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Research Article

Comparison of Audiometric Findings with Internet-based Hearing Screening Tests and the Relationship with Other Associated Factors in Adults

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Abstract

Hearing loss is one of the most challenging problems confronting medicine since it may affect the personality so adversely that it can lower someone's quality of life. The aim of the study is to establish the validity of internet based hearing test. The hearing status of adults was evaluated by comparing audiometric findings and internet-based hearing screening test along with questionnaires to assess the potential risk factors associated with hearing loss. This cross-sectional study included 256 participants (18 to 40 years of both genders) by simple random sampling method, of which 245 had completed all the procedures. The study was carried out by using Pure Tone Audiometry (PTA), two internet-based speech-in-noise tests: internet test 1 (HearCom Digit Triplet Test offered by MED-EL) and internet test 2 (Speech in Noise Test by National Health Service) and survey questionnaires. Descriptive statistics and Pearson Chi-Square test was used to analyze the data. All presentations and data evaluations were carried out by using SPSS version 21.0. The prevalence of hearing loss was 26.1% with PTA; 5.3% with internet test 1 and 47.3% with internet test 2. Among two internet-based hearing screening tests, internet test 1 is significantly correlated with PTA averages ($p < 0.05$, 2-tailed) and the correlation coefficients showed weak association between the different tests. The study showed a significant correlation between audiograms and internet-based hearing tests and significant differences with associated factors as evaluated by using an extensive questionnaire. This study suggests that internet-based hearing test is feasible to screen for hearing status online and the data are of great value in applications and for advanced studies. Though an internet-based hearing test cannot replace a clinical pure-tone audiogram, it is a feasible screening tool for hearing ability in a large-scale population.

Keywords: Internet Based Hearing Test; Audiometry; Hearing Loss; Noise; Pure Tone; Speech

Introduction

According to WHO global estimates there is a high prevalence of hearing loss in the Asia-Pacific region. Around 466 million people worldwide have disabling hearing loss and 34 million of these are children and it was estimated that by 2050 over 900 million people will have disabling hearing loss [1]. The 2017 World Health Assembly announced their resolution to prevent deafness and hearing loss and device strategies for improved service provision, especially in low and middle income countries [2]. However, the prevalence of hearing loss in Malaysia seems to be more than the WHO estimate. There are many reports of hearing studies conducted in Malaysia. One of the cross-sectional studies conducted at six quarries in a north-eastern state of Malaysia assessed the knowledge, attitude and practice towards noise-induced hearing loss. Poor knowledge, attitude and practice scores of the respondents and a high prevalence of noise-induced hearing loss (57%) was shown to be contributed by factors such as poor practice towards noise level and old age [3,4]. Early hearing effects related to Personal Listening Device (PLD) usage were evaluated in 35 young adult Malaysian PLD users (aged 18-30 years). This study used extended high-frequency audiometry and otoacoustic emissions and results indicated the presence of an early stage of hearing damage in the PLD user group [5]. Smartphone applications are used as a measurement tool in recent days for hearing test and the two broad categories are clinical (medically regulated) and consumer apps [6].

Recent study based on mobile based approach of screening test reported that smartphone-based self-hearing test demonstrated high concordance with conventional PTA in a sound-treated booth among school children [7]. A study conducted on grade five school children in Malaysia showed 15% prevalence of mild hearing loss among 257 primary school children [8]. As this problem could affect their academic performance, they have highly recommended the assessment of hearing on every child especially to those who have poor academic achievement. High prevalence of hearing loss was found in both adults and children pointed out that hearing screening should routinely be carried out.

Hearing impairment is most accurately measured by a clinical pure-tone audiogram but this method is not suitable for large-scale, population-based epidemiological studies because it requires trained personnel as well as the participants should visit a clinic. An alternative approach to measuring hearing ability is self-estimation through questionnaires but the correlation of questionnaires to clinical audiometric tests is different.

With advances in computer technology, low-cost computer-based hearing screening test has been developed. The evolutions of eHealth and telemedicine have shifted focus from patients coming to the hearing clinic for hearing health evaluation towards the possibility of evaluating the hearing status remotely at home. A quick-automated self-test to detect hearing loss is highly advantageous for large-scale population. For gross hearing status evaluation, internet-based hearing screening tests are valid, reliable and an alternative to Pure Tone Audiometry (PTA). Thus, this study was conducted to determine hearing status in adults comparing the audiometric findings with internet-based hearing screening test. To date, there are no known reports on the comparison of PTA with internet based hearing screening test in Malaysia. The study was therefore to compare the results of hearing status in adults by using PTA with that of online internet-based hearing tests. In addition, the potential risk factors associated with hearing loss were assessed by using questionnaires. The main objective is to compare the results obtained with audiometer and internet-based hearing screening test on hearing status of adults.

