent or the end-user in terms of receiving this follow-up where potentially in another part of the United States this would potentially be something that would be billed to insurance or be a cost to a parent to receive. • Project implementer of an ongoing telepractice service delivery program in the US
8.	One thing which we realized was that when you go to camps *(to conduct video-otoscopy)*, the patient expects something free of cost. So sometimes we ask the doctor if they can provide something in the camp. So ENTs always usually carry some kind of medication. Whatever is the medical treatment, the patients get it in the ground itself which is free of cost, and that also motivates them to come to the hospital. • Project implementer of a community-based telepractice service delivery program in India
9.	Patients with some neurological issues, some rare diseases, are more demanding and in general, it is more difficult in terms of rehabilitation. So we try to help such patients on-site, in the clinic. For example, patients with mental disorders and after *(sustaining)* some trauma. If we have some risk group, we say, "No, sorry but you cannot use the telemedicine solution because the results would be not optimal." • Project implementer of an ongoing telepractice service delivery program in Poland
10.	We have to do a better job of educating the patients and the consumers, the families that are accessing these services. We try to go through a lot of that orientation …... Making sure that we're setting appropriate expectations for the family that we're working with is very important. • Project implementer of a long term telepractice service delivery program in the US
<u>Organizational aspects</u>	
11.	It's a lot of change management, which means you need the leadership teams and those clinics organizations and private practices to be wanting to change. It is a mind shift. It's the leadership team driving the vision to understand that you're not just adding technology to a patient journey. You're using technology to assist the patient and patient journey. You're not automating things for the sake of automating things. You're automating things so that the face-to-face appointments with the patient become a more enhanced conversation. For this model to be integrated into routine service delivery, each one can integrate the way that suits

	their context. But a mindset change and some amount of training to be able to make decisions on what might work best in terms of which components should be integrated are necessary. • Project implementer of a hybrid telepractice service delivery program in South Africa
12.	Having the support of your institution or your hospital is critical - you need to know what you're doing so that they can get behind it. It can also be a way to reach the community, to get funding, to do other things - to demonstrate how you're serving the patient and the families that you're working with, in all of these different ways. So, the administrators certainly signed off on it; they saw the value in providing services to the families and the adults but also how it was going to enhance the training of the graduate students. I mean, that's our primary goal at the University - to teach and train the graduate students, so that when they leave they can become speech pathologists or audiologists. And so, it met all of these criteria - teaching, research and service delivery- these are the three areas that most universities are most concerned about. So we're able to demonstrate how having telepractice and having that lab satisfied all those areas. • Project implementer of a long term telepractice service delivery program in the US
Funding	
13.	There was an initial investment cost and we bought high-end digital audiometers, we had a website etc. But it was the funding that allowed us to start a digital-first company. So, those costs come into play if you're starting from the ground up. • Project implementer of a hybrid telepractice service delivery program in South Africa
14.	After an issue, an instrument got repaired and we didn't get funds to repair the instrument immediately. So suddenly, the process of intervention for hearing disorders stopped in the project. After some time, we got the funds, and we were able to procure new equipment. • Project implementer of an ongoing community-based telepractice service delivery program in South India
15.	So Medicaid in *xxx (referring to a state in the US)* did not reimburse telepractice. The only time that they would reimburse for telepractice was if the SLP or whoever was delivering the services to a public school district and working with a child who was on Medicaid and receiving those funds. And so, no other funding of telepractice before Covid. • Project implementer of a long term telepractice service delivery program in the US
16.	(In) the beginning, funds for the National Network of Teleaudiology were partially funded by the Norwegian funds …… for European Union. So in the beginning, it was from them. Some of the local projects are co-financed through different scientific grants. Always, we need to have our internal (financial) part, which we need to finance from our sources, which come from the services (we provide). ……. and some of them it's on a rental basis. So we don't buy flat, but we rent …. equipment…. Really, it's not easy. • Project implementer of an ongoing telepractice service delivery program in Poland

