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ORIGINAL RESEARCH

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A study on the IOS application "uHear" as a screening tool for hearing loss in Bangkok

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Abstract

Objective: This study was designed to compare the results of hearing tests performed using the uHear application with those of standard audiometry in Thai people in Bangkok.

Methods: From December 2018 to November 2019, a prospective observational study was conducted involving Thai participants aged between 18 and 80 years. All participants were tested using standard audiometry and the uHear application in a soundproof booth and in a typical hearing environment.

Results: This study included 52 participants (12 males and 40 females). The Bland–Altman plot with the Minimal Clinical Meaningful Difference of 10 dB between standard audiometry and the uHear in a soundproof booth found agreement at 2000 Hz. The uHear in a soundproof booth showed high sensitivity at all frequencies (82.5%–98.9%) and high specificity at 500 and 1000 Hz (85.7%–100%). uHear in a typical hearing environment showed high sensitivity at 4000 and 6000 Hz (97.6%) and high specificity at 500 and 1000 Hz (100%). When considering the pure-tone average, uHear in a soundproof booth showed high sensitivity (94.7%) and specificity (90.7%), whereas, in a typical hearing environment, uHear showed poor sensitivity (34%) and high specificity (100%).

Conclusion: uHear was accurate for hearing loss screening at 2000 Hz in a soundproof booth. However, uHear in a typical hearing environment lacked accuracy. The uHear application in a soundproof booth can be used to screen hearing loss in some situations where standard audiometry is impossible.

Level of Evidence: II.

KEYWORDS
hearing loss, screening tool, uHear

1 | INTRODUCTION

Hearing loss is a substantial health problem worldwide, which can worsen the quality of life of affected individuals and their families.[1] In 2018, the World Health Organization reported that 466,000,000 individuals globally had hearing loss.[2] In Thailand, over 80,000 adults have hearing trouble[3]; the estimated prevalence of hearing loss among Thai is 4.6%–22.7%.[4]

Screening for hearing loss among Thai is limited by the availability of diagnostic tools and audiologists, leading to delays in diagnosis and treatment. Adequate identification of hearing impairment would allow patients to receive fitted hearing aids, which would improve their quality of life and prevent psychiatric and functional impairments.[5,6] Therefore, a limited-resource screening tool is necessary, and such a tool must be evaluated for its sensitivity, specificity, and applicability.[7,8]

Many early screening tools for hearing loss are now available, such as applications for computers, tablets, and mobile phones, which are cheap and easy to use. Comparisons with standard audiometry show that application-based screening tools can accurately estimate a person's hearing level.[9] An evaluation of 11 eligible peer-reviewed studies that examined six hearing test applications identified uHear, an application for self-administered audiometry, as the most validated tool compared with the gold standard pure-tone audiometry.[10] However, the accuracy of uHear varied across these studies. One study found that uHear was a satisfactory screening test for moderate hearing loss, with 98% sensitivity and 82% specificity, compared with standard audiometry.[11] A study showed that its specificity improved to 90% when the application was used in a soundproof booth but decreased in a typical hearing environment.[12] These findings were replicated in many studies.[13–16]

Overall, studies indicated that the uHear application is easy to use and accurate and can be used to screen hearing loss. However, before this tool can be embraced in Thailand, it must be validated in this population.

2 | MATERIALS AND METHODS

This study was approved by the Institutional Review Board (IRB) of the Faculty of Medicine, Navamindradhiraj University, Bangkok, Thailand (IRB no 154/61). All participants provided written informed consent.

2.1 | Participants

The study was conducted at Vajira hospital between December 1, 2018 and November 31, 2019. The invitation poster to participate in the research was placed in the outpatient hall of every department and in the hospital elevator. The participants were recruited voluntarily. The inclusion criteria were as follows: Thai nationality and ethnicity and having lived in Bangkok for at least 10 years. Participants were excluded if they had a history of hearing loss or previous otologic surgery, were receiving an ototoxic drug or head and neck radiotherapy, or had a temporal bone fracture, moderate to severe head trauma, movement disorder, hand deformity, cognitive impairment, or claustrophobia. The study was discontinued if participants experienced claustrophobia or were unable to complete the examination because of physical and mental issues.

2.2 | Sample size

The sample size was calculated using data from Hajian-Tilaki K's study,[17] based on expected specificity of 0.94[14] and prevalence of 0.083.[4] The sample size was calculated to be 47 patients (94 ears) with an estimated dropout rate of 10%, and the total sample size was therefore 52 patients (104 ears).

