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An Experimental Investigation of the Impact of Electromagnetic Radiations Emitted from Mobile Phone on General Health, pH, Flow Rate and Electrolytes Concentrations of Saliva in Female Adults

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Abstract

The main objective was to determine the effect of mobile phone radiation on general health and electrolytes among students who use mobile phones. A questionnaire was designed and applied to 103 healthy and 36 deaf female students to select cases that meeting the inclusion criteria. For assessment of salivary parameters, the participants were classified into three groups. Group I was the control group, which included 17 deaf students. Group II was healthy students who have mobile phone for less than 5 years. Group III was healthy students who have mobile phone for 5 years or more. The results showed that the participants who use mobile phone had several problems in their health including dry mouth, bad odor from mouth, drooling of saliva, as well as ear and eye pain. The participants who use mobile phone complained of headache, anxiety and forgetfulness as compared to deaf participants. The study showed that there was no significant difference between pH and flow rate of saliva in all tested groups. This study has also shown that salivary level of Na+ and K+ were significantly lower in mobile phone users when compared to non users of mobile phone.

Keywords: Electromagnetic radiations; mobile phone; electrolytes; flow rate; stimulated saliva.

1. Introduction

Globally, over the last two decades, there has been a tremendous increase in use of mobile phones which resulted in an increase of the exposure to electromagnetic radiations in our life. A mobile phone is the most common telecommunication around the world, and its use is not limited to adults but to individuals belonging to all the age groups especially teenagers and children. Due to its advantages, this device has grown exponentially in recent years. Since the mobile phone comes very close to the head of users, attention about adverse effects of radiation emitted from these devices on the health increased.

Electromagnetic radiation can be classified into two types: ionizing radiation and non-ionizing radiation, based on it is capable of ionizing or non-ionizing atoms, molecular and breaking chemical bonds (Smitha et al., 2013; Adhauliya et al., 2015). Mobile phones send and receive information use electromagnetic, non-ionizing radiation in the microwave range (radio-frequency [RF] waves and microwaves) (Adhauliya et al., 2015; Varghese et al., 2018). Non-ionizing radiation include electric and magnetic fields, radio waves, microwaves, infrared, ultraviolet, and visible radiation.

The electromagnetic radiation in general and radiation emitted from mobile phone in particular affect all living systems and influence cells, tissues and organs, and may be disturb their functions (Adhauliya et al., 2015; Alattar et al., 2017). The electromagnetic radiation affect, for example, bees (Sharma and Kumar, 2010), ants (Cammaerts et al., 2013), mammals (Benlaidi and El Kharroussi, 2011), and even fruit flies (Panagopoulos, 2012). The impact of electromagnetic radiation on living systems depends on several factors such as the power level, exposure duration, frequency, pulsed or continuous wave and the properties of exposed tissue (Alattar et al., 2017 and 2018).

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Biological effects of mobile phone radiation on human body can be divided into two sections: thermal effects and non-thermal effects. Thermal effect is the one in which occurs at high frequencies where the radio-frequency radiation has heating properties which cause an increase in tissue or body temperature, and finally may cause disruption of cell function. The second effect is the non-thermal effect, which result from a direct stabilizing interaction of electric field with polar molecules with no rise in temperature. The non-thermal effect of radiation cause disruption of cell membrane integrity due to passage of electrically shaking eddy current formed from body absorption of radiation. Moreover, it cause dysfunction of endothelial, alterations in the blood-brain barrier, cellular signal transduction effects, as well as nervous system excitability defects (Agarwal et al., 2011; Alattar et al., 2018).

Experimental investigations on the effects of mobile phone radiation are very broad and heterogeneous. It includes both studies of cell cultures and tissues (in vitro) and of laboratory animals (in vivo), as well as of human. Recent investigations conducted reveals that long-term usage of mobile phones can damage health (Smitha et al., 2013). It is associated with headache and dizziness (Agarwal et al., 2008**)**, decrease in sperm count and mobility (Avendano et al., 2012), disruption of sleep and circadian rhythm (Singh and Pati, 2016), memory loss (Cech et al., 2008), decreased immune function, higher blood pressure and reduces DNA repair capacity (Tyagi et al., 2011). With increase mobile phone usage, D’Costa et al. (2003) and Kramarenko and Tan U (2003) observed alternation in electroencephalograph pattern and neuroendrocrine functions. Furthermore, usage of cell phones has also been shown to alter hormone secretion which may lead to altered cell proliferation (Röösli et al., 2007).

Of the thousands of articles on the biological effects of mobile phone radiation, few studies on the effect of these radiation on electrolyte and salivary function have been achieved. Special focus was paid on the effect of mobile phone radiation on human psychomotor performance (Curcio, 2018), thyroid function (Baby et al., 2018), oral health (Dagli and Hans, 2015), kidney cells (Mahmoudi et al., 2018), oral mucosa (Hintzsche and Stopper, 2010), heart rate variability (Misek et al., 2018), reproductive systems (Altun et al., 2018), neonatal birth weight and infant health status (Lu et al., 2017), lymphoma subtypes (Satta et al., 2018), orofacial Structures (Mishra et al., 2017; Mishra and Chowdhary, 2018), memory working and performance (Zubko et al., 2017; Brzozek et al., 2018). In addition, Volkow et al. (2011), studied the effects of cell phone radiofrequency signal exposure on brain glucose metabolism. Also Dabla and Singh (2016) on nerve conduction velocity of median nerve. Byun et al. (2013), investigated the association between mobile phone use and symptoms of attention deficit hyperactivity disorder (ADHD).

Multi-purpose mobile phone radiation studies were also conducted on animals. Rats were one of these animals where intensive investigations were carried out. For example Kaur and Khera (2018) studied the impact of cell phone radiations on pituitary gland and biochemical parameters in albino rat. Special focus was also carried out on the effect of mobile phone radiation on spermatogenesis (Oh et al., 2018), testicular function (Farag and Yousry, 2018), brain structure and functions (Saikhedkar rt al., 2014), thyroid glands (Gupta and Gautam, 2017), heart tumors (Falcioni et al., 2018), anxiety level (Esmaili et al., 2017) and on blood factors (Shojaeifard et al., 2018). In addition, Wyde et al. (2018) studied the effects of cell phone radiation on body temperature in rodents.

