Bluetooth versus non- Bluetooth earphones and their potential harmful effect on hearing: a cross-sectional study conducted among undergraduate medical students, Saudi Arabia

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ABSTRACT

BACKGROUND

The use of Bluetooth and non- Bluetooth earphones is increasing worldwide. Improper use of these devices is associated with a higher risk for hearing loss. The objective of this study was to determine the effect of use of Bluetooth and non -Bluetooth earphones on hearing function and to determine whether the combined use of both types have more negative impact on hearing or not.

METHODS

A cross-sectional study was conducted on 42 adult female students in medical college, Majmaah University. It included a questionnaire to evaluate earphone listening habits and pure -tone audiometry to assess hearing function. The data was analyzed using ANOVA and Chi-square tests to fulfill the objectives of the study.

RESULTS

Around 85.7 % of the students had hearing threshold ≥20 dB HL at one or more frequencies. Left ears were more affected than right ears. Hearing threshold > 40dB HL was observed in left ear. A significant higher difference was only observed between combined group and Bluetooth group at frequency of 250 Hz in left ear. No significant difference was observed between studied groups at other frequencies. Poorer hearing thresholds was observed in those who frequently used earphones.

CONCLUSION

Main hearing thresholds were poor in earphone users which could be interpreted as earphones use may have negative impact on hearing. The combined use of both types of earphones did not show more negative impact on hearing threshold. It is essential to implement education programs inorder to raise young people's awareness of proper earphone use and change their attitudes toward them.

Keywords: Earphones, Bluetooth, listening habits, pure tone audiometry, hearing threshold, hearing loss.

INTRODUCTION

The incorporation of earphones into cell phones and music devices, as well as their appropriate cost and

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technical advancements in sound quality, have made their use highly ubiquitous around the world. [1]Recently, there is increased tendency to use earphones in different learning activities including e-learning programs, zoom meeting, Microsoft team, videos etc. Moreover, adolescents and young adults commonly use these devices during leisure activities as playing games, listening to music and cell phone calls.

Many types of earphones are available including wired earphones and wireless or Bluetooth earphones. Bluetooth is a wireless technology, using ultra high frequency radio waves to exchange files between nearby fixed or portable devices. This type of wave is a part of the electromagnetic spectrum. [2]Many Bluetooth earphones are compatible with all Bluetooth enabled devices including cell phones, personal digital assistants, PCs, laptops and music players etc . Now a days, it is obvious that many people are using Bluetooth earphones while working, sitting, or doing any activities.[3]

Unfortunately, most of earphones users are unaware of their potential harmful effect. A variety of factors may contribute to the effect of earphones on hearing; the sound volume, the duration of exposure and the type of earphone used. [4]High sound can only be tolerated by the ears for few minutes. When using the earphones, the sound is directed into the ears. A volume of more than 85 decibels dB can impair hearing. On the other hand, the sound of earphones does not have to be particularly loud to cause harm to the ears. Even, using the earphones for prolonged duration at moderate volume can affect hearing. This is because the length of exposure can also cause damage to the ears.[5]

A previous study among 280 Swedish adolescents observed that increased frequency andduration of use of earphones were associated with poorer hearing thresholds. [6] Other audio logical problems as tinnitus have been reported after exposure to loud noise. [7] Impaired hearing has detrimental effect on language development as well as school and college performance, emotional wellbeing, and general quality of life.[8-10]

Bluetooth earphones may have additional negative effect. Bluetooth transmits energy at frequency level in the 2.4 GHz band and its range of signal transmission is very short. Thus, Bluetooth earphones users are exposed to both Bluetooth radiation and cell phone radiation. When using these Bluetooth earphones, many body organs including, the brain, the ears and the eyes are exposed to a powerful field of electromagnetic radiation with possible adverse effects on these organs. [3,11]The cochlear outer hair cells are highly vulnerable to damage by radiation emissions. An experimental study on rabbits reported that exposure to electromagnetic field had negative effect on ear particularly, in the organ of Corti and outer hair cells. The authors attributed this finding to diminished distortion product auto acoustic emission in higher frequency region located in the rabbit's cochlea which are similar to frequency spectra of human. [12]

