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EFFICACY OF SMARTPHONE-BASED SCREENING BY TEACHERS FOR EARLY IDENTIFICATION OF HEARING LOSS IN SCHOOL CHILDREN

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Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

Abstract

Introduction: The high prevalence of hearing impairment in school children highlights the need for regular school screening programs. However, lack of professionals and infrastructure can create a barrier for screening all children. Smartphones present an opportunity for school teachers to be trained to perform hearing screening among students. The current study aimed to determine the efficacy of smartphone-based hearing screening by school teachers.

Material and methods: The participants comprised 580 students, from grades 1 through 5 from various schools in Dharwad city. The children were screened by trained school teachers using the smartphone-based app Hearing Test developed by e-audiologia.pl. To test validity, the same children were again tested by a professional audiologist using a diagnostic clinical audiometer.

Results: The results of the current study found small but significantly higher mean thresholds across frequencies using the Hearing Test app compared to the diagnostic audiometer. However, thresholds obtained using both devices were within normal limits of –10 to 15 dB HL. Hence, it might be possible for the Hearing Test app to be used for hearing screening in primary school children.

Conclusions: After training, it appears feasible for school teachers to utilize the Hearing Test app to screen for hearing loss in school children. This could make hearing screening more routine and cost-effective, and may aid in the early detection of hearing loss. However, it appears that hearing thresholds established by teachers using the app were slightly worse than those established by an audiologist using an audiometer.

Keywords: school children • hearing screening • Hearing Test app • audiometry • hearing threshold

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SKUTECZNOŚĆ BADAŃ PRZESIEWOWYCH WYKONYWANYCH PRZEZ NAUCZYCIELI ZA POMOCĄ SMARTFONÓW W CELU WCZESNEJ IDENTYFIKACJI UBYTKÓW SŁUCHU U DZIECI W WIEKU SZKOLNYM

Streszczenie

Wprowadzenie: Wysoka częstość występowania zaburzeń słuchu u dzieci w wieku szkolnym implikuje potrzebę prowadzenia regularnych programów badań przesiewowych w szkołach. Jednak brak specjalistów i odpowiedniej infrastruktury może stanowić przeszkodę wykonywania badań przesiewowych u wszystkich dzieci. Wykorzystanie aplikacji na smartfony stwarza możliwość przeprowadzania w szkołach – po przeszkoleniu nauczycieli w tym zakresie – badań przesiewowych słuchu wśród uczniów. Niniejsze badanie miało na celu określenie skuteczności wykonywanych w szkołach przez nauczycieli badań przesiewowych słuchu za pomocą smartfonów.

Materiał i metody: W badaniu wzięło udział 580 uczniów z klas od 1 do 5 z różnych szkół w mieście Dharwad. Dzieci zostały przebadane przez przeszkolonych nauczycieli za pomocą aplikacji na smartfony Hearing Test opracowanej przez e-audiologia.pl. Aby sprawdzić poprawność wyników, te same dzieci zostały ponownie zbadane przez profesjonalnego audiologa z wykorzystaniem audiometru klinicznego.

Wyniki: Wyniki badania wykazały niewielkie, ale znacząco wyższe średnie progi słyszenia dla różnych częstotliwości uzyskane w aplikacji Hearing Test w porównaniu z audiometrem klinicznym. Jednak progi uzyskane za pomocą obu urządzeń mieściły się w granicach normy od –10 do 15 dB HL. Wynika stąd, że aplikacja Hearing Test może być wykorzystywana do badań przesiewowych słuchu u dzieci w wieku szkolnym.

Wnioski: Wydaje się możliwe, aby po przejściu szkolenia nauczyciele w szkołach korzystali z aplikacji Hearing Test do wykonywania badań przesiewowych w kierunku ubytku słuchu u dzieci w wieku szkolnym. Tym samym badania przesiewowe słuchu mogłyby stać się bardziej powszechne i przystępne cenowo, a dzięki temu mogłyby pomóc we wczesnym wykrywaniu ubytków słuchu. Jednocześnie należy wziąć pod uwagę, że progi słuchu ustalone przez nauczycieli w niniejszym badaniu były nieco gorsze niż te ustalone przez audiologa za pomocą audiometru klinicznego.

