

## Mobile Phone Users: Another High Health Risk Group

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**ABSTRACT** The mobile (cellular/cell) phone combines the technology of the wireless communication with that of the telephone and uses specific frequencies called microwaves, a sub-set of radio waves with frequencies ranging from 300 MHz to 3GHz. Cellular phones and their base stations emit pulsed microwaves in the environment with phone users exposed in the near-field and the general population exposed under far-field conditions. Some reported biological effects associated with these radiations include radiofrequency sickness, electroencephalographic and blood pressure changes, cancer risks and genotoxicity. A survey of persons using mobile phones was conducted in order to gather data on mobile phone usage patterns, which were maintained on a pre-designed questionnaire. There were 91 males and 9 females (16-55 yrs) of which 76 belonged to upper middle class socio economic status. They worked as businessmen, teachers, bank employees, doctors, surveyors, sales executives, mechanics, medical representatives and some of them were students. The duration of phone use varied from 1-5 yrs, with daily use of phone from 1-18 hr. They mostly kept the phones in their pockets while on move or on the table when in office or when at home. Some users complained of sleeplessness, headaches, memory loss, loss of attention and heating sensation on mobile phone use. Since exposure to radiofrequency radiations has been reported to affect physiological, neurological, cognitive and behavioural changes and to induce, initiate and promote carcinogenesis, such an underlying threat to human health also exists for mobile phone users.

### INTRODUCTION

There has been considerable public, scientific and media interest in the possible adverse health effects associated with the continuous or pulsed exposure to microwave radiation as emitted by mobile phones and their signal transfer towers. A mobile (cell) phone is a low power, single channel two-way-radio and emits signals via radio waves, which comprise radio frequency (RF) energy, a form of electromagnetic radiation. Mobile phone systems operate within the radio frequency section (30KHz - 300GHz) of the electromagnetic spectrum. The analogue phones operate between 450MHz - 900MHz and the digital phones operate between 900MHz - 1800MHz while the third generation phones operate at 2000MHz. Each base station covers phone use in a specific area or "cell" as great as 10 km in rural areas or as small as 0.2 - 0.5 km in towns where the demand is greatest.

The specific frequencies used by cell phones are called microwaves. The microwaves emitted by the mobile phones are very short waves of electromagnetic energy that travel at the speed of light (300,000,000 m/sec or 186,282 miles/sec).

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In addition to mobile phones these microwaves are used to relay long distance telephone signals, television programmes and computer information across the earth and for cooking food.

There are two sources of radiofrequency exposure from the mobile phone system: base station antennas and the mobile phone or handset. Exposure from the antennas is continuous but very low, irradiates the whole body and exposes an entire community. Exposure from the handset to the head is more intense, is only for intermittent periods and tends to be of concern to the user. RF radiations can cause physiological changes in brain, brain cells and cause other biological damage through heating effects. This can lead to headaches, blurring of vision, short-term memory loss, burning sensation and bad sleep (Lai and Singh, 1995, 1997; Hamblin and Wood, 2002). These effects may be associated with the "Specific Absorption Rate" (SAR) which is defined as rate of energy absorption at a point of absorbing body (expressed in W/kg). SARv (values) of various handsets include: for Motorola (0.10-1.58 W/kg), Nokia (0.22-1.45 W/kg), Ericsson (0.42-1.56 W/kg), Sony (0.41-1.39 W/kg), Philips (1.05-1.52 W/kg), Samsung (1.27-1.49 W/kg). The mobile phones with greater SARv may cause more ill effects on human body.

Although there is no clear molecular mechanism to explain the effects observed, yet some evidence has suggested that low

electromagnetic frequencies may induced a classic stress response in cells (Smith, 1996) involving the induction of heat-shock (hsp) genes. These genes encode heat-shock proteins (HSPs) which function mainly as molecular chaperones in protein transport and in protein folding/unfolding/refolding within the cells. Stressors such as heat, heavy metals and oxidative stress can cause damage to cellular proteins and the induced HSPs counteract the accumulation of such damage proteins by recycling those that are irreparably damaged for ubiquitination proteolysis (Parsell and Lindquist, 1993).