Subjects and Methods

This cross-sectional study was conducted at the Physiology Laboratory of a private Malaysian University with ethical approval. This study involved 256 participants aged between 18 to 40 years (both male and female) by simple random sampling method. A portable pure tone screening audiometer (model Maico MA 39, USA) was used for hearing screening. Two internet based hearing screening tests are internet test 1 (HearCom Digit Triplet Test) and internet test 2 (Speech in Noise Test by National Health Service). In this study, two sets of questionnaires (Likert Scale) were used. One questionnaire consisted of 36 questions concerning sociodemographi, past medical history and exposure to noise, and the other questionnaire "Youth Attitude to Noise Scale" (YANS) which consisted of 19 questions [9].

Visual examination of the ear canal was conducted by the investigator to ensure normal anatomy and no presence of debris. The average hearing threshold levels of the total study population was analysed. To simplify the results, hearing loss was evaluated using pure-tone averages calculated for 0.5, 1, 2 and 4 kHz ($PTA_{0.5,1,2,4}$) and for the noise-sensitive frequencies 3, 4 and 6 kHz ($PTA_{3,4,6}$).

Statistical analyses

Descriptive statistics was used to examine the collected data in terms of mean, standard deviation and frequencies. Simple random sampling and a total of 256 participants included in the data analyses. The Pearson Chi-Square test was used to determine the age and gender and for specific comparisons between the audiometric findings and internet-based hearing screening results. Bivariate correlation coefficients was tested by using Spearman's rho for internet-based hearing screening test and PTA-values. Error bars in the graph represents standard deviation. All presentations and data evaluations were carried out by using SPSS version 21.0.

Results

A total of 256 participants aged between 18-40 years (mean age 21.5 ± 4.6) had participated in the study, however, only 245 (95.7%) completed all the steps. Among 245 participants (104 males and 141 females), 220 were students (89.8%) and the rest were staffs (10.2%). Distribution and association between age groups and gender of participants (p = 0.083) are showed in table 1. Participants with different ethnicity were not evenly distributed in different age groups yielding no gender difference in all groups (p=0.08). Data of personal habits, medical history and exposure to noise data were summarized using descriptive statistics. Socio-demographic profiles of 245 participants showed that most of them i.e. 63.7% were Chinese followed by Indians, Malay and others (25.7%, 6.9% and 3.7% respectively). Mean age was 21.5 ± 4.6 (104 males, 141 females). While a few (4.1%) had a history of smoking and drinking alcohol (10.6%), none of them had any history of drug abuse and 4.1% had a past history of ear problem.

Results of the YANS were divided into three categories based on the quartiles of the sum of the entire YANS scale. The 25% of the sample in the lower quartile (0.0000_2.8420) were individuals who could be characterized as having an anti-noise attitude. 50% of the sample in the two middle quartiles (2.8421_3.5262) were characterized as having a neutral attitude, whereas the remaining 25% in the upper quartile (3.5263_5.0000) had pro-noise attitudes. Regarding the internal reliability of YANS questionnaire, Cronbach's alpha for the entire scale was 0.533. F1 showed the highest Cronbach's alpha (0.716), which consistently decreased throughout the other factors (F2, F3, F4). In table 2, mean and correlations between the factors and the entire scale are presented along with Cronbach's alpha.

Description	Age group			Total
Gender	I (≤ 20 years)	II (21 – 30 years)	III (31 – 40 years)	
Male	62	31	11	104
Female	103	27	11	141
Total	165	58	22	245

Table 1: Distribution and association between age groups and gender of participants.

Pearson Chi-Square = 4.990(2), p = 0.083.

Items	F1(19,18,13,15,3,12)	F2(9,4,1,10,6,8)	F3(17,11,14,16)	F4(7,5,2)	YANS (integer)
F1(19,18,13,15,3,12)	1	-	-	-	-
F2(9,4,1,10,6,8)	-.051	1	-	-	-
F3(17,11,14,16)	-.066	0.309**	1	-	-
F4(7,5,2)	0.040	0.110	0.250**	1	-
YANS(integer)	0.533**	0.581**	0.608**	0.527**	1
Mean	2.50	2.75	2.64	2.82	2.65
Cronbach's alpha	0.716	0.597	0.584	0.408	0.533
**. Correlation is significant at the 0.01 level (2-tailed)					

Table 2: Correlations between the factors and the entire YANS, Mean and Cronbach's alpha for each factor and the entire instrument.

