Investigating the Effects of Electromagnetic Fields (EMF) Emitted by Cell Phones on Human Health

By
Labiba Tasnim Zeba
ID: 20136040
Mahmood Hasan Gahon
ID: 20136016
Mehnaz Roshni Mostofa
ID: 20136006

A thesis submitted to the Department of Mathematics and Natural Sciences in partial fulfillment of the requirements for the degree of BS in Biotechnology

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Declaration

It is hereby declared that

1. The thesis submitted is our own original work while completing a degree at Brac University.
2. The thesis does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The thesis does not contain material that has been accepted or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all of the main sources of help.

Student's Full Name & Signature:

Labiba Tasnim Zeba

ID: 20136040

Mahmood Hasan Gahon

ID: 20136016

Mehnaz Roshni Mostofa

ID: 20136006

Approval

The thesis/project titled "**Investigating the Effects of Electromagnetic Fields (EMF) Emitted by Cell Phones on Human Health**" is submitted by

1. Labiba Tasnim Zeba (20136040)
2. Mahmood Hasan Gahon (20136016)
3. Mehnaz Roshni Mostafa (20136006)

Has been accepted as satisfactory in partial fulfillment of the requirement for the degree of BS in Biotechnology on 28.02.2024

Examining Committee:

Supervisor:

Dr. Munima Haque

Associate Professor, Department of Mathematics and Natural Sciences

BRAC University

Program Director:

Dr. Munima Haque

Associate Professor, Department of Mathematics and Natural Sciences

BRAC University

Departmental Head:

A F M Yusuf Haider

Professor, Department of Mathematics and Natural Sciences

BRAC University

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Abstract

The research delves into the complex relationship between the non-ionizing radiation (NIR) under the segment of electromagnetic fields (EMF) emitted from cell phones and the health complications of the residents of Dhaka city. The data on EMF levels of cell phones, usage parameters, and associated symptoms among the participants from Dhaka city were collected and analysis was done through a cross-sectional study design. To establish this connection, analysis by statistical approach was conducted between electric frequency (EF) vs. mobile networks, magnetic frequency (MF) vs. mobile networks, radio frequency (RF) vs. mobile networks, mobile usage duration (year) vs. symptoms, and mobile usage duration (hour) vs. symptoms. Results derived from the analysis indicated extensive usage of 4G mobile networks among the respondents, with most NIR measurements cohering to established safety threshold levels. However, younger individuals with heavy usage of cell phones were found to be heavily susceptible to symptoms like blurry vision, headaches, and insomnia. As relations have been found between those parameters, it can be said that prolonged usage of cell phones might have other health concerns, which could end up developing tumors and cancers.

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Chapter 1

Introduction

1.1 Concept of Electromagnetic Force

Electromagnetic force refers to the property of space which is caused by the movement of an electric charge. A stationary charge is responsible for producing only electric fields in its surrounding space but when this charge starts to move, it creates another special type of field known as the magnetic field. So, when a charge is moving it is creating both the electric and magnetic field. Therefore, when a current is passed or an electron is passed through a wire, it will create a field of energy, commonly known as an electromagnetic field or EMF. This energy is emitted in space in the form of radiation. So, when an electric field is created using voltage, electrons present in the wire or system start to move, and as the voltage increases thus the movement increases. As a result, the strength of EMF also increases and so does the radiation. The strength of EMF can be reduced rapidly by lowering the voltage supply or increasing the distance from its source (Ahlbom et al., 2004).

In terms of devices that are made up of numerous circuits and wires, EMF is produced by the flow of electricity in the devices. When the device is turned on, it will generate only the electric field but when it is in use meaning electrons are moving, it will generate an electromagnetic field. This energy will be released from the device in the form of radiation. Therefore, when a device is used, it continuously emits electric force (EF) and magnetic force (MF) from it. The electric field can be weakened by obstructions like walls or other objects. But magnetic fields can pass through objects like walls and even through the living (Ahlbom et al., 2004).

1.2 Established Limits for Electromagnetic Field Exposure

For this reason, the magnetic field tends to be more harmful than the electrical field. So, it's crucial to establish limits at both occupational and residential levels. A widely recognized standard level, ranging from 0.2 to 0.3 microtesla (μT) or 2.5 milligauss (mG), has been acknowledged globally in several countries. Regarding the electric field, the accepted value is 25 volts per meter (V/m). It's imperative that body radiation levels remain below the maximum endorsed limit, which is 10 milliwatts per square centimeter (mW/cm2), corresponding to 195 V/m in the United States and 0.1 mW/cm2, equivalent to 20 V/m in the CIS. Notably, the electric and magnetic fields generated by human activities typically measure around 25 V/m and 2.5 mG or 0.25 μT, respectively, significantly surpassing the natural environmental electric and magnetic

fields, which typically measure 10 to the power of negative 4 V/m and 10 to the power of negative 13 tesla (T), respectively (M. Quamruzzaman et al., 2021).

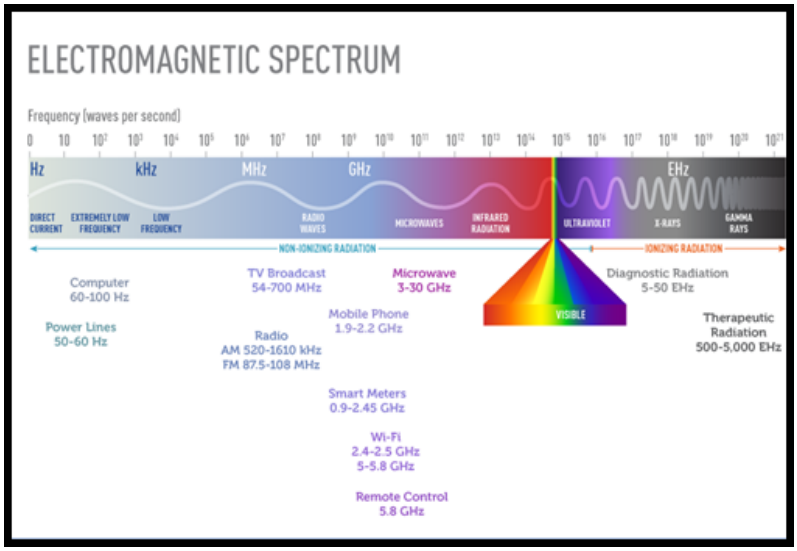

Fig. (1): The Electromagnetic Spectrum, (2022). NIH

1.3 Categories of EMF and The Devices

The EMF radiation can be divided into two categories – High-Frequency EMF and Low to Mid frequency EMF. The high-frequency radiation resides in the section of ionizing radiation in the electromagnetic spectrum. This includes X-rays and Gamma rays which can directly damage cells and organs. In contrast, Low to Mid-frequency EMF complies with the radiation from power lines, radio waves, infrared radiation, microwave, and visible light. The sources of non-ionizing radiation are shavers, electric wires, hair dryers and so on which come with low EMF values. On the other hand, the most common sources of non-ionizing radiation come with radiofrequency radiation which includes telecommunication devices, for example – cell phones, wireless devices, tablets, laptops, desktops, and many more. Moreover, radio, television, radar, satellite stations, MRI, microwave ovens, and WIFI are examples of EMF under the non-ionizing radiation section (M. Quamruzzaman et al., 2021).

One of the most common sources of non-ionizing radiation is radio waves, which are used for a wide range of communication applications such as television, radio, and cellular networks. These waves have a relatively long wavelength and low frequency and can penetrate buildings and other obstacles to reach their intended target. While exposure to radio waves is generally considered safe, excessive exposure to these waves can cause heating of the body-tissue (M. Quamruzzaman et al., 2021).

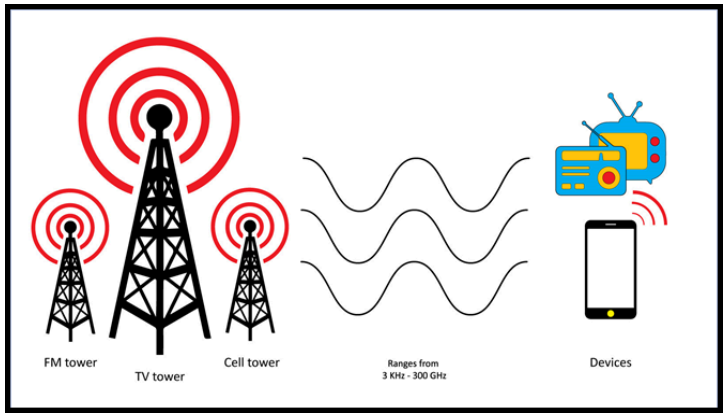

Fig. (2): Radiofrequency used for telecommunication

Moreover, Microwaves, another form of non-ionizing radiation, are used in a variety of applications including cooking, wireless internet, and radar. These waves have a shorter wavelength and higher frequency than radio waves and can also cause heating of the body's tissues, ranging from 300 MHz to 300 GHz. It is important to note that while microwave ovens are designed to contain microwaves inside the oven to prevent exposure, there have been reports of leakage from malfunctioning ovens, which can be harmful to people nearby (M. Quamruzzaman et al., 2021).