17.	The biggest challenge was some blockage from the local insurance government, which didn't want to give us more financial support. So we have had limitations concerning that and we still have them sometimes. So, in such cases, we need to tell patients that they need to choose a private solution that they need to pay for. So it's not very comfortable for them either. • Project implementer of an ongoing telepractice service delivery program in Poland
18.	I worked hard with all the stakeholders from the hospital to ensure that that encounter was billable, because if you're doing something that's not billable from a hospital perspective, then it's not sustainable. • Project implementer of an ongoing telepractice service delivery program in the US
Administration	
19.	A lot of it has to do with management; there is planning, proper performance and looking for funds and adjusting the project according to the funds…….. I will advise future telepractice implementers to analyze the needs and the target group and to check in with the team which will be dedicated to the project, several times. Because there could be some gaps and misunderstandings, which could influence a non-successful project. • Project implementer of an ongoing telepractice service delivery program in Poland
20.	This is a region that has a lot of middle ear diseases. We had to work with a school. We had to go to every school, we had to screen every child, and then the referral process. So, that was labour-intensive from a data collection standpoint for the study. Community health workers would say that “I don't want to do telemedicine because it's double the work. And, I'd rather just write it all down and then talk to a doctor on the phone.” But what we see is that we don't always get the right diagnosis when that happens. • Project implementer of an ongoing telepractice service delivery program in the US
21.	They (*technical and support staff)* try to work, they try to develop themselves and they earn money. I think salary is the first incentive and the second is the possibility of development……. So they work in something, which is a little bit unique. Of course, the money factor is important. Mostly, the incentive is looking at results. And the pay is also a good motivator. • Project implementer of an ongoing telepractice service delivery program in Poland
22.	The most interesting learning for me is the hesitancy of audiologists to embrace the model. I think that for me has been the most surprising, even through a COVID year. I think the audiologist's resistance and scepticism of such a model is interesting and maybe that's due to the fear of change. By no means, does the model remove the audiologist or remove the value of the audiologist; it is using technology to enhance the audiologist's value because you can take the conversation to a different level. You can use the time more efficiently.

	• Project implementer of a hybrid telepractice service delivery program in South Africa
23.	It's important to get that local connection. So that the patient, whenever he has some issues or some queries, can go directly to that person and get that sorted - that local connect is really important. It's also really important that they (*local liaison)* are able to put that commitment to work towards the community because there are very less people who want to work in communities and rural areas. • Project implementer of a community-based telepractice service delivery program in India
24.	There were other individuals that we had brought in the stakeholder team; several native individuals from the community who served as our community outreach specialists. So she *(a community outreach specialist)* took a lot of what we were trying to say and created infographics to explain the trial in a way that through visuals and narrative. And so, I think that a lot of that helped us to gain trust….. I think we didn't experience as many cultural barriers because we went in the correct way. We identified our stakeholders right away; we used individuals who were from the region at the very beginning of the formation of the research question, and also while moving forward. And that really helps just kind of have it blend in seamlessly. Having enough focus groups in the beginning, generating awareness, bringing insight into the design of the trial. And a documentary narrative really helped us in getting the story that different stakeholders are telling…. I didn't see a lot of cultural barriers. But I think that's because we brought those people in. • Project implementer of an ongoing telepractice service delivery program in the US
25.	You need to have a team - not only consisting of doctors and engineers, but also speech therapists. So we talk to audiophonologists and a whole management team starting from nurses and people who are dedicated to patient service; they could even be students. And this is quite important - to have that organizational service. It can not work with only one or two specialists. So having a team who worked earlier in medical centres, who know how to cope with patients, and can be dedicated to such a project. And there is no must for them to have a medical higher graduation. • Project implementer of an ongoing telepractice service delivery program in Poland
26.	In some instances, in some communities, it worked fabulously because the school and the clinic already do a lot of hand-in-hand care. Those communication channels were well developed and seamless. • Project implementer of an ongoing telepractice service delivery program in the US
27.	The program is unique and is growing. It was designed and came out of sheer need and it basically has local community members in a trained program. They complete some initial tests - to check if they have enough reading and basic math skills. And then once they're in the program, then it routes them through a series of certifications. And so there are five levels of community provider. So one, two, three, four, and five as a practitioner, and then they learn different skills along each way. And so they are so integrated into healthcare that it's unbelievable. I'm involved in the training of our onboarding audiologists. I give them several cultural materials to read. I want them to come in with a very humble sense of the culture. They go through a three-day orientation of the hospital, which also is pretty culturally intensive in terms of nativity and heritage. And then we do a lot of on-the-job training from a

