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ABSTRACT

Mobile phone "cell phone" use has dramatically increased over the last decade, but doubts remain over its safety. Epidemiological investigation of mobile phone (MP) users reported symptoms of discomfort feeling, warmth behind/around or on the ear and heat sensation of the cheek. These symptoms may be due to thermal insulation, conduction of the heat produced in the phone by the battery currents and running of the radiofrequency (RF) electronic circuits, and electromagnetic field (EMF) energy absorbed by the user's head. Using a Luxtron 790 fiberoptic thermometer we measured the temperature of the temporal skin due to GSM 1800 MHz MP radiated power (125 mW). To perform a sham exposure, we suppressed the EMF exposure by switching the RF signal from the antenna to a 50 Ω load. The ambient air temperature was 23°C, the relative humidity was 50 ± 10 %, the air flow rate in the room was 0.01 $m.s^{-1}$ (natural convection) and the MP was held in the normal position of use "*cheek position*" (CENELEC Standard 50361) for 30 minutes to reach the thermal steady state. With a switched off MP, the increase in skin temperature was statistically significant 1.88°C. When MP was switched on, the increase was 2.93°C in reception mode, 3.29°C in emission mode without load and 3.31°C in emission mode with load. The temperature difference with or without load was not significant (t_{17} = 0.707; p = 0.489), which means that the contribution of EMF absorption to skin heating is negligible. The highest temperature increases detected during these experiments (T_{skin} = 37.1°C ≈ core temperature) are in the environmental range and are lower than those physiologically experienced by the surface skin during hot summer days. No skin damage by thermal insult is experienced for T_{skin} < 44°C, whereby a pain sensation replaces the feeling of temperature elevation in humans. This local skin temperature increase will cause thermoregulation responses. The skin blood vessels will be dilated and skin will be wet. The result suggests that the heat sensations reported by the MP users are exclusively caused by thermal insulation and heat conduction from MP associated with long calling time. No thermal skin damage can be suspected using MP in normal use.

KEYWORDS

Mobile phone (MP); Electromagnetic field (EMF); Skin temperature; Thermal damage

INTRODUCTION

The ever-rising diffusion of 'cellular' mobile phone (MP) systems has determined an increased concern for possible users' health effects due to the field emitted by the handheld terminals. In fact, when a mobile phone is working, the transmitting antenna is placed very close to the user's head where a substantial part of the radiated power is absorbed. Many epidemiological investigations of MP users [1, 2] reported symptoms of discomfort feeling, warmth behind/around or on the ear and heat sensation of the cheek. These symptoms may be due to changes in the thermal exchange between the skin and the air due to the contact between the phone and the skin (thermal insulation), conduction of the heat produced in the phone by the battery currents and running of the radiofrequency (RF) electronic circuits transmitted to the tissue, and of a part electromagnetic field (EMF) energy absorbed by the user's head. The head exposure to EMF presents particular problems due to the close proximity between the source of emission (MP antenna) and the head of the user. A major part between 40-50 % of MP EMF energy is absorbed by user's head [3] and the absorption is highest in the skin ~ 38.5 % [4].

The aim of this study is to quantify the temporal skin warming of the MP user in the normal position with an investigation of the different parameters contribution and to compare the obtained temperature increases with the thresholds for the induction of thermal damages.

