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Effect of Radiofrequency Waves of Mobile Phones on Distortion Product Otoacoustic Emissions

Swetapadma Nayak[1] Rajeshwary Aroor[1] Usha Shastri[2] M. K. Goutham[1] Devika Sinha[1]

[1] Department of Otorhinolaryngology, Nitte (Deemed to be University), KS Hegde Medical Academy, Mangalore, Karnataka, India
[2] Department of Audiology and Speech Language Pathology, Manipal Academy of Higher Education, Kasturba Medical College, Karnataka, India

Address for correspondence Rajeshwary Aroor, MBBS, MS(ENT), Department of Otorhinolaryngology, Nitte (Deemed to be University), KS Hegde Medical Academy, Mangalore 575018, Karnataka, India (e-mail: rajeshwarisomayaji@gmail.com).

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Abstract

Objective The prolonged exposure to electromagnetic fields of mobile phones can damage the cochlear hair cells, which can be detected by otoacoustic emission (OAE). To know the effect of mobile phones on hearing, the young volunteers were subjected to prolonged mobile phone usage and changes in OAE were recorded.

Materials and Methods Twenty-eight volunteers with normal hearing were made to talk one full hour continuously on the mobile phone. Distortion product otoacoustic emission (DPOAE) was measured prior to the usage of mobile phones and immediately after the use (post-exposure 1) and 24 hours after the use (post-exposure 2). The values were compared.

Results Out of the 28 volunteers, 20 were females and 8 were males. Twenty-one volunteers preferred the right ear while using mobile phones, 7 preferred the left ear. There was no statistically significant difference between the baseline DPOAE values and values of post-exposure 1 and 2 when only the preferred ear was taken into consideration. When the preferred ear was compared with nonpreferred ear, a statistically significant difference was found only in the low frequencies between the pre-exposure and post-exposure 1 values.

Conclusion This study shows there was no significant correlation between OAE and prolonged mobile phone exposure when the preferred ear was not considered.

Keywords
- mobile phone
- otoacoustic emission
- hearing loss

Introduction

In the past few decades, wireless communication has become a part of our life. We have seen the revolution in the field of mobile communication from 1G (first generation) in the year 1981 to 3G (third generation) and 4G (fourth generation) in recent years.[1]

The mobile phones that are currently in use are based on GSM (global system for mobile communications), WCDMA (wideband code-division multiple access), Wi-Max (worldwide interoperability for microwave access), and LTE (long-term evolution) and work at 900 MHz (Megahertz), 2100 MHz, 2300 MHz, 1800 MHz, respectively.[1,2] The exposure to radiofrequency electromagnetic fields (RF-EMFs) on health is a worrying factor in recent times. Even when mobile phones are not in use, they are always in an active state with constant connection from the service provider. Many other powerful sources emit an intense electromagnetic field, but

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they have a lower effect on human beings as they are far from human dwellings.

Because mobile phone handsets are held next to the ear, these impact the surrounding tissues as they emit radio frequencies when being used and communicate with the service provider. Even though these emit a lower level of energy, they still cause warming of the ear. The energy waves penetrate the skull and transfer energy into the brain, leading to a potential rise in the temperature of ~0.11°C. This is more often seen in the newer handsets such as smartphones (digital) than the old, analog models.[3,4]

Otoacoustic emissions (OAE) are the sounds generated by the cochlear outer hair cells, recorded by a microphone kept in the external auditory canal. OAEs are simple and efficient indicators of healthy cochlear functions. It is well known that outer hair cells are most vulnerable to various forms of ototoxicity. Cochlear outer hair cell damage caused by prolonged exposure to electromagnetic fields generated by mobile phones can be detected by an OAE test. We performed this study to know the effects of mobile phones on cochlear outer hair cell function using distortion product (DP) OAE in volunteers subjected to prolonged mobile phone usage for 1 h.

