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*Article*

# 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:** During the recent years, 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. Human saliva is considered as a potential source of biomarkers to monitor changes that occur under pathological conditions. The main objective of the current experiment was to determine the effect of mobile phone radiation on general health, electrolytes and salivary function among Islamic University students who use mobile phones. A questionnaire was designed and applied to 167 healthy and 36 deaf female students to select cases whose meeting the inclusion criteria. A total of 103 students who met the inclusion criteria were included to investigate the influence of mobile phone radiations 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. 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. 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 ($\chi 2$) test. For all the tests, a P value of 0.05 or less was considered for statistical significance. 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 and forgetfulness as compared to deaf participants. Also, the study showed that there was no significant difference between salivary pH in all tested groups. Regarding to salivary 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.

**Keywords:** Electromagnetic radiations; mobile phone; saliva; electrolytes; flow rate; resting/unstimulated; stimulated saliva, radio-frequency.

## 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 [1,2]. Mobile phones send and receive information use electromagnetic, non-ionizing radiation in the microwave range (radio-frequency [RF] waves and microwaves) [2, 3]. 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 [2, 4]. The electromagnetic radiation affect, for example, bees [5], ants [6], mammals [7], and even fruit flies [8]. 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 [4, 9].

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 [10, 9].

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 [1]. It is associated with headache and dizziness [11], decrease in sperm count and mobility [12], disruption of sleep and circadian rhythm [13], memory loss [14], decreased immune function, higher blood pressure and reduces DNA repair capacity [15]. With increase mobile phone usage, D'Costa et al. [16] and Kramarenko and Tan U [17] 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 [18].

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 [19], thyroid function [20], oral health [21], kidney cells [22], oral mucosa [23], heart rate variability [24], reproductive systems [25], neonatal birth weight and infant health status [26], lymphoma subtypes [27], orofacial Structures [28, 29], memory working and performance [30, 31]. In addition, Volkow et al. [32], studied the effects of cell phone radiofrequency signal exposure on brain glucose metabolism. Also Dabla and Singh [33] on nerve conduction velocity of median nerve. Byun et al. [34], 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 [35] studied the impact of cell phone radiations on pituitary gland and biochemical parameters in albino

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rat. Special focus was also carried out on the effect of mobile phone radiation on spermatogenesis [36], testicular function [37], brain structure and functions [38], thyroid glands [39], heart tumors [40], anxiety level [41] and on blood factors [42]. In addition, Wyde et al. [43] 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 [44]. 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 [45, 46, 47].

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. 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 1 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 2, 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 4, for the rest nine health variables, no differences in their percentages were seen for Group II versus Group III.

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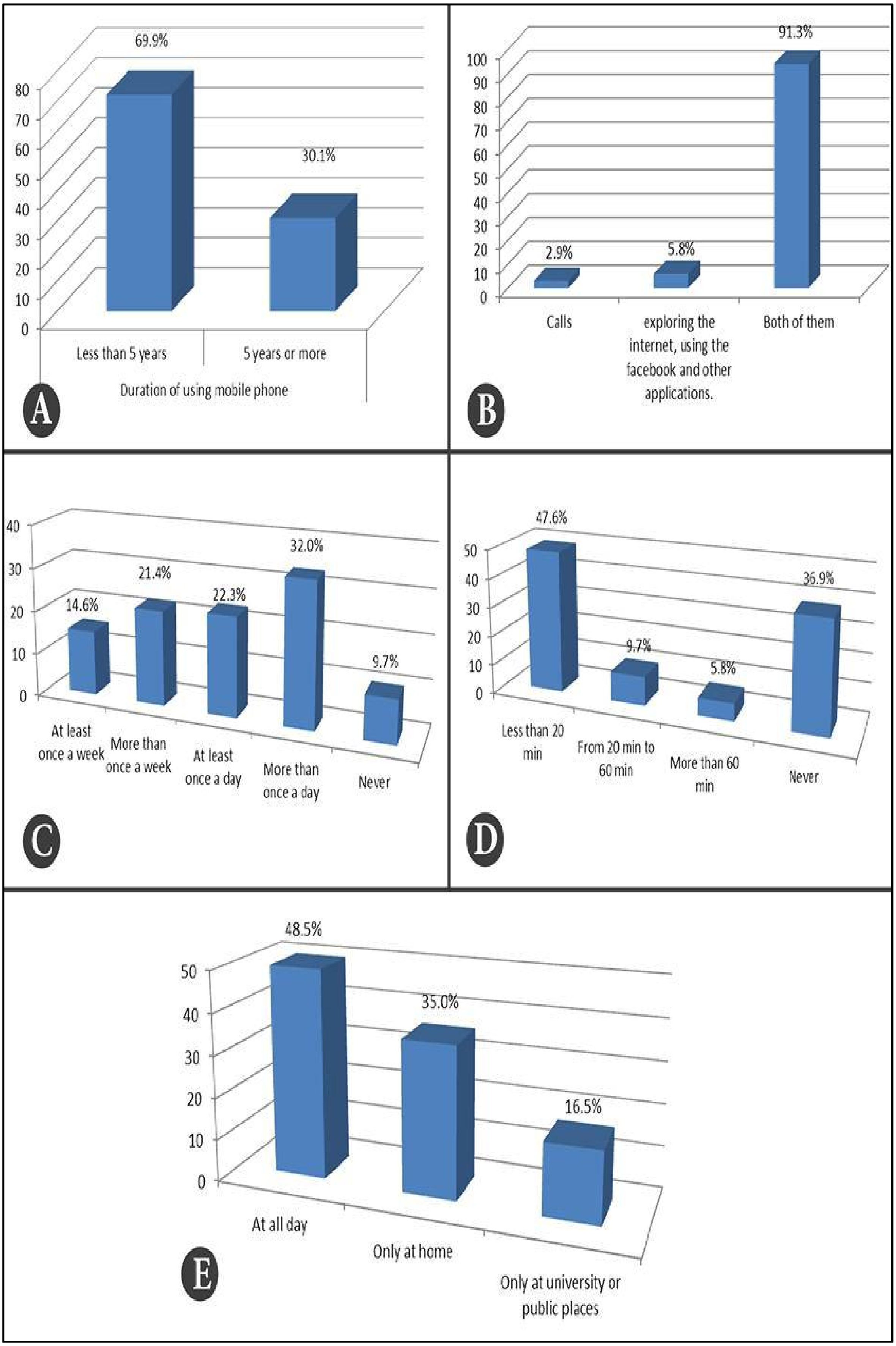