2.3 | Auditory tests

An otolaryngologist performed an otoscopic examination on all participants before the test. All participants were tested with standard audiometry in a soundproof booth using AudioStar Pro (Audiogram GSI) according to the ASHA 1987 standards (only air conduction at 250, 500, 1000, 2000, 4000, and 8000 Hz was tested).[18] The hearing test was then performed using the uHear application (IOS version 2.0.2) via Apple's iPad Pro 9.7 inches (2016) with Apple's EarPods with a 3.5-mm Headphone Plug in the soundproof booth and in a

TABLE 1 Demographic data

Data	Number (%)
Participants	52
Gender, *n* (%)	
Male	12 (23.1)
Female	40 (76.9)
Age, mean ± SD (years)	44.63 ± 16.87
Occupation, *n* (%)	
Government officer	15 (28.8)
Merchant	15 (28.8)
Company employee	11 (21.2)
Housewife	5 (9.6)
Others	6 (11.5)
Underlying disease, *n* (%)	
Hypertension	13 (25.0)
Diabetes	6 (11.5)
Hyperlipidemia	13 (25.0)
Other disease	10 (19.2)
Smoking history	1 (1.9)
Alcohol history	1 (1.9)
Hearing level, *n* (%)	
Normal	46 (88.5)
Mild	4 (7.7)
Moderate	1 (1.9)
Moderately severe	0
Severe	0
Profound	1 (1.9)
Hearing loss, *n* (%)	6 (11.5)
Unilateral	2 (3.8)
Bilateral	4 (7.7)

TABLE 2 Hearing level tested by Standard audiometry, uHear in soundproof booth and uHear in typical hearing environment

Hearing level (dB)		Standard audiometry (*N*, %)	uHear in Soundproof booth (*N*, %)	uHear in typical hearing environment (*N*, %)
500 Hz	<25 dB	97 (93.3)	81 (77.9)	17 (16.3)
	26–40 dB	4 (3.8)	18 (17.3)	45 (43.3)
	41–55 dB	2 (1.9)	2 (1.9)	34 (32.7)
	56–70 dB	0 (0.0)	2 (1.9)	6 (5.8)
	71–90 dB	0 (0.0)	1 (1.0)	1 (1.0)
	>90 dB	1 (1.0)	0 (0.0)	1 (1.0)
1000 Hz	<25 dB	95 (91.3)	88 (84.6)	37 (35.6)
	26–40 dB	6 (5.8)	12 (11.5)	48 (46.2)
	41–55 dB	0 (0.0)	1 (1.0)	16 (15.4)
	56–70 dB	2 (1.9)	2 (1.9)	1 (1.0)
	71–90 dB	0 (0.0)	1 (1.0)	1 (1.0)
	>90 dB	1 (1.0)	0 (0.0)	1 (1.0)
2000 Hz	<25 dB	90 (86.5)	93 (89.4)	75 (72.1)
	26–40 dB	11 (10.6)	10 (9.6)	27 (26)
	41–55 dB	2 (1.9)	0 (0.0)	1 (1.0)
	56–70 dB	0 (0.0)	1 (1.0)	1 (1.0)
	71–90 dB	0 (0.0)	0 (0.0)	0 (0.0)
	>90 dB	1 (1.0)	0 (0.0)	0 (0.0)
4000 Hz	<25 dB	83 (79.8)	87 (83.7)	86 (82.7)
	26–40 dB	10 (9.6)	14 (13.5)	14 (13.5)
	41–55 dB	9 (8.7)	1 (1.0)	2 (1.9)
	56–70 dB	1 (1.0)	2 (1.9)	1 (1.0)
	71–90 dB	0 (0.0)	0 (0.0)	1 (1.0)
	>90 dB	1 (1.0)	0 (0.0)	0 (0.0)
6000 Hz	<25 dB	85 (81.7)	92 (88.5)	88 (84.6)
	26–40 dB	7 (6.7)	7 (6.7)	7 (6.7)
	41–55 dB	7 (6.7)	4 (3.8)	8 (7.7)
	56–70 dB	4 (3.8)	0 (0.0)	1 (1.0)
	71–90 dB	0 (0.0)	1 (1.0)	0 (0.0)
	>90 dB	1 (1.0)	0 (0.0)	0 (0.0)

TABLE 3 Data of participants with normal hearing and hearing loss

	Normal hearing	Hearing loss	*p*
Participant, *n* (%)	46 (88.5)	6 (11.5)	
Gender, *n* (%)			.234[a]
Female	36 (90)	4 (10)	
Male	10 (83.33)	2 (16.67)	
Age, mean ± SD (Min–Max)	42.24 ± 15.71 (22–80)	67.1 ± 7.16 (55–77)	<.001[b]

[a]Fisher's exact test.
[b]Independent *t* test, *p*-value <.05.

typical hearing environment. The typical hearing environment test was performed in an examination room in the outpatient clinic of the Department of Otolaryngology. The noise was mainly from air conditioning. The distance from the air conditioning to the participants and the sound meter was 2 m. The noise was measured using the sound level meter 3 M, model BHP, for 5 consecutive days from Monday to Friday before testing. The noise ranged from 50 to 60 dB.

