Accuracy of Remote Hearing Assessment in a Rural Community

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Abstract

Background: *This study determined the accuracy of pure tone air conduction (AC) thresholds obtained using a synchronous telemedicine approach without a sound booth in a rural South African community. The global need for increased hearing healthcare currently far exceeds the capacity for delivering these services, especially in developing countries. A tele-audiology approach using a portable diagnostic audiometer could provide the solution, enabling hearing assessments to be conducted remotely and without a sound booth.* ***Materials and Methods:*** *Hearing thresholds in a sound booth and natural environment were obtained from an initial sample of 20 adults (age range, 19–63 years; mean age, 50 ± 13 years; 55% female), recruited from a rural agricultural community. A subgroup of 10 adults (20 ears) volunteered for the telemedicine threshold testing. AC thresholds (250–8,000 Hz) were determined and subsequently compared in these environments. Typical threshold variability was determined using test–retest correspondence as a reference for the threshold correspondence using a telemedicine mode.* ***Results:*** *Test–retest threshold correspondence in the booth and natural environments was within ± 5 dB in 96.7% and 97.5% of comparisons, respectively. No significant differences were obtained in AC hearing thresholds determined in the telemedicine configuration compared with those recorded in the gold standard booth environment. Threshold correspondence between the telemedicine compared with booth and natural environments were within ± 5 dB in 82% and 85% of comparisons, respectively.* ***Conclusions:*** *The current study demonstrates the validity of using synchronous telemedicine for conducting hearing assessments in a remote rural agricultural community without a sound booth.*

Key words: *e-health, telemedicine, technology, extreme environment, audiology*

Introduction

Increased access to hearing healthcare through telemedicine is an area of growing interest due to the global occurrence of hearing loss and limited access to care. With an estimated global prevalence of 5.3%, hearing loss is considered by the World Health Organization as the most prevalent disabling condition globally.[1] Worldwide 360 million people suffer from permanent bilateral disabling hearing, of whom more than two-thirds live in developing countries with severely limited access to care.[1]

Although the global need for increased hearing healthcare is recognized, in reality the need far exceeds the current capacity to deliver these services.[2–4] According to a recent survey by the World Health Organization, the majority of developing countries have less than one audiologist to serve every million people.[5] In South Africa, for example, the ratio of audiologists per capita is 1 to every 100,000 people.[3] The ratio, although far better than in most sub-Saharan African countries, is still five times less than in a typical developed country like the United Kingdom.[3] The shortage of audiologists, mostly urban distribution of professionals and limited resources, means access to services for most, especially those in rural areas, is limited.[2,3,6]

Access to audiological services is further compounded by the requirement for diagnostic assessments to be conducted in a sound booth.[7–9] This restricts the provision of hearing healthcare primarily to tertiary hospital-based institutions or specialized centers found in larger towns and cities.

As in many other developing countries, a large proportion (38%) of South Africans live in rural areas with limited access to healthcare services.[1,10] These communities face barriers such as large traveling distances at high costs and the inconvenience of being away from home or work for a day or two to visit a healthcare facility, especially one that may have some form of ear and hearing healthcare provider.[3]

Consequently, innovative means of bringing hearing health services to people using telemedicine holds promise for reaching remote communities with audiological care,[11,12] especially as the global revolution in Internet connectivity and the extensive roll-out of cellular networks are making it increasingly possible to provide access to underserved rural areas with tele-audiology.[13]

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A recent mobile diagnostic audiometer using increased ambient noise attenuation (covering insert earphones with circumaural earcups) combined with continuous environmental noise monitoring enables compliant hearing testing to be done outside conventional sound booths.[11] Studies using this diagnostic device on children[8] and elderly participants[7] have reported accurate threshold determination outside of conventional sound booth environments. The requirement for sound booths for diagnostic hearing assessments has limited access because these booths are usually not mobile and are prohibitively expensive.[7] A diagnostic computer-operated mobile audiometry system that provides a way to conduct hearing assessments without the requirement for a sound booth could increase access to services, especially if combined with a telemedicine model. This could enable audiologists to conduct hearing assessments remotely[14] and facilitate numerous locations simultaneously.