In the past few years, scientists have attempted to identify the importance of salivary components as biomarkers of malignancy, drug toxicity, systemic diseases, hormonal imbalances and infectious diseases (Kaufmann and Lamster, 2002). Despite the above mentioned studies, a very little research have been achieved to highlight the influence of electromagnetic radiation emitted from mobile phone base stations, Wi-Fi and mobile phone devices on saliva, electrolytes and salivary function. The focus was paid on the effect of mobile phone and Wi-Fi on oxidative stress indices, enzymes and total protein of saliva (Shivashankara et al., 2015; Singh et al., 2016; Taghavi-Zonuz et al., 2017).

The current study differs from previous studies in the selection of the target group, students, who were classified into categories according to number of years on use of mobile phones .The main objective of the current experiment was to determine the effects of radiation emitted from mobile phone, usually used in the home, on salivary pH and flow rate and other health-related problems among students who use mobile phone. In addition the salivary electrolytes, mainly sodium and potassium levels, of the participants have been compared.

2. Method

2.1. Experimental Procedures

Before carried out the study, ethical approval was obtained from the faculty of science, Islamic university of Gaza and Ministry of Education and Higher Education Palestine. The present cross-sectional pilot study was conducted at the Islamic university of Gaza, Gaza Strip, Palestine, between June and July 2018. The current study consisted of two stages. In the first stage of the study, a questionnaire was designed and applied to healthy and deaf female

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students to select cases whose meeting the inclusion criteria required for the present study. The validity of the questionnaire was tested prior to the examination by the specialists in healthy sciences. The questionnaire was piloted and further modified to capture the concerns raised by the students during the pre-test study. With respect to the contents of the questionnaire, the Alpha Cronbach coefficient was found to be 0.702. The value revealed good internal consistency and reliability of the items of questionnaire. Then students were informed by the investigators on the purpose of the study and also that their participation was voluntary. One hundred and three (N=103) students were requested to fill the questionnaire that included questions about the sociodemographic data, number of years on use of mobile phones, medical history, and questions related to their health problems such as sleep disturbances, headache, and forgetfulness. In addition, a total of 36 deaf students were also requested to fill the same questionnaire to determine their health condition. The completely filled questionnaire was analyzed and only those students who met the inclusion criteria were selected and subjected to the study.

In the second stage, the students who met the inclusion criteria were included in the study to investigate the influence of prolonged exposure to electromagnetic radiations from mobile phone on their general health. For assessment of salivary parameters, a total of 55 students were chosen and classified into three groups. Group I was the control group, which included 17 deaf students who did not use the mobile phone at all. The remaining groups were the case groups, which included 38 healthy students who have mobile phone and use it frequently and were divided based on the duration of using mobile phone. In other words, Group II comprised of 19 healthy students who have mobile phone for less 5 years. Group III comprised of 19 healthy students who have mobile phone for 5 years or more. Table 1 illustrates the inclusion and exclusion criteria used for the selection of the participants in the present study.

Evaluation of salivary parameters was conducted by trained investigators. After categorizing the participants according to the previous groups, the participants were requested for sample collection in the morning between 9.00 to 12.00 AM under standard temperature and humidity conditions. All the participants refrained from consumption of any food or drink, brushing of teeth and practicing any physical activity for a minimum of 1 hour before saliva collection. During the current experiment, all the participants were subjected to the same environmental conditions and other variables were kept constant. The protocol for collecting the saliva samples from all the participants was performed according to the instructions cited by Hamzany et al. (2013). Saliva testing involves both the stimulated and unstimulated saliva.

Table 1. Details on the requirements used for the selection of the students in the present study

Inclusion criteria	**Exclusion criteria**
Students who were:	Students who were:
1. Female students in the age group of 18 to 25 years.	1. Smokers and tobacco chewers.
2. Healthy students without any disease.	2. Students suffering from chronic diseases.
3. Deaf students who did not use the mobile phone at all.	3. Pregnant women.
4. Students who make phone calls.	4. Students who chew gum frequently.
5. Students who have mobile phones for less than 5 year.	5. Students under the influence of medical treatment during the study period (like antibiotics, anti-malarial drugs, analgesics etc.).
6. Students who have mobile phones for 5 years or more.	6. Had any acute illness such as malaria, fever and jaundice in the past one month.
	7. Regularly consumed anti-inflammatory medications, antioxidant supplements and multivitamins for the past one month.

For testing unstimulated pH saliva, the participants were directed to expectorate the saliva into a sterile collection cup for a duration of 5msinutes. Then, pH test strip was placed into the saliva sample for 10s, and then color change of the stripe was checked and compared with the testing chart available with the package of universal indicator paper (pH 1-14). Finally, the collected saliva was experimented for saliva electrolytes (sodium and potassium) by flame photometer (BWB XP).

For testing stimulated salivary flow rate, the participants were instructed to chew a piece of gum (to stimulate salivary flow) and then emptied their saliva immediately into the collection cup. The participants were asked to repeat chewing and expectorating for a duration of 5minutes. After that, the quantity of saliva was measured by using graduated cylinder.

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2.2. Statistical Analysis

Data were statistically analyzed using SPSS computer program version 22.0 for windows (Statistical Package for Social Sciences Inc, Chicago, Illinois). Graphs were plotted using Microsoft Excel program version 2010. Flow rate, pH, and electrolytes levels of saliva between the groups were compared for statistical significance. Descriptive data that included mean, standard deviation, and percentages was calculated for each group. Multiple group comparisons were made by one-way analysis of variance (ANOVA) followed by Tukey test for pairwise comparisons. Categorical data were analyzed by Chi square ($\chi2$) test. For all the tests, a P value of 0.05 or less was considered for statistical significance.

3. Results

Out of the designed questionnaire, the results of important questions are presented below in Figure 1. The age range of the participants was 19-25 years. Figure 1A shows the response of the participants in the case group regarding to the number of years of using mobile phone. As clearly shown, 69.9 % of the participants had mobile phone for less than 5 years, whereas 30.1% had for 5 years or more. Figure 1B also illustrated that the majority of the participants (91.3%) use mobile phone for several purposes such as calls as well as exploring the internet and other applications. 5.8% and 2.9% of the participants use mobile phone only for exploring the internet and making calls respectively.