	telemedicine perspective. So that's one of the first things they learn because we do so much of it. • Project implementer of an ongoing telepractice service delivery program in the US
Equipment and Infrastructure	
28.	The instrument has to be charged completely for hours together, continuously. We were able to use it only for a maximum of four hours continuously because it has to support the LED light source and the mobile phone. And also, it'll consume more power to transfer data to the cloud by using the network. So there was a challenge in using the instrument continuously. It was not very user friendly initially, but after some time we could adapt it after the initial phase. Also, the equipment had texts that were only in English. We requested the company to modify it into the local language so that the community-based health workers are able to also read. So these were the challenges we faced initially, these were the difficulties. • Project implementer of an ongoing community-based telepractice service delivery in South India
29.	I think that maybe the one important thing is having connectivity and that's the biggest issue right now. There's still sort of blackout areas where there's just very little connectivity or very very slow connectivity and that makes telepractice sometimes impossible to do. Most families do have internet services to some degree, but we still have some families that do not have internet. And that's the biggest problem that we run into, but not the most frequent. To figure out how they can get access to the connectivity can be a challenge from time to time. That probably happens 1% of the time; 99% of the time, they do have connectivity. • Project implementer of a long term telepractice service delivery program in the US
30.	Undersea cables and just the continued expanse of getting closer and closer to broadband in our region has been pretty incredible, and obviously essential for this type of stuff. • Project implementer of an ongoing telepractice service delivery program in the US
31.	Because in remote areas, the internet is still not available sometimes, it's usually store and forward technology that's used because it's much better than waiting for the community workers to come back and do it. It helps us save battery to do much more screenings and operationally that's viable also. • Project implementer of a community-based telepractice service delivery program in India
32.	We have to be available to where the patients are and what devices they're using and not what we want them to use. Being able to connect to what they already have is going to be critical and going forward anyone starting a telepractice or telehealth program needs to realize that and that's sort of one of the best practices.

	• Project implementer of a long term telepractice service delivery program in the US
33.	What's unique about *yyy (referring to a state in the US)* is that we've depended upon telemedicine early on, and so unique to conducting this trial in rural *yyy (referring to a state in the US)* is that we were building upon an established network and an established infrastructure on telemedicine. And so the goal of the study was really to use those resources that were available to us so that we knew when it came time to a sustainable solution that will continue beyond the research it's possible. We tapped into already existing infrastructure that people understand and know how to use, which was an asset for us both from completion and also a sustainability point of view. We did tweak it significantly to make it feasible. • Project implementer of an ongoing telepractice service delivery program in the US
34.	If it wasn't the patient themselves who had a phone, it was the significant other or the caretaker. So I think digital proficiency is not a barrier. I think that's the assumption we have as audiologists, but there's always a support network around. Not always, but most of the time, there's a support network around the patient where technology is available. • Project implementer of a hybrid telepractice service delivery program in South Africa
Ethical-Legal aspects	
35.	I think we have about seven states that have passed this legislature of COMPACT now and I think when we get to *zzz (referring to a district in the US)*, then the COMPACT will go into effect. If you are in your home state and you’re licensed in one of those states as a member of the COMPACT, then you can practice in any of the other states that are in the COMPACT. Though it is not an answer for everyone yet, these kinds of ideas have been out there and people have been trying to push those at the state level to get some of the legislation passed. • Project implementer of a long term telepractice service delivery program in the US
36.	There are about eight different bills in the US Congress to make some changes permanent; to have more access to telehealth and telepractice and to have reimbursement available. So hopefully, one positive thing that may come out of this pandemic is the availability of telehealth and telepractice, but also the reimbursement that would be there for the providers to be able to provide these services. • Project implementer of a long term telepractice service delivery program in the US