Although telemedicine offers unique opportunities for providing access to hearing healthcare services to underserved populations worldwide,[13–15] tele-audiology has been surprisingly slow to be incorporated into existing services. This is partly due to a limited number of studies investigating the applications and validity of tele-audiology services.[4] More evidence from clinical validation studies comparing tele-audiology applications with conventional face-to-face services is still left wanting.[13] In light of the pressing need to improve hearing healthcare access for underserved and rural communities, it is important to validate the potential benefit that mobile diagnostic audiometers combined with telemedicine models could have to increase access. Most studies in tele-audiology for hearing assessment have been proof-of-concept studies[14] conducted in clinical and laboratory environments. This study will therefore investigate the reliability and accuracy of synchronous diagnostic audiometry in a rural agricultural community where there is limited access to audiological services.

Materials and Methods

PARTICIPANTS

Approval from the institutional ethics committee of the University of Pretoria, Pretoria, South Africa, was granted, and all participants provided informed consent prior to participation.

This study was conducted in a remote agricultural community in Karino (Mpumalanga, South Africa). Twenty-five of 80 individuals working at a local farm volunteered to participate in the study. Because English was not the first language for the majority of the participants, a translator from the same community was made available both to facilitate the informed consent and to explain the research procedures in the participant's preferred language.

Participants provided biographical data, including age, gender, language, and literacy levels. This was followed by an otoscopic examination and immittance measurements of middle ear functioning done by an audiologist to determine middle ear pathology. Middle-ear pathology can cause temporary conductive hearing loss that may influence pure tone audiometry thresholds from one test session to another. Five participants with possible middle ear pathologies were excluded from the study and referred for medical management, reducing the final sample size to 20 individuals (40 ears; 55% female). The average age was 40 years (standard deviation [SD] = 13 years; range, 19–63 years).

EQUIPMENT

A Heine (Herrsching, Germany) Mini2000 handheld otoscope was used to examine the external meatus bilaterally to detect any abnormalities in the ear canal. Tympanometry was conducted as part of the screening procedure using a GSI 38 Auto (Tymp) tympanometer (Grason-Stadler, Eden Prairie, MN) using a 226-Hz probe tone with standard adult probe tips. The KUDUwave (eMoyoDotNet, Johannesburg, South Africa), a portable diagnostic type 2 audiometer (IEC 60645-1/2), was used to conduct the air conduction (AC) hearing assessment. The KUDUwave uses insert earphones covered by circumaural ear cups (with a built-in sound blocking feature called the Ambidome™ [eMoyoDotNet]) after insertion. The Ambidome provides noise attenuation similar to a single-walled sound booth. It has a microphone on each circumaural ear cup that monitors environmental noise in octave bands during testing. This is visually represented in real time by the audiometer's software. The noise-monitoring function of the KUDUwave uses low-pass (<125 Hz), seven single octave band-pass (125, 250, 500, 1,000, 2,000, 4,000, and 8,000 Hz), and high-pass (>8,000 Hz) filters to separate the incoming sound. The audiometer hardware is encased in each circumaural ear cup and is powered by a USB cable plugged into a laptop computer.

A SVAN959 digital type 1 (2007; SVANTEK Sp z.o.o, Warsaw, Poland) sound and vibration level meter and analyzer was used to record average noise levels in the natural environment during testing.

Two HP® Probook (S-series) laptops (Hewlett-Packard, Palo Alto, CA) were used. The one in the patient site was running the eMoyo software (eMoyoDotNet). The other laptop was located at the remote clinician site.

Control of the audiometer software by the laptop at the remote clinician site was performed through application sharing software (TeamViewer version 4; TeamViewer, Göppingen, Germany) enabling remote control by the clinician from a separate location. The remote clinician was in audiovisual contact with the patient through videoconferencing software (Skype™ Video call version 4; Skype, Luxemburg), and the laptops' built-in microphones and high-definition Webcams. A 3G cellular network was used to connect to the Internet at both sites.

TEST ENVIRONMENTS

Three test environments were used in validating the synchronous telemedicine use of the KUDUwave in a natural environment:

1. *Booth environment*. This was conducted in a clinical environment at a hospital, where the test was conducted face to face in a single-walled audiometric booth adhering to ambient noise levels required by ANSI (ANSI S3.1-1999 R2008) for AC testing.
2. *Natural environment (without a sound booth)*. This was conducted face to face in an office at the participants' workplace on a farm.
3. *Tele-audiology configurations in a natural environment (without a sound booth)*. A subgroup of 10 participants (20 ears) from the test population volunteered for further testing. Participants were tested in the same office used for the natural test environment, whereas the clinician was located at a remote office 1.2 km from the test site. A tele-audiology facilitator from the local community and with no formal audiology training or tertiary education facilitated the participants during the test, while an audiologist (clinician) conducted the AC hearing assessment through videoconferencing and the wireless 3G Internet connection. The tele-audiology facilitator was selected on a voluntary basis, based on his language abilities and willingness to participate. He was able to communicate with participants in several different home languages (i.e., Swazi, Portuguese, Shangaan, Zulu, and Sotho).

