Original Research Article

Duration of mobile phone usage and its measurable audiological effect

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Abstract

Background: Mobile phone usage is ubiquitous that communicates through electromagnetic (EM) fields, which interact differently with the biological systems of our body. The inner ear is the direct recipient of these EM waves, making it the most affected organ. Our study was to assess the effects of mobile phone usage on hearing and to quantify the symptoms with duration of its usage. **Methods and Material:** This observational study was conducted on 105 staff of our college. Based on hours of usage per day they were grouped into three groups. Their symptoms were recorded. Hearing assessment was done with Pure tone audiometry followed by to acoustic emission (OAE). **Statistical analysis used:** Descriptive and inferential statistical analysis has been carried out in the present study. Analysis of variance (ANOVA) has been used to find the significance of study parameters between three or more groups of patients. Chi-square/ Fisher Exact test has been used to find the significance of study parameters on categorical scale between two or more groups. **Results:** Hearing loss of 10 to 15dB and absent OAE was noted at high frequency in subjects in group III and group II. **Conclusions:** Usage of mobile phone for more than 1 hour a day for consecutive three years has detrimental effect on inner ear function and the loss of hearing is directly related to duration of usage.

Key Words: Mobile Phone, Hearing Loss, Pure Tone Audiometry, OAE.

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Email: smitha7315@yahoo.co.in
Received Date: 23/11/2017 Revised Date: 18/12/2017 Accepted Date: 10/01/2018
DOI: https://doi.org/10.26611/1016512

Access this article online	
Quick Response Code:	Website: www.medpulse.in
	Accessed Date: 12 January 2018

INTRODUCTION

Mobile phones have been an amazing and great invention in the history of mankind. It has become one of the basic needs of the day, used by almost all the age group. Its usage is over 5.6 billion worldwide and India ranks second with about 885 million users accounting to 74% of Indian population.[1] Over time number of cell phone, number of calls per day, the length of each call has increased. Especially in health care professional the usage of mobile phones are increased for communicating messages. Mobile phones use non-ionizing electromagnetic radiofrequency waves ranging from 800-2000 MHz. These waves excites rotation of water molecules and some organic molecules, causing thermal and non-thermal effects on humans[2]. There is increased concern regarding the deleterious effect of these radiations on our health, as they can penetrate skull and effect brain electrical activity,[3] permeability of blood brain barrier,[4] and brain glucose metabolism[5]. It has detrimental effects on eye, testis and other organs also.[6] Carcinogenic effect of these waves are controversial yet have drawn special attention. Ear is probably the first and main organ that receives the full impact of the Electromagnetic radiation. It is most susceptible due to its close proximity to the mobile phones and the delicacy of hair cells. The thermal and non-thermal effects of these waves are reported to cause pain or warmth in ear,[7] tinnitus,[8] altered hearing,[9] headache, sleep disturbance and memory loss.[10] These deleterious effect on ear can be objectively detected by measuring the hearing threshold by Pure Tone Audiometry (PTA) and changes in the Otoacoustic emission (OAE). The present study was designed to investigate the symptoms experienced after using mobile phone, the hearing loss associated with its use and its relationship with the duration of usage. And

How to cite this article: Smithachandra, George Sebastian. Duration of mobile phone usage and its measurable audiological effect. *MedPulse International Journal of ENT.* January 2018; 5(1): 04-10. https://www.medpulse.in/ENT/

also to obtain an objective evidence for the effect on cochlea using Otoacoustic emission.

MATERIALS AND METHODS

A clinical observational study was conducted on 105 health care professionals in our Department of ENT over a period of one year. The study included mobile phone users for more than 3 years with different duration of usage per day. Subjects were explained in detail about the aim of the study, the nature of investigation they were to undergo. Informed consent was obtained from all the interested subjects. Permission was taken from the Ethical committee and were in accordance with the ethical standards of the responsible committee on human experimentation and with the Helsinki Declaration of 1975, as revised in 2000. Subjects with previous ear pathology with or without ear discharge, trauma to ear, ear surgery and prolonged exposure to loud noise were excluded from the study. Subjects on any ototoxic medication and any systemic comorbidities like juvenile diabetes, epilepsy, neuropathies or chronic illness which can affect hearing were also excluded from the study. All subjects were given a preformed open type questionnaire. This included details about duration of usage, daily hours of usage and dominant ear during usage. Detailed history regarding any symptoms experienced after mobile phone usage was enquired. Thorough clinical ENT examination and tuning fork tests were done. A general systemic examination was done. Subjects using mobile phones for more than 3 years were selected for the study. The subjects were grouped into 3 groups based on the duration of daily usage of mobile phones.

