ORIGINAL ARTICLE

The Chromosomal DNA Damage in Buccal Mucosa Cells among Schools Children in The Vicinity Of Mobile Base Stations in Selangor

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ABSTRACT

Introduction: The increased use of mobile phones has increased the mobile base stations (MBS) deployment. While understanding of radiation protection is growing among the public, questions regarding early-life exposure to radiofrequency radiation (RFR) from MBS in children are of importance as to whether it will raise the chances of developing chronic diseases during adulthood. Taking into account the sitting location of MBS, the purpose of this study is to evaluate the chromosomal DNA damage in buccal mucosal cells between school children exposed to RFR emitted from base station antennas. **Method:** This is a comparative cross-sectional study in which two group of school children were sampled i.e. exposed groups are children whose school located near MBS (≤200 meters); unexposed groups are children whose school located distant far from the MBS (>200 meters). Digital RF Analyzer was used to measure RFR at the school surrounding. Buccal mucosa cells from the oral cavity were sampled to examine the level of micronuclei (MN) frequencies. **Results:** This study found that the densities of the RFR energy differed in range. Although all measurements showed the RFR reading below the acceptable exposure level, there were still significant variations at each location assessed. Statistically, the MN frequency is significantly different when compared to the exposed and non-exposed group. **Conclusion:** To understand the mechanism of health effects from exposure to low-level RFR emited from MBS, further study should consider environmental factors influencing MBS sitting on RFR emission, as well as examining the health effects into molecular levels.

Keywords: Radiofrequency Radiation (RFR), DNA Damage, Micronuclei Assay, Mobile Base Station, Children

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INTRODUCTION

Since the advent of mobile phone technology in the 1990s, mobile phones have become a vital part of our everyday lives. The benefits of using mobile phones are no without associated social and health costs. Growing use of mobile phones has led to an increase in mobile base station (MBS) deployment. In order to provide a better network coverage to fulfill the huge demands, many telecommunication companies are competing to set up MBS around the country. Over the past decades, MBS has often been found close to dwellings, houses, community facilities and residential areas. Although several organizations and government agencies such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the Institute of Electrical and Electronics Engineers (IEEE) and the World Health Organization (WHO) have developed guidelines to safeguard the general public and workers from excessive RFR radiation emitted from base station antennas, many of them have developed guidelines. As public awareness of radiation protection and exposure increases, concerns about early life and chronic low-frequency RFR exposure from MBS among children are of interest as to whether they will increase the chances of developing chronic diseases during their adulthood.

To date, conflicting reports on the inconclusive health effects of RFR exposure from mobile phones usage and the base-stations emission (1). However, most studies still maintain that RFR emissions from mobile phones are a direct cause of cancer development, and the location of base stations within communities has continued to give rise to strong concerns (2). In fact, past studies have suggested that long-term exposure to electromagnetic fields (EMF) would increase the potential for DNA damage through free radical formation within human

cells (3). Other studies have suggested that RFR can induce leakage in lysosome membranes (small bodies in living cells loaded with digestive enzymes) and release DNAase (an enzyme which destroys DNA) that explains the DNA damage seen in most cells exposed to low-level EMF signals (4).

Children, on the other hand, are more vulnerable to cell phone radiation as they absorb more energy than adults do from the same phone. This vulnerability is due to their smaller head and brain size, thinner cranial bones and skin, more elastic ears, lower blood cell volume, and increased nerve cell conductivity. These body structures cause RFR energy to penetrate deeply into their vulnerable target organ and make them susceptible to chronic health effects. Several researches indicated that early life sensitivity to non-ionizing RFR from different environmental factors increased the chances of young children contracting chronic diseases during their adulthood (5, 8-9).

Although the data on the identified health effects of RFR exposure in children remains uncertain (6), the issue is whether there is low level or long-term RFR exposure when considering the position of the MBS sitting. Given the sitting position of MBS, the purpose of this study is to evaluate chromosome DNA damage in oral mucosal cells between school children exposed to RFR from base station antennas.

MATERIALS AND METHODS

This is a comparative cross-sectional study conducted by stratified random sampling among primary school children. This study assumed that radiofrequency (RF) emitted from base station antennas was the primary cause of radiofrequency-induced human chromosome DNA damage. The MBS which found in the area of the school environment were first identified. Next, four (4) primary schools were selected based on the location of the MBS, i.e. two (2) schools located within 200 meters (< 200 meters) of the identified MBS were categorized as "exposed school" and two (2) schools located further away from the identified MBS (> 200 meters) were categorized as "non-exposed school". School children from these institutions were then paired together as either exposed or non-exposed categories based on the criteria of their school.