All subjects were tested for all three tests. The tests were conducted on the same day, with no washout period, starting with

TABLE 4 Mean and standard deviation of hearing level (dB) tested by Standard audiometry, uHear in soundproof booth and in typical hearing environment

Hearing level (dB)	Standard audiometry[a]	uHear in Soundproof booth[a]	p[b]	uHear in typical hearing environment[a]	p[b]
500 Hz	16.50 ± 8.19	20.10 ± 9.75	<.001	37.96 ± 13.76	<.001
1000 Hz	16.80 ± 8.91	26.70 ± 7.30	<.001	34.47 ± 11.78	<.001
2000 Hz	16.94 ± 9.14	17.18 ± 5.59	.684	21.94 ± 7.90	<.001
4000 Hz	18.25 ± 14.03	18.88 ± 8.85	.458	19.32 ± 9.45	.212
6000 Hz	17.38 ± 16.96	13.83 ± 9.61	.002	15.68 ± 11.94	.081

[a]Data are presented as mean ± SD.
[b]Paired *t* test, *p*-value <0.05.

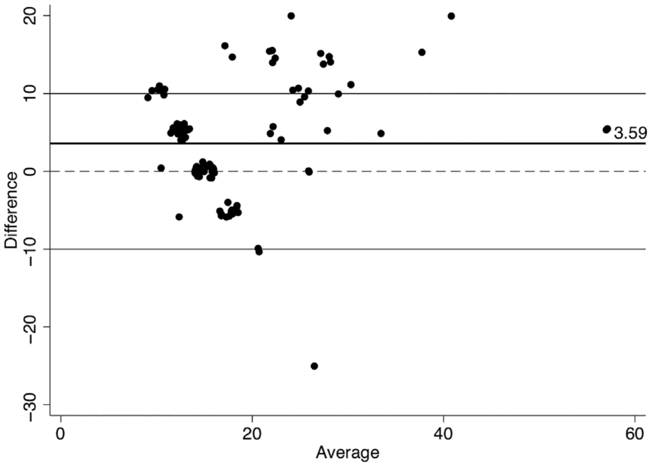

FIGURE 1 Bland–Altman plot of the hearing test at 500 Hz between standard audiometry and uHear in a soundproof booth. Difference: The standard audiometry value was subtracted from the uHear in a soundproof booth value. Average: The average of the standard audiometry value and uHear in a soundproof booth value. Mean = 3.59 dB. Differences between the uHear in a soundproof booth values and the standard audiometry values were not more than 10 dB in 89 ears (85.58%)

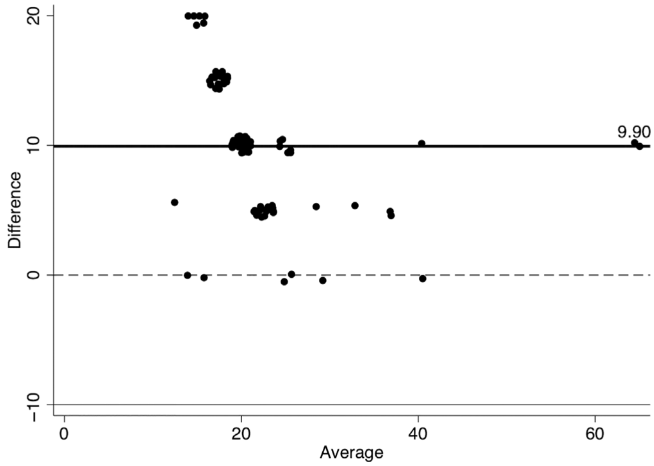

FIGURE 2 Bland–Altman plot of the hearing test at 1000 Hz between standard audiometry and uHear in a soundproof booth. Difference: The standard audiometry value was subtracted from the uHear in a soundproof booth value. Average: The average of the standard audiometry value and uHear in a soundproof booth value. Mean = 9.90 dB. Differences between the uHear in a soundproof booth values and the standard audiometry values were not more than 10 dB in 75 ears (72.12%)

standard audiometry and uHear in a soundproof booth (the subject remains in the soundproof booth) and finished with uHear in a typical environment consecutively.

The audiometric results were interpreted using degrees of hearing threshold modified from ASHA. Pure-tone average (PTA) (an average of 500, 1000, and 2000 Hz) ≤ 25 dB are considered normal, those from 26 to 40 dB are mild, those from 41 to 55 dB are moderate, those from 56 to 70 dB are moderately severe, those from 71 to 90 dB are severe, and those ≥91 dB are profound.[16]

2.4 | Statistical analysis

Hearing levels (dB) at each frequency (Hz) were estimated and summarized as means and standard deviations for each group. Data were statistically analyzed using paired *t* tests, clinical significance analysis (Bland–Altman plot), Fisher's exact test, independent *t* test, and Pearson's correlation coefficient. The analyses were performed using STATA, version 14.2 (Stata Corp).

3 | RESULTS

The demographic data of the participants are shown in Table 1. This study included 12 males and 40 females. The mean age was 44.63 years (range, 22–80 years). The participants were mostly government officers, merchants, and company employees. The most common underlying diseases of the participants were hypertension, hyperlipidemia, and other diseases. According to the PTA, six participants (11.5%) had hearing loss. Two of the participants had unilateral hearing loss, one had profound hearing loss (>90 dB), and another one had mild hearing loss (26–40 dB). Four participants had bilateral hearing loss, of whom three had mild hearing loss (26–40 dB) on both sides and one had moderate hearing loss (41–55 dB).