The health ill effects caused by microwaves radiations have been attributed to heating effects and the closeness of mobile phone handsets to the body as documented in various studies for defects as common as headaches to as serious as cancers. Some studies (Scarfi et al., 1993; Cranfield et al., 2001; McNamee et al., 2002; Zeni et al., 2003) have reported no significant effects of mobile phones on human health while others (Maes et al., 1993, 1997, 2000; Lai and Singh, 1995, 1997; Fritze et al., 1997; Malyapa et al., 1998; Svedenstal et al., 1999; Garaj-Vrhovac, 1999; Yaguchi et al., 1999; Zotti et al., 2000; D'Ambrosio et al., 2002; Cho and Chung., 2003; Mashevich et al., 2003) have shown mobile phone radiations to cause significant effects on human health or damage to cellular proteins or to DNA. Hence there is a plethora of information and equivocal evidence indicating both, a positive and/or a negative association with exposure to microwave radiations. In fact there are several possible sources of artifact in such studies and there is often no clear molecular mechanism to explain the observed effects, which may occur only within narrow windows of frequency and/or power level and/or pulse length/interval/and/or total exposure time (Goodman et al., 1995). However, the ever-growing incidence of mobile phone users globally (2 billion, [www.moremobile.co.uk/mobilephone-news](http://www.moremobile.co.uk/mobilephone-news)) and nationally (40.6 million, [www.ciol.com/content/news/2004](http://www.ciol.com/content/news/2004)) necessitate a comprehensive evaluation of mobile phone users. The present paper reports usage patterns of mobile phones, preferred brands, daily exposures to RF and other habit parameters in mobile phone users.

## MATERIALS AND METHODS

A survey was conducted to record information

from mobile phone users on a pre-designed questionnaire. Each individual was explained the reason for the present study and interviews were conducted only after voluntary agreement and written consent. Besides general information, pertinent records were maintained for queries on type of cell phone set, daily frequency of calls (incoming and outgoing), duration of calls, use period in 24 hours and in years, specific absorption rate value (SAR<sub>v</sub>), of the model and brand in use, etc. A family pedigree up to three generations was also recorded for each user. All the surveyed individuals used digital mobile phones of brands such as Nokia, Samsung, Sony, Motorola, etc. Changing phone models (handsets) can alter the specific absorption rate value. Mobile phone users were contacted through friends of friends or acquaintances, either in different vocations or having independent business and comprised residents of Amritsar or those visiting Amritsar from Batala, Gurdaspur, Tarn Taran, Jandiala, Ajnala, and Bhikiwind for business/work purposes during 2002-2003.

## RESULTS AND DISCUSSION

A random survey of 100 persons using mobile phones was undertaken for their phone usage patterns and life styles (Tables 1-4). The surveyed group consisted of 91 males and nine females (Table 1), 24 of whom belonged to the upper class as per criteria followed by Ramachandran et al. (2002), whereas rest of them were from middle class and they worked in different occupations, namely businessmen (n=38) or as college students (n=23) besides other. Based on their dietary habits, there were 26 pure vegetarians and 74 non-vegetarians, 41 took alcohol, eight were smokers while five individuals were both alcohol drinkers and smokers. Another three (non-smokers, not taking alcohol) were found to have chewing habits for *pan masala* (pan parag and chutki without tobacco, 5-6 sachets per day).