On-site training of the tele-audiology facilitator was conducted by the audiologist and included guidance on earphone insertion, headset positioning, and usage of the response button. A clear structured plan for conducting the tele-audiology assessment was developed and put in place before any remote testing was undertaken. The plan laid out testing procedures in a step-by-step manner for the facilitator to follow.

PROCEDURES

Right and left ear hearing thresholds of participants were assessed in each of the environments. To determine test–retest reliability, the face-to-face tests in the booth and in the natural environment were repeated. Test–retest was not done consecutively but took place on the same day, and testing was done in a counterbalance manner to avoid an order effect. The same audiologist conducted the hearing tests in all three environments.

In order to determine the validity of synchronous hearing assessments, hearing thresholds determined in a face-to-face setup with the KUDUwave audiometer at the remote site (natural environment) were first compared with thresholds determined inside a sound booth (gold standard test environment). Subsequently synchronous hearing assessments using a tele-audiology setup was conducted at the remote site (natural environment) and compared with the face-to-face testing determined in the sound booth (gold standard test environment) and the natural environment.

All pure-tone AC audiometry tests were conducted across octave-interval frequencies from 250 to 8,000 Hz and were identical between all the environments. A conventional 10 dB down and 5 dB up bracketing method (modified Hughson–Westlake method) was used to determine AC hearing thresholds. Testing commenced with the right ear at 1,000 Hz and proceeded to lower frequencies (250 and 500 Hz), before increasing to higher frequencies (2,000, 4,000, and 8,000 Hz) for all participants. Threshold testing was not done lower than 0 dB hearing level (HL).

The eMoyo software controlling the KUDUwave audiometer actively monitored ambient noise levels across octave bands throughout the test procedures. Whenever the noise exceeded the maximum permissible ambient noise level for establishing a threshold, the test was paused while the audiologist waited for the noise to subside back to a permissible level.[7]

To assess the ambient office noise levels during face-to-face testing in the natural environment, the sound and vibration level meter and analyzer was positioned 30 cm behind the participant's head to record the average environmental noise for each of the 20 participants over the duration of his or her hearing assessment.

Recording time was also documented for conducting the test in the natural environment and the booth environment and in the tele-audiology environment. Time recording was initiated with the first stimulus presentation to the first ear tested and was terminated after the last patient response recorded for the last ear tested.

DATA ANALYSIS

Normal ranges and distributions were used to demonstrate test–retest reliability in natural and booth environment and differences as well as absolute differences in AC thresholds obtained between (1) the natural and conventional booth environment, (2) the booth and tele-audiology environment, and (3) the natural and tele-audiology environment.

Accuracy of hearing thresholds determined outside a sound booth and remotely was ascertained via a comparison against the gold standard (in the booth environment). Average differences between corresponding thresholds in the different environments and their distributions (SD and range) were established. The percentage correspondences of threshold difference within specified ranges were also calculated.

Due to a nonparametric distribution of threshold values, the Wilcoxon matched-pairs tests was used to investigate the difference in thresholds between test environments at each frequency, with $p < 0.01$ indicating a significant difference.

Results

Hearing thresholds recorded in the gold standard sound booth environment ranged between 0 and 40 dB across frequencies tested (250–8,000 Hz). The average threshold level was 11.4 dB (SD = 7.1; range, 9.1–14.6 dB), with 10% of thresholds recorded at 0 dB.

TEST–RETEST RELIABILITY FOR HEARING THRESHOLDS

In the booth environment the average test–retest AC threshold differences varied between 0.8 and 1.6 dB, with SDs between 2.7 and 4.9 dB across the frequencies (*Table 1*). Test–retest correspondence was within ± 5 dB for 96.7% of cases.