The sample size was calculated based on the group comparison (two-group) design adopted from Lemeshow et al. (1990) formula as follows,

$$n = \frac{2\sigma^2\left(Z_{1-\frac{\alpha}{2}} + Z_{1-\beta}\right)^2}{(\mu 1 - \mu 2)^2}$$

The required number of children to be recruited in this survey is calculated to be the foundation for the overall experience of the revealed and monitored group of mobile phone users (7), where a total of 60 participants would be recruited to engage in this research.

School children between the ages of 10 and 11 years who have proclaimed themselves free from medical history of cytotoxic medicinal medications and have never been treated with these medical conditions, such as gum leakage, diarrhea, anemia, nephritis and hepatic diseases, as well as the approval of their family were invited to engage in this research. A total of 110 school children were recruited and later grouped as exposed group and 91 school children were grouped as a non-exposed group. In order to minimize the physical injury and reduce unwanted invasive techniques, exfoliated buccal mucosa cells were collected by gently scraping the mucosa of the inner lining of both cheeks. The buccal mucosa cells were used to analyze the frequency of micronuclei (MN) for each respondent by using the MN assay. Besides, RF measurement for each school was measured by using Digital RF Analyzer (Model: model: HF35C). This study was approved by the Ethics Committee of the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia [Ref: UPM/TNCPI/RMC/1.4.18.2 (JKEUPM)]

Micronuclei Assay

The formation of micronuclei (MN) has been used as a measure for chromosome damage caused by compounds that induce chromosome breakage (clastogens) as well as by agents which influence the spindle apparatus (aneugens) (10). The MN assay was performed based on the standard protocol mentioned in the previous study (11). The end point is to calculate cells with the involvement of MN(s), which are graded based on the cells presented with a main nucleus and smaller nuclei called micronuclei (MN). The MN are either round or oval and have a diameter of between 1/3 and 1/10 of the diameter of the main nucleus (Fig. 1).

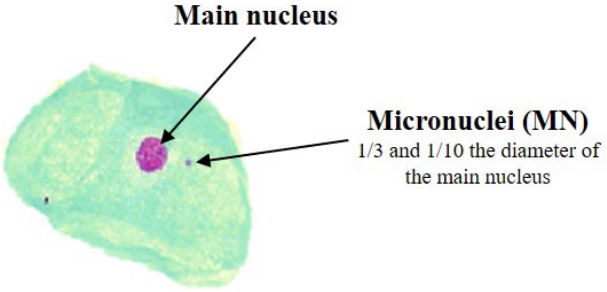

Figure 1: Photomicrograph showing Fast Green-stained mucosal cells with Micronuclei (MN) at x 40 magnification

RF Measurement

In this study, measurements of RFR in power density were carried out by using a Digital RF Analyzer (Model: HF35C). This instrument measured RFR exposure between 800 MHz and 2.5 GHz in (μW/m2) units. It covers the frequency of most public RF radiation emitting devices (e.g. GSM800, GSM1900, TDMA, and CDMA). In order to control the consistency of the RF reading, the measurement was repeated three (3) times to record the

average radiation levels during the school hours by the same person. This makes the measurement in a good relative and avoids the biologically measurement errors. Measurements were made starting at the foot of the base station, in the direction of the main beam of the antennas. The measurement is then repeated at 10 meters in each measurement. During the measurements, all digital and communication devices were switched off and researchers were not engaged in any activities involving the emission of RF radiation. In the case of exposed schools, measurements were carried out starting at the foot of the base station, facing towards the main beam of the antennas; in the case of non-exposed schools, measurements were carried out around the schools starting from the school gates.

RESULTS

A total of 90 school children aged 10-11 from exposed schools and 110 school children from non-exposed schools have been selected to take part in this study. Table I indicates that the age and gender classes are

Table I: Demographic Characteristics of the Study Population

Characteristics		Exposed (N=91)	Non-exposed (N=110)
Age	10	52 (57.1)	53 (48.2)
	11	39 (42.9)	57 (51.8)
Gender	Female	41 (45.1)	47 (42.7)
	Male	50 (54.9)	63 (57.3)
Body Mass Index (BMI)	Underweight	53 (58.2)	61 (55.5)
	Normal	27 (29.7)	40 (36.4)
	Overweight	7 (7.7)	8 (7.3)
	Obese	4 (4.4)	1 (0.9)
Either family member/parents are smoker		42 (46.2)	41 (37.3)

equally divided among the sample population groups. Most of the school children are either underweight or normal in weight. Generally, at least 40-45% of school children inhaled indoor tobacco smoke from their smoking relatives or other family members. The findings of this study showed that the RFR power densities varied in distance. There was a large discrepancy between the peak and the minimum values at each position and for each metric. Although all measurements indicated that the RFR reading was below the permissible exposure limit, large fluctuations were still recorded at each measured site. Fig. 2 to Fig. 5 shows the maximum to the minimum readings and the root mean squares at each school. Table II shows that there is a statistically significant difference between the frequency of school children's micronuclei (MN) between exposed and non-exposed groups, with the exposed group having a higher mean (11.50) MN frequency count in every 1,000 cells compared to the non-exposed group (8.04).