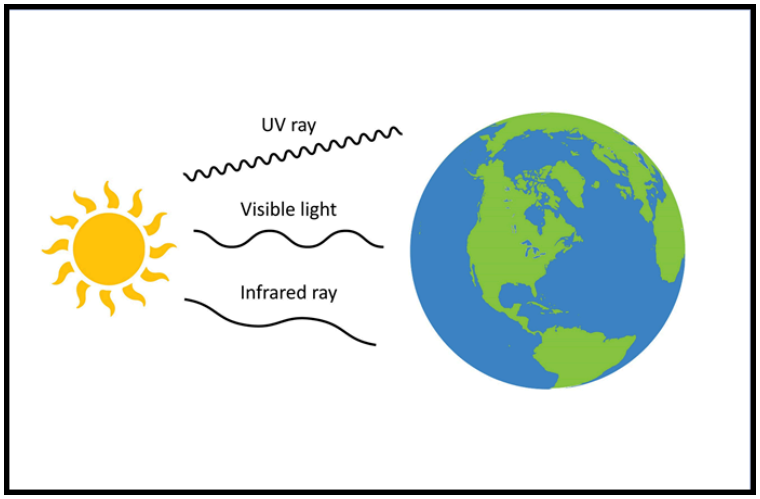

Fig. (3): One example of UV, Visible, and IR radiation source

Infrared radiation, which is a form of non-ionizing radiation, is emitted by warm objects such as the sun and human bodies. This type of radiation is responsible for the warming sensation felt on the skin when exposed to the sun or other heat sources. Infrared radiation is also used in many industrial and medical applications, such as heating, drying, and medical imaging. While the sun is the main source of infrared radiation, artificial sources of infrared radiation are heat lamps, remotes, electrical modulators, and so on (M. Quamruzzaman et al., 2021).

Visible light, which is a form of non-ionizing radiation, is the portion of the electromagnetic spectrum that the human eye can see. This type of radiation is responsible for the colors that we see in the world around us. While exposure to visible light is generally considered safe, excessive exposure to bright light sources such as the sun, can lead to eye damage and skin cancer. On the other hand, Ultraviolet radiation, which is a form of non-ionizing radiation, is emitted by the sun and other sources such as tanning beds (M. Quamruzzaman et al., 2021).

1.4 Potential Health Hazards of NIR

Though their non-ionizing radiations are supposed not to be harmful to health, there is some evidence that suggests that non-ionizing radiation has a potential effect on developing health hazard conditions and cancer. Therefore, brain cancer was seen to be developed among the U.S. Air Force personnel who work to maintain and repair radiofrequency and microwave emitting equipment. Another case-control study found an increased risk of death from brain cancer among

the workers who perform jobs in manufacturing, repairing, and installing electrical devices. Additionally, overuse of cell phones was found to be connected with tissue heating of the body part where cell phones are kept close during a call with others e.g., ears and head. Overuse of phones and overexposure to non-ionizing radiation of cell phones has led the evidence to experience headaches, blurred vision, and pain in the neck. Therefore, to evaluate different health conditional parameters such as headache, insomnia, vision loss, and skin irritation in association with cell phone usage is done in this research paper. Statistical analysis was performed to find the correlation between these parameters and non-ionizing radiation from cellphones under the electromagnetic field (Ahlbom et al., 2004).

1.5 Objectives of the Study

- This research focuses on the study to give an overall picture of the connection between non-ionizing radiation coming from cell phones and any possible health-related symptoms like insomnia, headaches and vision problems among people who are the long-term exposures to electromagnetic waves - non-ionizing radiation. The study examines the various effects that arise from over-utilizing cell phones, youth versus the elderly, for example.
- The study examines the various effects that arise from over-utilizing cell phones, youth versus the elderly, for example. This research will outline the groups of the population that may experience the most adverse effects of non-ionizing radiation exposure and therefore, will identify populations in need of targeted preventions and interventions.

Chapter 2

Literature Review

2.1 Electromagnetic Radiation and Mobile Phone

The electric potential difference generated in a circuit or conductor by an electrochemical cell is known as electromotive force. In general terms, it is the electrical difference rather than force that drives the electric current to function successfully in circuits. Electronics including daily gadgets like cell phones, radios, and other electric home appliances emit these electromagnetic fields in the form of energy (Omer, 2021). When these electromagnetic fields change their electric and magnetic fields due to changes in current, a combination propagates through space known as electromagnetic waves (EMW). According to the World Economic Forum, the number of cell phone subscriptions worldwide was more in comparison to the global population halfway through the year 2022 (Global Cooperation, 2023). With a growing number of users, concerns regarding electromagnetic waves and radiation have been raised. Health effects of electromagnetic waves generated from cell phones, and radiofrequency have yet to be identified. However, several international studies have found a positive association between health effects and exposure to microwaves from mobile phones and mobile tower base stations (Quamruzzaman and Haque, 2014) (IEG, 2000) (P.D Inskip et al., 2010). Electromagnetic wave radiation is the energy transmitted from a source; a cell phone containing the electric and magnetic field. Excessive radiation exposure can damage human tissue and organs depending on the source, radiation type, and dosage received.

2.2 Ionizing Radiation

It is the type of radiation with enough energy to remove tightly bound electrons from the atom causing it to become charged or ionized (Abu Bakar et al., 2019). All living organisms are exposed to radiation including diagnostic and therapeutic medical exposures (Desousky et al., April 2015). Ionizing rays including cosmic rays, radioactive rays, and radon decays are a few of the major sources of natural exposure to these rays. Consequently, these rays have been well-established to be carcinogens to living organisms. The carcinogenic risk associated with ionizing radiation has been explored by the International Agency Research on Cancer(IARC) throughout decades and in the updated review on all carcinogenic type of radiation, the evidence of carcinogenicity was stated furthermore, as overall conclusion IARC classified, all types of ionizing radiation as carcinogenic to humans (Group 1). It is because all ionizing radiation

transfers energy in the human body through clusters of ionization and excitation, mechanisms mediated by free electrons. DNA damage is one of the many consequences of this type of radiation (Hill and Ullrich, 2012).

The adverse effects of ionizing radiation can be categorized into two: deterministic effects and stochastic effects. Among these deterministic effects is cell killing, distinguished by threshold effect, below which no medical effects are recognized. Conversely, Stochastic effects are the long-term, low-level chronic exposure to radiation (Desousky et al., April 2015).

Sources of ionizing radiation include radioactive materials and radiation-generating machines. They can be both naturally occurring or manmade produced in a reactor or accelerator. Divided into types (a) directly ionizing or (b) indirect ionizing.

Direct ionizing radiations are radioactive sources- alpha radiation, beta particles, positron, and charged nuclei. Alpha radiation occurs when an atom undergoes radioactive decay, heavy in size thus when interacting with matter it can only travel a few centimeters. Thus it fails to penetrate dead skin cells (Abu Bakar et al., 2019). On the other hand, beta radiation has slightly less molecular mass than alpha and thus can go a bit further in distance and can penetrate and pose health risks in the human body (Abu Bakar et al., 2019).

Gamma and neutron rays of indirect ionizing radiation have similar or more effects on the human body as it has no mass and is neutral in charge thus imposing severe health risks to human beings (Abu Bakar et al., 2019).

2.3 Non-Ionizing Radiation

Non-ionizing radiation (NIR) consists of long wavelengths > 100 nm, low photon energy(<12.4 eV) part of the electromagnetic spectrum 1Hz to 3×10^{15} Hz. Since it has high wavelength and low frequencies thus in comparison to ionizing radiation, these waves cannot travel much distance hence has lesser impact on penetrating human skin and in change in cell. NIR encompasses a broad range of electromagnetic frequencies. They are less harmful as compared to ionizing radiation as in general it is not energetic to remove electrons from biomolecules (Tuieng et al., 2021). NIR undergoes rotational or vibrational transitions which require minimal changes in the stability of the electron-nucleus attraction and thus have negligible chemical effects as well. Non-ionizing radiation is divided into two categories: Optical radiation and radiofrequency

(RF). Optical radiation is composed of infrared (IR), visible and ultraviolet (UV) radiation in the universe. UV radiation is the highest form of optical energy with a wavelength of 100-400 nms. Excessive use of UV can lead to health hazards as well prominent examples can be skin cancer, sunburn or cataract formation.

RF radiation consists of extremely low frequencies (ELF), radiofrequency (RF) and microwaves (MW). These are the electromagnetic wave frequencies which are on mobile phones, radio stations, base stations and anti theft devices. Radiofrequency is absorbed in skin through a measuring unit known as specific absorption rate (SAR). The limit of SAR for a human head is 2 W/kg. This means the human head has the absorption rate of 2 W of RF in per kg tissue present in the head. Cell phones radiate both RF and magnetic field (MF) in the form of extremely low frequency (ELF) of 1 Hz- 100kHz according to ICNIRP.

2.4 Health effects of NIR

Due to the increment in mobile phone usage for long hours, many health-related disorders and diseases appear early on among them headaches, mind fog, digestive disorders, sleep disturbance, memory loss, and dizziness (Conway, 2015) (Haque and Qamruzzaman, 2016). Furthermore, According to WHO, the likelihood of adverse health effects from mobile phones is caused due to the higher radiofrequency involved.

Microwave radiations (MW) which fall in the electromagnetic spectrum between 1mm to 1m equivalent to 300 Hz-300MHz are mostly used in communications. Among these exposure to non-thermal-based MW has been reported to be associated with different neuropsychiatric diseases (Pall, 2016) (Omer, 2016). Tissue exposed to high MW along with high temperatures leads to tissue damage (Zhu et al., 2017) (Omer, 2016). Furthermore, it has been reported to cause sleep disorders along with memory impairment. Furthermore, some studies suggested the incidence of prolonged exposure to mobile phones with chances of developing a brain tumor (an et al. 2008).

2.5 Carcinogenic Health Effects and Cancer

RF fields have been associated with head cancers by the International Agency for Research on Cancer as carcinogenic to human beings (WHO, 2013).

Cell Phones and Other Diseases: Although scientists have claimed a close association between mobile phones and brain activity, reaction times, and sleep patterns, their credibility is yet to be confirmed (Haque and Quamruzzaman, 2016).

2.6 Cell Phones and Eye Health

Epidemiological studies have concluded that spending four to six hours a day with digital devices leads to potential vision problems and eye strain. Irritation, redness, dry eyes, blurred vision, back pain, neck pain, and headaches are included in this category. (J. C. Lin, 2003) (Haque and Quamruzzaman, 2016).

