Study of the Thermal Effects of EM Radiation From Mobile Phones on Human Head Using IR Thermal Camera

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Abstract: This study investigates the thermal effects of electromagnetic radiation on human head through mobile phones before and after call, in order to find the temperature variation on skin in the right outer ear (Concha) using a thermal camera. A study population of n=7 male subjects within the age group of 20-25 years were considered for the study. The subjects were allowed to use two mobile phones of different brands operating at same frequency and different SAR (specific absorption rate) for 5 minutes and 15 minutes. The goal of this study is to investigate the rise in temperature and validate it against the maximum theoretical temperature rise calculated from the SAR of the phone and Bio-Heat Equations. Both experimental and analytical results show that the thermal effects on human head are SAR (brand/model) and talk time dependent.

I. INTRODUCTION

Mobile phones emerged as an apparatus of luxury in the early 90's, but presently it has become an inevitable part of daily life for a human being. At present there are nearly 7 billion mobile subscriptions worldwide according to The International Telecommunication Union [1]. This is equivalent to 95.5% of the population [1]. India has the fastest growing telecom network due to its increasing population. The total number of mobile phone subscribers in India has reached 930.20 million [2].A smart phone is a mobile phone with an advanced operating system. It includes the features of a phone, along with other applications like media player, web browsing, motion sensors, GPS navigation etc. The total number of smart phone subscribers across the globe is 1.75 billion. India ranks 3rd among the top countries for smart phone subscription with an estimated 117 million subscribers [3]. Roughly 12.5% of mobile phone users in India are believed to be smart phone subscribers.

A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. The mobile phone usage for a long duration of time induces temperature increase. Therise in temperature is not due to battery heating but it is due to the electromagnetic radiation emitted through mobile phones. Specific absorption rate is a dosimetric quantity and is defined as the rate at which RF power is absorbed per unit mass by any part of the body [4]. Higher the SAR value higher the electromagnetic radiation absorbed by the human body and if the SAR value is low then the absorption level is low [5].

This work is basically to analyse the temperature rise in the outer ear due to the effects of electromagnetic radiation emitted from the mobile phones. 7 male subjects were chosen for this study. Subjects were allowed to make a call & talk for different durations like 5 and 15minutes. This was done on different days with 2 different mobiles. Mobiles were chosen based on the SAR value. Images of external ear canal were taken before and after making the phone call. Theoretical temperature was found using the SAR value of each mobile and further comparison was done with the experimental values.

II. METHODOLOGY

2.1 Measurement Setup

Seven healthy adult male subjects (age range 19-23 years, height range 1.64-1.85m, weight range 45-90 Kg) were chosen. The subjects were seated on a comfortable chair about 1m in front of the IR camera. Subjects were allowed to adapt to the room temperature by seating them inside the room for about 15 minutes. Thermal images were taken against a black non-reflecting background. Ambient room temperature was maintained at 20^0C with slight variations not exceeding $\pm 0.5^0$C. Core body temperature was measured from the subject's underarm using a digital thermometer. Thermal Camera was focused on to head region particularly on the right ear. Thermal images were acquired before making call. This was taken as the initial temperature. Subjects were allowed to make a call for 5 minutes and 15 minutes and the thermal images are captured immediately at the end of a call. For this work, two different mobiles HTC Desire 616 (SAR value of 0.69 W/Kg) and Samsung Note3 (SAR value of 0.29 W/Kg) operating at same GSM frequency were chosen. The phones operate at GSM 1800 MHz .Therefore both phones experienced the same field strength of the received signal from the base station. The battery charge was maintained between 80-90%. FLIR A305 IR camera is used to acquire thermal image. It is well suited to investigate the temperature rise

2.2 Measurement Protocols

Before the experiment the subjects were asked to rest in the room for at least 15 minutes to adapt to the room temperature. Instructions were given to hold the mobile phone in the right hand and to position it on the right ear. The movement of the head region was restricted and the right lateral side of the human subject was positioned perpendicular to the IR camera which is particularly focused on the right lateral part of head. Thermal images of right side of the head were taken first before the exposure, as reference. After 5 minutes of exposure, images for right side of the head were captured immediately with a time gap of less than a second after the call. The same procedure was repeated for 15 minutes of exposure. Images were taken using both the mobile phones following the same procedure. In order to avoid cumulative effect of radiation, the experiment was performed on separate days on each of the subject.