Słowa kluczowe: dzieci w wieku szkolnym • badania przesiewowe słuchu • aplikacja Hearing Test • audiometria • próg słyszenia

Introduction

If left untreated, communication disorders in childhood can result in severe consequences, such as limited educational achievement, reduced employment opportunities, and problems with social adaptation. We now have ample evidence that shows early identification of communication disorders reduces its impact on social, emotional, and educational outcomes [1–3]. A review of the literature from 1980 to 2020 showed that the prevalence of hearing loss in children in India ranged from 6 to 27% [4]. Another survey conducted in a rural population of India found that the prevalence of individuals at risk of communication disorders was 6.1%; among those at risk, the prevalence of audiological and or otological disorders was found to be 90.6% [5]. Similarly, in a retrospective analysis of clinical records of individuals having communication disorders, hearing impairment reached a prevalence of 30.8% in children [6].

A prevalence study in the Netherlands reported 7.8% of children 9–11 years old had sensorineural hearing loss in one or both ears, and that a history of recurrent acute otitis media and low maternal education were the most common predisposing factors for hearing loss [7]. A hearing screening in 67,416 school children from rural areas in Poland found positive results in 16.4%; untreated middle ear diseases were associated with a higher prevalence of hearing loss in rural areas [8]. Among 34,618 elementary school children screened in Poland, 11% had sensorineural hearing loss [9]. It is clear that in preschool and school age children the prevalence of communication disorders can be high, and it can often go undetected if they are not screened.

School screening typically uses a systematic approach involving otoscopy and pure-tone audiometry to examine a large number of children from a large geographical area [8]. In the Polish work, screening was carried out in an isolated room having low noise background, and results were considered normal if the child had air conduction hearing thresholds less than 20 dB HL [10,11]. Although audiological screening requires minimum equipment, costs involved in purchasing and maintaining it can be high. Smartphone apps are inexpensive, readily available, and easy to use. Several research groups have looked at hearing testing using a smart phone [12–15]. Smartphone apps have the potential to be a convenient alternative to employing professionals in screening children's hearing. Smartphone apps for basic hearing assessment might provide low-cost hearing screening at the Primary Health Centre (PHC) level [16].

There is growing evidence that smartphone-based hearing screening can be effective in identifying hearing loss. A systematic review and meta-analysis found that smartphone-based hearing tests have a sensitivity ranging from 0.71 to 1.00 and specificity ranging from 0.73 to 1.00 when compared to conventional audiometry. One study found that smartphone-based hearing tests were reliable and accurate across different smartphone models and operating systems [13]. Among adults, smartphone based self-test audiometry provided accurate and reliable results having a sensitivity of 90.6% [17]. Similarly, the sensitivity and specificity of a smartphone-based hearing screening app hearScreen were 81.7% and 83.1%, respectively; positive and negative predictive values of 87.6% and 75.6%, respectively, have also been reported [18]. Likewise, validity of the Hearing Test app revealed comparable sensitivity (75.0%) and specificity (98.5%) compared with conventional screening audiometry [19].

Here, the validity of hearing screening using Hearing Test smartphone-based audiometry is explored. In the self-test response mode, hearing screening with the similar hearTest app appears to be reliable in detecting hearing loss in adults and children with hearing loss [20]. These findings suggest that smartphone-based hearing screening might be a useful tool for identifying hearing loss, particularly in low-resource settings where access to traditional audiological services may be limited.

In school children, hearing screening is important to identify late onset hearing loss, unilateral hearing loss, or cases missed at newborn hearing screening. In India, hearing screening in school children is not universal due to the lack of professionals and infrastructure. The use of a smartphone app for hearing screening is promising as it requires low-cost instrumentation and minimal training. This study investigates the effectiveness of smartphone-based hearing screening by teachers of primary school children. We wanted to see whether teachers could be trained to use a smartphone app to obtain hearing thresholds in these children.

Material and methods

Participants

Primary school children aged between 5 to 10 years (mean age 7.2, *SD* 2.3 years) and studying in grades 1 to 5 were selected through a simple random sampling method. There were 580 (317 male, 263 female) participants in the study, as shown in **Table 1**. The participants had no symptoms related to hearing loss. There were 79 other students who had a history of ear pain, ear discharge, or difficulty in following instructions; data from them were analyzed separately for a subsequent study.