Results of the pure tone audiograms were divided into normal, minor, moderate and severe hearing loss according to the definition by WHO [10] as shown in table 3. For the comparison with internet-based hearing screening (speech-in-noise) tests, the pure tone averages were grouped into $PTA_{0.5,1,2,4}$ (important for speech intelligibility) and $PTA_{3,4,6}$ (noise-sensitive frequencies). PTA results for each groups are calculated. Internet test 1 (HearCom digit triplet test offered by MED-EL) results showed 232 out of 245 (94.7%) normal, 5 out of 245 (2%) may be below normal and 8 out of 245 (3.3%) below normal. Internet test 2 (offered by NHS) results showed 129 out of 245 (52.7%) normal, 98 out of 245 (40%) little below normal and 18 out of 245 (7.3%) below normal. Comparison results of the internet test 1 and test 2 showed statistically significant differences between normal and hearing loss ($p < 0.05$). Internet-based hearing tests were compared with pure-tone thresholds. The pure-tone thresholds $PTA_{0.5,1,2,4}$ (important for speech intelligibility) and $PTA_{3,4,6}$ (noise-sensitive frequencies) were used to compare with the internet-based hearing tests. In table 4, Chi-square test showed no statistical difference of internet test 1 between age group and $PTA_{3,4,6}$. ($\chi^2 = 0.417(2)$, $p = 0.812$). In $PTA_{0.5,1,2,4}$, 228 had normal and 17 had hearing loss while 232 showed normal and 13 showed hearing loss on the internet test 1. The Chi-Square test showed no statistical difference between internet test 1 and $PTA_{0.5,1,2,4}$ for different age groups. ($\chi^2 = 3.918(2)$, $p = 0.141$). Results of the hearing test with pure tone audiogram ($PTA_{0.5,1,2,4}$ and $PTA_{3,4,6}$) in comparison to the internet test 2 for age groups are shown in table 4 and table 5 respectively. Mean audiogram of left and right ears for specific age group are displayed in figures 1-6.

	Frequency (%)
Normal	181 (73.9%)
Minor Hearing loss	61 (24.9%)
Moderate Hearing loss	2 (0.8%)
Severe Hearing loss	1 (0/4%)
Total	245 (100%)

Table 3: Number and percentage of hearing loss according to WHO classification (0.125,0.25,0.5,1,2,3,4,6,8 kHz).

Description Normal Hearing loss			Internet test1 $PTA_{3,4,6}$		Total Hearing loss	Internet test2 $PTA_{0.5,1,2,4}$		Total
				Normal				
Normal	Age group (years)	I (≤ 20)	149	9	158	78	9	87
		II (21 - 30)	54	2	56	37	0	37
		III (31 - 40)	16	2	18	5	0	5
	Total		219	13	232	120	9	129
	Pearson Chi-Square		1.472[a]	2	0.479	4.671[a]	2	0.097
Hearing loss	Age group (years)	I (≤ 20)	5	2	7	72	6	78
		II (21 - 30)	1	1	2	19	2	21
		III (31 - 40)	4	0	4	17	0	17
	Total		10	3	13	108	8	116
	Pearson Chi-Square		2.136[b]	2	0.344	1.562[b]	2	0.458
Total	Age group (years)	I (≤ 20)	154	11	165	150	15	165
		II (21 - 30)	55	3	58	22	0	22
		III (31 - 40)	20	2	22	228	17	245
	Total		229	16	245	3.918[c]	2	0.141

Table 4: Comparative table of $PTA_{3,4,6}$ and Internet test 1 and 2 for age groups.

Internet test 2 Normal Hearing loss			$PTA_{3,4,6}$		Total
Normal	Age group (years)	I (≤ 20)	80	7	87
		II (21 - 30)	35	2	37
		III (31 - 40)	5	0	5
	Total		120	9	129
	Pearson Chi-Square		0.669[a]	2	0.716
Hearing loss	Age group (years)	I (≤ 20)	74	4	78
		II (21 - 30)	20	1	21
		III (31 - 40)	15	3	17
	Total		109	8	116
	Pearson Chi-Square		1.157[b]	2	0.561
Total	Age group (years)	I (≤ 20)	154	11	165
		II (21 - 30)	55	3	58
		III (31 - 40)	20	3	22
	Total		229	17	245
	Pearson Chi-Square		0.417[c]	2	0.812

Table 5: Comparative table of $PTA_{3,4,6}$ and Internet test 2 for age groups.

