

# High-Frequency Hearing Loss Among Mobile Phone Users

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**Abstract** The objective of this study is to assess high frequency hearing (above 8 kHz) loss among prolonged mobile phone users in a tertiary Referral Center. Prospective single blinded study. This is the first study that used high-frequency audiometry. The wide usage of mobile phone is so profound that we were unable to find enough non-users as a control group. Therefore we compared the non-dominant ear to the dominant ear using audiometric measurements. The study was a blinded study wherein the audiologist did not know which was the dominant ear. A total of 100 subjects were studied. Of the subjects studied 53% were males and 47% females. Mean age was 27. The left ear was dominant in 63%, 22% were dominant in the right ear and 15% did not have a preference. This study showed that there is significant loss in the dominant ear compared to the non-dominant ear ( $P < 0.05$ ). Chronic usage mobile phone revealed high frequency hearing loss in the dominant ear (mobile phone used) compared to the non dominant ear.

**Keywords** Mobile phones · Electromagnetic radiation · High frequency hearing loss · Dominant ear

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## Introduction

Mobile telephones have been available since 1983. Their usage has spread widely and rapidly. In 2005, it was estimated that there were more than 2.14 billion mobile phone users in the world, with an expected rise of 90% to 6 billion people by 2010.

Mobile phones transmit and receive signals using electromagnetic fields in the radiofrequency band. The Global System for Mobile Communications (GSM) is currently the most widely used digital mobile phone service operating at 900 to 1,800 MHz frequency bands [1]. Although the electromagnetic radiation emitted is within the accepted range, data on its long term effect is sadly lacking. The possibility that the EMR have an accumulative effect and subsequently preclude to cellular damage is a sobering thought. The ear, especially the inner ear, not only being the closest to the mobile phone, is the direct recipient of the EMR thus making it the most likely affected organ. The delicate hair cells in the organ of Corti does not have regenerative properties, thus damages are often permanent with little chance of recovery in advanced stages. Hair cells are known to be sensitive to chronic exposure to loud noise. Therefore, the ear is at risk of exposure to noise from the mobile phone as well as the electromagnetic radiation waves emitted by the phone.

Several studies have been conducted to assess the effect of mobile phone on hearing [2–8] there has been a case report of a hearing loss after a mobile phone use 9, a study suggesting hearing loss based on OAE, audiometry and Bera, [10–12]. A short exposure to mobile phone has no effect on OAE [12]. However, none of the have tested hearing loss of the higher frequencies (above 8 kHz) which are beyond the range of conventional audiogram. Thus, this is a pilot study that assesses not only the impact of mobile

phone usage of the frequencies above 8 to 16 kHz in a multicultural society but also the effect of duration of usage in terms of minutes per day and years of usage of mobile phone.

## Methods and Materials

This study was performed in a tertiary referral center. Healthy, volunteers, r, between the ages of 20 and 45 who have been using mobile phones for at least a year were included in the study. We were not able to find non mobile users as controls thus, as almost all of the subjects were using the mobile phone on only one ear (the dominant ear), we used the dominant ear as the study group compared to and the non dominant ear (not used with mobile phone) as control. The dominant ear has been used by another study [10], [11]. The volunteers comprised of students, university staff and the general population, from urban areas, who were well educated and understood the process.

They underwent a questionnaire including the average duration of their daily use of mobile phone and their dominant ear and gave informed consent prior to being included into the study after approval was obtained from the Medical Ethics Committee. Exclusion criteria included history of chronic ear disease, recent upper respiratory infection, exposure to loud noise, history of any chronic medication and past illness. Users of Bluetooth devices, portable music players, and hands-free devices were also excluded. All subjects in this study used GSM 2G mobile phones.

Otoscope examination was performed by ENT surgeon, following which high frequency hearing test was performed by an experienced audiologist at frequencies of 250, 500, 1,000, 2,000, 4,000, 8,000, 10,000, 12,000, 14,000 and 16,000 Hz. Subjects were considered to have normal hearing if verified by Pure Tone audiometry to have no loss exceeding 20 dB between 250 and 16,000 Hz and classified as having hearing loss if any of the hearing thresholds are above 20 dB between 250 and 16,000 Hz.

The study was a blinded study wherein the audiologist did not know which was the dominant ear. The audiograms were examined and the depth of the notch (dB) and frequency (Hz) were recorded. Subjects with bilateral hearing loss were excluded from the study.