From among the various brands of cell phones, Nokia was preferred by 53%, followed by Samsung (17%). Other brands were comparatively less used (Sony-8%, Panasonic-7%, Motorola-6%, Ericsson-5%, Siemens-3%, and LG-1%). The surveyed group availed the networking from Airtel, B.S.N.L. (Bharat Sanchar Nigam Limited), Connect, Reliance and Spice. The Hutch service provider is very recent having commenced networking in Punjab only from late

**Table 1.: General characteristics of mobile phone users.**

Total Mobile Phone Users (n)	=	100	
Male	=	91	
Female	=	09	
Socio-Economic Status:			Disease/Health Effects :
Middle (M) – 76			Sleeplessness : 12
High (H) – 24			Less Attentivity : 07
			Headache : 09
Alcohol Intake – 41			Memory Loss : 07
Non – Alcohol – 59			Heating Sensation : 06
			Heart Pain on : 05
			<b>Vibration</b>
Vegetarian – 26			
Non – Vegetarian – 74			<i>Placement of Phone When:</i>
			<i>On the move :</i>
Smokers – 08			Shirt Pocket : 32
Non – smokers – 92			Trouser Pocket : 33
			Bag : 07
Chewers – 03			Waist Pouch : 04
Non – Chewers – 97			In Hand : 24
Alcohol + Smokers – 5 (100)			<i>In Office :</i>
			Shirt Pocket : 18
			Trouser Pocket : 23
<i>Occupation:</i>			Table : 41
Government Jobs :10			Drawer : 09
In Bank : 04			Bag : 09
Teacher : 03			<i>At Home :</i>
Doctor : 03			Refrigerator : 02
Businessman : 35			Table : 46
Medical Shop : 15			Shelf : 14
Building : 04			
Contractor			Pocket : 16
Shopkeeper : 16			T.V. : 07
Private Jobs : 30			Bedside : 05
Med. Rep. : 09			
Customer : 04			
Care services			
Hardware : 09			
/Software engineer			
Salesman : 08			
Student : 23			
Other : 02			
Marital Status :			
Unmarried : 50			
Married : 50			

Age Range (yrs)	No. of Individuals		Total
	Male	Female	
15-25	34	07	41
26-35	31	02	33
36-45	14	00	14
46-55	12	00	12
TOTAL	91	09	100

September 2004 while data for the present work were collected during October, 2002-July, 2003.

The specific absorption rate (SAR) value, indicating the rate of radiation absorption per unit tissue, was noted for different mobile phone models. The SAR may have a direct effect in causing genetic damage though it may not be an exact and only parameter inducing biological effects. There were maximum numbers of individuals (43%) using sets of different models with SAR values (SAR<sub>v</sub>) ranging from >1.00-1.45 W/kg, followed by (38%) with those having models with SAR<sub>v</sub> in the >1.45-1.90 W/kg range. The National Council on Radiation Protection and Measurement (NCRP), the Institute of Electrical and Electronics Engineers (IEEE) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) have identified a whole body SAR value of 4W/kg as a threshold level of exposure at which harmful biological effects may occur. However a much lower limit has been given by the Federal Communication Commission (FCC, USA) whereby wireless phones need to comply with a safety limit of 1.6W/kg (Lai et al., 1995, 1997). In the present study, mobile phone users had phone models SAR<sub>v</sub> within and outside these limits.

The placement patterns of mobile phones were also noted for when the individual was on the move, in office, or at home. On the move, 93 individuals kept the sets much closer to one part of the body or other, i.e. in shirt pockets (n=32), trouser pockets (n=33), waist pouches (n=4) or in the hand (n=24). Seven individuals kept the set in bags, which were not placed close to the body. In the office, 59 individuals kept the sets away on tables, etc. while 41 individuals kept them on self [shirt pocket (n=18), trouser pockets (n=23)]. At the home only 16 individuals kept the set in their pockets while 84 individuals kept them away. The individuals who kept the mobile phones in their trouser pockets may be at higher risk for some direct reproductive outcomes. In rats, exposure to testis (2450 MHz for 30 min.) raised the temperature to 40-42°C and caused dyspermatogenic sterility (Fang et al., 1982). A 75% increase in embryo mortality in rats in the incubation period exposed to EMF from GSM mobile phone during embryonic development was reported by Grigor'evlug (2003). In a very recent study, it was reported that radiation could cause decrease in sperm count by 30% when individuals carry the cell phones (900 MHz -2000 MHz) in belt holsters or trouser pockets (Fejes and Challis, 2004). A prolonged use of cell phones may have a

negative effect on spermatogenesis (sperm production) and male fertility that deteriorates both, sperm concentration and motility.