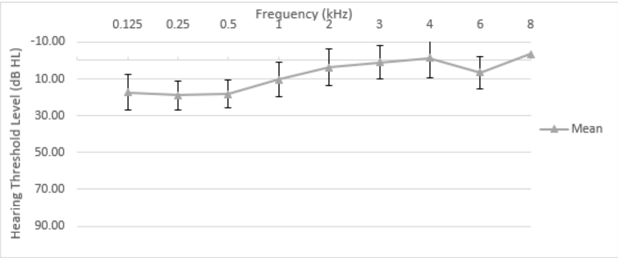

Figure 1: Audiometric thresholds of the left ears (LE) for the age group I (≤20 years). (Error bars represent standard deviation)

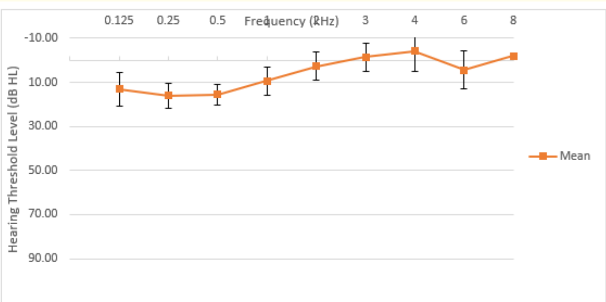

Figure 2: Audiometric thresholds of the right ears (RE) for the age group I (≤20 years). (Error bars represent standard deviation)

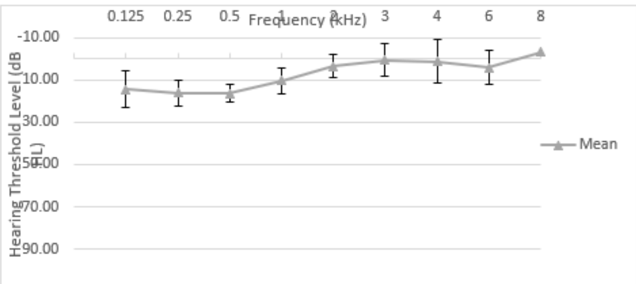

Figure 3: Audiometric thresholds of the left ears (LE) for the age group II (21-30 years). (Error bars represent standard deviation)

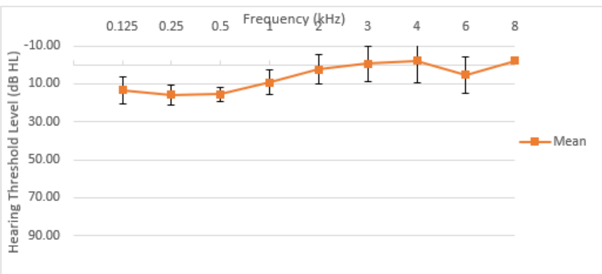

Figure 4: Audiometric thresholds of the right ears (RE) for the age group II (21-30 years). (Error bars represent standard deviation)

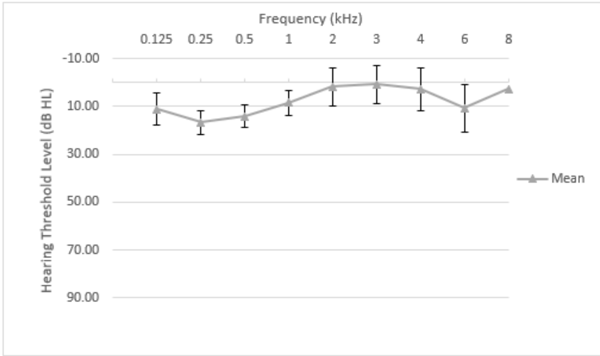

Figure 5: Audiometric thresholds of the left ears (LE) for the age group III (31-40 years). (Error bars represent standard deviation)

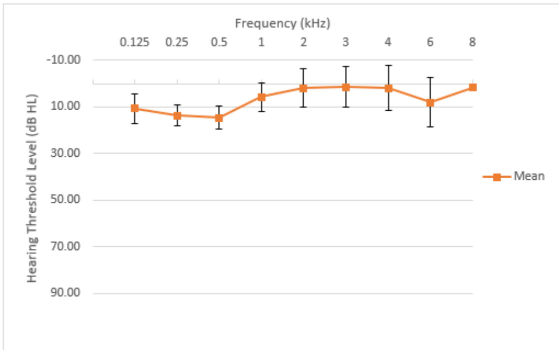

Figure 6: Audiometric thresholds of the right ears (RE) for the age group III (31-40 years). (Error bars represent standard deviation).