Materials and Methods

This is a prospective cross-sectional study, where 28 medical student volunteers aged between 20 ± two years with normal hearing and normal ear findings on examination who used mobile phones for more than 3 to 4 h per day over 5 to 7 years. Institutional ethical committee approval was taken for the study. After the written informed consent was obtained, the volunteers were subjected to a pure tone audiogram to know the hearing level. Volunteers with pure tone average better than 25 dB (dB) for frequencies 500, 1000, and 2000 Hz were considered as having normal hearing. All volunteers with normal hearing were subjected to prolonged mobile phone use using smartphones (GSM) for 1 h, continuously keeping the phone within a 2 cm distance from the ear. They were made to talk in a quiet room with a background noise level of roughly around 50 dB. The preferred ear of the subject was noted. The consistent choice of one ear or preponderance to hear from one ear was considered as the preferred ear (dominant ear). Using GSI Audera by VIASYS healthcare instrument, the OAE test was performed prior to the mobile phone use (baseline), and the test was repeated immediately after the use. Repeat OAE was done again after 24 h, during which the volunteers were restrained from using mobile phones.

Volunteers with pre-existing ear pathology, acute otitis media, chronic otitis media, those suffering from upper respiratory tract infection, history of chronic exposure to loud sounds, history of consumption of ototoxic medication, and hearing loss were excluded from the study.

After sealing the external auditory canal and placing a low noise microphone in the canal, the OAE was recorded. The auditory function was assessed using DP (represented as 2f1-f2 for two different frequencies). Clinically, the levels of the primary two tones were set at 65 dB sound pressure level (SPL) and 55 dB SPL. A 6dB amplitude to noise ratio was considered as a response. For interpretation of results, the amplitude of the DPOAE was compared with the normal values. The differences in DPOAE at baseline, immediately after exposure (post exposure 1), and after 24 h (post exposure 2) were compared. To compare the values, analysis of variance (ANOVA) was used. If data did not follow the normal distribution, Friedman's ANOVA, Student's *t*-test, and Mann–Whitney *U* test were used (inferential statistics). The *p*-value less than 0.05 was considered significant.[5]

Results

A total of 28 volunteers who fulfilled the inclusion criteria were included in the study. Out of them, 20 subjects (71%) were females and 8 subjects (29%) were males. Twenty-one volunteers had right ear dominance (preferred ear) (75%) and seven volunteers (25%) had left ear dominance.

There were no significant differences between the DPOAE values at baseline, post-exposure one, and post-exposure 2 when the preferred ear was not considered (►**Table 1**). There were no statistically significant differences between the DPOAE values in baseline evaluation when the preferred ear was compared with the nonpreferred ear, except for frequency 1371Hz on the left preferred ear (►**Table 2**). Mean DPOAE values for frequencies 1031,1371, and 2098 in the left preferred ear were statistically significant in post-exposure 1, whereas the mean values for higher frequencies were not statistically significant when the preferred ear was compared with the nonpreferred ear (►**Table 3**). The mean DPOAE values of post-exposure 2 were not statistically significant when the preferred ear was compared with the nonpreferred ear (►**Table 4**). When only the preferred ear was considered, there was no significant difference between the baseline value and post-exposure 1 values. Similarly, when baseline values were compared with values of post-exposure 2, no significant difference was found (►**Table 5**).

Discussion

Mobile phones are an easy and accessible mode of communication and have a significant impact on our social lives. We have reached a point in society where we are highly dependent on these gadgets. Mobile phones have become no longer a luxury, but they have become a daily necessity. Hence it is important to study whether this tiny gadget has any serious implications on our health.

Some of the recent studies have tried to link the exposure of electromagnetic radiations to increased risk of cancers (e.g., leukemia, brain tumors, lymphomas), various neurological diseases, sleep disturbances, genotoxic effects, increased risk of hypothyroidism, brain development of children, general microwave syndrome, increase in blood pressure, etc.[6–12]

The ear, being in close relation with the mobile phone, is at high risk because of electromagnetic radio waves.[13] There is a hypothesis that the usage of mobile phones is known to cause acoustic neuroma.[14,15] Long-term exposure to electromagnetic fields produced by mobile phones has been shown

Table 1 Comparison of DPOAE values at baseline, immediately after exposure, and 24 hours after exposure without preference ear was considered