Methods

For hearing screening the Android-based app Hearing Test (developed by e-audiologia.pl), available at no cost in the Google play store, was used. Compared to other apps, Hearing Test has a lower cutoff threshold (20 dB HL); further, it has good sensitivity (98%) and specificity (79%) and

Table 1. Distributions of students in terms of class and gender

	Class				
	I	II	III	IV	V
Gender					
Male	64	66	61	66	55
Female	32	35	44	43	35
Total	96	101	105	109	90

has been recommended for large-scale screening and epidemiological studies [15]. The app produces pure tones from 0.125 to 10 kHz at intensities ranging from 0 to 100 dB HL. Two different headphone options were available: a bundled headphone, in which calibration is automatically provided in the app, and an unbundled headphone which requires manual calibration prior to test commencement. In our study, teachers used unbundled headphones (Fingers Superstar H6) and calibration was performed before each session. Calibration was done on a young graduate having normal hearing sensitivity in both ears. The subject was asked to self-record his hearing thresholds by pressing or releasing the button as the intensity changed. Frequency was slowly increased from 125 Hz to 10,000 Hz at 1 octave per minute and 2 dB per second. The thresholds obtained during calibration were verified using a clinical audiometer. An Android v. 11.0 smartphone (Redmi note 10S) was used for the entire data collection. The clinical audiometer was an ALPS AD 2000 with TDH 39 headphones that were calibrated as per ANSI S3.6-2018 (R2023). The audiometer produced pure tones ranging from 0.25 to 8 kHz at intensities from −10 to 120 dB HL for air-conduction. Using the two devices, hearing thresholds could be established at 0.5, 1, 2, and 4 kHz.

Procedure

The study was conducted at various primary schools in Dharwad, North Karnataka, India. Informed consent was collected from the parents before the scheduled date of the hearing screening. The study was carried out in three phases (**Figure 1**), and adhered to the ethical guidelines of the institution (JSSMC/IEC/070326/02NCT/2023-24 dated 9.03.2024). In phase 1, 15 teachers were enrolled in a training program for a week and were provided with information on the screening process and hands-on training using the smartphone-based hearing app. They were trained by an experienced audiologist who outlined the importance of hearing, different types of hearing loss, and early identification of hearing loss. Training was done for an hour per day continuously for a week. Every teacher was given a manual in Kannada, describing step-by-step instructions on how to calibrate the headphones prior to the testing, how to modify the stimulus frequency and intensity, and how to save and retrieve test data. At the end of training, they were asked to answer a post-test containing simple questions related to hearing loss and its early identification; they were also asked to perform hearing screening using the mobile app. Six teachers who completed the post-test and hearing screening with 80% accuracy were chosen for further study. In phase 2, the 6 chosen teachers administered smartphone-based hearing screening for grade I to V students. Phase 3 involved use of the clinical audiometer, and conventional audiometric thresholds were established by an experienced clinical audiologist. The interval between the last two phases was less than one week. Phases 2 and 3 were carried out in a quiet room in the school that had low background noise. The validity of the smartphone-based screening was done by comparing the two sets of results.

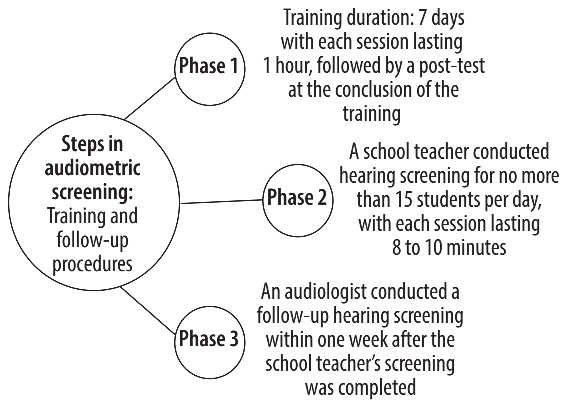

Figure 1. Steps involved in hearing screening

Results

The study compared hearing thresholds obtained using the Hearing Test app and a clinical diagnostic audiometer across four different frequencies (0.5, 1, 2, 4 kHz). The data was analyzed using Statistical Package for Social Sciences (SPSS), Windows version 21 software. The significance criterion was $p < 0.05$. The results were analyzed using mixed ANOVA where the testing devices served as within-subject independent variable, while class and gender served as between-subject variables. Hearing thresholds at a particular frequency served as the dependent variable.