Results of the hearing test with pure tone audiogram ($PTA_{0.5,1,2,4}$ and $PTA_{3,4,6}$) in comparison to the internet test 1 for gender is shown in table 6 and table 7 respectively. In $PTA_{0.5,1,2,4}$, 228 had normal hearing and 17 had hearing loss while 232 showed normal hearing and 13 showed hearing loss with the internet test 1. The Chi-Square test showed no statistical difference between internet test 1 and $PTA_{0.5,1,2,4}$ for gender. (Fisher's exact test, p = 0.129). In $PTA_{3,4,6}$, 229 had normal and 16 had hearing loss while 232 showed normal and 13 showed hearing loss on the internet test 1. For gender, Chi-square test showed no statistical difference between internet test 1 and $PTA_{3,4,6}$ in table 7. (Fisher's exact test, p = 0.605). Results of the hearing test with pure tone audiogram ($PTA_{0.5,1,2,4}$ and $PTA_{3,4,6}$) in comparison to the internet test 2 for gender showed that 129 was normal and 116 had hearing loss. Thus, internet test 2 showed higher percentage of hearing loss than PTA and internet test 1. The Chi-square test showed no statistical difference between internet test 2 and $PTA_{0.5,1,2,4}$ for gender. (Fisher's exact test, p = 0.129).

Comparison of $PTA_{3,4,6}$ with internet test 2 showed 129 normal and 116 hearing loss. The χ^2 test showed no statistical difference of genders between internet test 2 and $PTA_{3,4,6}$ in table 7. (Fisher's exact test, p = 0.605).

Internet test 1 Normal Hearing loss			$PTA_{0.5,1,2,4}$		Total
Normal	Gender	Male	93	3	96
		Female	125	11	136
	Total		218	14	232
	Fisher's Exact Test		0.163		
Hearing loss	Gender	Male	7	1	8
		Female	3	2	5
	Total		10	3	13
	Fisher's Exact Test		0.510		
Total	Gender	Male	100	4	104
		Female	128	13	141
	Total		228	17	245
	Fisher's Exact Test		0.129		

Table 6: PTA $_{05,1,2,4}$ Vs Internet test 1.

Description $PTA_{3,4,6}$ Normal Hearing loss			Internet test 1			Internet test 2		
			To-tal	$PTA_{3,4,6}$				
				Nor-mal	Hear-ing Loss	To-tal		
Nor-mal	Gen-der	Male	89	7	96	55	3	58
		Female	130	6	136	65	6	71
	Total		219	13	232	120	9	129
	Fisher's Exact Test		0.393			0.513		
Hear-ing loss	Gen-der	Male	7	1	8	40	6	46
		Female	3	2	5	68	2	70
	Total		10	3	13	109	8	116
	Fisher's Exact Test		0.510			0.112		
Total	Gen-der	Male	96	8	104	96	9	104
		Female	133	8	141	133	8	141
	Total		229	16	245	229	17	245
	Fisher's Exact Test		0.605			0.605		

Table 7: PTA $_{3,4,6}$ Vs Internet test 1 and 2.

Other associated factors (personal habits, medical history and exposure to noise) were measured using the questionnaire and Chi-square test was done to find the relationship between two categorical variables. Personal habits (alcohol drinking, regular physical activity, performed hearing screening test) showed no significant difference between normal and hearing loss in both PTA and internet-based hearing screening test. The relationship between PTA and internet-based hearing screening test for drug abuse was not available because there were no subjects with drug abuse in this study. The Chi-square test showed that internet test 2 showed statistically significant difference with $PTA_{3,4,6}$ among smoking and hearing loss (p = 0.018) as shown in table 8. Participants with medical history of diabetes and hypertension were very few in the study. Therefore, Chi-square test could not be used for these parameters. In table 8, normal hearing with internet test 2 showed significant difference with normal hearing with $PTA_{3,4,6}$ (ear use for mobile phone).

		$PTA_{0.5,1,2,4}$	$PTA_{3,4,6}$	Inter-net (1)	Inter-net (2)
Total Hearing Loss		**17**	**16**	**13**	**116**
Smoking	Yes	1	2	0	4
	No	16	14	13	112
	p	0.018*			
Years of mobile phone using	1 - 5 years	1	5	3	38
	6 - 10 years	15	8	4	51
	>10 years	1	3	6	27
	p	0.012*			
Ear use for mobile phone	Left	3	5	1	26
	Right	13	7	11	67
	No prefer-ence	1	4	1	23
	p	0.027*			
Duration of tin-nitus	No	15	14	11	106
	Occasion-ally	0	1	1	2
	Sometimes	1	1	1	5
	Most of the times	1	0	0	3
	p	0.019*			

Table 8: Significant findings between PTA averages and internet-based hearing screening tests.

