Original Article

Smartphone hearing screening in mHealth assisted community-based primary care

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ABSTRACT:

Introduction: Access to ear and hearing health is a challenge in developing countries where the burden of disabling hearing loss is greatest. This study investigated community-based identification of hearing loss using smartphone hearing screening (hearScreen^{TM}) operated by community health workers (CHWs) in terms of clinical efficacy and reported experiences of CHW's.

Method: The study comprised two phases. During phase one 24 CHW's did community-based hearing screening as part of their regular home visits over 12 weeks in an underserved community using automated test protocols employed by the hearScreen^{TM} smartphone application operating on low cost smartphones with calibrated headphones. During phase two CHWs completed a questionnaire regarding their perceptions and experiences of the community-based screening program.

Results: Data analysis was conducted on the results of 108 children (2-15 years) and 598 adults (16-85 years). Referral rates for children and adults were 12% and 6.5% respectively. Noise exceeding permissible levels had a significant effect on screen results at 25dB HL at 1kHz ($p<0.05$). Age significantly affected adult referral rates ($p<0.05$) demonstrating a lower rate (4.3%) in younger as opposed to older adults (13.2%). CHWs were positive regarding the hearScreen^{TM} solution in terms of usability, need for services, value to community members and time efficiency.

Conclusion: Smartphone-based hearing screening allows CHWs to bring hearing health care to underserved communities at a primary care level.

Active noise monitoring and data management features allow for quality control and remote monitoring for surveillance and follow-up.

Introduction

Hearing loss is one of the most frequently occurring sensory deficits affecting individuals, communities and societies. There are 360 million people worldwide (5.3% of the global population) who live with a permanent disabling hearing loss, the majority of which could be prevented or treated.[1] Hearing loss ranks third on the list of non-fatal disabling conditions.[2] It is a silent and invisible condition associated with various deleterious consequences, including higher unemployment rates, poor health, social isolation, depression, dementia and increased mortality.[3,4]

The burden of disabling hearing loss is greatest in developing world regions, such as sub-Saharan Africa, where access to good quality ear and hearing health care is a major challenge.[1,5,6] A greater concentration of human resources for ear and hearing health care is found in high- and upper-middle-income countries, while low- and middle-income countries account for more than 80% of individuals with hearing loss globally.[1,5] The WHO estimates that there is only one audiologist per 0.5 million to 6.25 million people in the developing world, with countries in sub-Saharan Africa typically presenting with less than one audiologist for every million people.[1,5]

The significant burden of hearing loss, and limited access to ear and hearing health services in developing countries require new methods of providing access to ear and hearing health care. Evidence suggests that primary health care visits may be the first and, in some instances, the only access to screening and treatment that individuals affected by disabling hearing loss may receive.[7] Implementing ear and hearing health care services within primary health care, particularly within developing contexts, could provide individuals and communities who previously did not have access to ear and hearing health care, an opportunity to benefit from these services.[8]

Unfortunately, many barriers exist to providing ear and hearing health care in primary health care settings. One obvious barrier is the high cost associated with screening and diagnostic equipment, which poses a serious challenge to the availability of ear and hearing care services in low- and middle-income countries.[9,10] Self-report of hearing loss in primary health care settings may be quick and cost effective to identify hearing loss in adults. However, there is no way to ensure that persons with a hearing loss will not be missed.[11] Furthermore, children are usually unable to self-report a hearing loss, and the use of questionnaires and checklists for identification in children may not always be accurate[12]. This is especially true of the more common mild hearing losses which may also lead to educational, social, and behavioral challenges.[12]

Novel approaches and service delivery models are required to increase access, for both adults and children, to ear and hearing health care services at a primary health care level. Studies have reported the use of health care personnel within primary health care settings, such as primary health care workers, nurses and community health care workers (CHWs), to successfully improve access of health care services within developing as well as developed countries.[13–16] The use of generalist health care workers may be extended to meet the ear and hearing health needs of a larger segment of the population.[17] WHO primary ear and hearing care training manuals have been recommended for training primary health care workers and CHWs in developing countries in order to stimulate and encourage greater prioritization of prevention, identification and treatment of ear and hearing health care needs.[18] This in turn may reduce the demand placed on already limited professional ear and hearing health human resources in developing countries.