Regarding to the number of calls in the previous month, the results showed that 32.0% of the interviewed participants confirmed that they made calls for more than once a day, 22.3% were at least once a day, 21.4% were more than once a week, 14.6% were at least once a week and finally 9.7% did not make calls at all.

As reflected from Figure 1D, 47.6% of the participants reported that the average daily time spent on making phone calls was less than 20 minutes, 36.9% did not make calls at all, 9.7% were from 20 minutes to 60 minutes and 5.8% were more than 60 minutes. With respect to exposure to Wi-Fi radiations, 48.5% of the participants reported that they exposed to Wi-Fi radiations at all day, 35.0% only at their homes and 16.5% at public places such as at work, universities, markets or parks (Figure 1E).

Table 2 summarizes the response of the interviewed participants (N=103) in the case groups to various questions with regard to using of mobile phone with the degree of approval. As can be seen in Table 3, among the 103 participants in the case groups, a significant differences were observed between group II and group III with regard to suffering from anxiety, insomnia and forgetfulness. The participants who have mobile phone for 5 years or more were more suffering from anxiety, insomnia and forgetfulness than other participants who have mobile phone for less than 5 years. It was reported that a majority of the participants who have mobile phone complained of sleep disturbances, headache, dizziness, concentration difficulties, dry mouth, drooling of saliva, as well as pain in their eyes and ears. However, as reflected from Table 3, for the rest nine health variables, no differences in their percentages were seen for Group II versus Group III.

Table 2. Response of the participants in the case group regarding to their using of mobile phone

Variable	Degree of approval									
	Very high		High		Moderate		Low		Very low	
	F	%	F	%	F	%	F	%	F	%
Using internet applications to make calls more than using of SIM card.	16	15.5	24	23.3	30	29.1	12	11.7	21	20.4
Using headphone while making calls.	7	6.8	8	7.8	21	20.4	24	23.3	43	41.7
Placing mobile phone near the ear while holding the calls.	26	25.2	45	43.7	18	17.5	5	4.9	9	8.7
Using mobile phone at night before sleeping on a dim light	33	32.1	40	38.8	14	13.6	7	6.8	9	8.7
Using mobile phone can increase effective communication with friends and relatives.	26	25.2	34	33.0	24	23.3	8	7.8	11	10.7
Ability to leave mobile phone for a long period of time.	20	19.4	24	23.3	28	27.2	14	13.6	17	16.5

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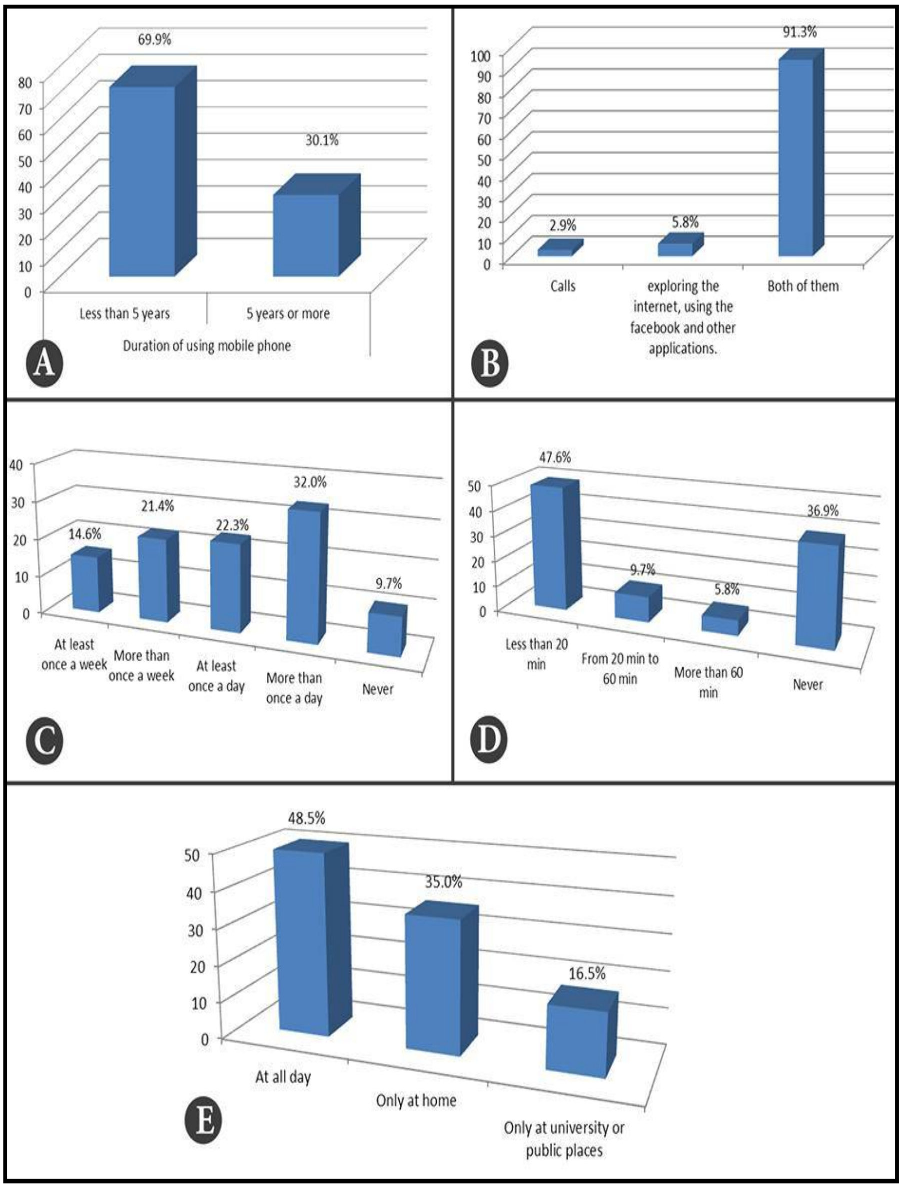

Figure 1. Response of the participants in the case group regarding to (A): the number of years of using mobile phone, (B): purpose of using mobile phone, (C): the number of calls in the previous month, (D): time spent on making phone calls every day, (E): exposure time to Wi-Fi radiations

In addition, the results showed that the mean pH of resting/unstimulated saliva among the case groups (group II and III) were found to be 7.24 ± 0.54 and 6.84±0.69 respectively, whereas the control group was 6.94±0.67. The results which are recorded in Table 4 showed that no significant difference was found between the three groups with $P > 0.05$. The results which are presented in Table 5 and 6 show the levels of unstimulated salivary potassium and sodium in each group. On statistical analysis by ANOVA test, on comparison of salivary sodium between Groups I and III, statistical significance values were obtained. But there was no significance between Groups II and III, as well as Groups I and II. The value for the salivary potassium showed high significance on comparison of Group I and Group II as well as Group I and Group III. The findings were not found to be statistically significant on comparison of Group II and Group III.