The hearing levels tested using standard audiometry, uHear in a soundproof booth, and uHear in a typical hearing environment are shown in Table 2. According to the PTA, screening by standard audiometry revealed that 90.38% (94 ears) had normal hearing. Ten ears

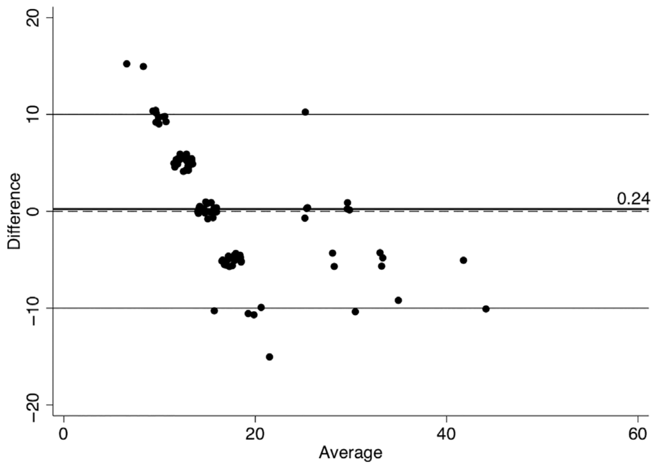

FIGURE 3 Bland–Altman plot of the hearing test at 2000 Hz between standard audiometry and uHear in a soundproof booth. Difference: The standard audiometry value was subtracted from the uHear in a soundproof booth value. Average: The average of the standard audiometry value and uHear in a soundproof booth value. Mean = 0.24 dB. Differences between the uHear in a soundproof booth values and the standard audiometry values were not more than 10 dB in 100 ears (96.15%)

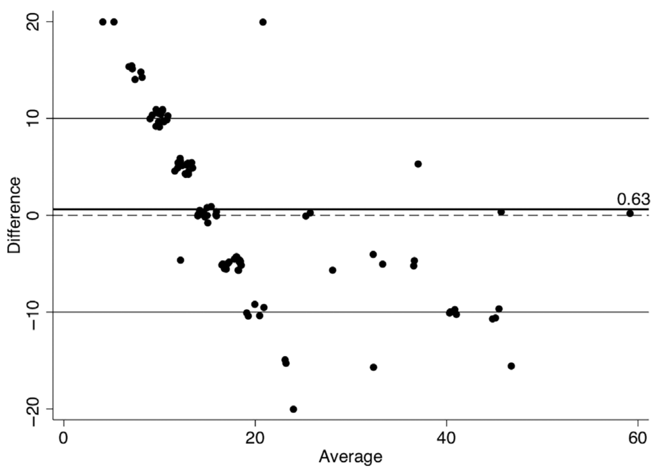

FIGURE 4 Bland–Altman plot of the hearing test at 4000 Hz between standard audiometry and uHear in a soundproof booth. Difference: The standard audiometry value was subtracted from the uHear in a soundproof booth value. Average: The average of the standard audiometry value and uHear in a soundproof booth value. Mean = 0.63 dB. Differences between the uHear in a soundproof booth values and the standard audiometry values were not more than 10 dB in 89 ears (85.58%).

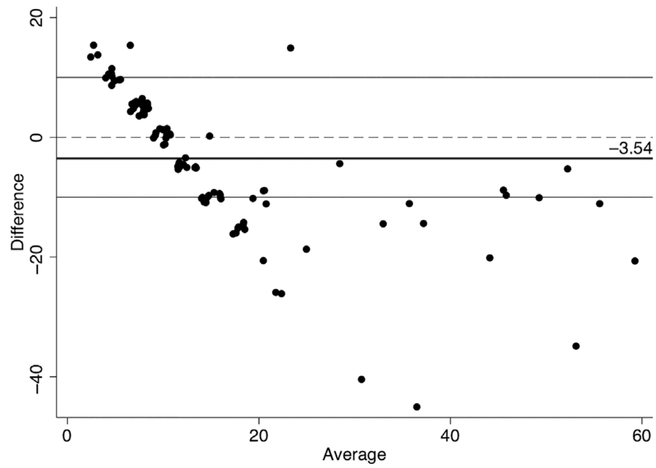

FIGURE 5 Bland–Altman plot of hearing test at 6000 Hz between standard audiometry and uHear in a soundproof booth. Difference: The standard audiometry value was subtracted from the uHear in a soundproof booth value. Average: The average of the standard audiometry value and uHear in a soundproof booth value. Mean = −3.54 dB. Differences between the uHear in a soundproof booth values and the standard audiometry values were not more than 10 dB in 80 ears (76.92%).