In conjunction with generalist health personnel, innovative tele-health technological developments could be harnessed to overcome barriers to accessing ear and hearing health care, such as mobile health (mHealth) using smartphones, tablets, computers and other portable devices.[10,19] These new developments offer the potential to provide asynchronous point of care diagnostics, allowing primary ear and hearing care services to be integrated with community-based programs, thereby enhancing access at grass-root levels and in homes to those in need.[20]

A recent study reported the use of a smartphone-based hearing screening application (hearScreen™, hearScreen Pty, Pretoria, South Africa) for community-based services. By utilizing smartphones and off-the-shelf headphones, clinical screening outcomes showed no significant difference from conventional hearing screening.[21,22] This type of screener offers an inexpensive alternative to conventional screening audiometry whilst adhering to required acoustic calibration standards and integrating quality control features like environmental noise monitoring and data management.[10,21] Since recommended screening protocols are automated, screening personnel with no or limited health care training can operate the device to screen patients for disabling hearing loss. These advantages allow for asynchronous hearing assessments to be conducted within communities after which patient specific data and results collected on the smartphone application can be uploaded to a centralized cloud-based server through cellular networks for data management. This can be integrated with current community-based mHealth initiatives such as using smartphones to collect and manage data and care in community-orientated primary care (COPC).[17,23]

Integrating low-cost, user-friendly asynchronous smartphone-based hearing screening into community-based primary health care initiatives could improve prevention and access to early identification of and treatment of disabling hearing loss in underserved regions. The current study therefore investigated a tele-assisted community-based program for identification of hearing loss using a smartphone-based hearing screener operated by generalist health workers (i.e. CHWs).

Method

Institutional review board clearance was obtained for this study before any data collection commenced. The study included two phases. The first phase evaluated the clinical efficacy of smartphone-based community hearing screening of children and adults by CHWs, and the second phase evaluated the experiences of CHWs conducting community-based hearing screening.

Phase 1: Clinical efficacy of smartphone hearing screening

Equipment

Samsung Trend Plus (S5301) smartphones (Android OS, 4.0), used by CHWs in the City of Tshwane, to collect and manage health status assessment data and care (using AITA Health™ software) were utilized for this study. The hearScreen™ application was installed on 24 of these phones to include hearing screening as an additional service, and supra-aural Sennheiser HD202 II headphones (Sennheiser, Wedemark, Germany) were supplied for each phone. The application was developed at the University of Pretoria who provided the application ($120), headphones ($35) and calibration service ($80) for this study. A private company (hearScreen Pty; www.hearscreen.co.za) has since licensed it from the University of Pretoria. The hearScreen™ calibration function was used to calibrate the headphones according to prescribed standards (ISO 389-1, 1998) adhering to equivalent threshold sound pressure levels determined for this headphone according to ISO 389-9:2009.[21] Calibration was performed using an IEC 60318-1 G.R.A.S. Ear stimulator connected to a Type 1 SLM (Rion NL-52). The hearScreen™ solution has been validated to monitor noise accurately within 1 and 1.5dB HL depending on the test frequency.[21] Noise levels are recorded and stored by the smartphone application during each screening conducted and a smart noise monitoring algorithm will repeat tests where a patient did not respond and noise levels exceeded maximum permissible ambient noise levels

(MPANL).

Participants

Participants were selected from the community of Mamelodi, City of Tshwane, Gauteng Province, South Africa. Convenience sampling was used to invite all community members, including children four years of age and older, and adults that were seen by CHWs during home-based visits to participate in this study. The CHWs who served this community were also participants in the study. Twenty-four CHWs conducted behavioral pure tone hearing screenings over a period of three months.

Setting and procedures

Hearing screenings were conducted as part of an existing community oriented primary care (COPC) initiative aimed at collecting and managing health status assessment data.[23] Community members were recruited as CHWs to carry out primary health care within the COPC service.[24] The implementation of COPC assists in meeting the health needs of communities for whom the classical institution-based model of care is inaccessible.[24] Health posts are located within communities and consist of a health post manager and approximately 20 to 40 CHWs who are each assigned to approximately 150 to 200 households.[23] CHWs offered hearing screenings to community members during home-based visits congruently to the collection and management of health status assessment data.

CHWs involved in this study had no formal training in ear and hearing health care. Prior to implementation of the first phase, a four-hour training session was held during which CHWs were provided with information regarding ear and hearing health care, and its importance, as well as training and hands-on practice with the hearing screening smartphone application.