A randomized controlled study was performed to investigate short-term effects of Bluetooth headset and cell phone EMFs on the auditory nervous structures in patients with Ménière's disease through intraoperative monitoring. The authors observed that Latency and amplitude of cochlear nerve compound action potentials were extremely sensitive to EMFs generated by cell phones. In contrast, the EMFs produced by Bluetooth device did not cause any significant change in cochlear nerve activity. The major limitation of that study was that the average auditory function in Ménière's disease subjects is low than normal, and they could not test normal subjects under the same conditions. Thus, they could not determine whether Bluetooth headsets exposure would have harmful effect in normal subjects.[13]Another previous study tested the short term effect of electromagnetic field emittedby Bluetooth headset on hearing, result showed that 30 persons were exposed to a Bluetooth headset device for 10 minutes in full power and 6 hours in standby mode. The results did not show reduction of hearing thresholds or alteration of distortion product otoacoustic emissions after exposure to both modes.[14] However, both previous studies on were short term studies.

Statement of novelty

Previous studies were either on Bluetooth or non -Bluetooth exposure. Moreover, studies for Bluetooth exposure were for only 10 minutes and 6 hours. In current study we selected the students that used Bluetooth, non -Bluetooth earphones or both daily for at least 1 year. Then, we compared the effect of combined use of Bluetooth and non-Bluetooth earphones versus using only one type of them.

The aims of this study were to assess the earphone listening habits and its effect on hearing function among medical college students, Majmaah University who used it daily for at least 1 year. Also, to compare the effect of combined use of Bluetooth and non -Bluetooth earphones with the use of either of

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them.

METHODS

Research design

This analytical cross-sectional study was conducted in physiology lab, college of medicine, Majmaah University in the period between 20-9-2020 to 28-1-2021.

Research Subject

All female students in college of medicine were invited for participation in the study. The inclusion criteria: Female students in college of medicine aged 18-23 years old who used earphones daily for at least 1 year. The duration of use in years and frequency of use per hours were assessed verbally and confirmed in the questionnaire.

Exclusion criteria: Students who used the earphones for less than 1 year, those with existing common cold, history of acute or chronic otitis media, ear surgery, Meniere's disease, traumatic head injury, mumps, meningitis, intake of ototoxic drugs were excluded from the study. Those with history of diabetes, Hypertension, renal impairment or family history of Wardenburg’s syndrome were also excluded. The data was collected from 42 participants. Power Analysis and Sample Size (PASS 2015) was used to calculate the sample size. In a one-way ANOVA study, sample sizes of 14, 14, and 14 are obtained from the 3 groups whose means are to be compared. The total sample of 42 subjects achieves 91% power to detect differences among the means versus the alternative of equal means using an F test with a 0.05 significance level. The size of the variation in the means is represented by their standard deviation which is 3.30. The common standard deviation within a group was 5.00. The students were divided into 3 groups: Group 1; included students using Bluetooth earphones, Group 2; included those using non-Bluetooth earphones and group 3, included those who are using both types of earphones. The study was done in 2 phases.

Phase 1: Questionnaire concern earphone listening habits and subjective hearing health.

It was divided into four parts. Part 1 included questions regarding the personal data. Part 2 addressed history of usage including type of earphones, age of starting using. Part 3 contained questions concerning use habits as the duration and frequency of use, preferred sound level and preferred ear. Phase 4 contained questions about some hearing symptoms, as tinnitus, vertigo and low hearing.

The questionnaire was designed and pretested in six students to ensure clarity.

Phase 2: measurement of hearing using pure tone audiometry (PTA).

Pure-tone audiometry is a gold standard test in assessing the hearing acuity. Pure-tone audiometry was performed using audiometer (Interacoustics ADD629 Diagnostic Audiometer) connected to headphones and vibrator in a quiet room (≤10 dB HL) by ENT consultant at physiology lab in college of medicine, Majmaah University.