No aberrant reproductive performance was observed from the pedigree records of the married individuals (n=50) and there was also no history of genetic disorders/spontaneous abortions/major illnesses such as diabetes, cancer, etc. However, some health effects reported with mobile phone usage included sleeplessness in 12 individuals, headaches in nine, followed by those with memory loss and loss of attentivity (n=7 each), heating sensation in six and five had heart pain on vibrations. Some overlaps included two with sleeplessness and memory loss and seven with sleeplessness, headaches and memory loss.

Symptoms such as headaches, feelings of discomfort, warmth behind/around or on the ear and difficulties in concentrating while using mobile phones have been also reported in literature. The number of complaints was reportedly higher for people using the digital (GSM) system i.e. with pulse modulated fields than for those using the analogue system (Sandstrom et al., 2001).

A statistically significant association between calling time/number of calls per day and the prevalence of warmth behind/around or on the ear, headaches and fatigue was there (Koivisto et al., 2001). However, no symptoms like headaches, dizziness, fatigue itching of skin, redness on the skin or sensation of the warmth on the skin in healthy subjects exposed to 902 MHz and 217 MHz pulse modulated EMF were reported.

**Table 2: Mobile Phone usage patterns**

Age (y)		No. of Indivi duals	Use period in 24 (hr)		Kept on "ON" Mode (hr)		Attending the Phone (Ears)				Using Mobile Phone at home		Spouse using Mobile Phone		Time Since Using Mobile Phone (y)	
Range	Mean		Range	Mean	Range	Maen	3	R	B	Total	Yes	No	Yes	No	Range	Mean
16-20	18.62	08	6-15	11.00	16-24	22.25	02	05	01	08	07	01	00	08	1-4.5	2.45
21-25	23.00	33	1-18	10.03	8-24	21.87	05	22	06	33	25	08	01	32	1-5	2.74
26-30	27.83	24	1-18	8.92	15-24	22.04	08	11	05	24	18	06	02	22	1.5-5	3.14
31-35	33.66	09	1-18	12.27	16-24	20.00	06	03	00	09	09	00	01	08	1-5	2.72
36-40	37.60	05	6-13	9.20	15-18	17.40	04	01	00	05	04	01	01	04	1-3	1.60
41-45	43.55	09	6-18	12.00	16-24	23.11	01	05	03	09	08	01	02	07	1.5-5	3.16
46-50	47.37	08	4-18	9.37	18-24	22.25	04	04	00	08	08	00	02	06	2-5	3.25
51-55	53.00	04	4-18	11.25	24	24.00	01	03	00	04	03	01	03	01	1-5	2.62
TOTAL		100					31	54	15	100						

L- Left Ear, R- Right Ear, B- Both Ears.

It was also observed that individuals below 30 years were extensive users (65%) of mobile phones (Table 2). The use period per day varied from 1 to 18 hours though the set was kept on "ON" mode from 8 hours to the entire day. The number of persons who attended the phones from their right ears (n=54) was more than those who (n=31) attended the phones from the left ears. There were 15 who attended the phones from both the ears. A 2.5 times risk of developing brain tumours among heavy users has been reported (c.f. Hardell et al., 1999). Right-handed users developed right-sided tumours and left-handed users developed left-sided tumours. Mobile phone users have a 30% increased risk for brain tumours, mainly acoustic neuromas, which occur close to the ear used for mobile phone listening (Lonn et al., 2004). Growth of leukaemia cells was also reported to increase dramatically after exposure to mobile phone radiation.

Other aspects of the survey included the use of mobile phone by other family members at homes of the mobile phone users. These were 20 individuals each whose relatives of 18-25 years, children of 5-10 years and 12, whose spouses also used the mobile phone. This indicates that mobile phone end-users can be more than the owners of the phones and technically all those using it may be exposed to the radiofrequency radiation (RFR). The youth and children may use it as for sending messages service (SMS) or playing games and hence a whole body exposure may also result.