2.7 World Perspective

As mobile devices have become an essential part of everyday life, maintaining threshold values has become important to maintain a healthy lifestyle. The intensity of radiation Maximum Permissible Dose (MPD) in the USA has a threshold level of 10m W/cm^2, 195 V/m and 0.1 W/c m^2, 20V/M in CIS. According to WHO, 2.5 mT MF (Milham, 1982) (Haque and Quamruzzaman, 2016). RF EMFs' possible harmful exposure has been recognized and given guidelines accordingly. The Federation Communications Commission (FCC), the governing body of the electromagnetic spectrum, has imposed limitations on specific absorption rate (SAR) to estimate safe exposure levels for both thermal and non-thermal MW. A Interphone Study involving 13 countries to assess the relationship between phones and brain tumors was conducted by the International Agency for Research on Cancer (IARC), a case control study concerning glioma, meningioma and acoustic neuroma. The reports were consistent in finding no overall association with long term cell phone usage (Klaeboe et al. 2007, Hours et al. 2007). Thus, results consisted of no increased relative risk with mobile phone users for ten or more years. In Japan, to further investigate the amount of mobile phone use and tumor risk, the maximum SAR was measured inside the tumor (Takebayashi et al. 2008). However, no

consistent pattern emerged from the experiment and both increased and decreased odds ratio were observed.

Furthermore, recent studies have indicated that the exposure level of current SAR may lead to energy deposition in children's heads twice and in bone marrow ten times more than normal (Gandhi et al. 2012) (Wall et al., 2018). On the other hand, evidence of non-thermal effects of RF EMF is not confirmed. Although changes in the brain were demonstrated in a study containing 47 healthy individuals in a 50-minute phone call, string association cannot be determined through this (Volkow ND, 2011) (Wall et al., 2018). Additionally, according to the classification of RF-EMF based on the exposure risk factors, IARC has classified RF-EMF as possibly carcinogenic to humans and past work has indicated that energy deposition exposed at the SAR level poses a greater threat in children than adults (IARC Working Group on the Evaluation of Carcinogenic Risk to Humans 2013) (Wall et al., 2018).

2.8 Bangladesh Perspective

Growing concern over possible diseases and disorders has also led to local advancement in research in this sector. An epidemiological survey of people working in the EMF field has been conducted. To inquire about possible health hazards surveys were being conducted on EMF emitted by Lab equipment. Epidemiological cross-sectional surveys have been conducted to examine the health effects of EMF emitted from cell phones on the students of Southeast University, Dhaka (Haque and Quamruzzaman, 2016) These analysis did show recurrent trend in symptoms like tissue heating, indigestion, fatigue, dizziness and insomnia however correlation pattern of these symptoms with respect to usage of long term cell phone or being near the RF-EMF field showed values below or at threshold levels. Several reasons can be given for this. One of the possibilities is that the respondents to be electromagnetic hypersensitive (EHS) also known as microwave syndrome where patients present wide characteristics of symptoms like nervous system syndrome which occurs following exposure to low frequency radiations. Furthermore, recall bias is a major part in every research analysis and tendency for accurate statistics is quite low in low sample analysis but social desirability bias may lead to possible inconsistent and vague results.

Chapter 3

Methodology

3.1 Material

Fig. (4): Multi-Field EMF Meter (Model: EMF450; Extech Instruments)

A Multi-Field EMF Meter (Model: EMF450; Extech Instruments) was used for measuring the magnetic field, electric field, and RF strength. It had two ELF (Enhanced Low Flow) sensors which included an Electric Field sensor and an RF sensor. The power of the meter was 4.5 V. And the measurement ranges were:- for Magnetic Fields [frequency response: 50-60 Hz, range: 20/200/2000 mG, 2/20/200 μT], for Electric Fields [frequency response: 50-60 Hz, range: 50-2000 V/m], for RF Strength [frequency response: 50 MHz-3.5 GHz, range: 36.1 mV/m-14.46 V/m].

3.2 Method

This is an epidemiological cross-sectional research. This research has been conducted by collecting data from the general people of different areas in Dhaka city.

3.2.1 Sample Data Collection Form

Data was collected from people living in different areas of Dhaka city. A questionnaire form was made with various parameters like EF, MF, distance from the source, power density value, age,

time spent per day, usage duration, network technology, mobile brands, and symptoms. An ethical consent section was also included in the form so that people could fill up the form without any hesitation.

3.2.2 Data Collection Period & Sample Data Size

Data were collected over three months, resulting in a total of 310 data samples.

3.2.3 Data Collection Process

For each device, values of EF, MF, and RF were recorded four times from four sides, with the maximum value noted for EF and MF, and the average for RF. Readings were taken with the mobile phones switched on. Epidemiological data taken from cell phone users were analyzed. The cell phone users were categorized by their cell phone brands, network, age, physical condition, cell phone's distance from the meter, years of cell phone usage, daily usage hours, potential cell phone usage symptoms, and so on. Lastly, the parameters were interrelated and analyzed statistically using software.

3.2.4 Data Analysis Tool

IBM SPSS Statistics version 25 was used.

3.2.5 Data Analysis

First, the percentages of the networks i.e., what percentage of people use which network or networks were figured out. Then frequency graphs of the electric field, magnetic field, and radiofrequency power per unit area were created. Following that, bar charts were generated to display the average values of electric fields, magnetic fields, and power density or RF strength per unit area by networks of different mobile phone users. Subsequently, a pie representing the rate of five most common symptoms generally considered as a result of non-ionizing radiation of mobile phones was shown. Additionally, a percentage bar showing the usage years was created for the sample mobile phones. After that, a correlation was made between symptoms and the average daily usage time of mobile phones to see how the time duration is relatable to the symptoms. Besides, age versus time-spent graph was constructed to show how long people of

different ages spend on their mobiles i.e., the usage patterns of individuals across different age groups. Next, crosstabulation was done between symptoms and age, accompanied by scattered graphs for individual symptoms, to show the relationship between the variables that determine which age of people are mostly affected by the symptoms of non-ionizing radiation of mobile phones. Lastly, correlation was made between all of these as part of analysis to discuss the final result.

Chapter 4

Results & Analysis

4.1 Results & Analysis

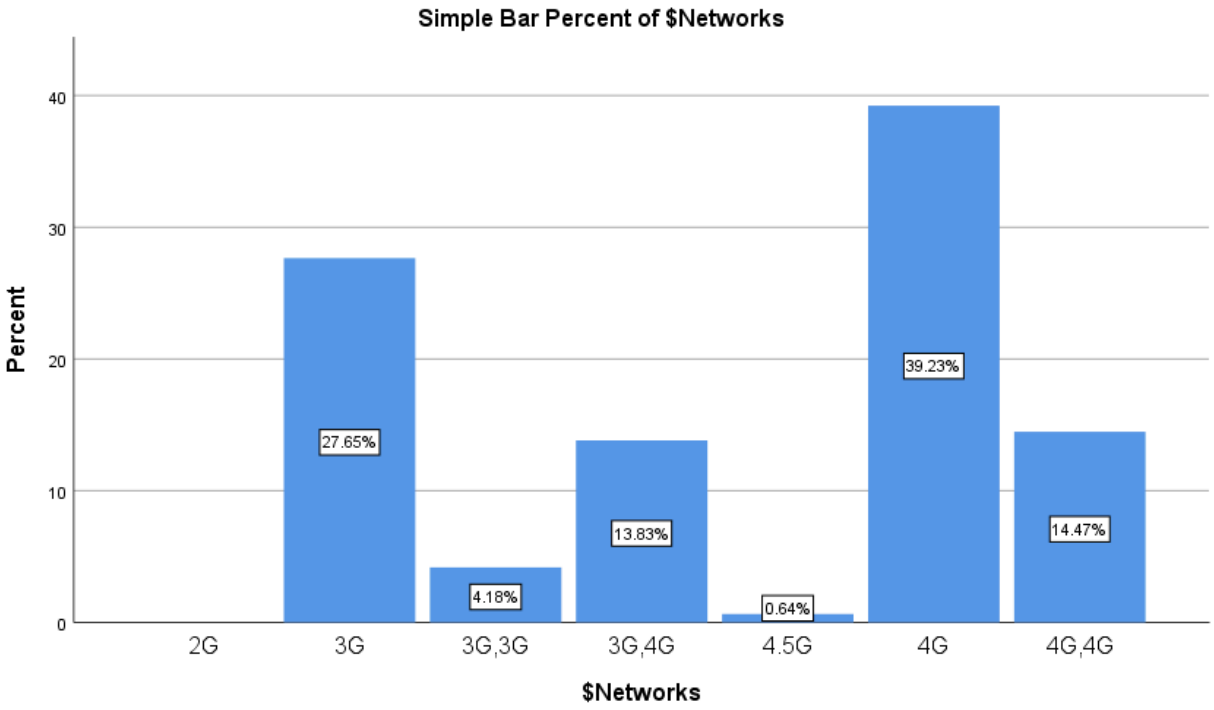

Fig. (5): Percentage of networks used by the sample users

From this bar, it can be said that most of the people in Dhaka city use a single 4G sim. The second highest users are the single 3G network users. Then comes the double 4G users and 3G, and 4G users respectively. The users of 4.5G networks are the lowest. It's noticeable that there's no 2G network users remaining in Dhaka right now, at least according to our respondents.