Validity of the internet-based hearing test was related to the correlation between the results of the hearing tests and other parameters of study. The p-value for the Fisher's exact test revealed statistically significant difference (p = 0.05) between normal and hearing loss for internet test 1 and $PTA_{0.5,1,2,4}$. For internet test 1 and $PTA_{3,4,6}$, the p-value for the Fisher's exact test revealed statistically significant difference (p = 0.04) between normal and hearing loss, shown in table 9. The Chi-square test showed no statistically significant difference between normal and hearing loss for internet test 2, shown in table 9.

Internet Test	Internet Test 1		Internet Test 2		Internet Test 2	
PTA	$PTA_{3,4,6}$		$PTA_{0.5,1,2,4}$		$PTA_{3,4,6}$	
	Normal	Hearing loss	Normal	Hearing loss	Normal	Hearing loss
Normal	219	3	120	9	120	9
Hearing loss	10	13	108	8	109	7
Total	229	16	228	17	229	16
Fisher's Exact Test	p = 0.04		p = 1.000		p = 0.80	

Table 9: Comparison of internet test 1, 2 and $PTA_{3,4,6}$ and $PTA_{0.5,1,2,4}$.

In addition, the relationship of the two internet-based hearing tests (speech-in-noise test) and pure-tone thresholds were assessed. Non-parametric Spearman correlation coefficients between the different internet-based hearing tests were calculated. Table 10 showed the correlation coefficients of internet-based hearing test (internet test 1 and test 2) and the pure-tone averages $PTA_{0.5,1,2,4}$ (important for speech intelligibility) and $PTA_{3,4,6}$ (noise-sensitive frequencies). The correlation between internet test 1 results and PTA were all statistically significant ($p<0.05$) and showed different degrees of association as shown in table 10. However, internet test 2 results and PTA showed no significant association. Sensitivity and specificity of the internet test in relation to PTA was calculated and internet test 1 showed higher sensitivity and specificity than internet test 2 and the results are shown in table 11.

Spearman's rho	Internet test 1 MED-EL	Internet test 2 NHS	$PTA_{0.5,1,2,4}$	$PTA_{3,4,6}$
Internet test 1 MED-EL	-	0.177**	0.150*	0.159*
Internet test 2 NHS	0.177**	-	0.002	0.019
$PTA_{0.5,1,2,4}$	0.150*	0.002	-	0.188**
$PTA_{3,4,6}$	0.159*	0.019	0.188**	-

Table 10: Bivariate correlation coefficients (Spearman's rho) for internet-based hearing screening test and PTA-values.

*., **. Correlation is significant at the 0.05 and 0.01 level (2-tailed) respectively.

PTA	Internet test	Sensitivity	Specificity
$PTA_{0.5,1,2,4}$	Test 1	82.4%	95.6%
	Test 2	47.0%	52.6%
$PTA_{3,4,6}$	Test 1	81.3%	95.6%
	Test 2	43.8%	52.4%

Table 11: Sensitivity and specificity of internet-based hearing screening tests in relation to pure-tone averages ($PTA_{0.5,1,2,4}$ and $PTA_{3,4,6}$).

PTA results of hearing threshold frequency from 125 to 8000 Hz showed almost three-fourths of the study participants had no hearing loss. Total percentage of hearing loss (minor, moderate and severe) was 26.1%. When findings of PTA averages and results of internet-based hearing screening tests (internet test 1 and 2) were compared, there was no difference between hearing status and socio-demographic characteristics and hearing tests ($p > 0.1$). However, the Chi-square test showed this difference to be statistically significant ($p < 0.05$) between internet test and PTA for other factors such as hearing loss among ethnicity, Hearing loss Vs Past history of ear problem, Hearing loss Vs Number of years using mobile phone and, Normal hearing Vs Ear using mobile phone. Non-parametric Spearman correlation coefficients was calculated for the relationship between internet-based hearing screening test (internet test 1 and 2) and PTA averages ($PTA_{0.5,1,2,4}$ and $PTA_{3,4,6}$). A significant correlation existed between PTA and internet test 1 results but it was not significant for internet test 2 (Table 10). More than half of the participants had been using a mobile phone for ≥ 2 hours per day for more than 5 years. Only 8.2% of them had tinnitus associated with mobile/headphone use revealing a significant difference both on PTA and internet test 1 (p = 0.019) (Table 8). YANS was employed to assess the participant's attitudes to noise exposure. Factor analysis revealed the four main attributing factors: (F1) noise associated with youth culture (e.g. loud music at concerts or discos); (F2) ability to concentrate in a noisy environment; (F3) daily noises (e.g. traffic noise); (F4) influencing the sound environment. While half of them showed neutral attitude, 25% had pro-noise and the remaining 25% had anti-noise attitude according to the quartiles of the sum of the entire YANS scale. The comparative findings of present study showed that result of the internet test 1 was more comparable to PTA averages than internet test 2.