DISCUSSION

The effects of this RF radiation analysis research are

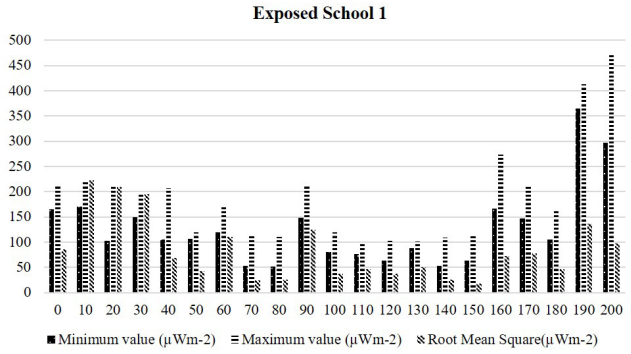

Figure 2: Power Densities ranges from 0-200 m from Exposed School 1

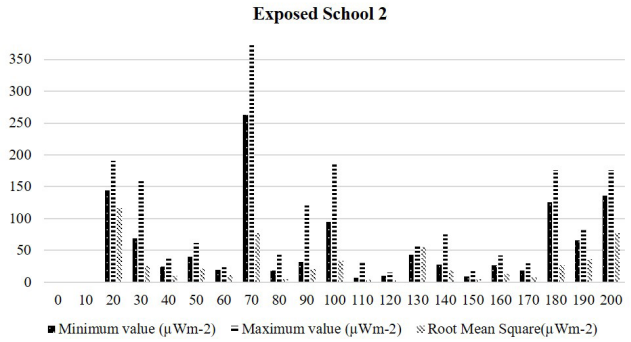

Figure 3: Power Densities ranges from 0-200 m from Exposed School 2

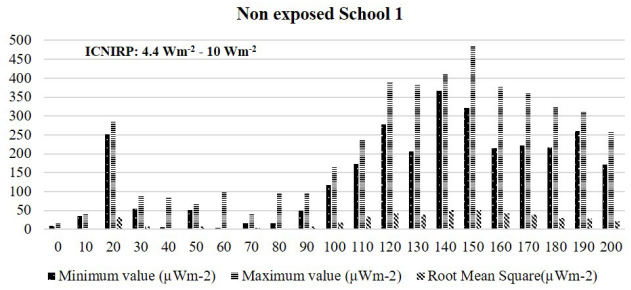

Figure 4: Power Densities ranges from 0-200 m from Non exposed School 1

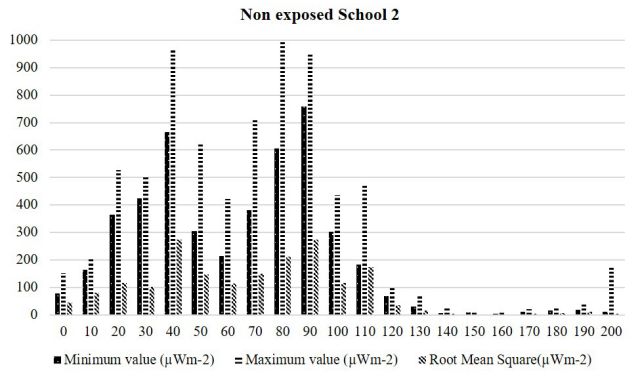

Figure 5: Power Densities ranges from 0-200 m from Non exposed School 2

compatible with the observations of past studies. For example, previous studies (12, 13) showed that the maximum RF radiation emitted from base stations was smaller than the ICNIRP allowable exposure limit. According to guideline of ICNIRP, 1998 the Maximum Permissible Exposure (MPE) reference levels for public

Table II: Comparison of Micronuclei Frequency among School Children

	Median (IQR)		t [a]	*p*-value*
	Exposed	**Non-exposed**		
Micronuclei frequency (per 1,000 cells)	14.55 (1.507)	8.04 (1.004)	35.252	<0.001

[a] Independent t-test, N=91 (Exposed), N=110(Non-exposed)
**p*-value is significant at 0.05 level

exposure for frequency 900 - 2400 MHz is 4.5 – 10 (W/m2) (14). In addition, most of the studies conducted to assess RFR emission from mobile phone base stations stated that the RFR rate rarely exceeded from accepted international guidelines (15).