**Figure 1.** Response of the participants in the case group regarding to (A): the number of years of using mobile phone, (B): purpose of using mobile phone, (C): the number of calls in the previous month, (D): time spent on making phone calls every day, (E): exposure time to Wi-Fi radiations.

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**Table 1:** Response of the participants (N=103) in the case group regarding to their using of mobile phone.

| **Variable** | Degree of approval | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Very high | | Very high | | Very high | | Very high | | Very high | |
| | 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 | 21 | 20.4 | 12 | 11.7 |
| Using headphone while making calls. | 7 | 6.8 | 8 | 7.8 | 21 | 20.4 | 43 | 41.7 | 24 | 23.3 |
| Placing mobile phone near the ear while holding the calls. | 26 | 25.2 | 45 | 43.7 | 18 | 17.5 | 9 | 8.7 | 5 | 4.9 |
| Using mobile phone at night before sleeping on a dim light | 33 | 32.1 | 40 | 38.8 | 14 | 13.6 | 9 | 8.7 | 7 | 6.8 |
| Using mobile phone can increase effective communication with friends and relatives. | 26 | 25.2 | 34 | 33.0 | 24 | 23.3 | 11 | 10.7 | 8 | 7.8 |
| Ability to leave mobile phone for a long period of time. | 20 | 19.4 | 24 | 23.3 | 28 | 27.2 | 17 | 16.5 | 14 | 13.6 |

**Table 2:** Comparisons of the participants (N=103) answering in the case group regarding to their health condition due to using of mobile phone.

| Parameter | Group II (< 5 years) | | Group III (≥ 5 years) | | $\chi^2$ Value | *P* value* |
|---|---|---|---|---|---|---|
| | F | % | F | % | | |
| Suffering from dry mouth | | | | | | |
| Very high | 0 | 0.00 | 1 | 3.23 | | |
| High | 3 | 4.17 | 1 | 3.23 | | |
| Moderate | 23 | 31.94 | 4 | 12.90 | 6.922 | 0.140 |
| 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 | | |
| High | 3 | 4.17 | 0 | 0.00 | | |
| Moderate | 9 | 12.50 | 7 | 22.58 | 3.148 | 0.364 |
| 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 | | |
| High | 0 | 0.00 | 0 | 0.00 | | |
| Moderate | 13 | 18.06 | 7 | 22.58 | 1.988 | 0.370 |
| Low | 34 | 47.22 | 10 | 32.26 | | |
| Very low | 25 | 34.72 | 14 | 45.16 | | |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 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 | | |

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| | | | | | | |
|---|---|---|---|---|---|---|
| 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 ($\chi^2$), *P* value significant at ≤ 0.05.

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 3 showed that no significant difference was found between the three groups with P > 0.05.

Table 3: Comparison of pH saliva in resting/unstimulated saliva among case groups.

| Resting/unstimulated saliva | | | | |
|---|---|---|---|---|
| Parameters (Mean±SD) | Control group (Deaf students) | Case groups | | *P* value* |
| | | Group II (< 5 years) | Group III (≥ 5 years) | |
| 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.

The results which are presented in Table 4 and 5 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.

**Table 4**: 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.

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**Table 5**: *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.

The results in Table 6 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.

**Table 6**: 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.

## 3. 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. [46] and Sharma and Lamba [48]. 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. [49], 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 [50] conducted an extensive survey to study the effects of mobile tower radiation on human health. They asked the participants about 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%

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participants blamed these mobile towers for cancer, 22% for Alzheimer's disease, 14% for multiple sclerosis and 10% for brain tumor.

More recently, Nath [51] 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 [51]. 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. [52]. 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 [53] and reduced melatonin production [54]. 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 [52]. Also, Altpeter et al. [55] 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 difference 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. [46]. 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 $7.09\pm0.52$ and $6.80\pm0.49$ respectively. More recently, Nanjannawar et al. [56] 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 [57]. 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. [58] 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

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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 [59], 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 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 [59]. 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. [46]. 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. [60] 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. [45], 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.

## 4. Materials and Methods

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 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.

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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 7 illustrates the inclusion and exclusion criteria used for the selection of the participants in the present study.

**Table 7**: Details on the requirements used for the selection of the students in the present study

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

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. [61]. Saliva testing involves both the stimulated and unstimulated saliva. Table 8 summarizes the saliva test steps that followed in this experiment.

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

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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).

**Table 8**: Steps of saliva test in the present experiment

| | | |
|---|---|---|
| **Resting/unstimulated saliva** | Step 1 | pH |
| | Step 2 | Estimation of saliva electrolyte |
| **Stimulated saliva** | Step 3 | Quantity/ flow rate |

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.

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 ($\chi 2$) test. For all the tests, a P value of 0.05 or less was considered for statistical significance.

## 5. Conclusions

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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**Conflicts of Interest:** The authors declare no conflict of interest.

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