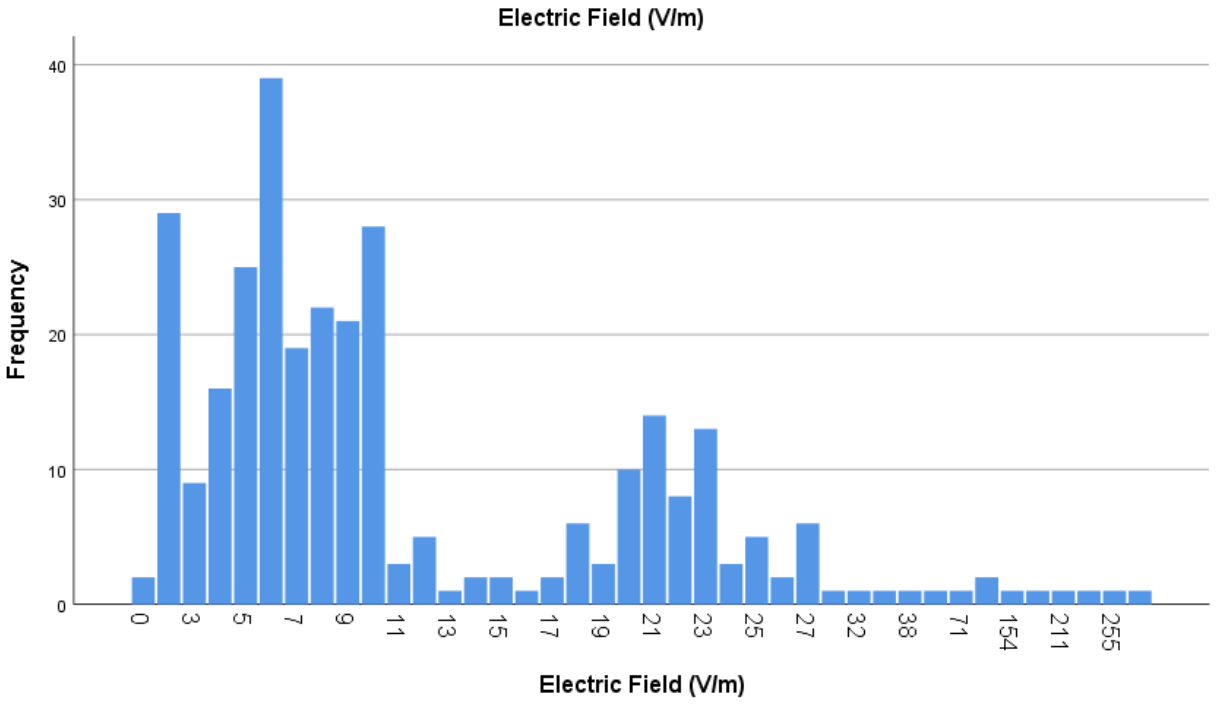

Fig. (6): Frequency of electric field

Since 25 V/m is the recommended threshold value for the electric field, and in the graph, it's clearly illustrated that most of the values are within the threshold value, it can be concluded that the electric fields emitted by mobile phones are within safe limits, at least in the conditions tested or represented by the graph.

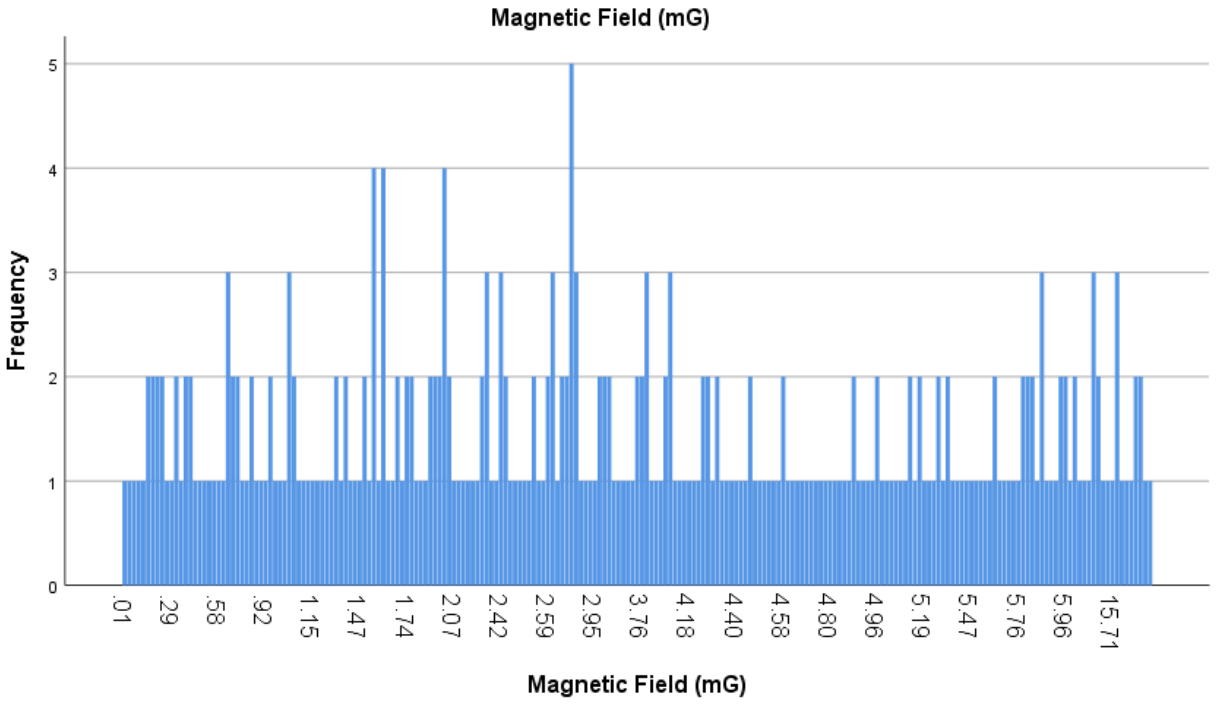

Fig. (7): Frequency of magnetic field

Since 2.5 mG is the recommended threshold value for magnetic fields, and the graph clearly shows that most of the values are within or around the threshold value, it can be said that the magnetic fields emitted by mobile phones are within safe limits, under the conditions tested.

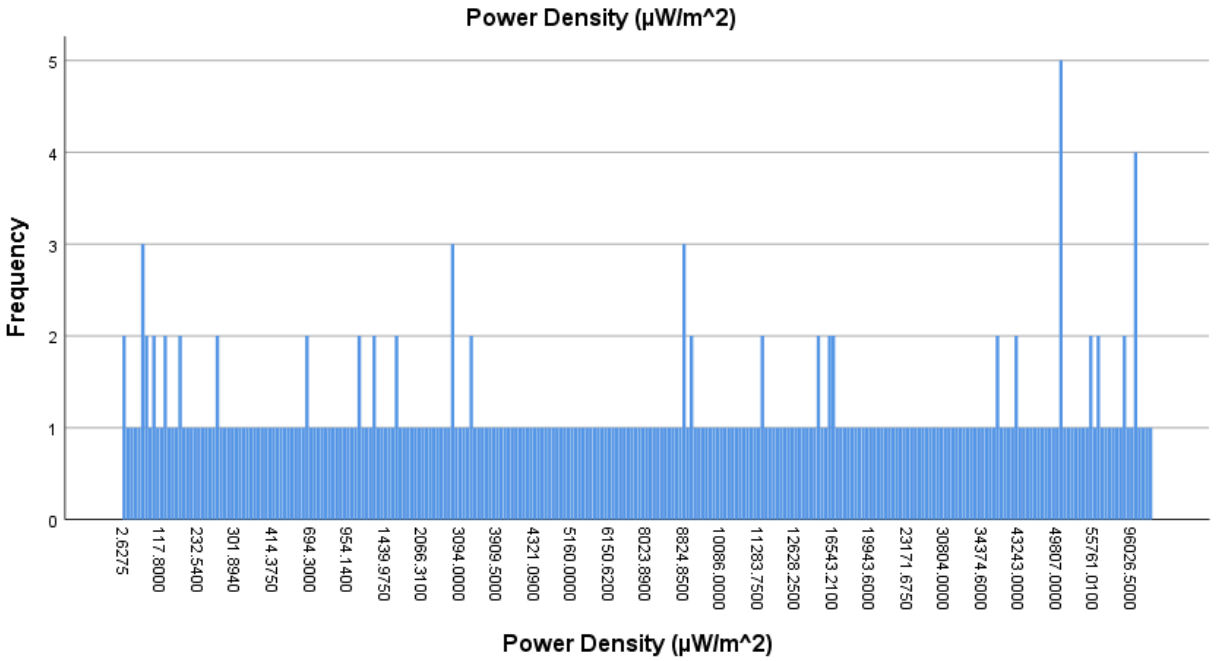

Fig. (8): Frequency of power density or RF power per unit area

The bar for the range 49807 µW/m² is the tallest, indicating that the majority of mobile phone samples have power density values within this range. So, this is the most common range.

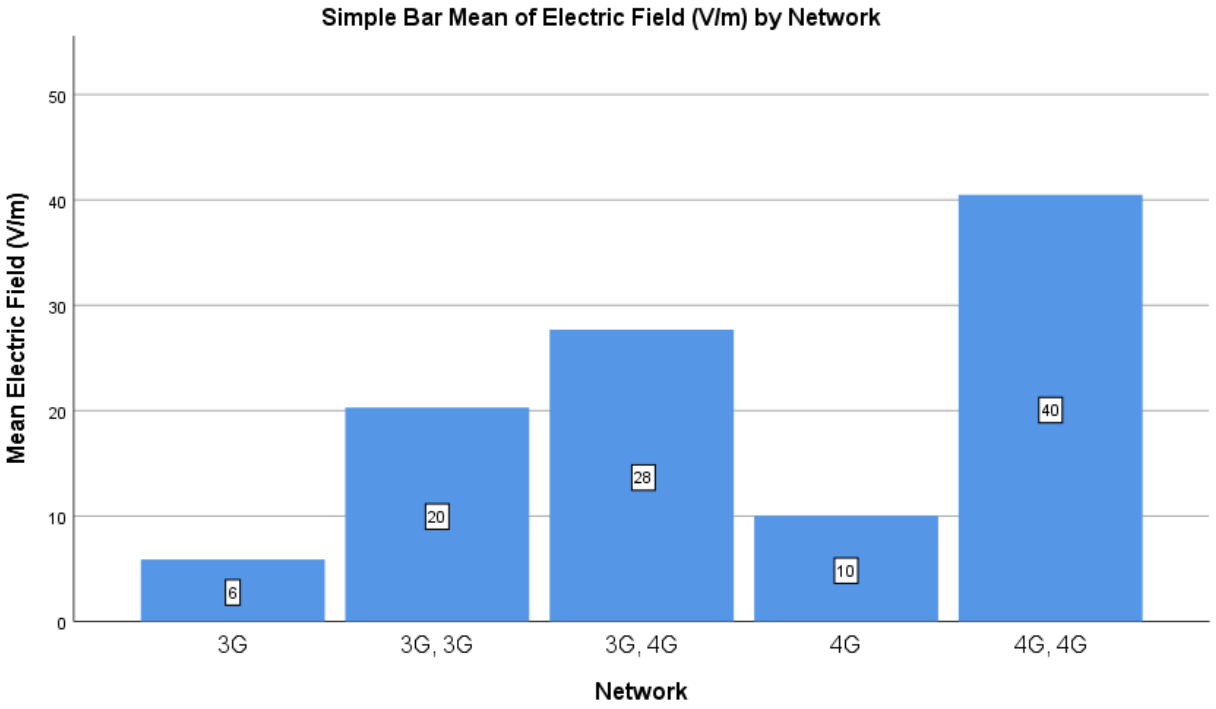

Fig. (9): Average value of electric fields of different networks used by the users

This graph illustrates the mean electric field strength for different mobile network types. It shows that on average, the electric field for double 4G networks is higher compared to other network/networks. So, it's evident that the newer network technologies might entail higher levels of electromagnetic radiation emission.