The test equipment and the stimuli were calibrated prior to performing the test as guided by Standardization (ISO) norm (ISO 11957:1996, 1996). [15] The students were instructed to avoid use of earphones 12 to 16 hours prior to PTA measurement to avoid Temporary threshold shift influence on the audiometric test result. All precautions for Covid-19 were taken. The students were examined by otoscopy for the presence of ear discharge or wax before PTA measurement. First, air conduction hearing thresholds were assessed for tonal stimuli throughout a frequency range of 250 Hz to 8000 Hz by using headphones. Then, bone conduction hearing thresholds were assessed for tonal stimuli throughout a frequency range of 250 to 4000 Hz. by using a headband with oscillator.Using PTA, the ENT consultant could adjust the frequency, stimulus level, sound routing to different transducers (headphone and a bone vibrator), and to turn the signal on and off. Masking was done during measurement of bone conduction by using narrow band tones at the untested ear. The response was graphed on the standard graph and then interpretation of the results was done.

Abnormal hearing threshold was determined as hearing threshold ≥20 Hz at one or more frequencies of 250,500,1000,4000 and 8000.[s]

Statistical analysis

The data were analyzed using Statistical Product and Service Solutions (SPSS) 28. Normality of quantitative variables was checked by one-sample Kolmogorov Smirnov test. Mean ± SD is reported for quantitative variables, whereas qualitative variables are expressed as frequencies and percentages. One Way ANOVA was applied to compare the groups (Bluetooth, non-Bluetooth and combined) with various

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hearing thresholds. Post-Hoc Tukey's test was applied to observe the pair-wise differences among significant groups. Fisher exact test was applied to observe associations between qualitative variables. A p-value of less than 0.05 was considered as statistically significant.

Ethical clearance

The study was approved by the deanship of scientific research, Majmaah University No. (MUREC-fan.28 / COVI-2020 / 19-L). A written consent was obtained from the students who agreed to participate and whole procedure was explained to them.

Results

Listening habits

The highest percentage of students (37.5%) started using the earphones in Bluetooth group was at age of 10-14. In non- Bluetooth group, the highest percentage (72.7%) started usage at the age of 14-18. In combined group more than half of students (57.1) started usage at age of 10-14.

Regarding purpose of use, the highest percentages in Bluetooth group (66.7%) and non- Bluetooth group (90.9%) were for entertainment. In combined group the highest percentage (71.4%) was for both academic and entertainment purpose.

Regarding the duration of use, the highest percentages of students in Bluetooth group (58.3%) and non - Bluetooth group (63.6%) were those who used the earphones for 4-8 years. In combined group all students used the earphones for more than 8 years.

Regarding the frequency of use, the highest percentages of students in Bluetooth group (62.5%) and non- Bluetooth group (54.5%) were those who listened for 1-4 hours per day. In combined group, all students listened for 4-8 hours per day.

Regarding the preferred volume, the highest percentages in Bluetooth (66.7%), non-Bluetooth (54.5%) and combined groups (71.4%) were those who prefer using medium volume. In noisy environment, 79.2% and 54.5% of students in Bluetooth and non-Bluetooth groups tended to increase the volume while in combined group, 57.1% tended to stop its use. About half of students in Bluetooth, non-Bluetooth and combined groups preferred to use both ears (58.3%,54.5%&57.1% respectively).

Subjective hearing problems

Regarding subjective hearing problems, 54.2% of students in Bluetooth, 18.2% in non-Bluetooth and 42.9% in combined groups complained of ear pain. 16.7% of students in Bluetooth and 28.6% in combined groups complained of low hearing. The percentage of students who had tinnitus in Bluetooth, non-Bluetooth and combined groups were 29.2% and 36.4% and 28.6% respectively.

The percentage of students complained of vertigo in Bluetooth, non-Bluetooth and combined groups were 25% ,36.4 % and 42.9% respectively.

The details of earphone listening habits and subjective hearing problems in each group are shown in table 1.