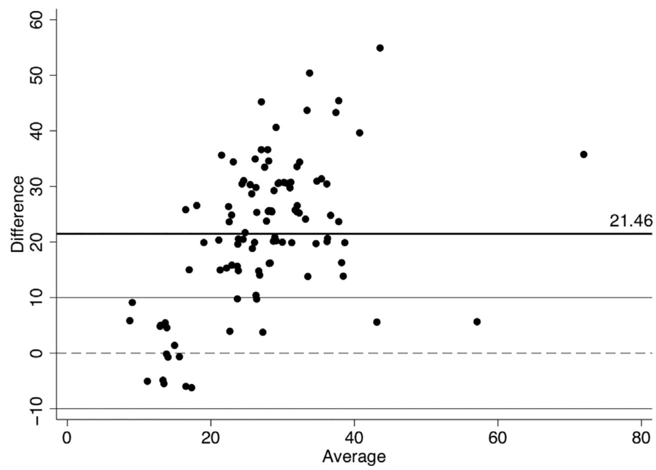

FIGURE 6 Bland–Altman plot of hearing test at 500 Hz between standard audiometry and uHear in a typical hearing environment. Difference: The standard audiometry value was subtracted from the uHear in a typical hearing environment value. Average: The average of the standard audiometry value and uHear in a typical hearing environment value. Mean = 21.46 dB. Differences between the uHear in a typical hearing environment values and the standard audiometry values were not more than 10 dB in 22 ears (21.15%)

had hearing problems: seven had mild hearing loss (26–40 dB), two had moderate hearing loss (41–55 dB), and one had profound hearing loss (>90 dB).

Data of the participants with normal hearing and hearing loss are shown in Table 3. Statistically significant differences in age were observed between the groups.

When the screening was performed in a soundproof booth (Table 4), the hearing threshold detected by the uHear application was significantly higher at 500 and 1000 Hz and lower at 6000 Hz than that detected by standard audiometry. No difference was observed between standard audiometry and uHear at 2000 and 4000 Hz.

The uHear application was also tested in an outpatient clinic environment, representing a typical hearing environment in which this tool would be used. Compared with standard audiometry, results indicated no significant difference in the detected hearing threshold at 4000

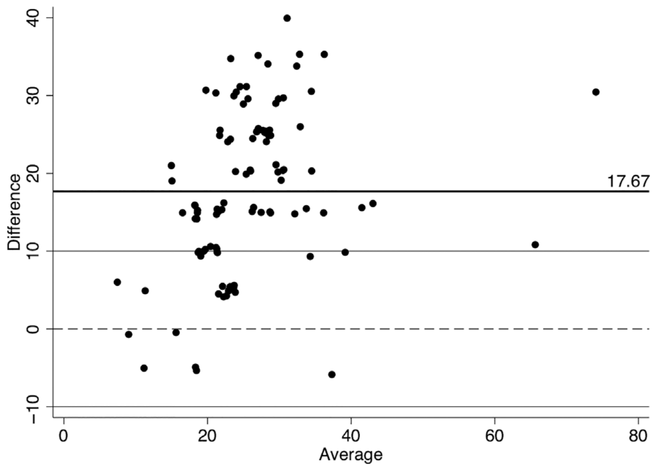

FIGURE 7 Bland–Altman plot of hearing test at 1000 Hz between standard audiometry and uHear in a typical hearing environment. Difference: The standard audiometry value was subtracted from the uHear in a typical hearing environment value. Average: The average of the standard audiometry value and uHear in a typical hearing environment value. Mean = 17.67 dB. Differences between the uHear in a typical hearing environment values and the standard audiometry values were not more than 10 dB in 31 ears (29.81%)

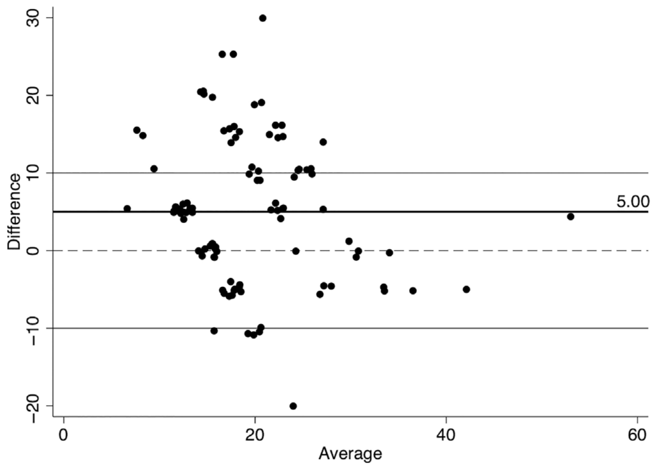

FIGURE 8 Bland–Altman plot of hearing test at 2000 Hz between standard audiometry and uHear in a typical hearing environment. Difference: The standard audiometry value was subtracted from the uHear in a typical hearing environment value. Average: The average of the standard audiometry value and uHear in a typical hearing environment value. Mean = 5 dB. Differences between the uHear in a typical hearing environment values and the standard audiometry values were not more than 10 dB in 79 ears (75.96%)