2.3 Experimental Results.

The thermal images were analysed using FLIR R &D software to find the temperature rise. Rainbow palette is used. Anatomical area of interest chosen is the concha which is the opening at the outer ear above the ear lobe. A spot was kept on concha and the temperature rise was found out.

Table 1 Temperature rise in Samsung Note 3& HTC desire 616 for 5 minutes

SUBJECT	TEMPERATURE RISE IN SAMSUNG NOTE 3(^{0}C)	TEMPERATURE RISE IN HTC DESIRE 616(^{0}C)
1	0.2	0.2
2	0.1	0.3
3	0.1	0.3
4	0.3	0.3
5	0.3	0.3
6	0.3	0.3
7	0.4	0.4

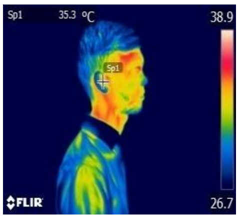

Fig.1a

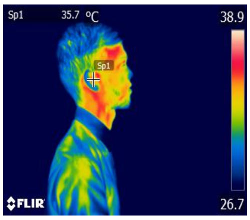

Fig.1 b

Fig 1.Temperature at concha before(a) and after (b)the EM exposure for 5 minutes

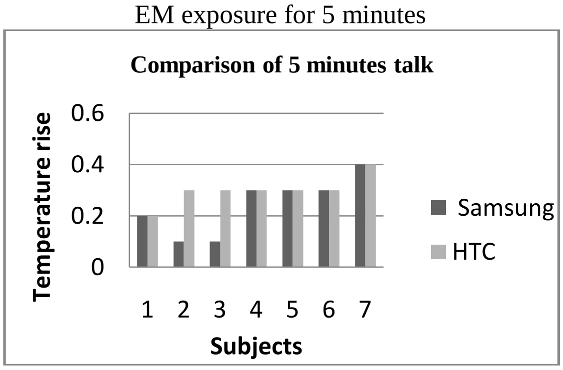

Fig 2.Temperature rise comparison between brands for 5 minutes talk time

Table 2 Temperature rise in Samsung Note 3& HTC desire 616 for 15 minutes

SUBJECT	TEMPERATURE RISE IN SAMSUNG NOTE 3(^{0}C)	TEMPERATURE RISE IN HTC DESIRE 616(^{0}C)
1	0.7	1.0
2	0.6	0.6
3	0.4	0.8
4	0.4	0.9
5	0.6	0.7
6	0.7	0.7
7	0.8	0.8

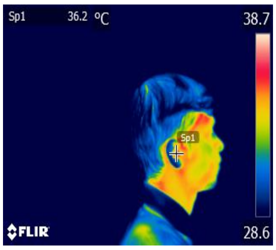

Fig.3a

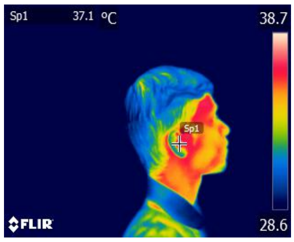

Fig.3 b

Fig 3.Temperature at concha before (a) and after (b) the EM exposure for 15 minutes