Table 1: Earphone listening habits and subjective hearing symptoms in studied group

Variables	Bluetooth		Non- Bluetooth		Combined	
	No	%	No	%	No	%
Starting age						
<10yrs	5	20.8	0	0	0	0
10-14	9	37.5	3	27.3	4	57.1
14-18	8	33.3	8	72.7	3	42.9
>18	2	8.3	0	0	0	0
Purpose of use						
Academic	2	8.3	0	0	0	0
Entertainment	16	66.7	10	90.9	2	28.6
Both	6	25	1	9.1	5	71.4
Duration of use in years						

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1-4		2	8.3	0	0	0	0
4-8		14	58.3	7	63.6	0	0
>8		8	33.3	4	36.3	7	100
Frequency of use in hours/day							
<1		1	4.2	0	0	0	0
1-4		15	62.5	6	54.5	0	0
4-8		6	25	3	27.3	7	100
>8		2	8.3	2	18.2	0	0
Preferred volume							
Medium		16	66.7	6	54.5	5	71.4
High		8	33.3	5	45.5	2	28.6
Behavior in noisy environment							
Stop use		5	20.8	5	45.5	4	57.1
Increase volume		19	79.2	6	54.5	3	42.9
Preferred ear							
Right		6	25	3	27.3	2	28.6
Left		4	16.7	2	18.2	1	14.3
Both		14	58.3	6	54.5	4	57.1
Subjective hearing problems							
Ear pain	Yes	13	54.2	2	18.2	3	42.9
	No	11	45.8	9	81.8	4	57.1
Low hearing	Yes	4	16.7	0	0	2	28.6
	No	20	83.3	11	100	5	71.4
Tinnitus	Yes	7	29.2	4	36.4	2	28.6
	No	17	70.8	7	63.6	5	71.4
Vertigo	Yes	6	25	4	36.4	3	42.9
	No	18	75	7	63.6	4	57.1

Pure Tone Audiometry

The percentage of students with hearing thresholds ≥20 dB HL at each frequency was determined. 85.7% of students have hearing threshold ≥20 dB HL at one or more frequencies. Hearing loss was categorized as mild (≥ 20 - 40 dB HL) and moderate (41- 70 dB HL).[7,9] Mild hearing loss was observed in both right and left ear while moderate hearing loss was only observed in left ear. In right ear, the highest percentage of students (42.9%) having mild hearing loss was at frequency of 500 Hz followed by equal percentages (38.1%) at 250 and 1000 Hz. In left ear the highest percentage of students (61.9) having mild hearing loss was at frequency of 250 Hz followed by 54.8% and 52.4% at 1000 and 500 Hz respectively. The highest percentage of students (14.3%) with moderate hearing loss was at frequency of 500 Hz followed by equal percentages (9.5%) at1000 and 8000 Hz (Table 2).

Table 2: The incidence of the degree of hearing for each tested frequency, in right and left ears

Variables	**Normal**		**Mild loss (≥20- 40dB HL)**		**Moderate loss (41-70 dB HL)**		**Total hearing loss (Mild &Moderate)**	
	Rt ear N (%)	**Lt ear N (%)**	**Rt ear N (%)**	**Lt ear N (%)**	**Rt ear N (%)**	**Lt ear N (%)**	**Rt ear N (%)**	**Lt ear N (%)**
250 Hz	26(61.9)	13(31)	16(38.1)	26(61.9)	0	3(7.1)	16(38.1)	29(69)
500 Hz	24(57.1)	14(33.3)	18(42.9)	22(52.4)	0	6(14.3)	18(42.9)	28(66.6)

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1000 Hz	26(61.9)	15(35.7)	16(38.1)	23(54.8)	0	4(9.5)	16(38.1)	27(64.2)
2000 Hz	40(95.2)	21(50)	2(4.8)	21(50)	0	0	2(4.8)	21(50)
4000 Hz	36(85.7)	26(61.9)	6(14.3)	14(33.3)	0	2(4.8)	6(14.3)	16(38)
8000 Hz	35(83.3)	19(45.2)	7(16.7)	19(45.2)	0	4(9.5)	7(16.7)	23(54.7)

On comparing the percentage of students having hearing loss among the three studied groups, it was found that Bluetooth group had higher percentage compared to non-Bluetooth and combined groups at all frequencies in left ear. The same was found in the right ear with exception at 1000 Hz where percentage of non -Bluetooth group with hearing loss was higher compared to Bluetooth group and combined group. Moreover, at 2000 Hz the percentage of Bluetooth and non-Bluetooth users with hearing loss was equal (Figure 1).