Salford et al. (2003) has reported that mobile radiation allows harmful proteins and toxins

**Table3: Daily frequency and duration of calls on mobile phones.**

Time Since using mobile phone (y)	Mean Duration (y)	No. of Individuals	Daily Frequency of Calls(No.)				Duration of Calls/day			
			Range		Mean		Range		Mean	
			Incoming	Outgoing	Incoming	Outgoing	Incoming	Outgoing	Incoming	Outgoing
1-2	19.54	35	5-30	4-30	11.88	10.80	2''-45''	1''-21''	7'21"	6'10"
>2-3	33.31	38	4-35	2-35	13.78	10.42	1''-21''	1''-35''	7'45"	6'43"
>3-4	44.28	14	6-75	4-70	24.07	19.78	1''-20''	1''-26''	14'11"	12'27"
>4-5	59.07	13	6-52	5-35	20.62	15.85	3''-35''	1''-31''	20'26"	14'54"
Total		100								

**Table 4: Preferred brands of mobile phones.**

Brand Name	Model	SAR (W/kg)	No. of individuals	Health effects*	Special offers availed	
					No	Yes
Ericsson	T-18	1.40	01	ML	01	-
	S-828	0.77	03		02	01
Nokia	LX-588	1.31	01	Hy	01	-
	CMD-C1	0.55	01		-	01
	751	1.33	01	Hd	-	01
	3310	1.24	14		MI, Hy(2)	11
	5110	1.45	02	01	01	
	3315	1.47	20	14	06	
	6150	0.69	02	01	01	
	3210	1.14	04	03	01	
	3110	1.27	04	03	01	
	2100	1.43	02	-	02	
	6210	0.99	01	01	-	
	3610	1.42	01	01	-	
Samsung	C-131	0.87	01	Hd, MI, Hp(2)	01	-
	620	1.38	01		01	-
	N-500	1.21	02		02	-
	AR-220	1.56	01		06	04
	315-E	1.65	01		01	-
	R-220	0.59	02		02	-
	SGC-100	0.99	03		0	-
Panasonic	9210	1.75	02	-	02	
	9215	1.92	02	02	-	
	EBGD-70	0.99	03	03	-	
Siemens	C-25	1.33	02	MI(1)	02	-
	C-35	1.43	01		01	-
Sony	CMB-1200	1.39	06	MI(1)	01	-
	CMD-C1	0.55	01		01	01
Motorola	T-100	1.66	01	MI(1)	01	-
	Startac-130	0.10	02		01	01
	N5517-A	1.58	01		01	-
	Startac	0.33	01		01	-
	Startac	1.25	01		01	-
	(TDMA)	1.36	01		01	-
LG	C350			MI(1)		
	2030	1.55	01		01	-
Total			100		75	25

\*MI- memory loss, Hy- hypertension, Hd-headache, Hp-heart pain on phone vibration.

through the blood brain barrier (BBB) in rats leading to significant degree of damage to brain neurons in adolescent rats. He further is quoted "If this effect was to transfer to young mobile users, the effects could be terrifying". Radiations from mobiles were also reported to increase blood pressure in the users.

With respect to the time since using mobile phones, these were 38 individuals using mobile phones for 2-3 years while 35 individuals were using them for 1-2 years, 14 individuals for 3-4 years and 13 individuals for 4-5 years (Table 3). The daily frequency of incoming (4-35) calls and outgoing (4-35) calls and duration of incoming

(1'-25') and outgoing (1'-25') calls were also noted and showed an extensive variation.