Average test–retest AC threshold differences in the natural environment varied between −0.3 and 1.3 dB, with SDs between 2.4 and 3.6 dB across the frequencies (*Table 1*). Test–retest correspondence was within ± 5 dB in 97.5% of cases.

The absolute average difference was slightly higher in the booth environment (2.6 ± 2.9 dB) than in the natural environment (1.8 ± 2.6 dB) (*Table 2*).

A comparison of test–retest thresholds in both the booth and natural environment revealed no statistically significant differences ($p > 0.01$) except at 500 Hz in the booth environment.

The ambient noise levels across 20 measurements for the test–retest natural office environment indicated average levels between 37.4 and 60.1 dB (A-weighted) (*Table 3*).

ACCURACY OF HEARING THRESHOLDS IN THE NATURAL ENVIRONMENT

Average AC threshold differences between the booth and natural environment (*Table 4*) varied between −2.9 and 1.0 dB, with SDs between 3.3 and 6.9 dB across the frequencies (*Table 4*).

Table 1. Test–Retest Differences in Air Conduction Thresholds Recorded in the Natural and Booth Environments and Correspondence

	FREQUENCY (HZ)						
	250	500	1,000	2,000	4,000	8,000	AVERAGE
Natural setting							
n	40	40	40	40	40	40	40
Average difference	0.3	0.4	1.0	−0.3	1.3	0.1	0.4
SD	3.6	2.9	3.6	2.5	3.5	2.4	3.1
95% CI	−0.9, 1.4	−0.5, 1.3	−0.2, 2.2	−1.1, 0.6	0.1, 2.4	−0.6, 0.9	−0.5, 1.5
± 5 dB (%)	95	100	95	100	95	100	97.5
± 10 dB (%)	100	100	100	100	100	100	100
Booth setting							
n	40	40	40	40	40	40	40
Average difference	0.9	1.6	1.5	1.3	0.8	0.9	1.2
SD	4.2	3.5	4.6	3.2	2.7	4.9	3.9
95% CI	−0.5, 2.2	0.5, 2.7	0.04, 2.9	0.2, 2.3	−0.1, 1.6	−0.7, 2.5	−0.1, 2.4
± 5 dB (%)	95	97.5	95	100	100	92.5	96.7
± 10 dB (%)	100	100	97.5	100	100	97.5	99

Retest thresholds were subtracted from initial thresholds for the given number of ears (*n*).

CI, confidence interval; SD, standard deviation.

Table 2. Absolute Differences Between Thresholds in Natural, Booth, and Telemedicine Environments

	FREQUENCY (HZ)						AVERAGE
	250	500	1,000	2,000	4,000	8,000	
Test–retest							
Natural	2.0 (2.9)	1.6 (2.4)	2.3 (2.9)	1.3 (2.2)	2.3 (2.9)	1.3 (2.1)	1.8 (2.6)
booth	3.1 (2.9)	2.6 (2.8)	3.5 (3.2)	2.2 (2.5)	1.5 (2.3)	2.9 (4.1)	2.6 (2.9)
Natural versus booth	5.3 (5.1)	3.6 (4.7)	2.8 (4.1)	3.5 (3.0)	2.1 (2.5)	4.0 (4.7)	3.5 (4.0)
Natural versus tele	4.3 (3.4)	5.5 (4.6)	5.3 (5.3)	4.0 (3.9)	3.0 (2.9)	6.0 (6.6)	4.7 (4.4)
Booth versus tele	6.5 (6.3)	6.3 (4.2)	2.8 (3.8)	3.5(4.0)	2.8 (3.8)	4.8 (4.9)	4.5(4.5)

Data are average (standard deviation) values.
tele, telemedicine.

Correspondence between the natural and booth environment was within ± 5 dB for 88% of thresholds.

A comparison of thresholds in the natural and booth environment revealed no statistically significant differences ($p > 0.01$) except at 500 Hz.

ACCURACY OF HEARING THRESHOLDS DETERMINED USING TELEMEDICINE

Average threshold differences between the booth and tele-audiology environments varied between −1.5 dB and 1.0 dB, with SDs between 5.6 and 8.3 dB across the frequencies for the initial test (*Table 5*). Average correspondence between the two environments was within ± 5 dB for 82% of thresholds.

Average threshold differences between the natural and tele-audiology environments were between −6.0 and 1.3 dB, with SDs between 3.6 and 5.8 dB across the frequencies (*Table 5*). Average threshold correspondence between the two environments was within ± 5 dB for 85% of thresholds.