The hearScreen™ application employs automated test protocols. A sweep was performed at the test frequencies of 1, 2 and 4 kHz bilaterally. A screening intensity of 25dB HL for the "child protocol" (4 to 15 years) and 35dB HL for the "adult protocol" (16 years and above) was used. The smartphone microphone measured noise levels in the environment and employed a smart noise-monitoring algorithm that only initiates a rescreen if noise levels exceeded maximum permissible ambient noise levels when there was a no response from a patient. In such cases CHWs received a warning on the software and could move to a quieter room or reduce background noise as much as possible before continuing the test. Testing would be completed on the second trial even if noise levels could not be reduced sufficiently. Noise levels were automatically recorded by the hearScreen™ application during the test.

At the end of the testing week data, including patient identifiers and test results, were uploaded from phones to the hearScreen™ cloud-based server by a secure 256-bit encrypted SSL link via a WIFI connection. The cloud-based service is owned by the University of Pretoria and hosted by a local hosting service. For this study, the hearScreen™ application and server front end was a research version. For commercial purposes, users will be required to subscribe to the data management service. Patient identifiers captured included participant's gender and national identity numbers from which their date of birth was extracted. Audiometric screening employs clearly defined referral algorithms based on the test results that allow CHWs immediate and automated interpretations. All data collected was exported from the hearScreen^{TM} cloud-based server to an MS Excel spreadsheet for data analysis. The server allows for text messages to be sent directly to the patient or their caregiver with test results and contact details of the closest hearing health providers based on the geo-location.

A CHW, seated behind each participant, instructed participants to raise their hand when they heard the tone presented through the calibrated headphones. Screening commenced in the left ear 10dB HL above the initial pass or fail test intensity at 1 kHz to condition the child/adult. The screener, depending on the response given by the participant, indicated "yes" or "no" to whether a behavioral response to the stimulus was observed. The hearing screening application automatically moved to the next test intensity and frequency. The stimulus was repeated once if the child/adult did not respond at any frequency and intensity level. Failure to hear a tone at any frequency in either ear constituted an overall 'refer' result after which an immediate rescreen was initiated by the software. Once testing was completed, the hearScreen^{TM} application immediately calculated and displayed the results at each frequency and an overall 'pass' or 'refer' result to the CHW.

If a participant obtained a 'refer' result on the immediate rescreen, he/she was referred to the closest primary health care clinic for diagnostic testing. This clinic was scheduled three times a week when fourth year audiology students from the University of Pretoria offered screening and diagnostic audiology services. Diagnostic testing comprised of otoscopy, immittance testing and pure tone (air and bone conduction) audiometry. Once diagnostic testing was completed, participants were referred to their closest secondary or tertiary hospital that offered the required services.

Data analysis

Data were extracted from the hearData cloud-based server to an MS Excel sheet and analyzed using SPSS v22 (Chicago, Illinois). Descriptive statistical measures were used to analyze referral rates and test times. An independent samples t-test was used to determine if age had an effect on screening results. Results of adults were divided into younger (below 45 years) and older adults (45 years and above) in order to conduct a Chi-square test to compare the effect of aging in referral rates with $p<0.05$ used to indicate a significant effect. A Chi-square test was also used to determine gender effects on screening results. Frequency distributions and cross-tabulations were used to investigate screening outcomes where MPANLs were exceeded.

Phase 2: CHW perceptions of community-based smartphone hearing screening

Participants

The 24 CHWs who conducted hearing screenings during the first phase of the study were asked to indicate their experiences and perceptions of the community-based smartphone hearing screening in terms of usability, need for services, value to community members, time efficiency and their involvement in ear and hearing health care service delivery after the 12 week pilot study.

Procedures

CHWs were required to complete a questionnaire consisting of 10 questions (Table 1) regarding their experiences with the hearing screenings they conducted. The questionnaire was completed at the end of the study. The questionnaire consisted of 10 questions to be answered using a five-point Likert rating scale (1-indicating strong agreement; 5-indicating strong disagreement). An open-ended question was included at the end of the questionnaire for CHWs to write any additional comments regarding the hearing screenings conducted. Participants completed the questionnaires anonymously.

Table 1. Questionnaire on CHW perceptions of community-based smartphone hearing screening. *Response categories ranged from (1) strongly agree, (2) agree, (3) neutral, (4) disagree, (5) strongly disagree.*

1. Instructions for conducting the hearing test are straightforward for testers.
2. The smartphone hearing test is easy to administer in adults.
3. The smartphone hearing test is easy to administer in children.
4. The smartphone hearing test is quick to administer.
5. Community members need hearing health care services.
6. Community members were positive about the receiving a smartphone hearing test.
7. Community members trust the results of the smartphone hearing test.
8. I trust the results of the hearing test.
9. The hearing test is important for community screening.
10. I would like to continue providing a hearing test as part of my service.