## Statistical Analysis

Analysis was performed using SPSS version 11.0. The level of significance was set at  $P < 0.05$ . Chi square tests and Pearson's correlation coefficient were used in our analysis.

## Results

One hundred volunteers fulfilled our criteria and thus were included in the study. Among the 100 subjects, 53% were males and 47% were females. The age of the volunteers was between 20 and 45 years with mean age of 27 years. The subjects were then categorized into two groups: those with hearing loss and those without hearing loss. Sixty-two (62%) volunteers had no hearing loss with 38(38%) had hearing loss greater than 20 dB in the frequencies between 250 and 16,000 Hz. Among the 38 volunteers with hearing loss, the higher threshold of hearing (above 20 dB) were at 10,000 Hz and above.

Comparisons were made between these two groups, those without hearing loss and those with hearing loss. There was a statistically significant difference in age between the no hearing loss group ( $26.4 \pm 5.3$  years) and the hearing loss present group ( $30.0 \pm 5.2$  years). Duration of usage of mobile phones ranged from 5 to 180 min per day. There was a statistically significant difference in usage time between the no hearing loss group ( $17.4 \pm 13.6$  min/day) and hearing loss present group ( $40.8 \pm 24.2$  min/day). Duration of use was also compared in terms of years of usage. Again there was a statistically significant difference between these two groups (Table 1). It appears that longer usage of mobile daily and longer duration of years using mobile can predispose to hearing loss duration. These may not be picked up early as most audiograms are only up to 8 kHz unlike in this study where a high frequency audiogram up to 16 kHz was used.

Among the study population, 36% were Malays, 28% Chinese, 30% Indians and 6% were others (Sudanese and Iranians). There were no statistically significant differences among the major races, or between sexes. There was also no correlation between the dominant ear and the dominant hand. Among our subjects 63% were dominant on the right ear, 22% left ear and 15% had no preference.

There was statistically significant hearing loss present in the dominant ear compared to the non-dominant ear, as well as those with no ear preference (Table 2). This was statistically significant value of  $P < 0.05$  under Chi-square tests. This indicates that the usage of mobile (as most of the

**Table 1** The frequency specific hearing loss among the 38 volunteers with hearing loss

Frequency	No of volunteers with hearing loss
10 kHz	6
10 and 12 kHz	17
10, 12, 14 kHz	33
10, 12, 14, 16 kHz	38

**Table 2** Summary of duration of using mobile phones daily and years of usage

	Hearing status	N	Mean	SD	Std error mean
Usage (min/day)	No hearing loss	62	17.35	13.612	1.729
	Hearing loss	38	40.84	24.219	3.929
Years using mobile phones	No hearing loss	62	6.21	3.720	0.472
	Hearing loss present	38	12.32	20.086	3.258

**Table 3** Summary of the occurrence of hearing loss among the volunteers, sorted by ear preference

	Dominant ear		No preference	Total
	Right	Left		
No hearing loss	44 (44%)	4 (4%)	14 (14%)	62 (62%)
Hearing loss present	19 (19%)	18 (18%)	1 (1%)	38 (38%)

respondents use it on their dominant ear) predisposes to high frequency hearing loss Table 3.

## Discussion

There is growing concern that the prolonged use of mobile phones can be detrimental to health. The inner ear is probably the first and main organ that receives the full impact of the EMR due to its close proximity and the delicate hair cells may be more vulnerable to injury compared to other structures. Several studies have been conducted, with this in mind to assess the hearing.

Pure tone thresholds were compared in users and non-users, and difference was found even though thresholds were within normal limits [5]. A study on the effects of mobile phone use on hearing function using frequencies ranging from 500 to 4,000 Hz. It was concluded that hearing loss is associated with long-term exposure to electromagnetic fields generated by mobile phones [6]. On the other hand, a 10-min exposure to EMF from a mobile phone had no effect on the hearing [7].

Again we would like to emphasize that we are looking at chronic exposure and the effects from it, not short-term exposure.

Studies have also been done on the effects of electromagnetic fields emitted by mobile phones on human sleep [8, 13].