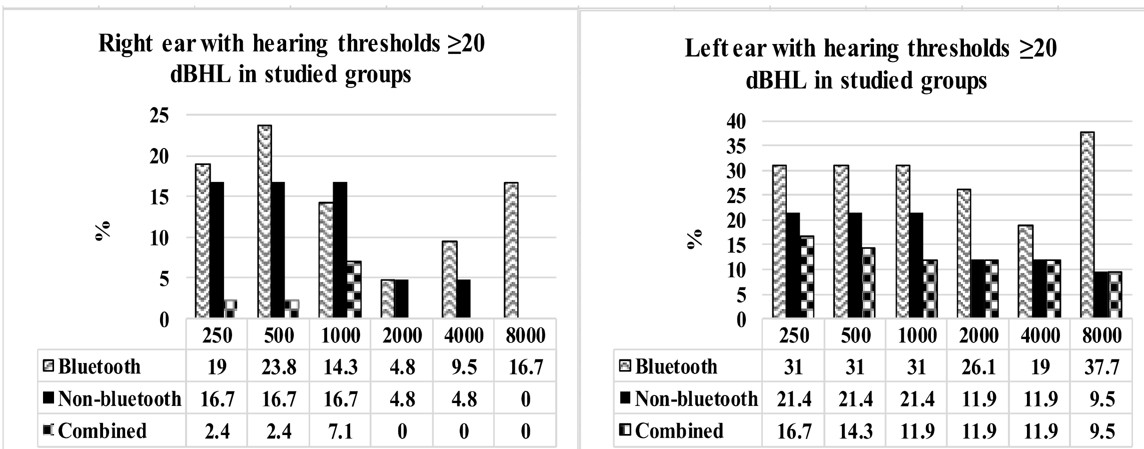

Figure 1: Percentage of hearing threshold ≥20dBHL in right and left ears in studied groups

On comparing the mean hearing thresholds in all participants, a significant difference was observed between the right and left ears in all frequencies (Table 3).

Table 3: Comparison of mean hearing thresholds for each frequency in all participants in right and left ears

Variables	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Rt ear	16.31±10.6	18.45±11.5	15.48±9.2	9.76±5.0	7.5±6.6	10.59±7.6
Lt ear	26.67±13.9	26.9±15.4	23.45±14.6	17.86±10.0	15.36±11.3	21.67±11.8
p value	0.0001*	0.002*	0.001*	0.000*	0.000*	<0.000*

*The results are significant at p<0.05

The mean hearing thresholds for each frequency in Bluetooth, non -Bluetooth and combined groups in the right and left ears are presented in Figure 2.

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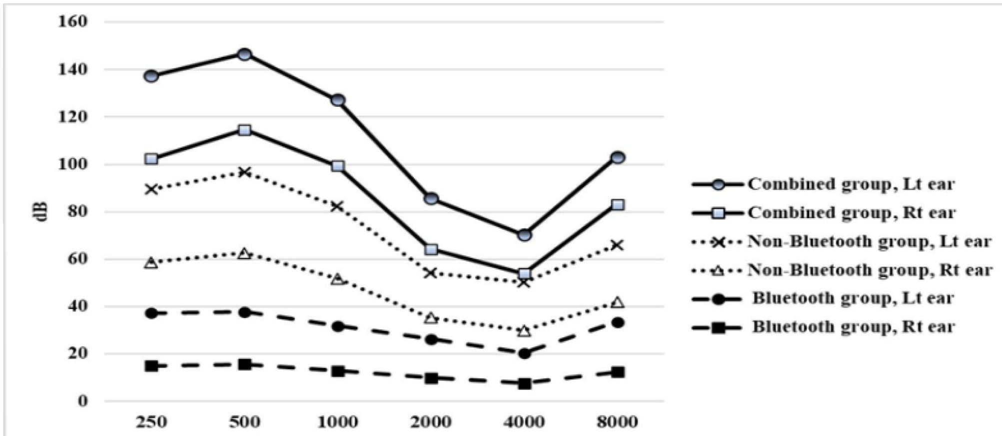