Frequency (Hz)	Side of the ear	Test	Mean SPL	Standard deviation	Friedman's Test *p*-value
6340	Left	Baseline	9.94	6.9	0.916
		Postexp. 1	10.18	6.89	
		Postexp. 2	10.17	8.78	
	Right	Baseline	11.31	7.45	0.204
		Postexp. 1	9.16	6.51	
		Postexp. 2	10.40	8.81	
4814	Left	Baseline	18.29	7.10	0.302
		Postexp. 1	17.75	7.11	
		Postexp. 2	20.71	7.24	
	Right	Baseline	20.47	7.53	0.164
		Postexp. 1	19.10	6.74	
		Postexp. 2	22.61	7.46	
3152	Left	Baseline	15.32	5.9	0.509
		Postexp. 1	13.69	5.61	
		Postexp. 2	14.73	5.06	
	Right	Baseline	16.5	6.09	0.164
		Postexp. 1	14.41	3.92	
		Postexp. 2	15.81	5.34	
2098	Left	Baseline	12.74	6.71	0.782
		Postexp. 1	11.96	6.01	
		Postexp. 2	12.67	4.82	
	Right	Baseline	13.10	5.61	0.084
		Postexp. 1	12.23	5.07	
		Postexp. 2	13.25	3.42	
1371	Left	Baseline	10.09	5.44	0.302
		Postexp. 1	9.59	5.48	
		Postexp. 2	47.72	191.42	
	Right	Baseline	11.73	4.52	0.102
		Postexp. 1	9.59	5.65	
		Postexp. 2	12.14	4.84	
1031	Left	Baseline	8.09	4.39	0.199
		Postexp. 1	7.37	4.96	
		Postexp. 2	8.93	4.6	
	Right	Baseline	8.23	3.64	0.568
		Postexp. 1	8.52	4.08	
		Postexp. 2	8.82	3.79	

Abbreviation: Postexp., post exposure.

to cause hearing loss at the cochlear level.[16] Both longer daily usage of mobile phones and longer duration (years) of using mobile phones can lead to hearing loss. These may not be evident early as most audiometers used routinely are only up to 8 kHz. A high-frequency audiogram up to 16 kHz is required to detect these early changes.[16] Studies have shown that short-term exposure to electromagnetic waves of mobile phones for 10 min did not cause any change in both DPOAE[17] and transiently evoked OAE.[18] Even 20 min of exposure did not cause any effect on the DPOAE.[19]

In the conventional sense, one would see individuals with their right hand occupied in work and the free left hand for

Table 2 Comparison of DPOAE values at baseline with preference ear consideration

Frequency (Hz)	Preference	Mean SPL	Standard deviation	Mann–Whitney *U* test
6340 (R)	Right	11.65	7.42	0.959
	Left	10.27	8.06	
6340 (L)	Right	10.48	7.25	0.435
	Left	8.32	5.8	
4814 (R)	Right	20.67	8.4	0.533
	Left	19.89	4.41	
4814 (L)	Right	18.38	7.62	0.917
	Left	18.03	5.76	
3152 (R)	Right	17.2	6.23	0.296
	Left	14.4	5.55	
3152 (L)	Right	15.67	6.3	0.678
	Left	14.25	4.72	
2098 (R)	Right	12.31	5.9	0.189
	Left	15.45	3.88	
2098 (L)	Right	11.66	6.59	0.348
	Left	15.97	6.45	
1371 (R)	Right	11.29	4.42	0.348
	Left	13.06	4.89	
1371 (L)	Right	8.89	5.53	0.055[a]
	Left	13.67	3.33	
1031 (R)	Right	7.81	3.95	0.604
	Left	9.49	2.29	
1031 (L)	Right	7.44	4.84	0.604
	Left	10.03	1.71	

[a]*p*-value is significant.

Table 3 Comparison of DPOAE values immediately after exposure with preference ear consideration

Frequency (Hz) post exposure 1	Preference	Mean SPL	Standard deviation	Mann–Whitney *U* test
6340 (R)	Right	8.85	6.86	0.568
	Left	10.06	5.67	
6340 (L)	Right	10.91	7.21	0.296
	Left	7.99	5.75	
4814 (R)	Right	19.03	7.02	0.959
	Left	19.33	6.35	
4814 (L)	Right	17.55	7.80	0.435
	Left	18.35	4.90	
3152 (R)	Right	14.75	4.19	0.466
	Left	13.38	3	
3152 (L)	Right	13.27	5.96	0.435
	Left	14.93	4.56	

Table 3 (*Continued*)

Frequency (Hz) post exposure 1	Preference	Mean SPL	Standard deviation	Mann–Whitney *U* test
2098 (R)	Right	12.47	4.89	0.756
	Left	11.51	5.94	
2098 (L)	Right	11.05	5.13	0.055[a]
	Left	14.7	7.96	
1371 (R)	Right	9.71	6.15	0.604
	Left	9.24	4.16	
1371 (L)	Right	8.07	5.13	0.008[a]
	Left	14.16	3.84	
1031 (R)	Right	8.1	4.61	0.604
	Left	9.78	1.28	
1031 (L)	Right	6.09	5.02	0.02[a]
	Left	11.21	1.97	

[a]*p*-value is significant.