The results in Table 7 illustrates the comparison between the tested groups with respect to flow rate of stimulated saliva. Analysis of the results revealed that the participants of control group demonstrated average salivation of 0.782±1.66. The case groups showed 0.992±2.56 and 0.962±2.6 salivary flow rate on the Group II and Group III respectively. On comparison of the salivary flow rate statistically, significant differences ($P < 0.01$) were found between the groups.

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Table 3. Comparisons the respone of the participants in the case group regarding to their health condition due to using of mobile phone

Parameter	Group II (< 5 years)		Group III (≥ 5 years)		χ^2 Value	*P* value*
	F	%	F	%		
Suffering from dry mouth						
Very high	0	0.00	1	3.23	6.922	0.140
High	3	4.17	1	3.23		
Moderate	23	31.94	4	12.90		
Low	21	29.17	9	29.03		
Very low	25	34.72	16	51.61		
Suffering from bad odor in the mouth						
Very high	0	0.00	0	0.00	3.148	0.364
High	3	4.17	0	0.00		
Moderate	9	12.50	7	22.58		
Low	27	37.50	9	29.03		
Very low	33	45.83	15	48.39		
Suffering from drooling of saliva						
Very high	0	0.00	0	0.00	1.988	0.370
High	0	0.00	0	0.00		
Moderate	13	18.06	7	22.58		
Low	34	47.22	10	32.26		
Very low	25	34.72	14	45.16		
Suffering from ear pain						
Very high	3	4.17	4	12.90	2.952	0.566
High	10	13.89	4	12.90		
Moderate	19	26.39	9	29.04		
Low	17	23.61	6	19.35		
Very low	23	31.94	8	25.81		
Suffering from headache						
Very high	4	5.56	4	12.90	3.005	0.557
High	8	11.11	5	16.13		
Moderate	19	26.39	5	16.13		
Low	16	22.22	6	19.35		
Very low	25	34.72	11	35.49		
Suffering from eye pain						
Very high	8	11.11	4	12.90	1.272	0.866
High	20	27.78	11	35.49		
Moderate	27	37.50	9	29.03		
Low	7	9.72	2	6.45		
Very low	10	13.89	5	16.13		
Suffering from anxiety and insomnia						
Very high	2	2.78	8	25.81	17.37	0.002
High	6	8.33	2	6.45		
Moderate	21	29.17	4	12.90		
Low	26	36.11	6	19.35		
Very low	17	23.61	11	35.49		
Suffering from forgetfulness						
Very high	7	9.72	11	35.49	16.02	0.003
High	4	5.56	5	16.13		
Moderate	24	33.33	4	12.90		
Low	9	12.50	4	12.90		
Very low	28	38.89	7	22.58		
Concerning about health risks associated with long time usage of mobile phone.						
Very high	13	18.06	6	19.35	8.348	0.089
High	16	22.22	14	45.16		
Moderate	26	36.11	4	12.90		
Low	5	6.94	3	9.69		
Very low	12	16.67	4	12.90		
Long time usage of mobile phone lead to drop of my studying level.						
Very high	6	8.33	5	16.13	2.215	0.696
High	16	22.22	8	25.81		
Moderate	19	26.39	6	19.35		
Low	10	13.89	7	22.58		
Very low	21	29.17	5	16.13		
Sleeping for sufficient time without insomnia.						
Very high	17	23.61	11	35.49	8.424	0.077
High	11	15.28	4	12.90		
Moderate	30	41.66	12	38.71		
Low	3	4.17	4	12.90		
Very low	11	15.28	0	0.00		

* Calculated by Chi square test (χ^2), *P* value significant at ≤ 0.05.

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Table 4. Comparison of pH saliva in resting/unstimulated saliva among case groups.

Resting/unstimulated saliva				
Parameters (Mean±SD)	Control group (Deaf students)	Case groups: Group II (< 5 years)	Case groups: Group III (≥ 5 years)	*P* value*
pH saliva	6.94±0.67	7.24±0.54	6.84±0.69	0.187

*The P values were calculated by one-way analysis of variance (ANOVA) using Tukey test for multiple group comparisons and was considered statistically significant if P value was < 0.05.

Table 5. Mean value and standard deviation of salivary electrolytes in the case and control groups.

Resting/Unstimulated saliva						
Treatment	Sodium (mmol/L)			Potassium (mmol/L)		
	Range	Mean±SD	*P* value*	Range	Mean±SD	*P* value*
Group I	9.10-24.05	14.55±4.90	0.029	16.35-29.55	22.68±3.41	0.004
Group II	8.70-23.00	12.56±3.77		9.65-27.40	18.05±4.27	
Group III	5.65-19.00	10.84±3.37		13.70-28.05	19.36±4.23	

*The P values were calculated by one-way analysis of variance (ANOVA) using Tukey test for multiple group comparisons and was considered statistically significant if P value was < 0.05.

Table 6. *P* values by ANOVA using Tukey test for multiple group comparisons of levels of salivary **Na$^+$** and **K$^+$**.

Salivary electrolyte	Comparison between groups	*P* values
Na$^+$	Group I vs. Group II	0.312 NS
	Group I vs. Group III	0.022*
	Group II vs. Group III	0.391 NS
K$^+$	Group I vs. Group II	0.003*
	Group I vs. Group III	0.042*
	Group II vs. Group III	0.576 NS

* *P* value significant at ≤ 0.05, NS: non-significant.

Table 7. Mean value and standard deviation of salivary flow rate in case and control groups.

Stimulated saliva				
Parameters (Mean±SD)	Control group (Deaf students)	Case groups: Group II (< 5 years)	Case groups: Group III (≥ 5 years)	*P* value*
Average salivary flow rate (Mean±SD) ml/min	0.782±1.66	0.992±2.56	0.962±2.61	0.364 NS

*The *P* values were calculated by one-way analysis of variance (ANOVA) using Tukey test for multiple group comparisons and was considered statistically significant if *P* value was < 0.05.