MATERIALS AND METHODS

The mobile phone used in this study was a GSM 1800 MHz Motorola mr 20 with a test card to control the use mode of the MP. It was used at maximal power during emission and their batteries allowed continuous emission without loss of power for the whole duration of the experiment. The emission parameters were as following: frequency: 1800 MHz; frequency of repetition of impulses: 217 Hz; duty cycle: 1/8; peak power/average power: 1 W / 125 mW.
We suppressed the EMF exposure by switching the RF signal from the antenna to a 50 Ω load. The efficacy of the EMF suppress was measured by the SAM phantom the Specific Absorption Rate (SAR) is negligible when using the load [5].
During experiments the MP was: switched off; switched on in reception mode, in emission mode without load and in emission mode with load.
Temperature was measured using a fiberoptic thermometer (Luxtron 790) with 4 SFF-5 surface temperature sensors which can be used in normal listening conditions. The temperature was measured every minute during the experiment until thermal steady state was reached and the data automatically recorded on a computer. The accuracy of measures was ± 0.1°C.
The sensors were calibrated at the beginning of each experiment in a water bath at ambient temperature (controlled by a mercury thermometer). For each volunteer, three sensors were used, one placed on the temple of the subject (skin sensor), another on the mobile phone surface in contact with the temple (phone sensor) and the last measures air temperature (air sensor). The 'skin sensor' was placed perpendicular to the line starting from the tragus in alignment with the lip edge, at the level of the temporo-mandibular joint, and held in position with porous adhesive tape. The 'phone sensor' was placed on the flat surface between the screen and the keypad on the middle line using adhesive tape. When the phone was in the normal using position, the two sensors were both parallel and contiguous. The use of these two sensors allowed the measurement of the kinetics of the raise in temperature at the skin-telephone interface until thermal equilibrium was reached.
After calibration, the sensors were placed on the skin and MP in their reference positions. The temperatures of skin and MP surface switched off at room temperature were measured before beginning measurement at normal using position of MP. Then mobile phone switched off was held in the normal using position and the variations in temperature recorded until temperature equilibrium was reached (approximately 30 minutes). The same experiment was done with switched on MP: in reception mode in emission mode without load and in emission mode with load suppressing EMF exposure.
The MP was held in the normal using position "*cheek position*" (CENELEC Standard 50361) to have the maximal contact between the MP surface and the skin of the MP user. This position may modify heat exchange between the skin and the ambient air and make the MP and the antenna close to the head of the MP user.
Three healthy male volunteers 25, 26 and 30 years old have participated for this study. For each trial 18 measurements were made to assess the repeatability of the measures. The mean values are given with one standard deviation (± 1 SD). The difference between experimental conditions was computed by Student's *t*-tests. The *t*-values are given with their corresponding of degrees of freedom (subscripts beneath *t*-values). The accepted level of significance was $p < 0.05$.
In all experiments, the mean value of ambient air temperature (T_{air}) was 23.0 ± 0.8°C, the relative humidity was 50 ± 10 %, the air flow rate in the room was 0.01 $m.s^{-1}$ (natural convection) and the MP was held in the normal position of use for at least 30 minutes to reach the thermal steady state.

RESULTS

Temperature measurements

Temperature is recorded until equilibrium was reached around 30 min after the beginning of the experiment. The mean value of temperature measurement concerns the steady state period.
The initial mean skin temperature (T_{skin}) of volunteers at normal room temperature (23.0 ± 0.8°C) was 33.8 ± 0.6°C (reference). The study of the raise in skin temperature due to the physical contact with the phone showed that the equilibrium temperature at the 'skin-phone' interface was 35.7 ± 0.2°C. This was due to the decrease of the skin heat loss with the environment (Table 1). The mobile phone contact causes heat insulation of the skin surface. The temperature increase is equal to + 1.88°C.
The mobile phone temperature -as the skin temperature- increases when the MP is in contact with the skin surface. The skin and the phone sensor were face to face and give the same value at thermal equilibrium at skin-phone interface.

Table 1: Equilibrium mean values (± 1 SD) 'n= 18' of air temperature (T_{air}, °C), skin temperature (T_{skin}, °C) and mobile phone surface temperature (T_{mp}, °C), in the different experimental conditions (reference, skin-phone interface: MP switched off, switched on in reception mode, in emission mode without load, in emission mode with load).

	Experimental conditions				
		Skin-phone interface			
	Reference	**Switched off**	**Reception**	**Emission**	**Emission + load**
T_{air} (°C)	22.6 ± 0.7	22.9 ± 0.8	23.1 ± 0.7	23.2 ± 0.8	23.4 ± 0.7
T_{skin} (°C)	33.8 ± 0.6	35.7 ± 0.2	36.7 ± 0.2	37.1 ± 0.2	37.1 ± 0.2
T_{mp} (°C)	22.8 ± 0.8	35.3 ± 0.4	36.7 ± 0.2	37.2 ± 0.20	37.4 ± 0.2

When MP was switched on, the increase in skin temperature from the initial value was 2.93°C in reception mode, 3.29°C in emission mode without load and 3.31°C in emission mode with load.

The skin temperature difference between the mobile phone switched on in emission mode with or without load experimental condition was not significant ($t_{17} = 0.707$; $p = 0.489$). There is no significant supplemental skin heating due to RF emission from the MP antenna, which means that the contribution of EMF absorption to skin heating is negligible.