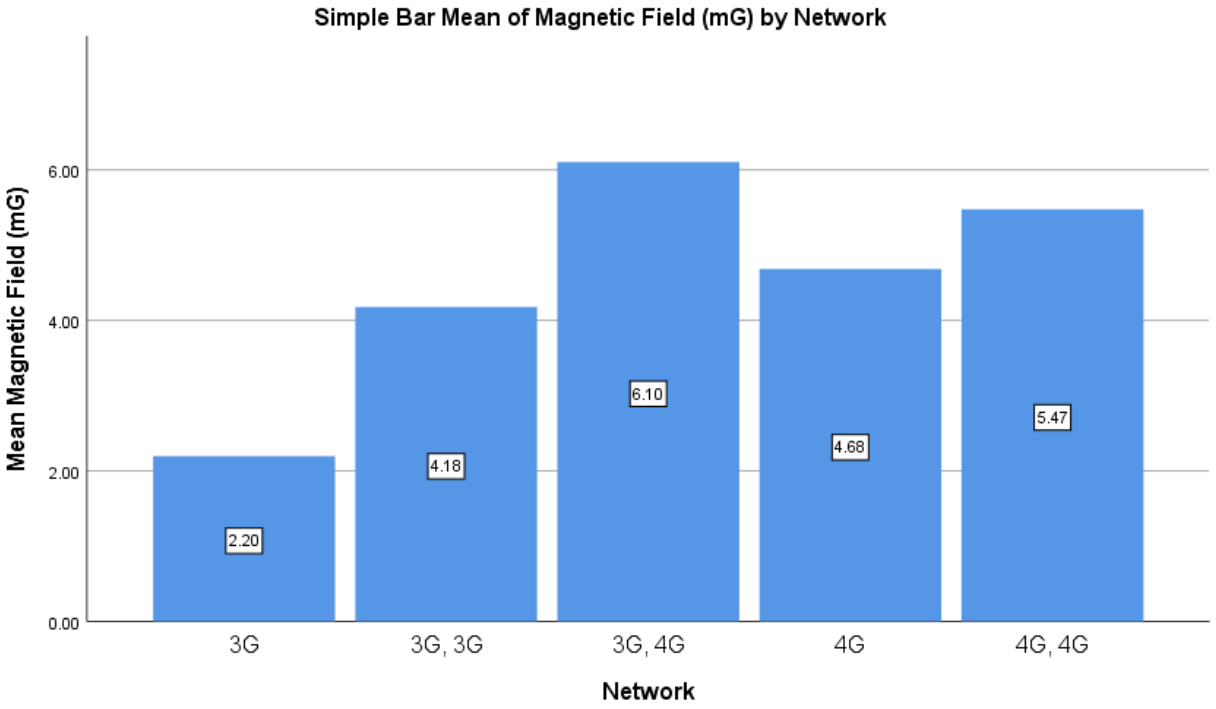

Fig. (10): Average value of magnetic fields of different networks used by the users

This graph illustrates the mean magnetic field strength for different mobile network types. It shows that on average, the magnetic field for 3G, and 4G (double sim) networks is higher compared to other network/networks. It is because maybe the lower frequency bands of 3G networks which tend to have longer wavelengths led to a higher mean magnetic field strength because the magnetic field extends further from the source. Or, some of the 3G networks were transmitting at a higher power level compared to the 4G network, which resulted in a higher mean magnetic field strength for the 3G/4G SIM. The other possible reason could be there were more 3G towers in a particular area compared to 4G towers which led to a higher mean magnetic field strength for the 3G/4G SIM.

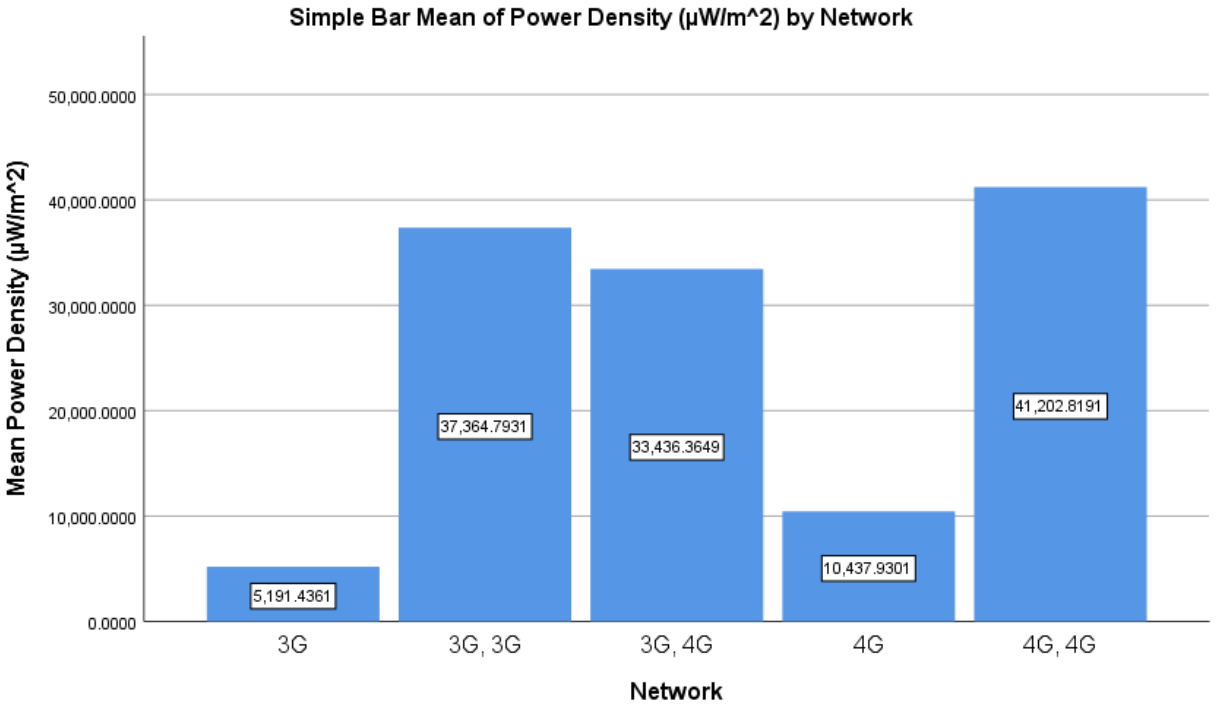

Fig. (11): Average value of RF power per unit area of different networks used by the users

This graph shows the mean power density for different mobile network types. In the given result, 4G,4G has the highest power density. But 3G,4G has less power density than the 3G,3G network. Maybe the 3G networks were then experiencing higher usage or congestion compared to the 4G network, for that, power density was probably higher as more power was needed to maintain connectivity and provide service to users. Or, if the 3G signal strength is weaker or the coverages poorer compared to 4G in a particular area, devices may be needed to increase their transmission power to maintain a connection, resulting in a higher mean power density.

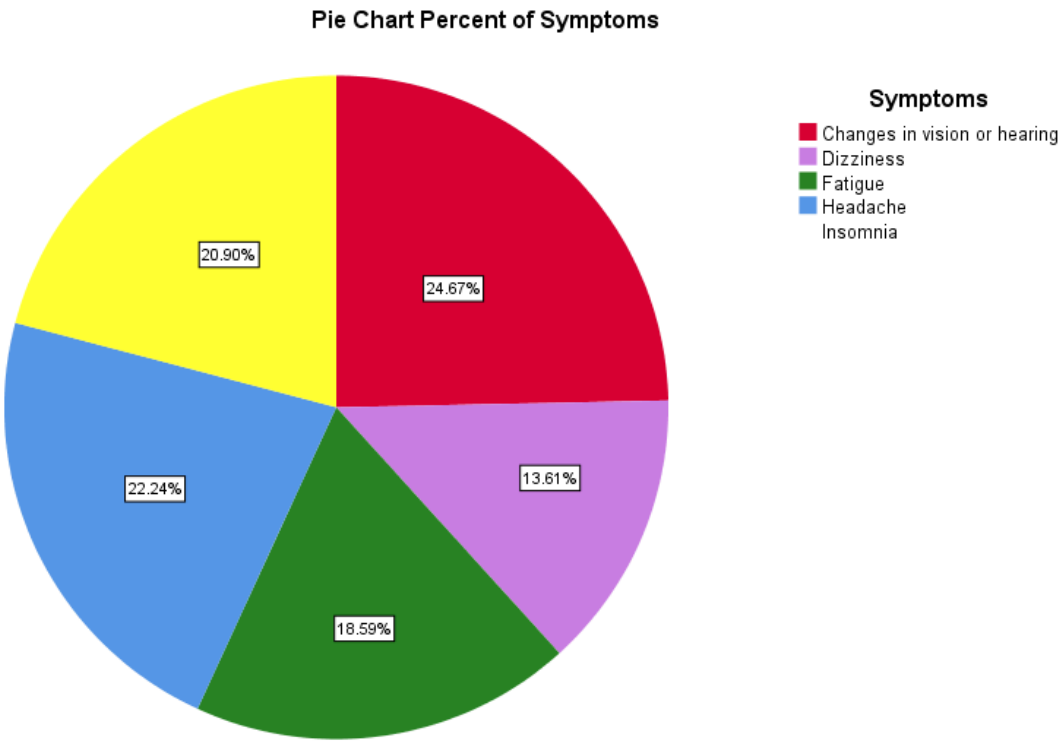

Fig. (12): Percentages of the most common symptoms of mobile phone users

According to this pie chart, vision or hearing problems are the most common symptoms among all, followed by headaches. Then come insomnia, fatigue, and dizziness, respectively, in order of prevalence.