The details with respect to the model numbers and the SAR values (SAR<sub>v</sub>) of various mobile phone brands are given in Table 4. The SAR values (0.10-1.92 W/kg) were not too specific to the particular models used. Motorola (5 models, 0.10-1.58 W/kg), Nokia (12 models, 0.55-1.47 W/kg), Sony (3 models, 0.55-1.66 W/kg), Samsung (6 models, 0.59-1.65 W/kg), Ericsson (3 models, 0.77-1.51 W/kg), Panasonic (3 models, 0.99-1.92 W/kg), Siemens (2 models, 1.33-1.43 W/kg), LG (1 model, 1.55 W/kg). It was further observed that special offers for SMS (short messages service), free talk-time etc. were availed by 25 individuals. This probably adds to their exposure because they may be more frequently on line and also sending messages. However no facilities for e-mail connecting score cards for games, stock exchange, etc. were available to the mobile phone users of the surveyed population. Some of the health effects pertaining to mobile phone use included sleeplessness (n=12), headaches (n=9) memory loss and loss of attention (n=7 each), heating sensation (n=6) and heart pain on phone vibration (n=5). These were many overlaps also, viz. sleeplessness and memory loss and less attentivity and memory loss.

Individuals who used sets with higher SAR values, using mobile phones from 4-5 years, their daily frequency of calls (incoming and outgoing) and duration of calls (incoming and outgoing) are more or extensive users of mobile phones as well as individuals who kept their mobile phones on "ON" mode for 8 hours to whole day. In the literature reviewed, documented effects of RFR (900 MHz-2000 MHz) at SAR values at par with those to which mobile phone users of the present study are exposed, include neurological, physiological, behavioral and reproductive changes as well as carcinogenic and mutagenic effects.

Use of cellular phones induced significant changes in local temperature and in physiological parameters of the central nervous and cardiovascular systems (Khudnitskii et al., 1999) while Lebedeva et al. (2001) reported that EEG correlation dynamics and the relation of sleep-stages in humans changed under the influence of the electromagnetic field of a GSM standard mobile phone. Electromagnetic field (from mobile phones) also altered regional cerebral blood flow and induced sleep and waking EEG changes

(Huber et al., 2002). However, an increase in reaction time was also observed for the neural activity in 12 volunteers exposed to mobile phone radiation (Hamblin et al., 2004) though a significant increase in incorrect answers in a memory task following an exposure to a digital 902 MHz field was observed in humans (Krause et al., 2004) and there was also a significant reduction of the T-cell mediated anti-bacterial activity in human peripheral blood lymphocytes exposed to 1.5-2.0GHz frequency for 5 or 10 min (Jirillo et al., 2003). On the other hand, no effect on heating, at least at outer ear, middle ear and cochlear levels exposed to EMFs on hearing levels of 30 volunteers was observed by Ozturan et al. (2002) and there was also observed no disruption in melatonin circadian profile in 37 volunteers who were exposed to GSM900 MHz or DCS 1800 MHz for 2hr/day, 5 days/week, for 4 week by De seze et al. (1999).

Changes in the blood brain barrier (BBB) permeability are related to tumour formations. In rats exposed to 900 MHz microwave for different durations at a SAR range of 0.3-7.5 W/kg, there were significant changes in the BBB permeability. However no effects on brain tumor promotion was reported by Adey (1997) in F344 rats exposed to 0.836 GHz radiation 2 h/day for 23 months though Repacholi et al. (1997) reported an increased incidence of lymphomas in transgenic mice, exposed to 900 MHz microwaves daily for 30 min at SARs ranging from 0.008 to 4.2 W/kg. Similarly no effects on tumour appearance in rats exposed to whole body SAR<sub>v</sub> in the range of 0.075-0.270 W/kg (Chagnaud et al., 1999) were seen. Also no effects on the incidence of spontaneous tumours after exposure to FDMA (835.62 MHz) and CDMA (847.74 MHz) at SAR of 0.85-0.34 W/kg was reported by La Regina et al. (2003) in 120 T344 male and female rats. Lonn et al. (2004) reported an increased incidence of acoustic neuroma, a benign tumour in mobile phone users using mobile phones for ten or more years.

Hence it can be hypothesized that individuals of the present survey may also be susceptible to adverse effects from RFR which have been reported, viz., neurological, behavioural, cognitive and physiological alterations. Carcinogenicity from exposure to radio frequency fields in different tissues of several mammalian species as well as mutagenic and genotoxic effects of RF at cellular and molecular levels are other effects which have

also been debated upon (Heynick et al., 2003).

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