The only statistically significant difference between thresholds was at 250 Hz in the natural compared with the tele-audiology environments ($p < 0.01$).

Table 3. Average Ambient Noise Levels in the Natural Environment for Test ($n = 20$) and Retest ($n = 20$) Audiometry Measurements Combined

	PEAK (dB C)	MAXIMUM (dB A)	MINIMUM (dB A)	LEQ (dB A)
Average	80.4	65.5	31.6	45.1
SD	6.6	5.4	7.2	4.5
Range	70.8–97.6	56.8–77.4	22.2–43.4	37.4–60.1

LEQ, time-averaged noise level; SD, standard deviation.

Discussion

Remote hearing assessment through tele-audiology has the potential to provide access to previously underserved populations. An important barrier to the provision of valid tele-audiology hearing assessments is finding a suitable test environment because audiometric sound booths are unavailable in rural and remote areas.[13,16] This study used a mobile audiometer that provides attenuation and monitoring of environmental noise to allow for testing outside a booth as has been demonstrated recently.[7] Test–retest reliability and accuracy of AC threshold testing outside a sound booth were determined against the gold standard of face-to-face testing in an audiometric sound booth as reference variability against which the accuracy of synchronous telemedicine hearing assessment in the natural environment can be compared. It should be noted that the average ambient noise level recorded in the natural environment (37.4–60.1 dBA) was representative of a typical office environment.[17]

Results from the current study demonstrated that hearing thresholds determined in a natural environment through a synchronous telemedicine setup provides clinically equivalent thresholds compared with the gold standard of testing inside a sound booth.

Test–retest reliability of AC thresholds in the booth and natural environment showed no statistically significant difference across frequencies (except at 500 Hz in the booth), with 96.7% and 97.5% of thresholds corresponding within ± 5 dB in the booth and natural environment, respectively. Average differences and SDs were within expected ranges compared with results from a recent meta-analysis reporting test–retest differences across studies.[18] The absolute AC threshold difference in the natural environment was 1.8 ± 2.6 dB, which was also within the range of previously

Table 4. Difference in Air Conduction Thresholds Recorded in the Booth and Natural Environments

INITIAL TEST	FREQUENCY (HZ)						AVERAGE
	250	500	1,000	2,000	4,000	8,000	
n	40	40	40	40	40	40	40
Average difference	−2.5	−2.9	−1.8	−1.8	0.4	1.0	−1.3
SD	6.9	5.2	4.2	4.3	3.3	6.1	5.0
95% CI	−4.7, −0.3	−4.5, −1.2	−3.2, −0.3	−3.1, −0.4	−0.7, 1.4	−1.0, 3.0	−2.9, 0.36
±5 dB (%)	75	85	85	92.5	100	90	88
±10 dB (%)	90	95	97.5	100	100	95	96.25

Booth thresholds were subtracted from the natural thresholds for the given number of ears (*n*).

CI, confidence interval; SD, standard deviation.

reported average test–retest absolute difference values (3.2 ± 3.9[18] and 3.5 ± 3.8[19]).

When compared directly with the booth environment, 88% of the threshold correspondences obtained in the natural environment was within ± 5 dB. This finding is lower than the 95% reported by Maclenna-Smith et al.[7] However, the average absolute difference (2.7 ± 2.9 dB) was similar to their findings (2.7 ± 3.1 dB).[7] This confirms the findings of Maclennan-Smith et al.[7] that valid AC audiometry can be conducted in a natural environment without a booth, using insert earphones covered by circumaural earcups with integrated active monitoring of ambient noise levels.

There was no statistically significant difference in AC hearing thresholds determined in the synchronous telemedicine

Table 5. Difference in Air Conduction Thresholds Recorded in the Natural Compared with the Tele-audiology Environment, as Well as Booth Compared with Tele-audiology Environments