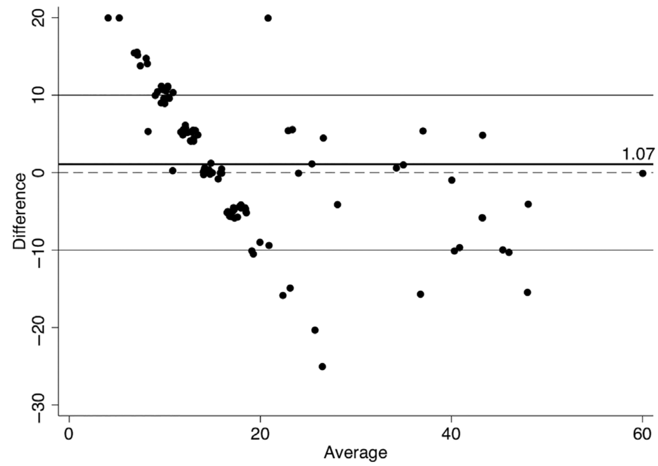

FIGURE 9 Bland–Altman plot of hearing test at 4000 Hz between standard audiometry and uHear in a typical hearing environment. Difference: The standard audiometry value was subtracted from the uHear in a typical hearing environment value. Average: The average of the standard audiometry value and uHear in a typical hearing environment value. Mean = 1.70 dB. Differences between the uHear in a typical hearing environment values and the standard audiometry values were not more than 10 dB in 88 ears (84.62%)

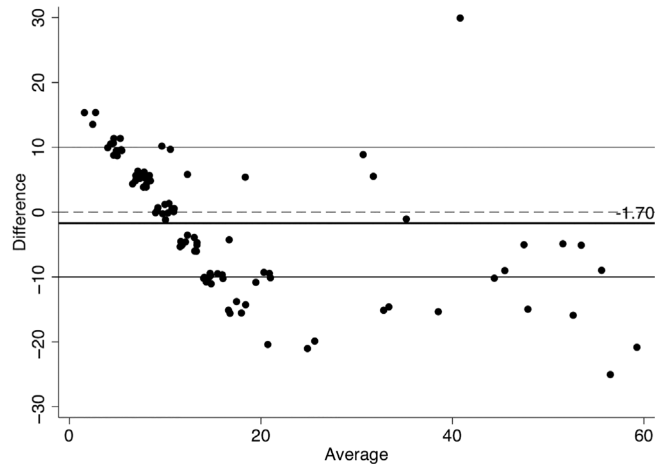

FIGURE 10 Bland–Altman plot of hearing test at 6000 Hz between standard audiometry and uHear in a typical hearing environment. Difference: The standard audiometry value was subtracted from the uHear in a typical hearing environment value. Average: The average of the standard audiometry value and uHear in a typical hearing environment value. Mean = 1.07 dB. Differences between the uHear in a typical hearing environment values and the standard audiometry values were not more than 10 dB in 84 ears (80.77%)

and 6000 Hz. However, significantly higher detectable hearing thresholds were observed at 500, 1000, and 2000 Hz.

We analyzed the clinical significance between standard audiometry and the uHear application using the Bland–Altman plot with a Minimal Clinical Meaningful Difference (MCID) of 10 dB (Figures 1–10).[19] We found that ≥95% of ears were in the agreement area of ±10 dB in the Bland–Altman plot of the hearing test between uHear in a soundproof booth and standard audiometry only at 2000 Hz and none between uHear in a typical environment and standard audiometry. The summary of results of the Bland–Altman plots are shown in Table 5.

The results of the Pearson correlation between standard audiometry and uHear in both environments are shown in Table 6. The correlations

TABLE 5 Summary of results of the Bland–Altman plot with a Minimal Clinical Meaningful Difference of 10 dB between the standard audiometry and the uHear application

	Frequency				
Test	500 Hz	1000 Hz	2000 Hz	4000 Hz	6000 Hz
uHear in soundproof booth, *n* (%)	89 (85.58)	75 (72.12)	100 (96.15)	89 (85.58)	80 (76.92)
uHear in typical environment, *n* (%)	22 (21.15)	31 (29.81)	79 (75.96)	88 (84.62)	84 (80.77)

Note: *n* is the number of ears that differences of value between uHear and the standard audiometry not more than 10 dB.

TABLE 6 The correlations between standard audiometry, uHear in soundproof booth, and uHear in typical hearing environment

	Correlation between Standard audiometry and uHear in the Soundproof booth			Correlation between Standard audiometry and uHear in typical hearing environment		
Hearing level (dB)	*r*	95%CI	*p*[a]	*r*	95%CI	*p*[a]
500 Hz	0.698	(0.583–0.785)	<.001	0.404	(0.228–0.554)	<.001
1000 Hz	0.843	(0.776–0.891)	<.001	0.535	(0.381–0.660)	<.001
2000 Hz	0.766	(0.672–0.836)	<.001	0.440	(0.269–0.584)	<.001
4000 Hz	0.811	(0.732–0.868)	<.001	0.799	(0.716–0.860)	<.001
6000 Hz	0.763	(0.669–0.834)	<.001	0.826	(0.752–0.879)	<.001

Note: *r* is the correlation coefficient.
[a]Pearson's correlation coefficient.