Group A: Consisted of subjects using mobile phone for less than 1 hour a day.

Group B: Cconsisted of subjects using mobile phone for 1 to 2 hours in a day.

Group C: Consisted of subjects using mobile phone for more than 2 hours in a day.

Pure Tone Audiometry (PTA) was performed using Maico MA 42 at frequencies from 250Hz to 8000 Hz. The frequencies were classified as PTA 1 which included hearing level at low frequencies of 250Hz, 500Hz, 1kHz and 2kHz and PTA2 included hearing level at high frequencies of 1kHz, 1.5kHz, 2kHz, 4kHz. The 1000 Hz tone falls in the middle of the most sensitive area of the hearing spectrum. In the speech spectrum, 1000Hz is the frequency separating the high frequency consonants from the low frequency vowels as well as few low frequency consonants. So any hearing loss noticed in PTA2 would directly correlate to the hearing loss in high frequency consonants. If 1000Hz is excluded from PTA2, the speech spectrum information which is concentrated in between 1000-2000Hz would be lost.[11] So both PTA1 and PTA2 had 1 kHz and 2 kHz frequencies in them. But with PTA 2 having only 1kHz, 1.5kHz, 2kHz, 4kHz frequencies we did not find much difference in the hearing level among the groups and there was no correlation with OAE findings. Moreover the radiations of EM waves are more concentrated above 2kHz hence in PTA 2 we added 6kHz and 8kHz. Measurement of DPOAES was carried out using the Otodynamics Differential Potential Otoacoustic Emission (DPOAE) system. The probe was placed in subject's one ear and sealed through a foam ear tip. Two pure tone signals, fi and f2 were simultaneously presented to record the distortion product 2f1-f2. The 2f1-f2 frequencies produce the most robust emission where f2: f1 = 1: 2 and the intensity level of f1 is 10dB higher than f2. f2 frequencies were set at 1500, 2000, 2500, 3000, 4000, 6000 and 8000 Hertz. The same procedure was repeated on the other ear.

Statistical Methods: Descriptive and inferential statistical analysis has been carried out in the present study. Results on continuous measurements are presented on Mean SD (Min-Max) and results on categorical measurements are presented in Number (%). Significance is assessed at 5 % level of significance. Analysis of variance (ANOVA) has been used to find the significance of study parameters between three or more groups of patients. Chi-square/ Fisher Exact test has been used to find the significance of study parameters on categorical scale between two or more groups. The Statistical software namely SAS 9.2, SPSS 15.0, Stata 10.1, MedCalc 9.0.1, Systat 12.0 and R environment ver.2.11.1 were used for the analysis of the data and Microsoft word and Excel have been used to generate graphs and tables.

RESULTS

The subjects in the study were between the age group of 15-35 years. The mean age group of the health care professional was 23.39 $\pm$ 3.71 years. Of 105 subjects only 94 subjects underwent audiological investigations, in whom 36 were males and 58 were females. Different brands of phones were used by the subjects. The duration of usage of mobile phone was three to five years with mean usage being 4.51$\pm$1.70 years. Left ear was the dominant ear in most individual, followed by subjects using both ears and only few using only right ear for hearing through mobile phone. Symptoms experienced after mobile phone usage in three groups of subjects was studied. Tinnitus was the most common symptom experienced in subjects from all the groups. Ear warmth was significantly experienced by subjects in group C compared to other groups. This was followed by ear pain or discomfort, headache and hearing loss. All the symptoms were more experienced by subjects in Group C and Group B.