4. Discussion

The current study revealed changes in general health, quantity of stimulated saliva, pH of saliva and salivary levels of potassium and sodium in mobile phone users in comparison to non mobile phone users (deaf students).

The present study showed that the participants who use mobile phone had several problems in their health including dry mouth, bad odor from mouth, drooling of saliva, as well as ear and eye pain. The majority of the participants who use mobile phone complained of headache, anxiety, insomnia (sleep disturbances) and forgetfulness as compared to deaf participants. Similar results have been reported in the studies of Singh et al. (2016) and Sharma and Lamba (2017). They observed that people living in the vicinity of base stations complained of concentration difficulties, nausea, vertigo, sleep disturbances, irritability, depression, blurred vision, lack of appetite, confusion, headache and poor academic performance. In addition, these findings seem to be coincide with that stated by Blettner et al. (2009), they found out that a majority of the participants who use mobile phone complained of headache and dizziness. It was also observed that the participants were concerned of adverse effects from exposure to radiations emitted from mobile phone. Vijay and Choudhary (2017) conducted an extensive survey to study the effects of mobile tower radiation on human health. They asked the participants about

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occurrence of any diseases. They found out that 90% of the participants admitted that they are facing problem of headache. 86% are undergoing depression, 72% reported sleep disturbance (insomnia), 50% reported nausea and 48% reported fatigue. The participants also reported that they are facing some type of physical and mental illness due to these mobile towers. The author showed that 64% participants complained that they have become patients of asthma, 50% participants blamed these mobile towers for cancer, 22% for Alzheimer's disease, 14% for multiple sclerosis and 10% for brain tumor.

More recently, Nath (2018) carried out a comprehensive study on negative effects of mobile phone on human health. He documented several problems related to eye, lifestyle, posture, focus. Regarding to problems created on eye, he reported that the intense change in graphics, figures, brightness and details is considered one of the main causes of chronic dry eye syndrome. There are many diseases resulting from wrong postures of using mobile phones for long hours such as muscle spasms and restlessness, cervical spondylitis, golfer elbow, stiffness in thumbs, neck and back. In addition, the author reported that using of mobile phone contributes to the development of insomnia. The author mentioned that the participants who exposed to mobile phone radiation had a significantly more difficult time falling asleep and changes in brainwave pattern as compared to others who did not exposed to mobile phone radiation. Also, sleeping near a phone or in a home with Wi-Fi can create chronic sleep problems as the constant bombardment of Wi-Fi pollution interferes with falling asleep and sleep patterns (Nath, 2018). The reasons standing behind difficulty of sleeping and suffering from insomnia were found to be similar to the reasons reported previously by other study Wood et al. (2006). They reported that the evening exposure to mobile phone radiations may affect melatonin production. Studies on humans have reported the adverse effects of electromagnetic radiation emitted from mobile phones on sleep electroencephalograms (Loughran et al., 2005) and reduced melatonin production (Jarupat et al., 2003). It has been hypothesized that the association between exposure to mobile phone radiations and sleep disorders was due to the suppressed nightly melatonin excretion by exposure to electromagnetic field radiations (Wood et al., 2006). Also, Altpeter et al. (2006) found that sleep quality improved after withdrawal of magnetic field exposure (shut-down of the broadcast transmitter), and they found evidence suggestive of a rebound in nightly melatonin excretion in poor sleepers.

Based on the present study, the results showed a slight difference in mean of salivary pH in the exposed participants, but the di erence was not found statistically significant. In the case groups and control groups, the participants have almost the same salivary pH. Similarly these results were obtained by Singh et al. (2016). They revealed that there were no significant differences in pH salivary among the participants who were residing near the mobile phone base station and the other participants (control) who were living 1 km away from mobile phone base station. They pointed out that the mean pH of unstimulated saliva among the case group and control group was 7.09±0.52 and 6.80±0.49 respectively. More recently, Nanjannawar et al. (2017) carried out an experiment to assess the level of nickel ions in saliva and pH of saliva in mobile phone users undergoing fixed orthodontic treatment. Statistical analysis of their study revealed that though the pH levels were reduced in the experimental group compared to the control group, the results were non-significant. They concluded that mobile phone usage may affect the pH of saliva of patients with fixed orthodontic appliances in the oral cavity.

With respect to flow rate of saliva, the results showed that flow rate increased in the case group as comparison to control one. Similarly, Bhargava and his colleagues previously found a significant increase in salivary flow rate in the case of heavy users of mobile phones (participants used mobile phone for more than 2 hours daily on average) as compared to control group (participants used mobile phone for less than 2 hours daily (**Bhargava et al., 2012)**. In 2014, Hashemipour and his colleagues conducted an innovative study which evaluated the effect of mobile phone use on salivary concentrations of protein, amylase, lipase, immunoglobulin A, lysozyme, lactoferrin, peroxidase and C-reactive protein of the parotid gland. They revealed that salivary flow rate was significantly higher on the right side compared to the left in those that predominantly held mobile phones on the right side. The side of dominant mobile phone use was associated with differences in salivary flow rate, in right-dominant users. Moreover, Arbabi-Kalati et al. (2014) investigated the effects of duration of mobile phone use on the total antioxidant capacity of saliva. They divided the participants into 3 groups: Group 1: was the persons using mobile less than 20 minutes per day, second group: those using mobile phone 20-60 minutes per day and third group: those using mobile phone more than an hour per day. They showed that there was a statistically difference existing between the first (less than 20 min) and second (between 20 min and 1 hour) groups in terms of un-stimulated salivary flow rate. Salivary flow was reduced in the people speaking on the mobile phone between 20 minutes and 1 hour. However, as the time of mobile phone use exceeds 1 hour, the salivary flow will increase too. In the study of Goldwein and Aframian (2010), they documented that salivary flow rate was increased in mobile phone users, when the mobile phone use was increased over years, salivary flow was increased too. More recently, Mishra et al. [28] documented that the salivary flow rate is increased and there is alteration of the cytokine expression profile of

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the salivary gland in heavy cell phone users. The reasons standing behind increase in the salivary flow rate were found to be similar to the reasons mentioned previously in the study Goldwein and Aframian (2010). They reported that radiations emitted from mobile phones are a type of microwave energy which absorbed by the water contained in cells and tissues and then lead to raise their temperature. Prolonged exposure to heat which releases from mobile phone increases the capillary blood flow adjacent to the parotid glands and result in an increase of perfusion and increase in the salivary flow rate.