Figure 2: Mean hearing threshold in studied groups in right and left ears

On comparing the mean hearing thresholds in three studied groups, a significant increase was observed in combined group compared to Bluetooth group at frequency of 250 Hz in left ear. No significant difference was observed between the three studied groups at 500, 1000, 2000, 4000 and 8000 Hz in left ear. In right ear, no significant difference was observed between the three studied groups at all frequencies (Table 4).

Table 4: Comparison of mean hearing threshold for each frequency in Bluetooth, non -Bluetooth and combined groups right and left ears

Variables		250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Right ear	**Bluetooth**	15±10.4	15.62±10.9	12.91±7.7	10±6.2	7.70±7.2	12.4±8.5
	Non - Bluetooth	21.36±11.6	25±12.8	20±11.1	9.09±3.01	9.54±6.5	8.5±4.7
	Combined	12.85±8.1	17.85±7.5	17.14±9.0	10±2.8	3.57±2.4	7.14±6.3
	p value	0.168	0.777	0.095	0.882	0.174	0.170
Left ear	**Bluetooth**	22.29±14.1	22.08±14.8	18.95±13.9	16.25±11.8	12.70±9.7	21.04±11.5
	Non - Bluetooth	30.90±13.1	34.09±13.5	30.45±13.1	19.09±6.2	20.45±15.7	24.09±15.4
	Combined	35±9.1	32.14±16.2	27.85 ±15.2	21.42±8.0	16.42±5.5	20±5.7
	p value	0.049*	0.060	0.062	0.447	0.169	0.725

*** p<0.05**

There was significant association between use of earphones for 1-4 years and hearing loss at frequency of 8000 Hz in right ear. Non-significant difference was observed in other frequencies. In left ear non-significant difference was observed in all frequencies. Regarding the frequency of use per day, a significant difference was observed between use of earphones for more than 8 hours and hearing loss at frequency of 250 Hz in right ear and at 1000 Hz in left ear (Table 5).

Table 5: Association of hearing frequency in right and left ear with the duration and frequency of use (n=42)

Variables	**250 Hz**			**500 Hz**			**1000 Hz**			**2000 Hz**			**4000 Hz**			**8000 Hz**		
	Normal hearing	**Mild HL**	**Moderate HL**	**Normal hearing**	**Mild HL**	**Moderate HL**	**Normal hearing**	**Mild HL**	**Moderate HL**	**Normal hearing**	**Mild HL**	**Moderate HL**	**Normal hearing**	**Mild HL**	**Moderate HL**	**Normal hearing**	**Mild HL**	**Moderate HL**
Right ear																		