Table 1: Symptomatology of subjects after using mobile phones

SYMPTOMS	Group A (n=30)	Group B (n=34)	Group C (n=30)	Total (n=94)	*P* VALUE
Hearing Loss	1(3.3%)	2(5.9%)	2(6.7%)	5(5.3%)	1.000
Tinnitus	6(20%)	8(23.5%)	12(40%)	26(27.7%)	0.178
Ear warmth	1(3.3%)	0(0%)	4(13.3%)	5(5.3%)	0.040
Ear Pain	2(6.7%)	3(8.8%)	3(10%)	8(8.5%)	1.000
Vertigo	0(0%)	0(0%)	0(0%)	0(0%)	1.000
Headache	0(0%)	2(5.9%)	4(13.3%)	6(6.4%)	0.113
Sleep Disturbance	0(0%)	0(0%)	0(0%)	0(0%)	1.000
Examination of ear	0(0%)	0(0%)	0(0%)	0(0%)	1.000

Audiological evaluation of right ear. PTA levels in right ear of subjects in all three groups was studied by using Chi-Square and Fisher Exact test. At low frequency there was no significant difference (*P = 0.059*) in hearing loss among the three Groups. But at high frequency (PTA2) there was statistically significant difference (*P<0.001*) seen between the groups.

Table 2: PTA levels of right ear in three groups of subjects studied by using Chi-Square and Fisher Exact test

Right ear	Group A (n=30)	Group B (n=34)	Group C (n=30)	Total (n=94)	P Value
PTA 1					
10-15	29(96.7%)	31(91.2%)	23(76.7%)	83(88.3%)	0.059
16-20	1(3.3%)	3(8.8%)	7(23.3%)	11(11.7%)	
PTA 2					
10-15	26(86.7%)	22(64.7%)	10(33.3%)	58(61.7%)	
16-20	4(13.3%)	10(29.4%)	10(33.3%)	24(25.5%)	<0.001*
21-30	0(0%)	2(5.9%)	10(33.3%)	12(12.8%)	

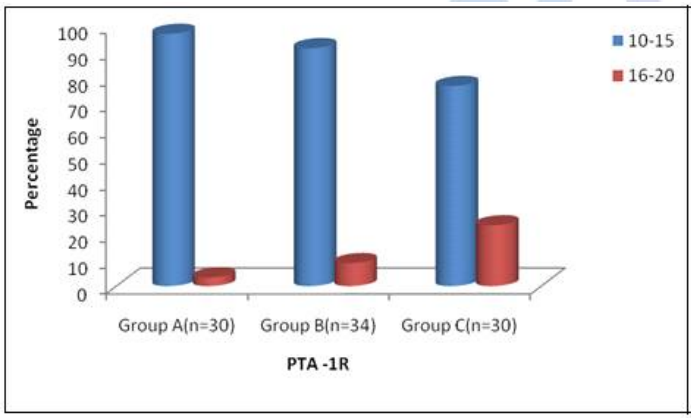

Figure 1: Hearing threshold levels at low frequency in right ear

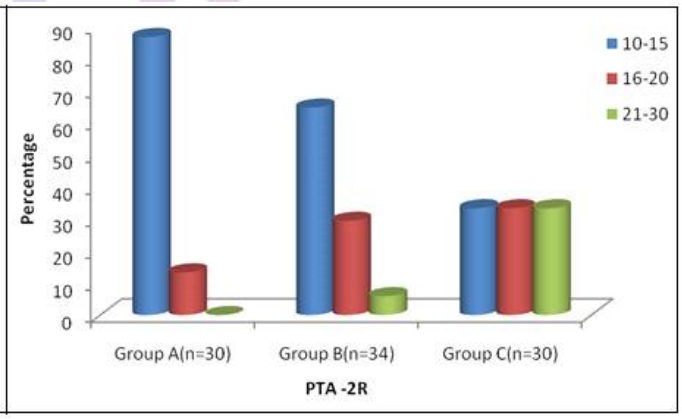

Figure 2: Hearing threshold levels at high frequency in right ear

Table 3: Comparison of mean PTA levels in all three groups studied by ANOVA method

Right ear	Group A	Group B	Group C	Total	*P* value
PTA 1	12.37±1.83	12.82±1.88	13.43±1.96	12.87±1.92	0.096
PTA 2	13.47±2.42	15.76±2.55	18.53±3.39	15.91±3.44	<0.001*

Comparison of mean PTA levels also showed no significant difference at low frequency *(P = 0.096*). But at high frequency there was significant statistical difference with *P* value *<0.001* between the Groups.