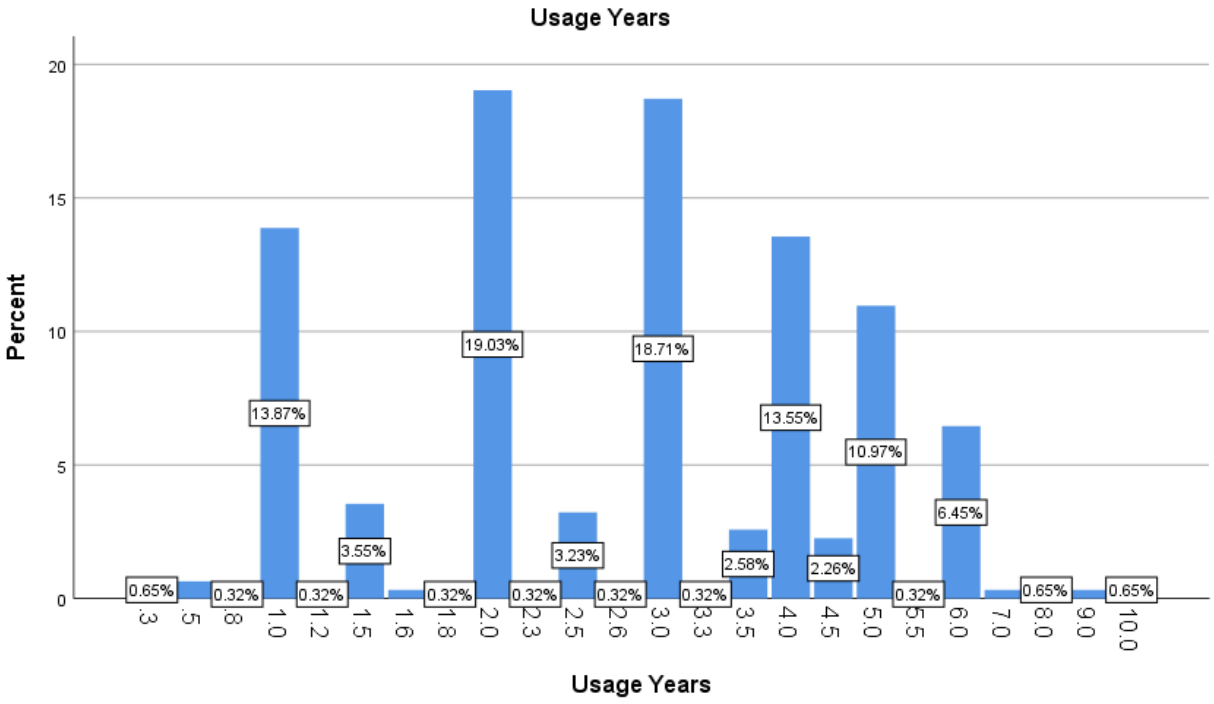

Fig. (13): Percentage of mobile phone user's years of usage

The graph shows that the majority of people nowadays use a mobile for only 2-3 years.

Table-1: Distribution of time spent per day (hours) using mobile phone and symptoms of the respondents (n=310)

	Frequency	Changes in vision or hearing	Headache	Insomnia	Fatigue	Dizziness
< 7 hours	97	30 (30.93%)	33 (34.02%)	28 (28.86%)	23 (23.71%)	13 (13.40%)
7-12 hours	190	154 (81.05%)	132 (69.5%)	130 (68.42%)	112 (58.95%)	82 (43.2%)
> 12 hours	23	19 (82.61%)	18 (78.26%)	14 (61%)	18 (78.26%)	17 (73.91%)
Total	310	203 (65.5%)	183 (59.03%)	172 (55.5%)	153 (49.4%)	112 (36.13%)

In this table, it's shown how many hours people spend their time using mobile phones and how that time duration is relatable to the symptoms. People who spend more than 12 hours are the most affected by the electromagnetic radiation of mobile phones. Then comes people spending 7-12 hours on mobiles. People who use their mobiles less than 7 hours per day are the least affected ones.

But it's seen in the table that, in the case of insomnia, people who spend over 12 hours on mobiles are less affected than the people who use mobiles for 7-12 hours. It may be because shorter durations (7-12 hours) might lead to more interruptions due to inconsistent usage patterns, while longer durations (over 12 hours) might indicate a more stable routine. Individual differences, such as genetics, age, health conditions, and lifestyles can influence susceptibility to sleep disturbances from phone usage. Additionally, factors like stress, anxiety, and lifestyle habits can also influence sleep deprivation, which may vary among individuals who spend different amounts of time on their phones.

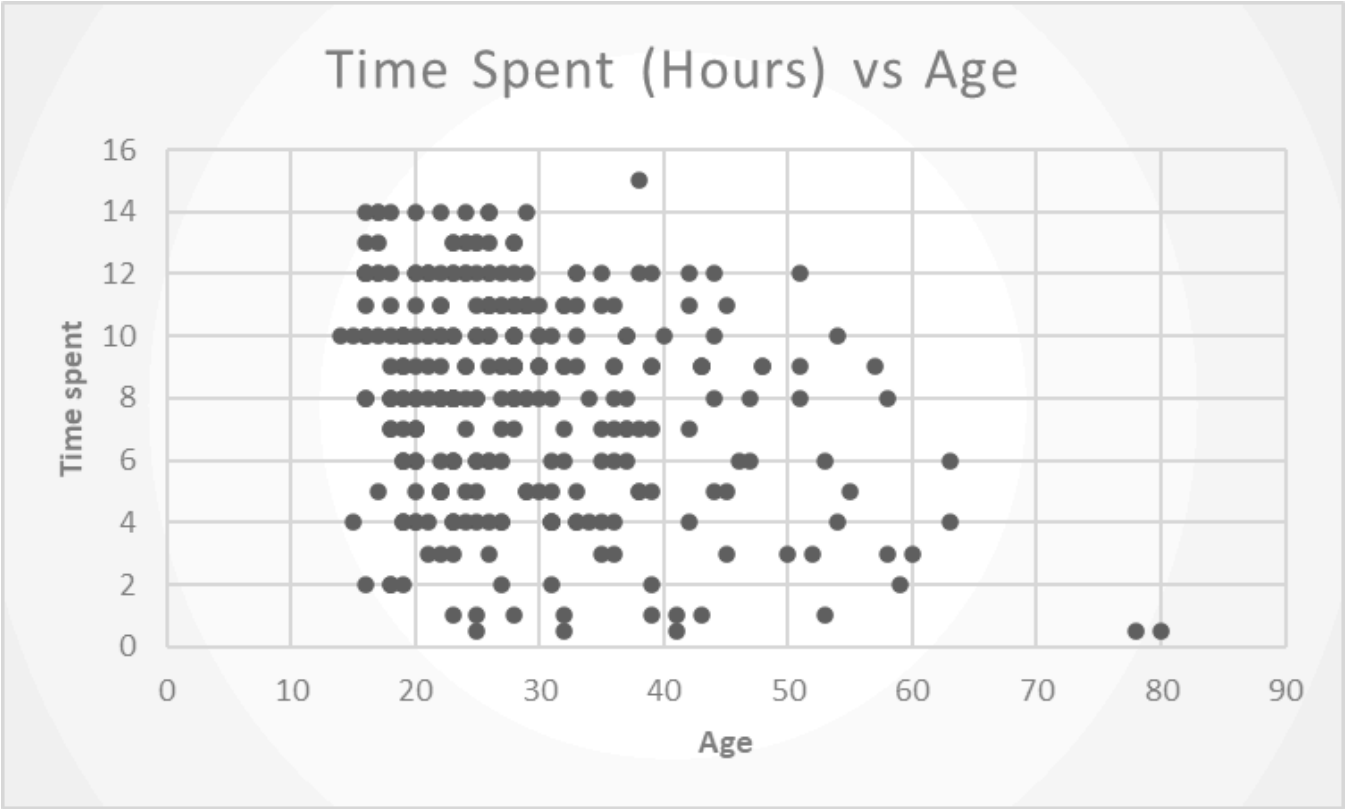

Fig. (14): Time spent (Hours) VS Age

This graph is clearly showing the relationship between age and time spent. It indicates that individuals in the 16-30 age group tend to spend the most time on their mobile devices, followed by those aged 31-45. The time spent gradually decreases for individuals aged 46-60, with the least amount of time spent by those over 60.

Table-2: Distribution of age groups and symptoms of the respondents (n=310)

	Frequency	Changes in vision or hearing	Headache	Insomnia	Fatigue	Dizziness
Under 16 years	3	3 (100%)	1 (33.33%)	3 (100%)	1 (33.33%)	2 (66.67%)
16-30 years	206	146 (70.87%)	131 (63.59%)	114 (55.34%)	111 (53.88%)	84 (40.77%)
31-45 years	77	42 (55%)	44 (57.14%)	41 (53.25%)	33 (47.83%)	23 (29.87%)
46-60 years	20	11 (55%)	7 (35%)	14 (70%)	8 (40%)	3 (15%)
Above 60 years	4	1 (25%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Total	310	203 (65.5%)	183 (59.03%)	172 (55.5%)	153 (49.35%)	112 (36.13%)

The table illustrates the correlation between age groups and symptoms among the respondents. It indicates that individuals aged between 16-30 years generally exhibit the highest number of symptoms, followed by those aged between 31-45 years. Individuals aged between 46-60 years are less affected by the symptoms, and people above 60 years show almost no radiation-related symptoms. [**NOTED:** since there are only 3 data samples of individuals under 16, the symptoms for this group have been disregarded.]