TABLE 7 Sensitivity and Specificity of the uHear in soundproof booth and typical hearing environment for hearing screening

	Sensitivity % (95% CI)	Specificity % (95% CI)	PPV (95% CI)	NPV (95% CI)
uHear in soundproof booth				
500 Hz	82.5 (73.4, 89.4)	85.7 (42.1, 99.6)	98.8 (93.3, 100)	26.1 (10.2, 48.4)
1000 Hz	92.6 (85.4, 97)	100 (66.4, 100)	100 (95.9, 100)	56.3 (29.9, 80.2)
2000 Hz	98.9 (94, 100)	71.4 (41.9, 91.6)	95.7 (89.4, 98.8)	90.9 (58.7, 99.8)
4000 Hz	98.8 (93.5, 100)	76.2 (52.8, 91.8)	94.3 (87.1, 98.1)	94.1 (71.3, 99.9)
6000 Hz	98.8 (93.6, 100)	57.9 (33.5, 79.7)	91.3 (83.6, 96.2)	91.7 (61.5, 99.8)
PTA	94.7 (88, 98.3)	90 (55.5, 99.7)	64.3 (35.1, 87.2)	98.9 (94, 100)
uHear in typical hearing environment				
500 Hz	17.5 (10.6, 26.6)	100 (59, 100)	100 (80.5, 100)	8.1 (3.3, 15.9)
1000 Hz	38.9 (29.1, 49.5)	100 (66.4, 100)	100 (90.5, 100)	13.4 (6.3, 24)
2000 Hz	78.9 (69, 86.8)	71.4 (41.9, 91.6)	94.7 (86.9, 98.5)	34.5 (17.9, 54.3)
4000 Hz	97.6 (91.6, 99.7)	76.2 (52.8, 91.8)	94.2 (87, 98.1)	88.9 (65.3, 98.6)
6000 Hz	97.6 (91.8, 99.7)	73.7 (48.8, 90.9)	94.3 (87.2, 98.1)	87.5 (61.7, 98.4)
PTA	34 (24.6, 44.5)	100 (69.2, 100)	13.9 (6.9, 24.1)	100 (89.1, 100)

Abbreviations: NPV, negative predictive value; PPV, positive predictive value; PTA, pure tone average (average of 500, 1000, and 2000 Hz).

between standard audiometry and uHear in a soundproof booth were moderately positive (*r* between 0.5 and 0.69) at 500 Hz and strongly positive (*r* between 0.7 and 0.9) at 1000, 2000, 4000, and 6000 Hz. The correlations between standard audiometry and uHear in a typical hearing environment were weakly positive (*r* between 0.3 and 0.49) at 500 and 2000 Hz, moderately positive (*r* between 0.5 and 0.69) at 1000 Hz, and strongly positive (*r* between 0.7 and 0.9) at 4000 and 6000 Hz.

When a hearing threshold of >25 dB was used as a cutoff point for hearing loss, uHear in a soundproof booth showed high sensitivity at all frequencies (500–6000 Hz) (82.5%–98.9%), high specificity at 500 and 1000 Hz (85.7%–100%), and high positive predictive values (PPV) (91.3%–100%). uHear in a typical hearing environment showed high sensitivity at 4000 and 6000 Hz (97.6%), high specificity at 500 and 1000 Hz (100%), and high PPVs (94.2%–100%). When considering PTA, uHear in a soundproof booth showed high sensitivity (94.7%) and specificity (90%), and uHear in a typical hearing environment showed poor sensitivity (34%) (100%) but high specificity (100%) (Table 7).

4 | DISCUSSION

This study excluded participants with known previous hearing problems, showing that 11.5% of the participants had hearing loss. These findings were similar to the result of Study 2 by Prasansuk S in 2000 (8.3%).[4] Subpopulation analysis revealed a significant difference in age between participants who had hearing loss and those who had normal hearing. However, no significant difference in sex was observed.

According to the results of the paired *t* test (Table 4), in our opinion, using the paired *t* test to analyze the hearing results may not accurately reflect the clinical usage of the test because some results of the paired *t* test showed no statistically significant difference between the tests, which were in contrast to the results of the Bland–Altman plot with an MCID of 10 dB, which showed no agreement between the tests (<95% of ears were in the agreement area of ±10 dB).

We used an MCID of 10 dB as the limit of agreement in the Bland–Altman plot instead of the standard limit of agreement (±1.96 SD) because it did reflect clinical use. For each frequency, it was inaccurate if the results from uHear were different from those from standard audiometry by >10 dB.

From the result of uHear in a soundproof booth, we found a strong correlation at 1000, 2000, 4000, and 6000 Hz from the Pearson correlation coefficient, high sensitivity, and specificity; the Bland–Altman plot with an MCID of 10 dB found agreement between uHear in a soundproof booth and standard audiometry at 2000 Hz. Thus, uHear in a soundproof booth was accurate for hearing screening at 2000 Hz. This result was similar to that of Abu-Ghanem et al.,[13] who reported that uHear's pure-tone thresholds in 26 elderly individuals were significantly different from audiometric thresholds at all frequencies, except for 2000 Hz.