Results of Audiological evaluation of left ear: PTA levels of left ear in subjects of three groups was studied by using Chi-Square and Fisher Exact test

Table 4: PTA levels of left ear in three groups of subjects studied by using Chi-Square test/Fisher Exact test

Left ear	Group A (n=30)	Group B (n=34)	Group C (n=30)	Total (n=94)	*P* VALUE
PTA 1					
10-15	27(90%)	26(76.5%)	22(73.3%)	75(79.8%)	
16-20	3(10%)	7(20.6%)	8(26.7%)	18(19.1%)	0.287
21-30	0(0%)	1(2.9%)	0(0%)	1(1.1%)	
PTA 2					
10-15	24(80%)	17(50%)	6(20%)	47(50%)	
16-20	6(20%)	11(32.4%)	10(33.3%)	27(28.7%)	<0.001*
21-30	0(0%)	6(17.6%)	14(46.7%)	20(21.3%)	

At low frequency there was no significant difference (*P = 0.287*) seen but at high frequency (PTA2) there was statistically significant difference (*P<0.001*) seen between the groups.

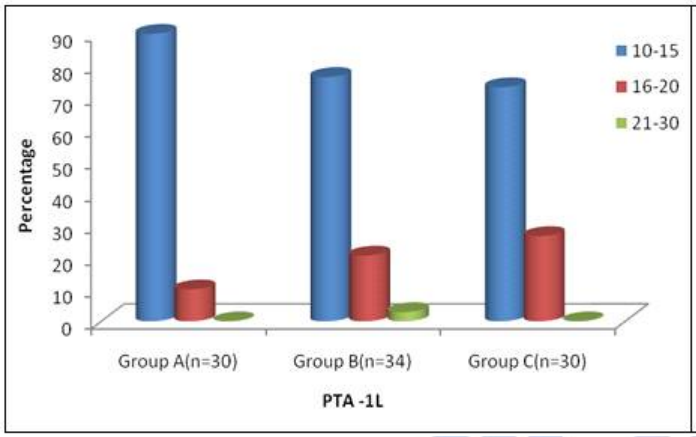

Figure 3: Hearing threshold levels at low frequency in left ear

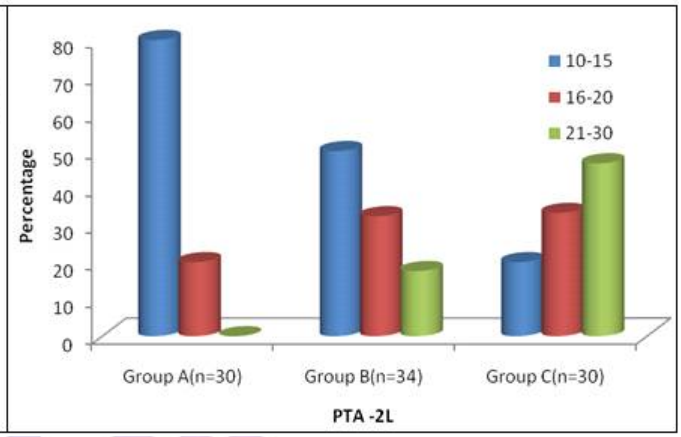

Figure 4: Hearing threshold levels at high frequency in left ear

Comparison of mean PTA levels showed slight significant difference at low frequency (*P=0.006*). But at high frequency there was statistically significant difference with *P* value <0.001 seen between the three groups.

Table 5: Comparison of mean PTA levels of left ear in three groups of patients studied using ANOVA test

Left ear	Group A	Group B	Group C	Total	*P value*
PTA 1	12.57±1.59	13.85±2.57	14.13±1.46	13.53±2.06	*0.006*
PTA 2	13.97±1.83	17.65±3.44	19.50±3.61	17.06±3.80	*<0.001*

Results of OAE OAE was done in all subjects at different frequencies at 1500, 2000, 2500, 3000, 4000, 6000 and 8000 Hertz.

Table 6: Comparison of PTA levels and OAE results in Group A

Average PTA	OAE		Total
	PRESENT	ABSENT	
Group A			
10-15	23(95.8%)	2(33.3%)	25(83.3%)
16-20	1(4.2%)	4(66.7%)	5(16.7%)
21-30	0(0%)	0(0%)	0(0%)
Total	**24(100%)**	**6(100%)**	**30(100%)**

In Group A OAE was present in 23 of 25 subjects with PTA levels between 10-15 dB. It was absent in four of five subjects with PTA levels 16-20 dB. Comparison of mean PTA values and OAE results in Group A was done using ANOVA test. OAE was present in most of the subjects at low mean PTA levels. At high mean PTA levels OAE was significantly absent in considerable number of subjects.

Table 7: Comparison of mean PTA values and OAE results in Group A done using ANOVA test.