Discussion

Prevalence of hypoacusis among participants were reported using pure tone audiogram (PTA) at 125, 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz, 64 out of 245 (26.1%) had hearing loss. Of these 61 (24.9%) had minor hearing loss, 2 (0.8%) had moderate, and 1 (0.4%) had severe hearing loss, according to the definition by WHO classification of hearing loss [11]. This suggests a subset of the current subjects had hearing loss that they were not aware of. Since, the present study included the participants with self-reporting normal hearing sensitivity. This is similar to that found by Widén *et al* who reported a 26% referral rate from a college-aged student sample (258 American undergraduates) using a 20 dB HL pass criterion at 0.5, 1, 2, 4 and 6 kHz [12]. Similar sub-clinical deficits of hearing loss in normal young individuals were observed in the previous reports [13,14].The present study showed 26.1% hearing loss with PTA at cut-off level of 25 dB. By using PTA at a cut-off level of 25 dB, the prevalence of hearing loss was 24.3% among elderly Malaysians which is consistent with our PTA results [15]. The prevalence of hearing loss in Malaysia remains more than the WHO estimate. Nevertheless, the current study measured the hearing status of young population (18 - 40 years) and compared the audiometric findings to internet-based hearing screening test. The DTT (digit triplet test) using a signal-in noise rationale is the most documented telephone/internet based test. Smartphone applets are the latest trend in platforms for hearing screening [16].

Present study of internet-based hearing screening test showed 5.3% hearing loss with internet test 1 and 47.3% hearing loss with internet test 2. Using the conventional screening (PTA), as a gold standard, the specificity of the internet-based hearing screening test was low, based on the overall screening data. When 125 and 250 Hz results were excluded, the specificity of the internet test improved in value. Taking a 25 dB hearing loss (HL) as a baseline average, by PTA for frequencies at 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz, the prevalence of hearing loss among participants was reduced to 11.8%. This figure is in agreement with internet-based hearing screening test. This is consistent with the previous comparison study of computer-based and conventional audiometry in school children [17].

In the previous study of internet-based hearing test with study population (20-60 years) with high exposure to impulse noise, showed high prevalence (52%) of hearing impairment [18]. Although our result from the internet-based hearing screening test 2 showed a prevalence of 47.6% hearing loss, which indicates high prevalence for aged between 18 to 40 years. Since the present study population is not an excessive noise exposure group, the prevalence of hearing loss with internet test 2 seems to be higher, probably due to the lower sensitivity and specificity of the internet test 2 (Table 11).

For speech intelligibility ($PTA_{0.5,1,2,4}$) and noise-sensitive frequencies ($PTA_{3,4,6}$), internet-based screening test 1 was comparable to the conventional screening instrument (Table 9). Previous study reported the difference between speech intelligibility of participants with noise-induced hearing loss and normal hearing [19]. The results of present comparison study revealed that internet-based hearing screening (speech-in-noise) test differentiated between normal hearing and hearing loss. The internet test 1 proves to yield reliable results. The internet test 2 was not strongly related to pure-tone thresholds, whereas PTA gives accurate hearing threshold result for each frequency. In the present study, there was no difference in normal-hearing and hearing loss with respect to age that is contrary to the previous studies [20].

Earlier report by Plomp and Mimpen observed that the hearing loss subjects had a mean age of 56 years [21]. This corresponds to a median speech reception threshold (SRT) of only 1 dB poorer than the median SRT for the young normal-hearing subjects. Age range of current study participants was between 18 to 40 years. Poor speech-in-noise recognition was rare in this age range.

In the present study, the correlation coefficients (Spearman's rho) of test validity for internet-based hearing screening test are 0.150 - 0.159 for internet test 1 and 0.002 - 0.019 for internet test 2 (Table 10). Previous studies done in Netherland using Dutch language reported moderately high correlation coefficients of 0.72 - 0.84 between results of the speech-in-noise test and pure-tone averages for normal hearing and hearing-impaired listeners [22]. The findings of Leensen *et al*[19] showed similar correlations; r is 0.82 comparing the results of the speech-in-noise test with PTA averages ($PTA_{0.5,1,2,4}$ and $PTA_{2,4}$). Although the correlation coefficients between results of each internet test and PTA averages (both $PTA_{0.5,1,2,4}$ and $PTA_{3,4,6}$) of the present study was low, all the correlations between internet test 1 and PTA-averages were statistically significant (Table 10). Lower correlation coefficient in the present study is probably due to English version of the speech-in-noise tests and it was done on bilingual Malaysian adults who acquired English as a second language.