From the results of uHear in a typical environment, we found a strong correlation at 4000 and 6000 Hz from the Pearson correlation coefficient and high sensitivity at 4000 Hz, 6000 Hz; the Bland–Altman plot with an MCID of 10 dB found no agreement between uHear in a typical environment and standard audiometry at all frequencies.

A study by Al-albri et al.[12] involving 70 students with normal hearing found that 64% of the students had hearing loss using uHear in a side room. They concluded that uHear was highly unreliable in providing exact hearing thresholds in clinical settings.

Szudek et al.[11] examined 100 adults who were tested using uHear in a soundproof room and showed a sensitivity of 100% (95% confidence interval [CI] = 92%–100%), a specificity of 90% (95% CI = 83%–94%), and a positive likelihood ratio of 9.7 (95% CI = 6–15). Moreover, uHear in clinical settings (ambient noise level < 50 dBA-weighted sound pressure level) showed a sensitivity of 98% (95% CI = 89%–100%), a specificity of 82% (95% CI = 75%–88%), and a positive likelihood ratio of 5.5 (95% CI = 4.2–6.2). Abu-Ghanem et al.[13] examined 26 elderly in a quiet room (ambient noise level < 50 dBA-weighted sound pressure level) and found a sensitivity of 100% and a specificity of 60%. The sensitivity and specificity in the aforementioned studies[11,13] were different from our results (poor sensitivity and high specificity). These may be explained by different settings (i.e., frequencies for calculating the PTA, criteria to calculate sensitivity and specificity, iPad vs. iPod, type of earphones, and environments).

From the Bland–Altman plot, we found that uHear was more accurate at mid and high frequencies than at low frequencies. This was similar to the results of previous studies.[11,12,14,15] In this study, at low frequencies, uHear in a soundproof booth was more accurate and more sensitive than uHear in a typical environment.

The Bland–Altman plot revealed that uHear in a soundproof booth was accurate at 2000 Hz, whereas, in a typical environment, uHear was inaccurate at all frequencies. However, at 4000 Hz, uHear had similar accuracy (85.58% vs. 84.62%) in both environments, and at 6000 Hz, uHear in a typical environment was more accurate than that in a soundproof booth (80.77% vs. 76.92%). This may be caused by the sequence of the tests (starting with standard audiometry, uHear in a soundproof booth, and then uHear in a typical environment), which made the participants more familiar with uHear when they were tested in a typical environment.

The noise in a typical environment was from the air conditioning that was mostly low to middle frequency. Thus, the noise may not affect testing at high frequencies (4000 and 6000 Hz). However, it affected tests at low and middle frequencies (500, 1000, and 2000 Hz). This noise caused uHear in a typical environment to have poorer accuracy than that in a soundproof booth at 500, 1000, and 2000 Hz.

We used Apple's EarPods with a 3.5-mm Headphone Plug because it is easy to provide across the country. However, this type of earphone cannot be fitted to every participant's ear canal. Therefore, the participants may have been confounded by the noise during testing outside a soundproof booth. This may cause poor sensitivity of uHear testing in a typical environment. These results differed from the study by Barczik J and Serpanos YC,[14] who found that uHear had high sensitivity (90%–94%) and specificity (88.5%–100%) using earbud earphones. Another limitation of the uHear application is that it cannot test at 8000 Hz.

This study has some limitations. Our participants were predominantly women. Thus, the results may not be generalizable to the population at large. The participants did not have a washout period between each test, and having the same sequence of testing made them more familiar with uHear when they were tested in a typical environment. The noise in a typical hearing environment was not measured during the test; therefore, whether the noise increased or other noises were present other than the air conditioning was unknown. Moreover, the results of the tests in our typical environment may not be applicable to tests performed in environments outside the clinic space because each area has different noises. When using uHear outside soundproof booths or clinic spaces, noises in these environments may differ from those in our typical environment. The results of the tests performed in a typical environment may not be applicable to tests performed in other environments.

uHear is a portable self-testing application. It is easy to use and requires only a smartphone and earphones. Thus, it can be used in situations where standard audiometry is unavailable, for example, rural areas, individuals in quarantine, and situations that need a portable screening tool. However, uHear still has some limitations. When testing outside a soundproof booth, uHear was not accurate enough to measure the exact hearing threshold as standard audiometry. Providers should be cautious in interpreting the results from uHear. uHear is not a substitute for standard audiometry.

Future studies should enroll participants with various levels of hearing impairment and perform tests in different environments. Multicenter studies across the country are also needed to validate the uHear application before it can be adopted for nationwide use.

5 | CONCLUSION

uHear was accurate for hearing loss screening at 2000 Hz in a soundproof booth. uHear in a typical environment was inaccurate. uHear in a soundproof booth could be used for screening hearing loss in some situations before being confirmed by standard audiometry. Providers should be cautious in interpreting the results from uHear, and it is not a substitute for standard audiometry. Further research is needed.

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