Table 2 shows that the mean thresholds obtained using the Hearing Test app were slightly higher than that of the diagnostic clinical audiometer at all frequencies in all five classes. Mean thresholds obtained using the Hearing Test app ranged between 13–16 dB HL (SD 3–8 dB HL) across the four frequencies, whereas using conventional audiometry, the hearing thresholds ranged between 2–12 dB HL (SD 4–8 dB HL).

Table 3 shows the results of mixed ANOVA at all four frequencies, where a significant main effect of testing device ($p < 0.05$) and an interaction between testing device and

Table 2. Means and standard deviations across four frequencies of hearing thresholds [dB HL] obtained using the Hearing Test app and diagnostic clinical audiometer in children from 1st to 5th class

		Class									
		I		II		III		IV		V	
Frequency		Aud	App	Aud	App	Aud	App	Aud	App	Aud	App
500 Hz	Mean	5.39	14.32	10.71	13.14	9.90	13.47	11.46	14.40	7.58	13.69
	SD	5.05	3.54	7.00	4.11	8.48	4.55	7.11	4.22	6.61	4.29
1000 Hz	Mean	7.26	13.75	11.78	13.49	9.66	13.59	9.70	15.60	8.25	14.22
	SD	4.63	3.22	6.27	4.28	7.94	4.72	8.62	4.46	6.15	4.77
2000 Hz	Mean	9.06	14.11	14.38	14.00	11.64	13.78	8.30	14.52	12.16	14.47
	SD	5.53	3.18	4.65	4.09	4.78	5.12	6.10	4.37	4.45	4.87
4000 Hz	Mean	2.83	14.09	8.63	13.81	8.14	15.21	6.51	16.55	4.91	15.16
	SD	4.56	3.94	5.83	3.99	5.77	4.98	6.23	4.56	4.79	4.36

Note: Aud = clinical audiometer; App = Hearing Test app

Table 3. Results of mixed ANOVA showing significant interactions

	Variables			
	500 Hz	1000 Hz	2000 Hz	4000 Hz
Testing device and class	$F = 8.794$	$F = 4.838$	$F = 13.501$	$F = 10.203$
	$p < 0.0005$	**$p = 0.001$**	**$p < 0.0005$**	**$p < 0.0005$**
Testing device and gender	$F = 0.138$	$F = 0.127$	$F = 0.775$	$F = 0.058$
	$p = 0.710$	$p = 0.722$	$p = 0.379$	$p = 0.810$
Gender and class	$F = 0.390$	$F = 0.314$	$F = 0.976$	$F = 1.343$
	$p = 0.816$	$p = 0.869$	$p = 0.420$	$p = 0.253$
Testing device, gender, and class	$F = 1.567$	$F = 2.536$	$F = 2.958$	$F = 3.007$
	$p = 0.182$	**$p = 0.039$**	**$p = 0.020$**	**$p = 0.018$**

Note: bold = results statistically significant

class ($p < 0.05$) can be seen. Further, the interaction between testing device, gender, and class were also significant for 1, 2, and 4 kHz ($p < 0.05$). However, there was no interaction between testing device and gender ($p < 0.05$). Between subjects, the main effect of gender ($p > 0.05$) and class ($p > 0.05$) was not significant. Similarly, there was no interaction between gender and class ($p > 0.05$).

Since there was a significant interaction between testing device and class, hearing thresholds obtained using the two devices were compared in each class using a paired sample *t*-test. **Table 4** shows that at all the frequencies, hearing thresholds obtained using the diagnostic clinical audiometer were significantly better ($p < 0.05$) than the Hearing Test app in all 5 classes.

Discussion

The main objective of the study was to investigate the effectiveness of using a smartphone-based hearing app for screening of primary school-children by teachers. Comparison of hearing thresholds between the app and the diagnostic audiometer showed that smartphone-based screening gave significantly higher thresholds than the audiometer. The smartphone gave hearing test thresholds of 13–16 dB HL across frequencies from 0.5 to 4 kHz, whereas conventional audiometry gave hearing thresholds of 2–12 dB HL. Comparing classes, the thresholds for all five classes were similar. A previous study among adults which compared hearing thresholds using an audiometer and the Hearing Test app showed that hearing thresholds were 0–6.5 dB using the audiometer and 0–7.5 dB using the app [15]. The study noted that the low thresholds recorded from both devices were possible because all measurements were carried out in a sound booth. In contrast, we measured thresholds in a quiet room in the school having low background noise.