Contradictory results were obtained by were previously reported in the study of Singh et al. (2016). They found out that the participants residing near mobile towers had low salivary secretion as compared to the control group. Also, De Souza et al. (2014) reported that parotid salivary flow rate was not altered due to exposure parotid glands to cell phone radiations. In the study of Shivashankara et al. (2015), they assessed the levels of salivary enzymes, protein and oxidant-antioxidant system in young college-going cell phone users. The cell users were categorized in to two groups: group 1 was less mobile users and group 2 was high mobile users, based on the duration and frequency of cell use. Statistical analysis of their study revealed that though the salivary flow rate were reduced in group 2 compared to group 1, the results were non-significant.

This study has also shown that there was significant difference between the salivary Na+ and K+ levels of the three groups. Salivary level of Na+ and K+ were significantly lower in mobile phone users when compared to non users of mobile phone. Contrary to our results, Ali Taghavi-Zonuz et al. (2017) found that there was no significant difference between Na+ and K+ levels between mobile phone users and other deaf participants.

In conclusion, The results of the present study show adverse effect of mobile phone use on general health. The results showed that the participants who use mobile phone had several problems in their health including dry mouth, bad odor from mouth, drooling of saliva, as well as ear and eye pain. The majority of the participants who use mobile phone complained of headache, anxiety, insomnia (sleep disturbances) and forgetfulness as compared to deaf participants. Salivary biochemical parameters have served as sensitive indicators of health in mobile users such as pH, flow rate and electrolytes level of salivary. Regarding to salivary pH and flow rate, the differences were no significant in all tested groups. In addition, this study has also shown that there was significant difference between the salivary Na+ and K+ levels of the three groups. Salivary level of Na+ and K+ were significantly lower in mobile phone users when compared to non users of mobile phone.

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References

Adhauliya, N., Annigeri, R. G., Ali, I. M., & Kalappanavar, A. N. (2015). Is radio-frequency radiation emitted by mobile phones, a cause for concern? A dentist's review. *Journal of Medicine, Radiology, Pathology & Surgery*, *1*, 15–20.

Agarwal, A., Deepinder, F., Sharma, R. K., Ranga, G., & Li, J. (2008). Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. *Fertility and sterility*, *89*(1), 124-128.

Agarwal, A., Singh, A., Hamada, A., & Kesari, K. (2011). Cell phones and male infertility: a review of recent innovations in technology and consequences. *International braz j urol*, *37*(4), 432-454.

Altpeter, E. S., Röösli, M., Battaglia, M., Pfluger, D., Minder, C. E., & Abelin, T. (2006). Effect of short‐wave (6–22 MHz) magnetic fields on sleep quality and melatonin cycle in humans: the Schwarzenburg shut‐down study. *Bioelectromagnetics: Journal of the Bioelectromagnetics Society, The Society for Physical Regulation in Biology and Medicine, The European Bioelectromagnetics Association*, *27*(2), 142-150.

Al Attar, E.M., El Wasife, K.Y., Radwan, E.S., & El Rifi, Y.A. (2017). Response of corn (Zea Mays), basil (*Ocimum Basilicum*) and eggplant (*Solanum Melongena*) seedlings to WI-FI radiation. *Romanian Journal of Biophysics*, *27*(4), 137–150.

Al Attar, E.M., El Wasife, K.Y., Radwan, E.S., & Al Agha, A.M. (2018). Effect of microwave treated water on the growth of corn (*Zea Mays*) and Pepper (*Capsicum Annuum*) seedlings. *Romanian Journal of Biophysics*, *28*(3), 115–124.

Altun, G., Deniz, Ö. G., Yurt, K. K., Davis, D., & Kaplan, S. (2018). Effects of mobile phone exposure on metabolomics in the male and female reproductive systems. *Environmental research*, Arbabi-Kalati, F.,

Peer-reviewed version available at *International Journal of Biology* **2018**, *11*, ISSN 1916-9671; doi:10.5539/ijb.v11n1p10

Salimi, S., Vaziry-Rabiee, A., & Noraeei, M. (2014). Effect of mobile phone usage time on total antioxidant capacity of saliva and salivary immunoglobulin A. *Iranian journal of public health*, *43*(4), 480-484.

Avendano, C., Mata, A., Sarmiento, C. A. S., & Doncel, G. F. (2012). Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation. *Fertility and Sterility*, *97*(1), 39-45.

Baby, N. M., Koshy, G., & Mathew, A. (2017). The effect of electromagnetic radiation due to mobile phone use on thyroid function in medical students studying in a medical college in South India. *Indian journal of endocrinology and metabolism*, *21*(6), 797-802.

Bhargava, S., Motwani, M. B., & Patni, V. M. (2012). Effect of handheld mobile phone use on parotid gland salivary flow rate and volume. *Oral surgery, oral medicine, oral pathology and oral radiology*, *114*(2), 200-206.

Benlaidi, F. Z., & El Kharroussi, M. (2011). Effets des ondes électromagnétiques générées par le GSM sur la mémoire et le comportement chez le rat. *Journal of plant physiology*, *2*, 149-156.

Blettner, M., Schlehofer, B., Breckenkamp, J., Kowall, B., Schmiedel, S., Reis, U., Potthoff, P., Schuez, J., & Berg-Beckhoff, G. (2009). Mobile phone base stations and adverse health effects: phase 1 of a population-based, cross-sectional study in Germany. *Occupational and environmental medicine*, *66*(2), 118-123.

Brzozek, C., Benke, K. K., Zeleke, B. M., Abramson, M. J., & Benke, G. (2018). Radiofrequency Electromagnetic Radiation and Memory Performance: Sources of Uncertainty in Epidemiological Cohort Studies. *International journal of environmental research and public health*, *15*(4), 592-.

Byun, Y. H., Ha, M., Kwon, H. J., Hong, Y. C., Leem, J. H., Sakong, J., Kim, S.Y., Lee, C.G., Kang, D., Choi, H.D., & Kim, N. (2013). Mobile phone use, blood lead levels, and attention deficit hyperactivity symptoms in children: a longitudinal study. *PLoS One*, *8*(3), e59742-10.1371/journal.pone.0059742.