In case of insomnia, the case is slightly different. The percentage suddenly increased for the group 46-60 years instead of decreasing. It could be because in a developing country like Bangladesh, individuals of this age range generally worry a lot about supporting their family financially; so their sleep is disturbed.

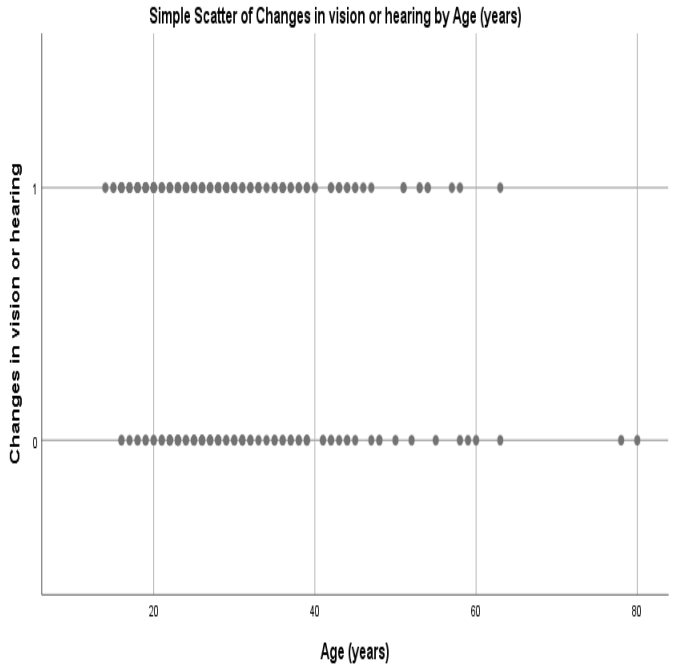

Fig. (15): Age vs. Changes in vision or hearing

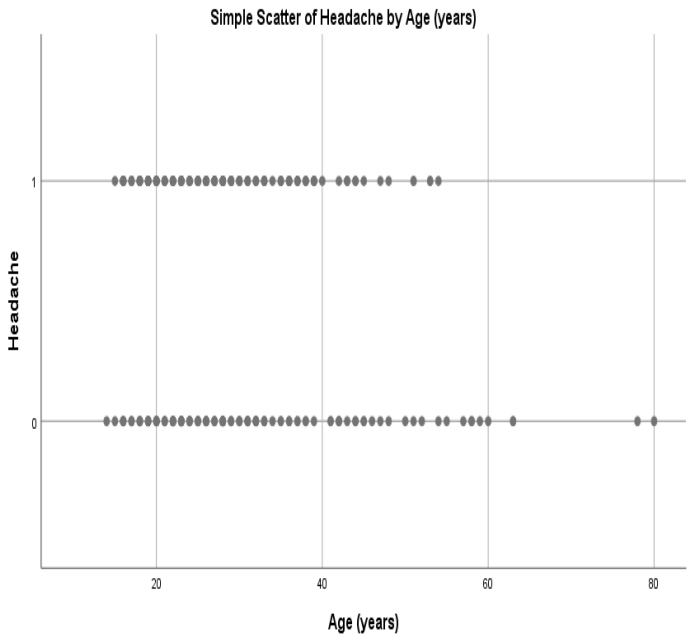

Fig. (16): Age vs. Headache

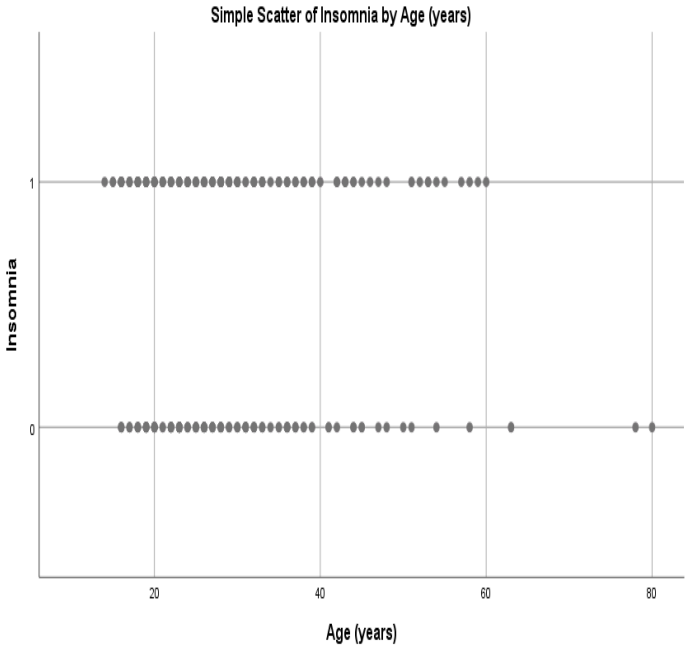

Fig. (17): Age vs. Insomnia

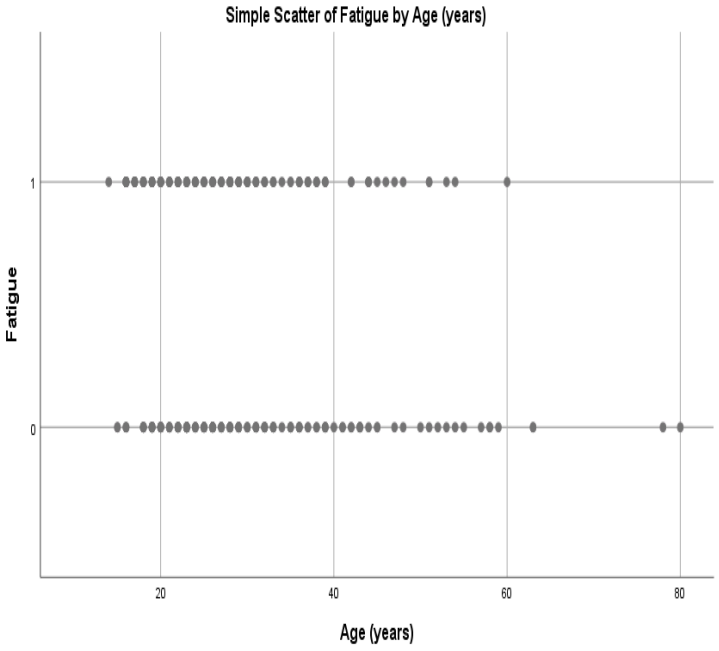

Fig. (18): Age vs. Fatigue

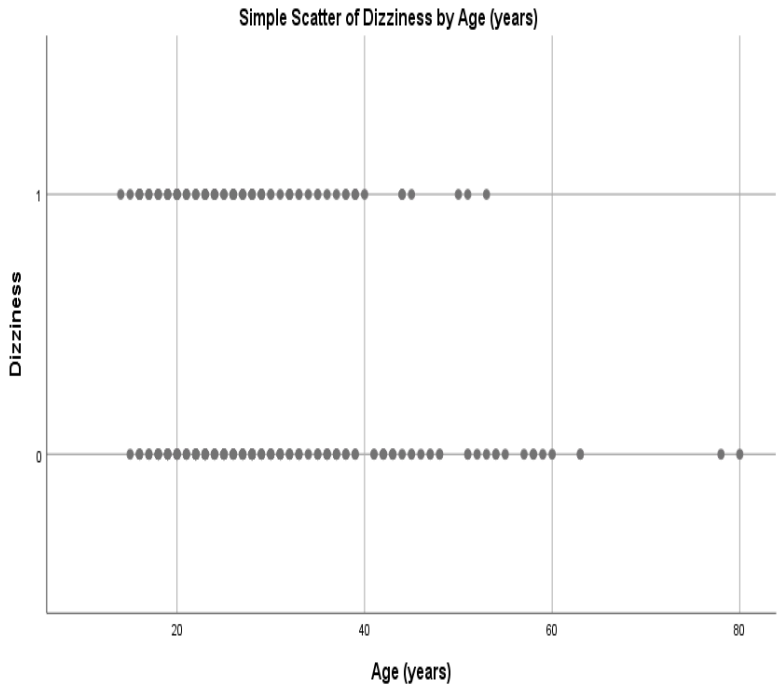

Fig. (19): Age vs. Dizziness

These five scattered graphs are the visual representation of Table-2.

4.2 Result Summary

From the charts, graphs, and tables demonstrated above, it's observed that most people use a single 4G sim (around 39.23%). But the people who use a double 4G sim have the highest non-ionizing radiation effect. Individuals using double 4G sim have the highest number of radiation-related symptoms. Among the symptoms, vision or hearing problems are the most common ones. Then comes headache, insomnia, fatigue, and dizziness, respectively. From the symptoms-time spent table, it's observed that mostly individuals who use mobile phones for a long time regularly (usually more than 7 hours per day) are affected with the symptoms in a higher number. Noticeably, people ages 16-45 years old are the most affected ones, because they're the ones who spend most of their time using mobile phones; relationship between age and time spent using mobile phones, cross tabulation between age groups and symptoms and the scatter graphs have led to similar conclusions.

Chapter 5

Discussion

5.1 Discussion

From the results, it's seen that most of the mobile phone users i.e., 39.23% users use a single 4G sim. Then comes the single 3G sim users which is 27.65%. And then comes double 4G users (14.47%). After that, there are 3G, 4G (13.83%), double 3G (4.18%), and 4.5G (only 0.64%) users. Notably, there are no 2G sim users, according to our collected samples.