Data analysis

Responses from the self-administered questionnaires were also coded into quantitative data in MS Excel 2011, and then analyzed using SPSS v22

(Chicago, Illinois). Descriptive statistical measures were used to analyze the data in terms of frequency distributions. The researcher analyzed additional comments provided by CHWs by using thematic analysis. This is a method for identifying, analyzing and coding themes within data collected in order to meaningfully organize the responses.[25] Data were read carefully to identify and code significant comments after which these were arranged in potential themes along with all relevant data to each potential theme.

Results

Phase 1: Clinical efficacy of smartphone hearing screening

A total of 820 participants including children and adults underwent hearing screening. All data were successfully uploaded to the hearScreen™ cloud-based sever on the first attempt from where it was exported to an MS excel spreadsheet. Each CHW screened an average of 32 participants (range 7-63; SD 16.6). Of these, 78 participants were excluded from the study, as their date of birth could not be accurately ascertained. An incorrect screening protocol (adult vs. child) was selected for 3.6% of children and 5.1% of adults. These participants were excluded from the study as well. A total of 108 children (2-15 years) and 598 adults (16-85 years) were included for data analysis.

Initial screen referral rates were 20.4% for children (n=108 participants) and 13.7% for adults (n=598 participants; Table 2). There was no significant difference between the initial referral rates in adults and children for left ears compared to right ears ($p>0.05$; Chi-Square). Immediately following a 'refer' result from the initial screening, a rescreen was initiated automatically. A total of 20 children and 69 adults were rescreened. Fifteen participants (2 children; 13 adults) failed to complete the rescreening due to a CHW inadvertently electing to skip this process. The overall screen referral rates were 12% for children and 6.5% for adults.

Table 2. Referral rates for screening in children and adults using the hearScreen™ smartphone application.

	Children		Adults	
	(n)	**Refer (%)**	**(n)**	**Refer (%)**
Initial Screen	108	20	598	14
Left	108	19	598	11
Right	108	12	598	7
Immediate Rescreen	20	55	69	28
Left	20	55	69	28
Right	20	55	69	28
Overall	108	12	598	7
Initial Screen				
Left 1 kHz	108	13	598	7
Left 2 kHz	108	13	598	6
Left 4 kHz	108	8	598	6
Right 1 kHz	108	8	598	5
Right 2 kHz	108	7	598	6
Right 4 kHz	108	6	598	5
Immediate Rescreen				
Left 1 kHz	20	30	69	23
Left 2 kHz	20	30	69	20
Left 4 kHz	20	35	69	16
Right 1 kHz	20	20	69	19
Right 2 kHz	20	25	69	19
Right 4 kHz	20	35	69	20

Age had a significant effect on the initial screening referral rate for adults ($p<0.05$; Independent Samples t-test) with average age for referring adults (46.2 years, SD 11.4) higher than for those who passed (35.6 years, SD

13.2). Furthermore, significantly fewer adults younger than 45 years of age failed the final screening test (4.3%), compared to adults aged 45 years and older (13.2%; $p<0.05$; Pearson Chi-Square). More females (n=422) than males (n=176) were screened. Although more females (14.5%) than males (11.9%) failed the initial screen, the difference was not significant ($p>0.05$; Pearson Chi-Square).

MPANLs were exceeded during some hearing screenings in children and adults at 1, 2 and 4kHz (Table 3). In children, a significant effect of exceeded MPANLs on passing or failing a screening was evident at 1kHz ($p<0.05$, Chi-square test), but not at 2 or 4kHz ($p>0.05$, Chi-square test). Noise levels demonstrated no significant effect on initial screen outcomes in adults at any frequency ($p>0.05$, Chi-square test).

Table 3. Distribution of noise levels above maximum permissible ambient noise levels (MPANL's) for adults (screening level 35 dB HL) and children (screening level 25 dB HL).

Frequencies	Adults (%) (n=598)	Children (%) (n=108)
Left 1kHz	13	52
Right 1kHz	13	50
Left 2kHz	5	22
Right 2kHz	1	18
Left 4kHz	1	5
Right 4kHz	0	0

Mean test duration recorded for children was 47.4 seconds (SD 20.0), with a rescreen mean duration of 50.0 seconds (SD 21.6). Adults displayed slightly lower average initial screen duration of 47.0 seconds (SD 28.8) and rescreen duration of 46.2 seconds (SD 19.6).