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Duration of use in years																		
1-4	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	0	100	0
4-8	57.1	42.9	0	57.1	42.9	0	66.7	33.3	0	90.5	9.5	0	81	19	0	81	19	0
>8	63.2	36.8	0	52.6	47.4	0	52.6	47.4	0	100	0	0	89.5	10.5	0	94.7	5.3	0
p value	0.485			0.437			0.346			0.350			0.625			0.003[b]		
Frequency of use in hours /day																		
< than 1	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0	0	100	0
1-4	71.4	28.6	0	61.9	38.1	0	71.4	28.6	0	95.2	4.8	0	76.2	23.8	0	71.4	28.6	0
4-8	68.8	31.3	0	68.8	31.3	0	56.3	43.8	0	100	0	0	100	0	0	100	0	0
>8	0	100	0	0	100	0	50	50	0	100	0	0	100	0	0	100	0	0
p value	0.026[b]			0.052			0.409			0.00[a]			0.012[a]			0.011[a]		
Left ear																		
Duration of use in years																		
1-4	0	100	0	0	100	0	0	100	0	100	0	0	100	0	0	0	100	0
4-8	47.6	47.6	4.8	47.6	33.3	19	47.6	47.6	4.8	57.1	42.9	0	66.7	23.8	9.5	57.1	28.6	14.3
>8	15.8	73.7	10.5	21.1	68.4	10.5	26.3	57.9	15.8	36.8	63.2	0	52.6	47.4	0	36.8	57.9	5.3
p value	0.191			0.143			0.346			0.154			0.270			0.185		
Frequency of use in hours /day																		
<than 1	0	100	0	0	0	100	0	100	0	0	100	0	0	100	0	0	0	100
1-4	33.3	61.9	4.8	33.3	52.4	14.3	33.3	66.7	0	57.1	42.9	0	71.4	19	9.5	52.4	42.9	4.8
4-8	37.5	50	12.5	43.8	43.8	12.5	50	25	25	43.8	56.3	0	56.3	34.8	0	37.5	50	12.5
>8	0	100	0	0	100	0	0	100	0	50	50	0	50	50	0	50	50	0
p value	0.608			0.108			0.027[b]			0.642			0.362			0.085		

HL, hearing loss
[a] $p<0.05$ when compared with normal hearing
[b] $p<0.05$ when compared with hearing loss

DISCUSSION

The use of earphones become popular among adolescents and young adults. Improper use of these devices is associated with a higher risk for hearing loss.[16]

Pure-tone audiometry showed increased hearing threshold ≥20 dB HL at one or more frequencies in 85.7% of the student. lower percentages (26% &75%) were observed in previous studies conducted on adolescents and young adults using portable music players (PMP)with earphones.[5,6] The higher percentage in the current study may be due to different listening behavior and increased use of earphones for academic and entertainment purpose especially due to covid-19 lock down.

On comparing the mean thresholds of Bluetooth group with non-Bluetooth and combined groups, a significant higher difference was only observed between combined and Bluetooth group at frequency of 250 Hz in left ear. No significant difference was observed between other frequencies in right and left ears. This result could be explained by the study of Mandalà et al. who reported that Bluetooth operates at a higher frequency (2.4 GHz) than cell phones, so, it would cause more damage to nervous tissue if it has the same transmission power. However, as Bluetooth devices have much lower transmission power (2.5 mW) than cell phones, the resulting impact on brain structures would be lower. In addition, higher frequencies decrease the depth of penetration of the electromagnetic field (EMF), so that a lower intensity EMF would reach deeper nervous structure including auditory nerve. Thus, using Bluetooth earphones did not add

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additional risk for users. [13]
The present study showed significant increase in mean thresholds of the left ear compared to right ear in all frequencies. This may be due to that more than half of the students (57.1%) preferred using both ears. In contrast, a previous study demonstrated poor hearing thresholds in the right ear compared to left ear.[7] Other previous studies did not show significant difference in hearing thresholds for the right and left ears.[6] Hearing loss was categorized as mild (≥ 20 - 40 dBHL) and moderate (41- 70 dBHL) according to Basjo et al. and Fedar et al. Mild hearing loss was observed in both right and left ear while moderate hearing loss was only observed in left ear.[7,9]
In right ear, poor hearing threshold was more in low frequency pure tone audiometry (LFPTA) as the highest percentage of students (42.9%) having mild hearing loss was at frequency of 500 Hz followed by equal percentages (38.1%) at 250 and 1000 Hz. In left ear, poor hearing threshold was also observed in LFPTA as the highest percentage of students (61.9) having mild hearing loss was at frequency of 250 Hz followed by 54.8% and 52.4% at 1000 and 500 Hz respectively. Moderate hearing loss was observed in low frequency of 500 Hz (14.3%) followed by equal percentages (9.5%) at 1000 Hz and high frequency pure tone audiometry (HFPTA) at 8000 Hz.
These results coincide with the results of a previous study where most of the participants (75%) had mild hearing loss in lower frequencies of 250 Hz and 500 Hz.[5] The presence of poor hearing thresholds at LFPTA may be attributed to the high sensitivity of cochlea at frequencies of 500 Hz - 2000 Hz. It may be also due to temporary threshold shift resulting from exposure to loud noise for long time. The results are higher than the study of Feder et al who reported LFPTA hearing loss in 15.4% among Canadian aged 20 to 79. [17]