Cammaerts, M. C., Rachidi, Z., Bellens, F., & De Doncker, P. (2013). Food collection and response to pheromones in an ant species exposed to electromagnetic radiation. *Electromagnetic biology and medicine*, *32*(3), 315-332.

Cech, R., Leitgeb, N., & Pediaditis, M. (2007). Current densities in a pregnant woman model induced by simultaneous ELF electric and magnetic field exposure. *Physics in Medicine & Biology*, *53*(1), 177-186.

Curcio, G. (2018). Human Psychomotor Performance Under the Exposure to Mobile Phones-Like Electromagnetic Fields. In *Encyclopedia of Information Science and Technology, Fourth Edition* (pp. 6124-6135), DOI: 10.4018/978-1-5225-2255-3.ch532

Dagli, R., & Hans, R. (2015). Effect of mobile phone radiations on oral health. *Journal of international oral health*, *7*(1), i-ii.

Dabla, K., Singh, K. (2016). Effect of Electromagnetic Waves Emitted from Mobile Phone on Nerve Conduction Velocity of Median Nerve in Adult Males. *International Journal of All Research Education and Scientific Methods*, *4*, 23-27.

De Souza, F. T., Silva, J. F., Ferreira, E. F., Siqueira, E. C., Duarte, A. P., Gomez, M. V., Gomez, R, & Gomes, C. C. (2014). Cell phone use and parotid salivary gland alterations: No molecular evidence. *Cancer Epidemiology and Prevention Biomarkers*, 23(7):1428–1431.

Esmaili, M., Masoumi, H., Jadidi, M., Miladi-Gorji, H., & Nazari, H. (2017). The Effects of Acute Mobile Phone Radiation on the Anxiety Level of Male Rats. *Middle East Journal of Rehabilitation and Health*, *4*(2), e43478.

Farag, E. A., & Yousry, M. M. (2018). Effect of mobile phone electromagnetic waves on rat testis and the possible ameliorating role of Naringenin: A histological study. *Egyptian Journal of Histology*, *41*(1), 108-121.

Falcioni, L., Bua, L., Tibaldi, E., Lauriola, M., De Angelis, L., Gnudi, F., Mandrioli, D;Manservigi, M.; Manservisi, F; Manzoli, I.; Menghetti, I.; Montella, R.; Panzacchi, S.; Sgargi, D.; Strollo, V.; Vornoli, A., & Belpoggi, F. (2018). Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission. *Environmental research*, *165*, 496-503.

Goldwein, O., & Aframian, D. J. (2010). The influence of handheld mobile phones on human parotid gland secretion. *Oral diseases*, *16*(2), 146-150.

Peer-reviewed version available at *International Journal of Biology* **2018**, *11*, ISSN 1916-9671; doi:10.5539/ijb.v11n1p10

Gupta, S., Gautam, P. (2017). Effect of mobile phone radiation on thyroid glands of rats. *Journal of the Anatomical Society of India*, 66, S1-S78. https://doi.org/10.1016/j.jasi.2017.08.036

Hamzany, Y., Feinmesser, R., Shpitzer, T., Mizrachi, A., Hilly, O., Hod, R., Bahar, G., Otradnov, I., Gavish, M., & Nagler, R.M. (2013). Is human saliva an indicator of the adverse health effects of using mobile phones? *Antioxidants & Redox Signaling,* 18(6), 622-627.

Hintzsche, H., & Stopper, H. (2010). Micronucleus frequency in buccal mucosa cells of mobile phone users. *Toxicology letters*, *193*(1), 124-130.

Jarupat, S., Kawabata, A., Tokura, H., & Borkiewicz, A. (2003). Effects of the 1900 MHz electromagnetic field emitted from cellular phone on nocturnal melatonin secretion. *Journal of physiological anthropology and applied human science*, *22*(1), 61-63.

Kaufman, E., & Lamster, I. B. (2002). The diagnostic applications of saliva—a review. *Critical Reviews in oral biology & medicine*, *13*(2), 197-212.

Kaur, M., & Khera, K. S. (2018). Impact Of Cell Phone Radiations On Pituitary Gland And Biochemical Parameters In Albino Rat. *Octa Journal of Biosciences*, *6*(1), 1-4.

Kramarenko, A. V., & Tan, U. (2003). Effects of high-frequency electromagnetic fields on human EEG: a brain mapping study. *International Journal of Neuroscience*, *113*(7), 1007-1019.

Loughran, S. P., Wood, A. W., Barton, J. M., Croft, R. J., Thompson, B., & Stough, C. (2005). The effect of electromagnetic fields emitted by mobile phones on human sleep. *Neuroreport*, *16*(17), 1973-1976.

Lu, X., Oda, M., Ohba, T., Mitsubuchi, H., Masuda, S., & Katoh, T. (2017). Association of excessive mobile phone use during pregnancy with birth weight: an adjunct study in Kumamoto of Japan Environment and Children's Study. *Environmental health and preventive medicine*, *22*(52), 1-8.

Mahmoudi, G., Nikzad, S., Mehrpouyan, M., Moslehi, M., Baradaran-Ghahfarokhi, M., & Dashty, A. (2018). Effects of mobile phone prolonged radiation on kidney cells; An in-vitro study. *Journal of Renal Injury Prevention*, *7*(3), 175-179.

Misek, J., Belyaev, I., Jakusova, V., Tonhajzerova, I., Barabas, J., & Jakus, J. (2018). Heart rate variability affected by radiofrequency electromagnetic field in adolescent students. *Bioelectromagnetics*, *39*(4), 277-288.

Mishra, S. K., Chowdhary, R., Kumari, S., & Rao, S. B. (2017). Effect of cell phone radiations on orofacial structures: A Systematic review. *Journal of clinical and diagnostic research*, *11*(5), ZE01-ZE05.

Mishra, S. K., & Chowdhary, R. (2018). Does radiations emitted from cell phone effects orofacial structures and dental implants?. *International Journal of Environmental Health Engineering*, *7*(1), 1-1.

Nanjannawar, L. G., Girme, T. S., Agrawal, J. M., Agrawal, M. S., Fulari, S. G., Shetti, S. S., & Kagi, V. A. (2017). Effect of Mobile Phone Usage on Nickel Ions Release and pH of Saliva in Patients Undergoing Fixed Orthodontic Treatment. *Journal of clinical and diagnostic research: JCDR*, *11*(9), ZC84- ZC87.