According to our analysis, most of the mobile phones' electric field value, magnetic field value, and radiofrequency strength are either lower than or equal to the threshold values which is a good sign. But some mobile phone's EF, MF, and RF strength values exceed the threshold value which means those mobiles emit more radiation. Due to this, many radiation-related symptoms like headache, insomnia, fatigue, dizziness, tissue damage, skin irritation, burning sensation, changes in vision or hearing, tissue heating, changes in melatonin levels, etc. occur. However, there are other parameters to consider for radiation-related symptoms. For example, the user's age, fitness, how many hours he/she uses mobile phones, for how many years the mobile is being used etc. Even though there are several symptoms of radiation-related illnesses, the most commonly found ones are headache, insomnia, fatigue, dizziness, and changes in vision or hearing. We found out that individuals experiencing symptoms of radiation exposure from mobile phones tend to experience vision or hearing impairments predominantly (24.67%). Some often experience symptoms such as headache (22.24%), insomnia (20.90%), fatigue (18.59%), and dizziness (13.61%).

From our electric field and power density bar by networks, it's observed that double 4G sim has the highest values of electric field and power density. It's because 4G networks use higher frequencies which generally result in shorter wavelengths, which can lead to more rapid signal attenuation over distance but can also support higher data transfer rates. So, it's confirmed that double 4G networks emit more radiation than the others. But it's not true that only the double 4G network users will have symptoms of radiation-related illnesses. It's also not true that 4G network users have these symptoms or any of the symptoms. Other factors also influence the symptoms of the diseases.

It's seen from the time spent- symptoms table (Table-1) that the majority of people who exhibit the symptoms use mobile phones 7 to more than 12 hours daily. In the age-time spent graph **(**Fig. 14), it's observed that individuals aged between 16-30 spend most of their time (more than 12 hours per day) using mobile phones, regularly. And it's seen from the age groups- symptoms table (Table-2**)** that individuals whose age ranges from 16-30 are the ones affected mostly with the symptoms. From here it's clear that mostly the younger generations are addicted to mobile phones and so they exhibit the symptoms and possess radiation-related illnesses the most.

Considering all these, our suggestions would be to create awareness among the people, mostly the young generations, so that they minimize the use of mobile phones by refraining from unnecessary mobile usage.

From Table-2, it's seen that the percentages of symptoms gradually decrease with the increasing age groups. But in case of insomnia, the picture is different. Here, in the 46-60 years age group, the percentage increased (from 53.25% to 70%) instead of decreasing. And Table-1 illustrates that the percentages of symptoms tend to increase with the increasing amount of time spent per day. Again the picture is opposite in case of insomnia; the percentage decreased (from 68.42% to 61%) for individuals who spend more than 12 hours per day on mobile devices compared to those who spend 7-12 hours per day. This discrepancy was unexpected.

However, from Fig. (14) graph, it's observed that people aged between 46-60 years typically don't use mobile phones for more than 12 hours, at least according to our volunteer respondents. Despite this, their rate of insomnia is higher than that of people who use their mobiles for more than 12 hours. By interconnecting Table-1, Table-2, and Fig. (14), it can be concluded that the rate of insomnia is higher among individuals aged between 46-60 years, even after using mobiles for less than 12 hours. The reason behind this could be the economic perspective of Bangladesh.

As it is known, Bangladesh is a developing country where a significant portion of the population belongs to the middle class, lower middle class, or poor. In such a socioeconomic context, individuals in the age range of 46-60 often experience heightened financial worries, which disrupt their sleep patterns. This economic strain may be a major contributing factor to the higher rate of insomnia in this age group.

5.2 Limitations

The first limitation to be mentioned in this study is the small sample size. The data of only three hundred and ten respondents lacks sufficiency to establish any adequate conclusion. Therefore, a large sample size must be conducted in this study so that a great insight could be observed about the effects of NIR from cell phones on human health and potential health hazards. Moreover, the lack of the opportunity to do experiments with model organisms is another drawback of this research. As the result is established on the basis of personal opinion and answers, there could be a chance of bias towards a particular symptom. But if a model organism could be managed and its behavior was observed under the environment of over-EMF radiation, then a concrete result could be obtained. Lastly, if there was a control sample of the people who never used a phone or do not use a phone on a regular basis, then the study could have a great contrast in comparison as well as could develop a better conclusion about health concerns for the effects of EMF radiation of cell phones.

5.3 Future Direction

Future directions follow the limitations of this research. For example, collecting data from a large sample size is the very next step to be followed in this study, which will cover the respondents from all of Bangladesh and not only Dhaka city. Opinions from different people of different age intervals will be collected in the upcoming days. Secondly, experiments with a model organism will be performed for a better understanding of the effects of EMF radiation on the organism's cells. So that we can predict the effects of EMF radiation on human cells as well. Thirdly, identifying the local cell phones that are actually exceeding the regulatory standards for cell phone radiation emission will be the next step to creating awareness about the phones and encouraging people to not use these phones for their own health.

Chapter 6

Conclusion

Flourishing advancement in technologies and mobile phones has led to the global rise in mobile phone usage. Mobile phones emit low-frequency EMF, radiofrequency, and magnetic fields. The International Agency for Research on Cancer (IARC) has classified mobile phones as possibly carcinogenic to humans. Over the years, countless research have been conducted to understand the correlation and effect of low-frequency electromagnetic waves, and radiofrequency on human beings. Brain-related diseases including glioma, tumor have been researched but no potential increased risk of glioma have been detected so far.

The main objective of this research was to investigate possible symptoms with low electromagnetic wave frequency and radio frequency. Regulatory agencies have set ELF for 25 (V/m) and according to the data, most of the values were within the established threshold value. Secondly, for magnetic fields the phones researched were also within safe limits. However, results from different electric field densities were 4G/4G > 3G/4G >3G/3G respectively. But for the magnetic field density, different outcomes were revealed where 3G/4G were greater than 4G/4G and other network types respectively.

The percentage of an individual's years of usage was maximum within the range between 2-3 years. It has been observed that a high percentage of individuals from the age group from early 20 to late 30s use the highest; 14-15 hours a day on mobile phones. These are individuals whose both personal and occupational life revolves around gadgets thus usage rate is also high. Accordingly, symptoms correlate with the ages of individuals as the percentage of symptoms like changes in vision, headache, insomnia, and fatigue are less likely from under 16 years than 16-29 and 30-40 years respectively. Proper correlation and reasonings behind the symptoms are vague and cannot be directly associated with mobile phone usage. Thus any conclusion is almost uncertain and tentative. More studies and thorough research are required to establish a proper association and connect the reasoning behind the high risk of a possible brain tumor or brain-related disease to NIR and low radiofrequency.

Chapter 7

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Chapter 8

Appendix

Questionnaire form

Effects of non-ionizing radiation from cell phones and cell towers

Reg no: **Date:**

Name:	
Address:	
Contact:	Age:
Weight:	

Education Primary Secondary (SSC) Higher Secondary (HSC) Graduate Postgraduate	Occupations Housewife Service holder Businessman Doctor Teacher Student Others Habitation Urban Rural

1. Do you work in an industry where you are regularly exposed to radiation, such as nuclear energy or radiology?

Yes	No

2. Have you ever experienced any symptoms that you believe may be related to radiation exposure?

Yes Vision loss / Tissue heating / Skin reddeni Changes in melatonin levels / Cataracts / Sunburn	No

3. Have you ever been advised to undergo/ exposed to radiation therapy for a medical condition?

Yes	No

4. How far do you live from a cell tower? / nuclear power plant or other source of ionizing radiation?

<400 meters away	=400 or >400 meters away

5. Do you regularly use electronic devices that emit non-ionizing radiation, such as a cell phone or laptop?

Yes	No

6. Do you limit your use of electronic devices to avoid non-ionizing radiation exposure?

Yes	No

7. Have you ever had a job that required you to be exposed to both ionizing and non-ionizing radiation?

Yes	No

8. Do you have any family history of radiation-related illnesses, such as cancer?

Yes	No

9. Have you ever undergone a full-body scan for radiation exposure?

Yes	No

10. Have you ever experienced any skin irritation or burns from exposure to radiation?

Yes	No

11. Have you ever experienced any changes in your vision or hearing that you believe may be related to radiation exposure?

Yes	No

12. Have you ever had a bone density test that involved radiation exposure?

Yes	No

13. Have you ever undergone a mammogram or other diagnostic imaging test that involved radiation exposure?

Yes	No

14. Have you ever been advised to take supplements or make dietary changes to help protect against radiation exposure?

Yes	No

15. Have you ever considered getting a radiation exposure assessment or having your home or workplace tested for radiation levels?

Yes	No

16. How many hours do you spend on the technological devices like phone, laptop etc. each day?

Less than an hour	1-2 hour
3-4 hour	5-6 hour
7-8 hour	More than 8 hours

17. Do you smoke? If yes, for how long?

Yes	No
For-	
Less than 20 minutes	20-30 minutes
40-50 minutes	1 hour
More than 1 hour	

18. What network technology mobile phone are you using?

19. Have you been experiencing any symptoms like prolonged headache, nausea, back pain or others?

Headache	Nausea
Back pain	Fatigue
Dizziness	Insomnia
Burning sensation	Skin cancer

20. Do you perform physical exercise regularly?

Yes	No

Epidemiological Survey on the effect of cell phone and cell phone users

Location:

Date:

Time:

SL No	Name	Male/ Female	Age	Profession	Living duration	Distance from the source (cm)	Electric field (v/m)	Magnetic field(μT)	Radiated power (mW/cm^2)	Effects /complains/ symptoms	Comments (Knowledge of EMF health)

EMF and MF values measured for cell phones:

SL No.	Brand Name, Day of Installation	EF Front V/m	EF Back V/m	EF Left V/m	EF Right V/m	EF Max V/m	MF Front mG	MF Back mG	MF Left mG	MF Right mG	MF Max mG	Power Density RF Strength μW/m^2

The participant voluntarily participated in this survey and provided permission for obtaining his/her information. I have explained to the participant that his/her identity will remain confidential. This questionnaire survey will be used for research purposes only. All information provided here is all true to my knowledge.

Name of survey taker_____ Signature _____ Date _____