This discrepancy may be due to the younger age of the students where the plasticity of neurons is higher with a great possibility of temporary threshold shift to return to normal levels. Furthermore, it was suggested that the tendency of earphone users to increase their volumes after prolonged period of use may be a predictor of the ongoing permanent hearing loss. [18]

The current study showed that the percentage of students having HFPTA at 4000 and 8000 Hz was 38% &54.7% in left ear and 14.3% &16.7% in right ear. 64.3% of students preferred the high-volume usage. These results are in agreement with a previous study that reported poor hearing thresholds in earphone users with highest finding at thresholds of 6000 and 8000 Hz. This finding is a feature of noise induced hearing loss (NIHL) with diminished hearing sensitivity as a consequence of early and continual loud sound exposure. [5-7]

NIHL has become a worldwide challenge in the past two decades owing primarily to increased usage of cellphones and personal listening devices, including earphones. [8] Unfortunately, user may be unaware of the harmful effect of listening at high volume.[10] The average listening sound pressure was tested by Park et al. and was found to be 74dB on listening to music with earphones in a quiet environment. In a noisy background, it increased to 84dB. [19] Noise exposure may have cumulative effect. It was observed that exposure to noise up to 60 dB over than 60 min resulted in reversible hearing loss. Permanent hearing loss may occur on exposure to 85 dB for a minimum of 8 hours per day. [8]

This in consistent with our results as significant association was observed between use of earphones for more than 8 hours and hearing loss at frequency of 250 Hz in right ear and 1000 Hz in left ear. Moreover, there was significant association between use of earphones for 1-4 years and hearing loss at frequency of 8000 Hz in right ear.

In current study, 41 (97%) students used the earphones for more than 1 hour. This high percentage may be due to the use of earphones for academic purpose as online sessions, different teaching activities and for entertainment purpose. A similar study observed that using earphones over than 1 hour daily was associated with hearing loss in middle and high students of Korea. [10]

Haring loss due to loud noise can be explained by damage to cochlear hair cells which is the most sensitive and vulnerable to damage by loud noise. [20] Loud noise cause fraction and distortion of stereocilia. Hence, transmission of shearing force is decreased with disruption in the tip link between the stereocilia and affection of mechano-transduction. In addition, exposure to loud sound affects the sensitivity of auditory nerve with development of temporary noise induced hearing loss which become permanent with prolonged exposure. [1,10,21]

Limitation of the study: first, the sample size was small due to COVID -19 pandemic. Despite taking all precautions, many students did not agree to participate in the study. Second, it was not possible to precisely

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determine the level of noise exposure as the questionnaire contained questions of mild, moderate, or high volume.

Based on current results, it is important to screen earphone users for early detection of hearing loss. Also, it is crucial to design and implement guidelines and education programs to improve young people's awareness of the proper use of earphones, change their attitude towards their use as well as keeping safety measures during their use

CONCLUSION

Pure-tone audiometry showed poor hearing thresholds in those using earphones for more than 1 year. 85.7% of the students had hearing thresholds ≥20 dB HL at one or more frequencies. Mild hearing loss was observed in both right and left ears. Moderate hearing loss was observed in left ear only. On comparing the mean hearing thresholds of the three studied group, a higher hearing threshold was only observed between the combined and Bluetooth groups at frequency of 250 Hz in left ear. In right ear no difference was observed between the three studied groups at all frequencies. Thus, combined use of Bluetooth and non-Bluetooth earphones did not show more risk on hearing function in relation to either Bluetooth or non - Bluetooth alone.

CONFLICT OF INTEREST

The authors declared no conflict of interest

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CONTRIBUTORS

All authors contributed evenly to the research.

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