Nath, A. (2018). Comprehensive Study on Negative Effects of Mobile Phone/Smart Phone on Human Health. *International Journal of Innovative Research in Computer and Communication Engineering*, *6*(1), 575- 581.

Oh, J. J., Byun, S. S., Lee, S. E., Choe, G., & Hong, S. K. (2018). Effect of Electromagnetic Waves from Mobile Phones on Spermatogenesis in the Era of 4G-LTE. *BioMed research international*, *2018*, 1-8.

Panagopoulos, D.J. (2012). Gametogenesis, embryonic and postembryonic development of Drosophila melanogaster, as a model system for the assessment of radiation and environmental genotoxicity. New York, USA, 1–38, ISBN: 978-1-61470-279-5

Röösli, M., Michel, G., Kuehni, C. E., & Spoerri, A. (2007). Cellular telephone use and time trends in brain tumour mortality in Switzerland from 1969 to 2002. *European Journal of Cancer Prevention*, *16*(1), 77-82.

Saikhedkar, N., Bhatnagar, M., Jain, A., Sukhwal, P., Sharma, C., & Jaiswal, N. (2014). Effects of mobile phone radiation (900 MHz radiofrequency) on structure and functions of rat brain. *Neurological research*, *36*(12), 1072-1079.

Satta, G., Mascia, N., Serra, T., Salis, A., Saba, L., Sanna, S., Zucca, M., Angelucci, E., Gabbas, A., Culurgioni, F., Pili, P., Mura, E., Cappai, M., Ennas, M., Cocco, P., & Pili, P. (2018). Estimates of Environmental Exposure to Radiofrequency Electromagnetic Fields and Risk of Lymphoma Subtypes. *Radiation research*, *189*(5), 541-547.

Peer-reviewed version available at International Journal of Biology 2018, 11, ISSN 1916-9671; doi:10.5539/ijb.v11n1p10

Sharma, V. P., & Kumar, N. R. (2010). Changes in honeybee behaviour and biology under the influence of cellphone radiations. *Current Science(Bangalore)*, *98*(10), 1376-1378.

Shivashankara, A. R., Joy, J., Sunitha, V., Rai, M. P., Rao, S., Nambranathayil, S., & Baliga, M. S. (2015). Effect of cell phone use on salivary total protein, enzymes and oxidative stress markers in young adults: a pilot study. *Journal of clinical and diagnostic research*, *9*(2), BC19-BC22.

Sharma, A. B., & Lamba, O. S. (2017). A Review: Source and Effect of Mobile Communication Radiation on Human Health. *Advances in Wireless and Mobile Communications*, *10*(3), 423-35.

Shojaeifard, M. B., Jarideh, S., Owjfard, M., Nematollahii, S., Talaei-Khozani, T., & Malekzadeh, S. (2018). Electromagnetic Fields of Mobile Phone Jammer Exposure on Blood Factors in Rats. *Journal of Biomedical Physics and Engineering, 8(3), I-VI.*

Singh, K., Nagaraj, A., Yousuf, A., Ganta, S., Pareek, S., & Vishnani, P. (2016). Effect of electromagnetic radiations from mobile phone base stations on general health and salivary function. *Journal of International Society of Preventive & Community Dentistry*, *6*(1), 54-59.

Singh, M. M., & Pati, A. K. (2016). Effects of radiation emanating from base transceiver station and mobile phone on sleep, circadian rhythm and cognition in humans–a review. *Biological Rhythm Research*, *47*(3), 353-388.

Smitha, C. K., & Narayanan, N. K. (2013, August). Effect of Mobile Phone Radiation on EEG. In *Advances in Computing and Communications (ICACC), 2013 Third International Conference on* (pp. 111-114).

Taghavi-Zonuz, A., Jamali, Z., Pourzare-Mehrbani, S., Rahbar, M., Tamgaji, R. (2017). Effect of Mobile Phone Waves and Wi-Fi on Electrolytes and Oxidative Stress Indices of Saliva. *World*, *8*(5), 370-373.

Trueman, G., Tang, L., Abdel-Rahman, U., Abdel-Rahman, W., Ong, K., & Cosic, I. (2003). Human brain wave activity during exposure to radiofrequency field emissions from mobile phones. *Australasian Physics & Engineering Sciences in Medicine*, *26*(4), 162-167.

Tyagi, A., Duhan, M., & Bhatia, D. (2011). Effect of Mobile phone radiation on brain activity GSM Vs CDMA. *International Journal of Services Technology and Management*, *2*(2), 1-5.

Varghese, R., Majumdar, A., Kumar, G., & Shukla, A. (2018). Rats exposed to 2.45 GHz of non-ionizing radiation exhibit behavioral changes with increased brain expression of apoptotic caspase 3. *Pathophysiology*, *25*(1), 19-30.

Vijay, S., & Choudhary, M. P. (2017). Study on Health Effects of Mobile Tower Radiation on Human Beings. *International Research Journal of Engineering and Technology*, *4*(11), 1548-1552.

Volkow, N. D., Tomasi, D., Wang, G. J., Vaska, P., Fowler, J. S., Telang, F., Alexoff, D., Logan, J., & Wong, C. (2011). Effects of cell phone radiofrequency signal exposure on brain glucose metabolism. *Jama*, *305*(8), 808-813.

Wood, A. W., Loughran, S. P., & Stough, C. (2006). Does evening exposure to mobile phone radiation affect subsequent melatonin production?. *International journal of radiation biology*, *82*(2), 69-76.

Wyde, M. E., Horn, T. L., Capstick, M. H., Ladbury, J. M., Koepke, G., Wilson, P. F., … McCormick, D.L (2018). Effect of cell phone radiofrequency radiation on body temperature in rodents: Pilot studies of the National Toxicology Program's reverberation chamber exposure system. *Bioelectromagnetics, 39*(3), 190-199.

Zubko, O., Gould, R. L., Gay, H. C., Cox, H. J., Coulson, M. C., & Howard, R. J. (2017). Effects of electromagnetic fields emitted by GSM phones on working memory: a meta‐analysis. *International journal of geriatric psychiatry*, *32*(2), 125-135.