Phase 2: CHW perceptions of community-based smartphone hearing screening

Two thirds of CHWs (67%) indicated that hearing screening was easy to administer in children compared to 100% who agreed it was quick and easy to administer in adults (Table 4). The majority of CHWs were of the opinion that members of the community needed hearing health care services (87.5%) and that community members were positive about receiving this service (83.3%). CHW all agreed and strongly agreed that they would like to continue to provide hearing screenings as part of their services. Table 5 summarizes the central themes and illustrative quotes identified from the thematic analysis of CHWs comments.

Table 4. Distribution of CHW responses (%) on usability of smartphone screener, value of hearing screening to community and perceptions on involvement in hearing screening (n=24).

Questions	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Instructions straightforward	88	8	4	-	-
2. Administration easy (adults)	75	25	-	-	-
3. Administration easy (children)	33	33	17	13	4
4. Administration easy (quick)	67	33	-	-	-
5. CHW trust result	54	33	13	-	-
6. Important for community	38	46	13	4	-
7. Community needs hearing health	38	38	25	-	-
8. Community positive	46	25	29	-	-
9. Community trust results	67	25	8	-	-
10. Would continue service	63	38	-	-	-

Table 5: Thematic analysis of CHW's comments regarding hearing screening.

Central Themes	Illustrative Quotes
Community need and satisfaction	- *"Community members are happy with the hearing screenings because they need to know about their ears"* - *"Community members want hearing screenings for toddlers."* - *"Community members want the audiologist to follow up on hearing screenings through home visits."*
Need for community education	- *"Most community members welcome the hearing screening but others do not understand the need for the screenings."* - *"Some community members do not want their hearing screened because they are afraid to be consulted."*
CHWs' commitment to provide services	- *"Hearing screening is important for the community to detect hearing problems and we need to know more about hearing."* - *"Hearing screenings should go out into the community in the form of a campaign so that a large number can be screened"* - *"Hearing screening is important for the community to detect hearing problems at an early stage."*

Discussion

Empowering CHWs through the use of mHealth applications is a novel approach to improve the range and access of primary care services such as ear and hearing health in both developing and developed contexts.[26,27] However, the use of mHealth applications by CHWs to improve health care still requires expansion and evaluation in areas such as accessibility, productivity, quality and sustainability over time.[27] To date, there has been a shortage of research evidence for community-based hearing loss detection programs, particularly in developing countries such as those in sub-Saharan Africa. In order to promote awareness of and access to ear and hearing health care in underserved populations, contextual evidence and guidelines are necessary for effective CHW programs. This study provides the first report on the efficacy of a community-based hearing screening program in a developing country, using an mHealth screening solution.[21]

Twenty-four CHWs screened the hearing of 820 community members within a period of three months in addition to their regular workload. Results of 706 participants were used for data analysis since some exclusions were necessary because ages could not be determined from incorrect date of birth selections and wrong screening protocols selected (adult vs. child). The majority of adults screened (70.6%) were female, which is likely due to the fact that households were visited during the week within work hours.

The referral rate found in children (2-15 years) using the hearScreen™ application was 12%. A higher screen referral rate of 21.5% in children (±2-6 years) was found using conventional pure tone audiometry at a stimulus intensity of 5dB lower than the current study's child protocol (20dB HL)[28]. Recent studies reported hearScreen™ smartphone referral rate of 4.3% for children aged 5 to 7 and 3.2% for children aged 6 to 12.[21,22] Higher referral rates in the current study are likely due to the effects of environmental noise. The MPANLs, as measured by the smartphone microphone, were exceeded in more than 50% of instances at 1kHz when screening children at an intensity of 25dB HL (left ears: 52% cases; right ears: 50% cases) and demonstrated a significant effect on referral rates at this frequency. Environmental noise poses a challenge to the successful implementation of hearing screening programs in uncontrolled environments such as schools, and in the case of the present study, during home-visits in underserved communities.[29,30] Recent studies using smartphone applications have also reported effects of environmental noise on screening results, particularly at lower frequencies.[21,31] This effect may be minimized in the future by considering increasing screening intensities to 30 or 35dB HL at 1 kHz. MPANLs were only exceeded in approximately 12.5% of cases when screening at an intensity of 35dB HL at 1kHz.