Temperature increase at skin-phone interface and thermal equilibrium

An example of the kinetics of the raise in temperature at the skin-telephone interface is presented in Figure 1. To reach the skin-phone interface thermal equilibrium we must wait at least 30 min. The calling time is an important parameter for heat sensation and discomfort feeling. More important is the time calling with MP skin contact, more is the prevalence of warmth sensation.

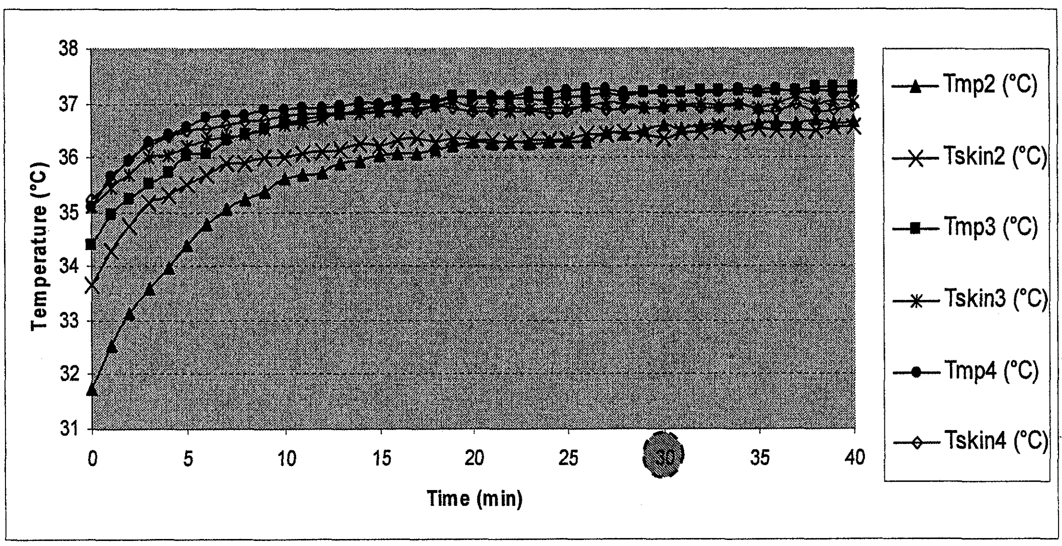

Figure 1: Skin (T_{skin}, °C) and mobile phone temperature (T_{mp}, °C) plotted against time (min), with MP switched on in reception mode (2), in emission mode without load (3) and with load (4) during one experiment. Thermal equilibrium was reached around 30 min.

Pain threshold

Studying the bioelectromagnetic interaction from a thermal point-of-view, it is interesting to compare the obtained temperature increases with the thresholds for the induction of thermal damages.

For partial body exposure, the limiting hazard may be local temperature rise, rather than excessive thermal load to the body. Thermal injury is characterised by a rate process, such that the threshold for injury depends on the duration of contact and how 'perfect' the contact is which will be related to pressure, differences in epidermal thickness and magnitude of temperature rise depending on the reactions to materials correlated well with the thermal inertia's (thermal dose). The constitution of human cells is such that at temperature above around 44°C, damage can begin to occur if exposure to that temperature is sufficiently long. It is generally true therefore, that if skin temperature in contact with solid surface is below about 43°C, discomfort and pain sensations will be avoided and no skin damage will occur. An interesting point is that the lowest surface temperature that was responsible for cutaneous burning was 44°C for an exposure of 6 h. It can be expected that if (relatively cool) blood flows at the site of hyperthermia (thermoregulation), this would protect the skin against burning [6]. The threshold temperature increase for neurone damage is about 4.5°C (for more than 30 min) [7]. Experiments performed on the eye have evidenced a threshold increase of 3°C-5°C in the lens for the induction of the cataract [8].

The highest temperature increases detected during the present study (T_{skin} = 37.1°C) is in the environmental range and are experienced by the surface skin during hot summer days. No skin damage by thermal insult is experienced for $T_{skin} < 44$°C, whereby a pain sensation replaces the feeling of temperature elevation in humans. No thermal skin damage can be suspected using MP in normal use.

CONCLUSION

The results show that the heat sensations reported by the MP users are exclusively caused by thermal insulation and heat conduction from MP associated with long calling time. The power of EMF emitted by the MP antenna is not sufficient to cause increase in cheek skin temperature when using MP. These results suggest an awareness of the symptoms, but no thermal damaging on skin is suspected.

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