In the current study, the mean difference in hearing thresholds between audiometer and the Hearing Test app ranged from 2 to 12 dB (SD 1–4 dB). In comparison, the study by Masalski et al. [15] reported a mean difference of 2.6 (*SD* 8.3 dB). The significant difference in thresholds obtained using the two devices in the current study can be attributed to several reasons. The present study used unbundled headphones that were calibrated before every test, whereas the former study used bundled headphones that were calibrated specific to the smartphone manufacturer. In the

Table 4. Results across frequencies of paired sample *t*-tests comparing hearing thresholds obtained using the Hearing Test app and a diagnostic clinical audiometer in children from the 1st to 5th class

Frequency	*t*-test	Class I	Class II	Class III	Class IV	Class V
500 Hz	*t*-value	14.425	2.872	3.940	3.811	6.663
	df	95	100	104	108	89
	p	**< 0.0005**	**0.005**	**< 0.0005**	**< 0.0005**	**< 0.00005**
1000 Hz	*t*-value	11.087	2.256	4.179	6.065	7.397
	df	95	100	104	108	89
	p	**< 0.0005**	**0.026**	**< 0.0005**	**< 0.0005**	**< 0.0005**
2000 Hz	*t*-value	8.112	–0.610	3.063	8.105	3.924
	df	95	100	104	108	89
	p	**< 0.0005**	**0.543**	**0.003**	**< 0.0005**	**< 0.0005**
4000 Hz	*t*-value	20. 344	7.726	9.804	14.146	13.580
	df	95	100	104	108	89
	p	**< 0.0005**	**< 0.0005**	**v0.0005**	**< 0.0005**	**< 0.0005**

Note: *df* = degree of freedom; *p* = statistical significance; bold = results statistically significant

Masalski study, the tone used was 100% modulated, which is easy to detect in noise, whereas in the current study a steady pure tone was used. Further, in the Masalski study, the entire testing procedure was under the guidance of an audiologist whereas in the current study the entire testing was performed by a teacher. Another study of adults that compared hearing thresholds obtained using an audiometer and the Hearing Test app found mean threshold differences up to 8.8 dB [19].

Using the Hearing Test app, none of the children had hearing thresholds greater than 20 dB HL at any frequency, indicating that all hearing thresholds were within normal limits. In general, screening results are considered normal if a child has air conduction thresholds better than 20 dB HL [10,11,19]. Hence, in an Indian context, we conclude that the Hearing Test app can be used by teachers for hearing screening of school children.

The present study validates the use of smartphone-based hearing screening in school children between grades 1 to 5. Most researchers have studied the specificity and sensitivity of app-based identification of hearing loss in adults [13–17]. However, a few studies have compared conventional screening audiometry and smartphone-based screening in normal and hearing-impaired in children as well as adults [18,20]. The findings of the current study reinforce the appropriateness of smartphone-based hearing screening among primary school children.

In the current study, comparisons were made in both males and females, and both had similar hearing thresholds within the normal limits. There was no gender difference across frequencies, testing devices, and classes, supporting earlier reports [21,22]. It may be concluded from the current study that some school teachers can be trained to use the smartphone-based Hearing Test app for hearing screening of school children. Nevertheless, it should be noted that not all school teachers were able to perform screening: some found it difficult to understand the procedure and others lacked spare time in their busy schedules.

Conclusions

The major objective of the study was to investigate the effectiveness of smartphone-based hearing screening by school teachers among primary school children. It was found that the Hearing Test app resulted in slightly higher but significantly different thresholds than an audiometer. However, hearing thresholds obtained using the smartphone application were within normal limits. Hence, it can be concluded that it is possible for schoolteachers to utilize the Hearing Test application to identify hearing loss among primary school children. The findings suggest that hearing screening by teachers could help with the early detection of hearing loss in school children, increase the incidence of referral, and make testing more practical and affordable.

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