Table 4 Comparison of DPOAE values at 24 hours after exposure with preference ear consideration

Frequency (ear used) post exposure 2	Preference	Mean SPL	Standard deviation	Mann–Whitney *U* test
6340 (R)	Right	10.64	9.47	0.796
	Left	9.65	7.04	
6340 (L)	Right	11.42	9.50	0.126
	Left	6.41	4.90	
4814 (R)	Right	22.41	8.24	0.917
	Left	23.20	4.86	
4814 (L)	Right	21.12	7.48	0.756
	Left	19.47	6.84	
3152 (R)	Right	15.76	5.47	0.717
	Left	15.94	5.33	
3152 (L)	Right	14.57	5.33	0.756
	Left	15.22	4.53	
2098 (R)	Right	12.90	3.3	0.272
	Left	14.3	3.82	
2098 (L)	Right	12.66	5.04	0.678
	Left	12.73	14.49	
1371 (R)	Right	11.75	5.19	0.533
	Left	13.31	3.71	
1371 (L)	Right	58.24	221.33	0.113
	Left	16.15	7.47	
1031 (R)	Right	8.59	3.57	0.640
	Left	9.51	4.62	
1031 (L)	Right	8.17	4.7	0.228
	Left	11.24	2.79	

Table 5 Comparison of baseline value with post exposure 1 and post-exposure 2

Frequency (Hz)	Comparison between baseline to post exposure 1		Comparison between baseline to post exposure 2	
	t-Value	*p*-Value*	*t*-Value	*p*-Value*
6340	−1.647279	0.11109	−0.952115	0.34949
4814	−0.799976	0.43071	1.099374	0.28131
3152	−1.805984	0.08208	−0.594912	0.55686
2098	−0.230265	0.81962	−0.331958	0.74248
1371	−1.018788	0.31735	0.842562	0.40688
1031	0.638586	0.52847	1.064903	0.29635

* *p*-value is insignificant.

receiving phone calls. However, studies have shown that most right-handed people have a dominant left hemisphere of the brain and also left auditory hemispheric dominance. Hence, they hold the cell phone in their right hand and use the right ear for hearing. Similarly, most left-handed people hold their cell phones in their left hand.[20] Even in our study, the majority of the subjects had a dominant right ear.

We observed that on immediate exposure, there was a decrease in the DPOAE level for some of the lower frequencies in the dominant ear, which reverted to the normal or near-normal within 24 h. This implies that on prolonged exposure, the dominant ear gets more affected as compared with the non-dominant ear. A similar observation was made by Velayutham et al[16] and Sharma et al,[21] where the dominant ear had a significant difference in hearing compared with the non-dominant ear. It has been proved by Velayutham et al that chronic mobile phone usage can cause high-frequency hearing loss in the dominant ear. In contrast to this, we had observed that lower frequencies are more affected. This result was seen explicitly in participants with left ear dominance. Such a result could be because of fewer participants (seven) and may not be reliable. This should be replicated in a large number of participants. High-frequency hearing loss is most often missed because most routinely used audiometers assess only up to 8 kHz. When dominance of the ears is not considered, the changes in DPOAE are not significant.[22] We observed similar results. This is probably due to the high absorption of electromagnetic radiation on the side the phone is held, and it decreases to almost one-tenth on the opposite side.[23]

Further experiments have to be conducted to find a relation between the exposure of phones and cochlear functioning, brainstem auditory function, and the auditory cortex. Various other modalities should be explored and research should be conducted on a larger population for more conclusive results. More studies should be conducted to evaluate whether prolonged usage of mobile phones affects the onset of age-related hearing loss over many years.

Conclusion

The use of mobile phones is increasing rapidly, and hence we need to analyze whether prolonged use of mobile phones affects our health. The present study showed no significant correlation between hair cell functioning and prolonged mobile phone exposure when the ear preference was not considered. However, on consideration of one ear's dominance, there was a significant change in DPOAE of the lower frequencies on the dominant ear than on the nondominant ear.

Note

Both institutional ethical clearance and consent from participants were taken.

Conflict of Interest

None declared.

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