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Figures

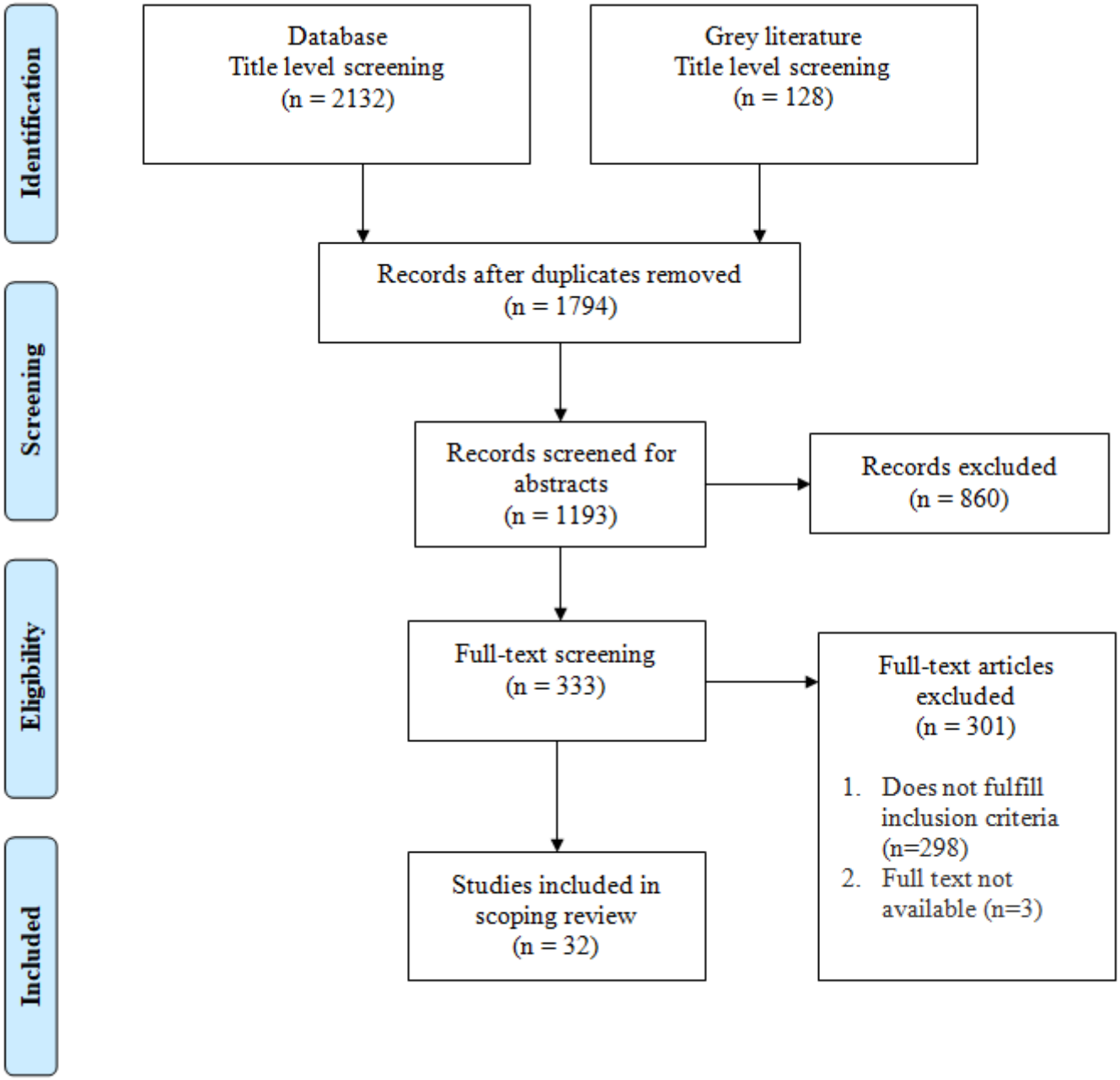

Figure 1

PRISMA flow diagram representing the study's search process