	FREQUENCY (HZ)						AVERAGE
	250	500	1,000	2,000	4,000	8,000	
Natural							
n	20	20	20	20	20	20	20
Average difference	−6.0	−3.3	−1.3	−1.5	−0.5	1.3	−1.9
SD	5.8	5.7	5.4	5.4	4.3	3.6	5.0
95% CI	−8.7, −3.3	−5.9, −0.6	−3.7, 1.3	−4.0, 1.0	−2.5, 1.5	−0.4, 2.9	−4.2, −0.5
±5 dB (%)	70	75	90	80	95	100	85
±10 dB (%)	80	100	95	100	100	100	96
Booth							
n	20	20	20	20	20	20	20
Average difference	−1.5	0.7	0.7	1.0	−0.7	−1.5	−0.22
SD	5.9	7.2	5.6	8.3	6.2	8.2	6.9
95% CI	−2.7, 5.7	−4.3, 2.8	−2.9, 1.4	−3.4, 1.4	−1.4, 2.9	−1.9, 4.5	−2.8, 3.1
±5 dB (%)	70	70	95	90	85	80	82
±10 dB (%)	75	90	95	95	100	95	92

Tele-audiology thresholds were subtracted from thresholds in the natural and booth environments for the given number of ears (*n*).

CI, confidence interval; SD, standard deviation.

configuration in the natural environment compared with those recorded in the booth environment. Results of the current study are in close agreement with previous studies that compared pure tone audiometry thresholds obtained remotely and face to face.[14,20,21]

Comparing the AC threshold determined in the tele-audiology configuration and the natural environment showed a significant difference ($p < 0.01$) at 250 Hz only. Whether this translates to a clinical significance is questionable as the average absolute difference at this frequency (4.3 ± 3.4 dB) was actually lower than the average absolute difference between the natural and booth environments (5.3 ± 5.1 dB).

Threshold correspondences within ± 5 dB between the tele-audiology configuration and the booth and natural environments were 82% and 85%, respectively. This is slightly lower than the correspondence between the booth and natural environment (88%) and also compared with the findings of Choi et al.[20] (89%) and Swanepoel et al.[14] (96%). There are several differences between the current study and those of Choi et al.[20] and Swanepoel et al.[14] that could explain the slight differences. First, tele-audiology was conducted in a natural environment in the current study, whereas in the other two it was conducted in a booth environment. By conducting the tele-audiology assessment in a natural environment, an additional layer of potential variability was added to the current study that could explain this lower correspondence. Second, both Choi et al.[20] and Swanepoel et al.[14] used clinicians to facilitate the tele-audiology, whereas the current study used a facilitator with no formal clinical or audiological training. A trained clinician would have minimized the possibility of incorrectly inserted earphones, which could have contributed to a slightly lower correspondence (±5 dB). The fact that there were no significant differences in the data obtained in the tele-audiology environment, where a facilitator was used, and the booth environment, which was solely under the clinician's control, suggests the facilitator training and structural plan was adequate. Finally, sample sizes in both Choi et al.[20] ($n = 37$; 74 ears) and Swanepoel et al.[14] ($n = 30$; 60 ears) were larger than that of the current study (20 ears)—reducing the significance each data value has on the sample population as a whole and diluting any error values.

Some limitations to the current study include the relatively limited sample size for the tele-audiology component and the fact it was drawn from a single rural community. A follow-up study using several larger samples drawn from rural communities in different provinces and working in different environments (agricultural, industrial, and mining) would allow for investigation in terms of replication of the current findings in different demographic, social, and environmental situations. In addition to this, the inclusion of children, the elderly, and those with different degrees of hearing loss would ensure that tele-audiology approaches were suitable for assessing hearing health for the whole community. Finally, due to time constraints with the subjects, the current study only measured AC thresholds and not bone conduction thresholds. As both are important in accessing hearing health, any future studies should investigate AC and bone conduction thresholds in order to evaluate the appropriateness of tele-audiology in assessing hearing health.

Conclusions

The current study demonstrates the validity of hearing thresholds determined through synchronous tele-audiology in a nonclinical setting. It also highlights the potential for using nonclinical facilitators in remote locations, which could reduce the burden on the limited number of clinical human resources. There was no significant difference in pure tone hearing thresholds determined in the conventional face-to-face clinical setting and a telemedicine setup. The study is the first of its kind to report synchronous telemedicine hearing assessments conducted in a natural environment in a rural community. Results demonstrate telemedicine hearing assessments to be comparable to the current "gold standard." These technologies make it possible for diagnostic hearing assessments to be included as part of a remote telemedicine kit and can give new opportunities in telemedicine support. Tele-audiology has the potential to expand hearing healthcare provision to enable remote rural populations to access services.

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Disclosure Statement

No competing financial interests exist.

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