PTA in Group A	OAE		Total	*P* value
	PRESENT	ABSENT		
1 R	11.79±1.32	14.67±1.86	12.37±1.83	<0.001
2 R	12.67±1.55	16.67±2.73	13.47±2.42	<0.001
1 L	11.96±0.95	15.00±1.26	12.57±1.59	<0.001
2 L	13.33±1.37	16.50±1.05	13.97±1.83	<0.001

In Group B, OAE was present in all 21 subjects with PTA levels between 10-15 dB. It was absent in six of ten subjects with PTA levels of 16-20 dB and in all three subjects with PTA levels 21-30dB.

Table 8: Comparison of PTA levels and OAE results in Group B

Average PTA	OAE		Total
	PRESENT	ABSENT	
Group B			
10-15	21(84%)	0(0%)	21(61.8%)
16-20	4(16%)	6(66.7%)	10(29.4%)
21-30	0(0%)	3(33.3%)	3(8.8%)
Total	**25(100%)**	**9(100%)**	**34(100%)**

Comparison of mean PTA values and OAE results in Group B using ANOVA test showed OAE was significantly absent in subjects with higher PTA levels.

Table 9: Comparison of mean PTA values and OAE result in Group B using ANOVA Test.

PTA in Group B	OAE		Total	*P value*
	PRESENT	ABSENT		
1 R	12.12±1.17	14.78±2.17	12.82±1.88	*<0.001*
2 R	14.68±1.14	18.78±2.99	15.76±2.55	*<0.001*
1 L	13.04±1.37	16.11±3.72	13.85±2.57	*=0.001*
2 L	16.04±1.77	22.11±2.98	17.65±3.44	*<0.001*

In Group C OAE was absent in two of twelve subjects with PTA levels between 10-15 dB. It was absent in seven of eleven subjects with PTA levels 16-20 dB and in a five of seven subjects with PTA levels 21-30 dB.

Table 10: Comparison of PTA levels and OAE results in Group C

Average PTA	OAE		Total
	PRESENT	ABSENT	
Group C			
10-15	10(62.5%)	2(14.2%)	12(40%)
16-20	4(25%)	7(50%)	11(36.6%)
21-30	2(12.5%)	5(35.7%)	7(23.3%)
Total	**16(100%)**	**14(100%)**	**30(100%)**

Comparison of mean PTA values and OAE results in Group C using ANOVA test showed OAE was significantly absent in subjects with higher PTA levels.

Table 11: Comparison of PTA values according to OAE in Group C using ANOVA test

PTA	OAE		Total	*P value*
	PRESENT	ABSENT		
1 R	12.44±1.34	14.92±1.83	13.43±1.96	*<0.001*
2 R	16.89±2.63	21.00±2.92	18.53±3.39	*<0.001*
1 L	13.50±1.25	15.08±1.24	14.13±1.46	*0.002*
2 L	17.39±2.35	22.67±2.74	19.50±3.61	*<0.001*

DISCUSSION

Mobile phones play an important role in our life by being the fastest and easiest means of communication. The dramatic worldwide increase in use of cellular telephones has raised concerns regarding harmful effects of exposure to radiofrequency waves. There are two ways through which these waves effect our body. First the thermal effect, as these waves travel through the tissue they cause polarization of water molecules and hence produce heat of approximately 1^0C. [12, 13] This is the principle used in oven and medical diathermy. Second the non-thermal effect. The radiofrequency waves are known to increase heat shock protein synthesis in the cells, these proteins affect the cell defense response against oxidative stress