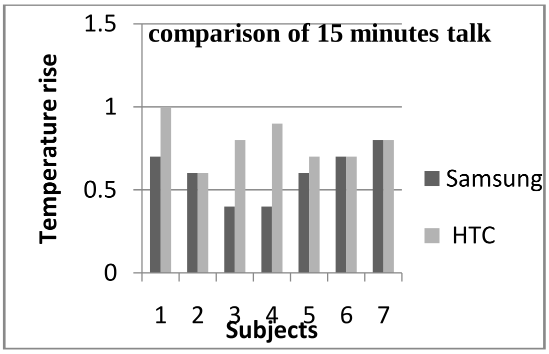

Fig 4.Temperature rise comparison between brands for 15 minutes talk time

III. THEORETICAL TEMPERATURE CALCULATIONS

3.1 Short term temperature calculations

SAR stands for specific absorption rate. SAR is a measure of the rate at which energy is absorbed by the human body when exposed to a radio frequency (RF) electromagnetic field according to the Cellular Telecommunications Industry Association (CTIA). A mobile phone's SAR rating is measured between 0.0 and 1.60 with 1.60 set by the Federal Communications Commission (FCC) as the maximum level of radiation permissible. The short term increase in temperature can be calculated from the SAR value through a linear equation [6]

$$\Delta T = SAR * \Delta t / C$$

Where,

ΔT is the temperature rise

SAR denotes the specific absorption rate of the mobile in W/Kg

C is the heat capacity of the tissue (in J/kg/K)

Δt is the time in seconds

3.2 Long term temperature calculation

Bio heat transfer is the study of heat transfer in biological systems. Heat transfer has an important role in biological systems of living beings. The increase of temperature in function of time and position is related the thermoregulation and the blood flow of the tissue. The heat transport in brain tissues is dominated by the heat input mechanisms caused by electromagnetic heating and the heat dissipation mechanisms provided by conduction and convection. The maximum temperature rise can be found from the Bio heat equation given below [7],

$$Tmax = q/lamda\ [1-(\sqrt{lamda}* A+1)\ e^{-\sqrt{lamda}* A}]$$

Table 3 Comparison of experimental Maximum temperature rise with the maximum temperature rise calculated using bio heat equation.

Samsung note 3		HTC desire 616	
Max. Temp. rise (^{0}C)	Max. Temp. from bio heat equation(^{0}C)	Max. Temp . rise (^{0}C)	Max. Temp. from bio heat equation (^{0}C)
0.8	0.6953	1.0	1.654

The bio heat equation is used for long duration of time like 5 & 15 minutes to find the maximum temperature rise. Short term formula is to calculate the temperature increase only for short duration of time i.e. in seconds.

IV. DISCUSSION & CONCLUSION

The result of the work showed that there is an increase in temperature from forehead to the carotid gland. High temperature increase was noted across the ear region especially on the concha which is above the earlobe. Samsung note 3 & HTC desire 616 are most popular and commonly used mobile. Samsung note 3 mobile costis high but it has the low SAR value of 0.29w/kg. During 5 minutes conversation the increase in temperature ranges from 0.1-0.4^{0}C. 0.1^{0}C was the lowest temperature rise & 0.4^{0}C was the maximum temperature rise. During 15 minutes conversation the increase in temperature ranges from 0.4-0.8^{0}C. 0.4^{0}C was the lowest temperature rise &0.8^{0}C was the maximum temperature rise. The maximum temperature during 15 minutes talk exceeds the temperature calculated from the bio heat equation but it is quite near to the value.

HTC desire 616 cost is moderate with the SAR value of 0.69w/kg but it does not exceeds the maximum SAR threshold which is about 1.6w/kg. During 5 minutes conversation the increase in temperature ranges from 0.2-0.4^{0}C. 0.2^{0}C was the lowest temperature rise & 0.4^{0}C was the maximum temperature rise. During 15 minutes conversation the increase in temperature ranges from 0.6-1.0^{0}C. 0.6^{0}C was noted as lowest temperature rise & 0.8^{0}C was the maximum temperature rise. Comparing with the bio heat equation, the maximum temperature is less than the maximum temperature which is theoretically calculated.

From our study, we conclude Samsung note 3 emits low electromagnetic radiation compared with HTC desire 616. So the effect of radiation to the human body is less. The mobile with low SAR value should be preferred irrespective of its price. The whole right lateral face is affected due to the use of mobile phone and with an increase in temperature. It is found that concha is the region which is affected the most compared to other region and also has a high temperature increase. Longer the duration we use the mobile, it induces more electromagnetic radiation which increase the temperature by heating the skin tissues.

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