Sensitivity and specificity of the internet test 1 are ~ 81% and 95.6% respectively, which is higher than the previous study of speech-in-noise test (a Digit Triplet test) in which specifically in noise-exposed workers was investigated by Leensen *et al* and reported sensitivity and specificity values of 55% and 94%, respectively [20]. The reason for these rather weak results may be due to the stimuli that were employed.

Statistical significance was found among the underlying factors (personal habits, exposure to noise, tinnitus and attitudes towards noise) with audiometric findings and/or internet-based hearing screening tests. Several factors might have contributed to this outcome. A weak but significant association between smoking and hearing loss in the elderly has been reported previously [23]. The effect was only found in males, not in females, suggesting that the effect of smoking was sex-dependent. In the current study, we could not find the effect of gender and smoking on hearing status as there were no female smokers among the study participants. Personal habits (alcohol drinking, regular physical activity) had no significant difference between normal and hearing loss in both PTA and internet-based hearing screening test.

For the exposure to noise, there was association of the number of years using mobile phone and duration of tinnitus between normal and hearing loss (Table 8). Duration of use of mobile phone with respect to number of years and internet test 2 showed statistically significant difference with $PTA_{0.5,1,2,4}$ in hearing loss (Table 8). Many earlier reports have suggested that exposure to mobile phone microwaves has no influence on the activity of cochlear outer hair cells or of cochlear nerve electrical conduction, both in vivo and *in vitro* [24-26]. But, our results from the internet test 2 showed statistically significant difference with $PTA_{3,4,6}$ in normal hearing group (ear use for mobile phone). For internet test 1, the Chi-square test showed statistically significant difference between $PTA_{0.5,1,2,4}$ and normal hearing in variable group (the number of years using mobile phone) ($p = 0.012$) which is in correlation with the previous study [27]. Since only PTA measurements were done on normal-hearing subjects in the present study, it is not possible to conclude at this stage whether the cochlea of subjects with inner ear conditions would be more sensitive to mobile phone electromagnetic radiation.

In this study, participants had self-reported normal hearing. According to the research questionnaire, prevalence of tinnitus (ringing in the ear) after mobile/headphone use was found in 20 participants of the study (8.2%) and among them, most had tinnitus sometimes (4.5%), 2% had occasionally, and 2.9% had tinnitus most of the times after using the mobile phone. None of our subjects reported permanent tinnitus. The percentage of observed tinnitus in the present study is comparable to other studies [9,11].

The YANS questionnaire has been used in many countries, including Sweden, USA, China and Brazil [28-30]. To the best of our knowledge, the present study reports the first adaption of YANS for Malaysian population. The current study indicates that the Bahasa Melayu version of YANS is valid and reliable (Cronbach's alpha general = 0.533) (Table 11), lower than the earlier results in USA (0.82) and Brazil (0.75) [28,29]. The distribution of factors in our factorial analysis differs slightly from previously published YANS studies. Notably, the mean overall YANS score (2.65) in our study was lower than Belgium (3.10), Brazil (2.80) and China (3.46) but higher than Sweden (2.10) [9,28,30,32]. Overall mean YANS score showed most of our study participants had positive attitude towards noise. This study indicates that the lesser validity and reliability of Bahasa Melayu version of YANS (Cronbach's alpha general = 0.533), compared to other study results. The possible reason for this may be due to sample size. Since there were more women than men in our study, the difference between average YANS scores of both genders was not statistically significant, which is consistent with the results in Chinese [31,32].

Conclusion

With the results that has been obtained and analysed, there is evidence to support that the self-administered internet-based hearing screening test is approximately similar in comparison to the gold standard hearing assessment with PTA with high sensitivity and specificity with few limitations. Hearing health education must develop programs to educate youth on the potential implications of noise exposure. Hence, this study suggests internet-based hearing test as an alternative test to PTA is feasible to screen for hearing status online. Large-scale investigation is required to compare the internet-based hearing screening test among normal-hearing and hearing impaired individual in various age-groups with measured speech recognition threshold (SRT) to confirm our findings and further to explore the significance of additional findings. Test-retest of YANS questionnaire considered as a screening instrument for identifying individuals who might be at risk for developing hearing damage would be a task for future research.

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Conflict of Interest

Authors declare no conflicts of interest.

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