*Other health effects* [13]: There are a lot of controversies regarding brain tumors associated with mobile phone users, for and against [14], [15], [16], [17]. Mobile phones generate electromagnetic radiation in two ways. First, from the antennae that are present around our towns and secondly from the telephones themselves. Present international

standards permit GSM 900 mobile phones to transmit at a pulsed power of 2 W with an average output of 0.25 W) [12]. Mobile phones have been found to generate electromagnetic radiation well below the guidelines of the International Commission on Non Ionizing Radiation Protection (ICNIRP) [13].

Radiofrequency emitted from mobile phones are not sufficiently energetic to destabilize electron configuration within DNA molecules. Thus there is no direct link between radiofrequency exposure and genotoxic effects such as DNA mutations [13].

There have been numerous studies on electromagnetic radiation from mobile phones and its effects on public health [2], [3–9]. However, as mobile phones were not popular until the 1990s, there have not been many studies that can provide information on the effects of chronic usage for a large population. Long-term subscribers of 15 years or more comprise only a small proportion of users.

The European multicenter project named GUARD involved nine centers and aimed to assess potential changes in auditory function as a consequence of exposure to low-intensity electromagnetic fields (EMFs) produced by GSM cellular phones [8]. Auditory function was assessed immediately before and after exposure to EMFs, and only the exposed ear was tested. The procedure was conducted twice in a double-blinded design, once with a genuine EMF exposure and once with a sham exposure (at least 24 h apart). Tests for assessment of auditory function were hearing threshold level (HTL), transient otoacoustic emissions (TEOAE), distortion product otoacoustic emissions (DPOAE), and auditory brainstem response (ABR). Exposure was given for 10 min.

Analysis of the GUARD project data showed that exposure to GSM mobile phone signals had no effect on the main measures of the status of the auditory system. What we would like to emphasize is that the exposure was only for 10 min, while our study looks into whether chronic exposure causes hearing loss. So an exposure of merely 10 min may not obtain the expected results, as was proven in the GUARD study.

To date no studies have been conducted on children, even though they are increasingly heavy users. These children may have a higher cumulative exposure to the

electromagnetic radiation than today's adults when they are of the same age. The electromagnetic radiation emitted from mobile phones is within the accepted range. What we don't know is whether with chronic usage, the emitted radiation will destroy the hair cells.

Anatomically, the mobile phone is held close to the ear with an approximate distance of 3 cm to the inner ear. The most common cause of deafness is sensorineural hearing loss. As we age, damage to the hair cells in the inner ear causes deafness. The first to be affected is the higher frequency. This is because the base of the cochlea transmits the high frequency and the apex the low frequency. Repeated exposure to loud noise has been proven to cause harm to the hair cells resulting in deafness. Unfortunately there has been no easy way for researchers to access and study the hair cells. Consonants have higher frequencies compared to vowels. Hearing loss in the higher frequencies can affect speech. Once the hearing loss is significant the only option is to use hearing aid devices.

Electromagnetic absorption is maximum on the side the phone is held and decreases to one-tenth on the opposite side of the head [13]. Thus the ear that is frequently used with the mobile receives maximum electromagnetic rays. This ear is identified as the dominant ear by our respondents in this study. In our study we were able to conclude that the dominant ear has significant hearing loss compared to the non-dominant ear. We also noted that the longer the duration of use, both in term of daily usage and length of years using mobile, the more significant the hearing loss.

There were some limitations in this study. A larger population based study needs to be done. We were not able to get non users of mobile phones to have a comparative study. This is an issue that needs emphasis because it reflects that the number of mobile phone users is increasing rapidly. These subjects need to be followed up to document the hearing threshold with continued usage. No laboratory co-relations were investigated. It would be ideal if we can study the effect of electromagnetic radiations on the hair cells. The authors would like to suggest some recommendations for mobile phone users: (1) set the lowest volume. (2) Short dialogue periods. (3) Hands free device (4) Use of mobile phones with low EMF emissions.

## Conclusion

Our study shows that the use of mobile phones predispose to hearing loss at the dominant (exposed) ear (the ear which is often used with the mobile). The fact that there was unilateral hearing loss in the dominant ear implies that the mobile phone as the cause of hearing loss. There appears to be correlation between the duration of usage of mobile daily and the length of years using mobile phone to the

degree of hearing loss. This is often unnoticed as most audiograms assess only up to 8 kHz. Hearing loss and other health hazards resulting from chronic use of mobile phones are important factors that need further research.

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