The fluctuation in RF readings at these schools has shown that the distance between where the MBS is sitting, and the target building is not the only factor contributing to the RF emission (16-17). Field observation in this study also showed that both exposed schools and non-exposed schools are surrounded by different environmental settings that contribute to variations in power densities in time and space. In addition, past studies have shown that the rates of RF obtained by human body varies rely on mobile phone activity and the use of certain electrical devices in the vicinity. In addition, different building materials could also serve as shielding materials that either raise or decrease RF radiation (18). In some areas, existing vegetation (trees, wood and foliage) may also affect the quality of signal propagation (19). The study concludes that the most significant restricting factors are range and line of sight to the antenna location, but also the positive typology of the residential area (16).

Depending on the mobile phone network service operation, the increasing number of base stations in a building or area would improve signal penetration and therefore rising EMF emissions. This is because mobile phones only need to relay fewer electricity over a short distance to the closest base station. Although a certain minimum signal strength is required for adequate reception, the signal strength of the signal is rapidly reduced from base stations and mobile phones. School children from non-exposed schools are therefore experiencing an equal boost in RF capacity, as the mobile base station is situated more than 200 meters away from their campuses. Although the power densities around the base stations in this experiment were all below the normal limits, many experiments have shown that both human and animal biological effects can react to small and very low power densities (20-22). For example, a questionnaire interview with the majority of residents living < 200 m in the vicinity of a mobile base station claimed that they experienced "microwave syndrome" such as chronic fatigue, irritability, depression, memory loss, dizziness, sleep disturbance, concentration difficulties, etc. (23-25). However, there is ongoing disagreement where biophysical considerations suggest that there is little theoretical basis for predicting that RF energy would have substantial biological effects at the power levels emitted from their base station antennas, particularly when epidemiological evidence of a causal link between cancer and RFR energy is relatively weak and limited (26-27).

The findings of this study indicate that school children from exposed schools from the mobile base station has an increased number of micronuclei (MN) count as compared to school children from non-exposed schools. DNA disruption is a key cause for growing tumors and cancer. If the level of DNA disruption exceeds the rate at which DNA can be restored, it is possible to retain mutations and to promote disease into the lifespan of our children today (5). In fact, the findings of this study are consistent with past studies which showed that there is a significant cytogenetic change in MN formation, increased the DNA strand breaks and chromosome aberrations in lymphocytes of human residing in the vicinity of mobile phone base station (28- 31). In addition, long-term exposure to low-intensity electromagnetic microwaves that are continuously emitted by mobile phone base stations may cause ill-health effects that may further lead to cancer development (32).

Other studies have indicated that the deep penetration of RFR in the living cells can cause overproduction of free radicals, especially the reactive oxygen species (ROS), resulting in adverse effects in the living cells (33). Uncontrolled generation of ROS can allow oxidative stress in the cells to accumulate. This increasing oxidative stress may lead to an increase of cancer (34, 35). Other than that, the measured RFR emitted from mobile phone base stations showed that there is a connection with sleep disturbances, nausea, health problems and mental and physical health (36). Even so, past studies have shown that children's cells multiply quicker than adults, rendering cancers more lethal, while the immune system is not as fully established as adults, making it less active to fight cancer development. Other studies have shown that childhood leukemia peak was caused by some facet of residential electrification (37,38).

For decades, the non-ionizing thermal emissions generated from mobile base station have had adverse health effects attributable to mobile bases located near the population in the area. However, most studies have concluded that children have longer lifetime exposures, which are more likely to be exposed to chronic and low levels of RF exposure during early life, which may lead to chronic health effects during adulthood (38).

The distance from the mobile base station is not the only factor that influences the RFR emission, but rather other environmental settings such as the direction of the main beam, the building shielding, other EMF sources (transmission towers, transmission lines, broadcast satellites and so on), the antenna site viewing line, the constructive typology of the area as well as the existing

vegetation. RF emitted from mobile base station is absorbed into human bodies, which may produce a heating effect depending on the intensity of exposure. There is no dispute about this thermal effect; however, the non-thermal effects have continued to be the subject of disputes between researchers, mobile phone operators, communities and a host of other stakeholders. It is therefore important to find out that, in order to understand the process of the health effects of sensitivity to low-level RFR released from mobile base station, more research on environmental factors impacting MBS sitting and RFR emissions should be contemplated, as well as the health effects on molecular scales.

CONCLUSION

Overall, RFR radiation level measured from exposed school and non-exposed school is lower than the permissible exposure limit. School children from exposed schools have higher MN frequency as compared to non-exposed schools. This study also suggested that, the single health effects of mobile base station sitting should not be comparable as there is fundamental difference between human exposures to this environmental stimulus.

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