and cause variation in the osmotic pressures. The involvement of these heat shock protein in inhibiting apoptosis in cells and hence oncogenesis is still controversial.[14] The extensive exposure to these RF waves has been found to affect brain electrical activity,[3] electrochemistry, blood brain permeability,[4] immune system,[15] and dopamine opiate system.[16,17] Nora D Volkow and group observed increased glucose metabolism in the part of brain closest to the antenna.[5] Numerous studies have been done to assess the effect off mobile phone usage on ear and auditory system. Increased cellular degeneration and increased anti-Caspase3, indicator of apoptosis was seen in the cochlear nuclei of rats exposed to EM waves for 30 days by Abdulkadir and group. [18]Hence we conducted this observational study to determine the effect of the EM waves on the ear, the organ most proximate and most vulnerable to these waves. In our study, tinnitus (27.7%) was the main symptom experienced by the subjects followed by ear pain (8.5%), headache (6.4%) and ear warmth (5.3%). All these symptoms were experienced most by group C subjects, to be followed by group B individuals. In a study by Mahesh Chandra *et al* ear block sensation (15%) was main symptom followed by tinnitus (10%.)[15] Tahvanainen K and group have observed increase in the ear canal temperature after 35 min exposure to the mobile phones.[13] This increase was thought to be firstly by the battery warming during usage of mobile phones and secondly, by the polarization of water molecules by these waves which causes heat generation as explained by Aracy.[19] Effect on hearing. In right ear at low frequency (PTA1) there was no statistically significant difference (*P = 0.059*) in hearing loss between the groups. At high frequencies (PTA2) four (14%) subjects in Group A, ten (29.4%) subjects in Group B and ten (33.3%) subjects in group C had 5dB of hearing loss. But ten (33.3%) subjects from Group C had 10 – 15dB hearing loss compared to two (5%) subjects in Group B and none in Group A, this was statistically significant(*P<0.001)*. In left ear, again at low frequencies there was no much difference in the hearing level among the Groups. But at high frequencies 5dB of hearing loss was noted in three (10%) subjects from Group A, seven (20.5%) subjects from Group B and eight (26.6%) subjects from Group C. Hearing loss of 10-15dB was seen in fourteen (41.1%) subjects in Group C, six (17%) subjects in Group B and none in Group A. Hearing loss was noted more in left ear compared to right ear as it was the dominant ear among the subjects. Our study was in agreement with the study done by Karthikeyan P and group, who found hearing loss in subjects using mobile phones for more than 2 hours a day.[1] Similar observation was seen by Mahesh Chandra and group, where 10 dB hearing loss was seen in 6.6% and 15 dB in 1.6% in the study group who used mobile phones for more than 2 hours.[15] Similarly Panda and groupalso found hearing loss at high frequencies in subjects using mobile phones for more than 60 mins a day.[20]Callejo and Santamaria showed an increase in hearing threshold between 1 to 5dB more in study group using mobile phone followed up for 3 years.[21] Study by Velayutham P and group also showed hearing loss at high frequencies above 8 kHz in chronic mobile users.[22] The mechanical activity within the cochlea generates sound, which can be picked up, recorded and measured by placing a microphone in the deep external meatus. This sound is called Otoacoustic emission. When two sounds of different frequencies are presented simultaneously to ear, a new sound is obtained from cochlea which is called as Distortional product Otoacoustic emission (DPOAE). If a DPOAE response is obtained after using two primary frequencies, it indicates normal hearing at one of the frequency. By changing frequencies hearing threshold can be ascertained at different frequencies. Absent DPOAE at higher frequencies indicates early cochlear damage.[23] In the study DPOAE was found to be present in all subjects at lower frequencies. Four (13.3%) of five subjects in Group A whose hearing threshold was between 16 to 20dB had absence of DPOAE at higher frequencies. In Group B all three (8.8%) subjects with hearing threshold between 16 to 20 dB and six of ten (17.6%) subjects with hearing threshold between 21 to 30 dB had absent OAE at higher frequencies. In Group C seven (23.3%) of eleven individuals with hearing threshold between 16 to 20 dB and five of seven (16.6%) individuals with hearing threshold between 21 to 30 dB had absent OAE at higher frequencies. All together OAE was absent in 14 subjects (46.6%) in Group C, in nine individuals (26.7%) in Group B and 13% of subjects in Group A. Absent OAE was observed where mean PTA values were higher. The comparison of mean PTA values and absent OAE also showed statistically significant differences among the groups. This was similar to the study by Karthikeyan and group where they observed absent OAE in 39% of study population who used mobile phone for more than two hours per day.[1] S Bhagat and group observed absent DPOAE in 21.3% subjects using mobile phone for more than 2 hours a day.[2]

CONCLUSION

Our study has shown significant hearing loss of 5 – 15 dB in individuals using mobile phones for at least three years and for more than two hours a day. This is substantiated with significant loss of DPOAE at higher frequencies in individual with hearing threshold above 15dB. Hence we conclude, the adverse effect of EM waves on ear is

directly proportional to the duration of usage per day. As the younger generation is more addicted to mobile phones, an awareness needs to be created regarding the duration of usage of mobile phones and its adverse effects on ear and hearing.

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Source of Support: None Declared
Conflict of Interest: None Declared