The referral rate in adults was 6.5%. Age had a significant effect on referral rates with approximately 1 in 7 adults (13.2%) older than 45 failing the screen, in line with the effects of age-related hearing loss demonstrated in epidemiology studies.[32,33] For example, overall prevalence of hearing loss in the Beaver Dam Offspring Study (pure tone average [PTA] > 25dB HL) increased from 2.9% in persons aged 21 to 34 years, to 10.9% in persons aged 45 to 54 years, and to 42.7% in those aged 65 to 84 years.[32]

Rescreens have been recommended directly after initial screening refers in order to minimize the number of false positive results, and has proven to reduce the number of failures in children by half.[29] Referral rates in children and adults dropped by 8.4% (from 20.4%) and by 7.2% (from 13.7%) respectively after the immediate rescreen.

Counter-intuitively pass rates were higher for children and adults when noise levels exceeded MPANLs. This is likely related to the way that the screening application records noise levels. If a child or adult failed the initial screen, CHWs were prompted by the application to reduce noise levels before rescreening. The hearScreen™ application would only record new noise levels for the rescreen if they exceeded the initial screening noise levels.

Therefore, when participants passed the rescreen, recorded noise levels represented the loudest noise levels recorded during the initial and rescreen.

Average test time for the smartphone hearing screening, excluding test setup and instructions, was less than a minute (children: 47.4s, SD 20.0s; adults: 47.0s, SD 28.8). In comparison, other studies reported average testing time for conventional hearing screening of more than two minutes for children.[28,34] The short testing time and minor investment in additional resources (viz. application and headphones) allows for smartphone hearing screening to be integrated in COPC initiatives facilitated by CHWs with additional primary health care duties.

All CHWs indicated that the hearScreen™ application was easy to administer in adults, whilst 16.7% reported that testing children was difficult. CHWs may require more information and experience to ensure better competency and confidence in testing children. CHWs also expressed the need for community education regarding the necessity and importance of ear and hearing health care. mHealth tools have shown to be useful in supporting education of CHWs.[27] CHWs can be trained to successfully screen for hearing loss within their communities using smartphone technology. This supports the notion that non-specialist hearing health care personnel could implement community-based health services which could in turn ease the demand placed on already limited professionals.[5,16,18,35]

Some problems were identified with the CHW community-based screening. Firstly, the test protocol for adults and children was incorrectly selected for 3.6% of children and 5.1% of adults in the sample. A secondary problem was that fifteen participants who referred on the initial screening did not undergo a rescreening. This was because CHWs inadvertently exited the smartphone application before the rescreen commenced or before the rescreen could be completed. Changes in the software should be made to automatically select adult/child protocols based on date of birth to avoid any possible error, as well as to disable the option of canceling a rescreen or exiting the application during a rescreen.

The current study would have benefitted from information on what transpired following the referral for diagnostic assessment. Follow-up rates could not be established however, due to record keeping errors for identification numbers and/or birth dates and the limited monitoring period at primary health care clinics post screening. Diagnostic hearing testing at the primary health care clinic was terminated at the end of the data-collection period due to end of year exams commencing for students. Recent studies indicated that although individuals are screened for hearing loss, the actual follow up rate to seek further assessment after failing a hearing screen was low.[36,37] The integration of informational counseling could provide CHWs with clear guidelines and prompts to assist them in explaining screening results, and to educate and motivate those who referred to pursue follow-up services. Integrating a system for sending reminders directly to patients by means of text messages, for example, may also increase follow-up return rates and direct them to the nearest clinic offering relevant services.[38–40]

Conclusion

Generalist CHWs can successfully screen the hearing of both children and adults during home-based visits as part of a telehealth-assisted COPC program. An mHealth hearing screening application with automated test sequences, integrated noise monitoring, data capturing and data sharing makes asynchronous hearing assessment possible. Furthermore, centralized data management allows for immediate and automated interpretations of results obtained through asynchronous hearing screenings by CHWs. The hearScreen™ adult protocol allows for hearing screenings to be conducted on community members during home-based visits within the community. However, environmental noise poses a challenge when screening at the lower frequencies (viz. ≤1 kHz) when using a 25 dB HL level intended for children. Improvements in the data collection process were also recommended to better record keeping of patient details. CHWs displayed a positive attitude towards smartphone hearing screenings and wanted to continue providing the service. Screening hearing in children was identified by CHWs as an area in which they required additional experience. CHWs showed commitment to improve the hearing health status within their community and were motivated to continue this mHealth hearing screening service.

Acknowledgements

We would like to thank all participants involved with this study, including the team leaders and community health workers of the community of Mamelodi.

Funding aknowledgements

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

Declaration of conflicting interests

All authors declare that we have no conflict of interests.

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