An-Najah National University

Faculty of Graduate Studies

The Exposure Effects of the Signals of Cell Phones on the Employees of Nablus and Jenin Municipalities

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This Thesis is Submitted in Partial Fulfillment of Requirements for the Degree of Master of Physics, Faculty of Graduate Studies, An-Najah National University- Nablus, Palestine

2014

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Dedication

To my dear father

To my mother tenderness spring

To my precious wife

To my brothers and sisters

To my children

To my professors

To my friends

To my university An-Najah National University

To beloved Palestine

To our prisoners valiant

To the martyrs

To all those who contributed to the success of this work

Acknowledgments

I would like to thank my supervisor Prof. Dr. Issam Rashid Abdelraziq for his guidance, continued support and precious time. I will always be thankful for his wisdom and knowledge. Next, I would like to thank my co-supervisor Dr. Zeid Qamhieh for his encouragement and valuable suggestions for the work done in this thesis; it has been an honor to work with them. Special thanks to the administration and employees in Nablus and Jenin municipalities for their cooperation and help in the success of this work.

الاقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

The Exposure Effects of the Signals of Cell Phones on the Employees of Nablus and Jenin Municipalities

أقر بأن ما اشتملت عليه هذه الرسالة، انما هو نتاج جهد الباحث نفسه، باستثناء ما تمت الاشارة اليه حيثما ورد، وأن هذه الرسالة ككل، أو أي جزء منها لم يقدم من قبل لنيل أي درجة علمية أو بحث علمي لدى أي مؤسسة تعليمية أو بحثية أخرى.

Declaration

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's name: **اسم الطالب:**

Signature: **التوقيع:**

Date: **التاريخ:**

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List of Abbreviation

Symbol	**Abbreviation**
BTS	Base transceiver station
CDMA	Code division multiple accesses
dB	Decibel
DBP	Diastolic blood pressure
ELF	Extremely low frequency
EMF	Electromagnetic field
EMR	Electromagnetic radiation
FCC	Federal communications commission
FM	Frequency modulation
GSM	Global system for mobile communication
HPR	Heart pulse rate
IARC	International agency for research on cancer
ICNIRP	International commission on non-ionizing radiation protection
LI	Light intensity level
Lux	Unit of illumination
MW	Microwave
NIOSH	National institute for occupational safety and health
OSHA	Occupational safety and health administration
P_d	Power density
P-value	Probability
R	Pearson correlation coefficient
RF	Radio Frequency
RICNIRP	Russia international commission on non-ionizing radiation protection
S.D	Standard deviation
SAR	Specific absorption rate
SAR_N	SAR values for employee's tissues in Nablus municipality
SAR_J	SAR values for employee's tissues in Jenin municipality
SBP	Systolic blood pressure
SPL	Sound pressure level
SPO_2 %	Blood oxygen saturation
T	Tympanic temperature
VLF	Very low frequency
W/kg	Watt per kilogram
W/m^2	Watt per meter square
WHO	World health organization

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Abstract

This study focuses on the effect of electromagnetic radiation (EMR) emitted by cell phone towers on human tympanic temperature (T), blood oxygen saturation (SPO_2%), heart pulse rate (HPR), systolic blood pressure (SBP) and diastolic blood pressure (DBP).

The sample is 136 employees of both genders (56 female, 80 male), with mean age 40 Yrs., and the mean duration of employment 14 Yrs., were randomly chosen as a sample to reach the desired objective. This sample was taken from Nablus and Jenin municipalities, which are 70 m and 50 m from cell phone towers, respectively.

The mean values of the measured power flux density were 52.58 $\mu W/m^2$ and 31.76 $\mu W/m^2$ in Nablus and Jenin municipalities, respectively. The electric field and the magnetic field values were calculated from the measured power flux density, which were less than the standard levels for exposure to EMR of cell phone towers. The measurements of tympanic temperature, blood oxygen saturation, heart pulse rate and arterial blood pressure (systolic and diastolic) of the selected employees were measured before and after exposure to signals of cell phone towers. This study shows

that the health effects of signals of cell phone towers depend on the power flux density.

The statistical results showed that Pearson correlation coefficient (R) between power flux density and the dependent variables are varying from 0.294 to 0.657, and the probabilities (P) are < 0.05 for all health factors.

Chapter One

Introduction

1.1 Background

During the last three decades, a rapid growth in various areas of technology has been noticed especially in wireless communications, which had a large role in facilitating human life. The most important aspect of this development is the evolution of cellular networks serving the cell phones. They offer communication services and roaming for all users, whether at home or abroad. The cellular network is divided into several cells; where each is used by a transceiver or more. In order to avoid interference and provide guaranteed bandwidth, every cell uses a set of frequencies different from the neighboring cells. Nowadays, cellular networks provide many services such as phone calls, internet, information transfer, and so on (Zdenek, 2009).

The demand of using cell phones increases daily with population growth. Competing manufacturers and operators to provide better services caused a widespread use of cell phones on a large scale. This in turn led to a deployment increase operators that needs to put more cell phone towers on the roofs of some buildings. The spread of cell phone towers increases people's worry about their impact on their health, and increases concern over the commitment of operators to international standards (ITU, 2010).

There are many researchers and international organizations showed large interest in the search for the potential health effects of exposure to radio and microwave radiation emitted by cell phones and their towers. The International Agency for Research on Cancer (IARC), the World Health Organization (WHO) (IARC, 2011), and Occupational Safety and Health Administration (OSHA) are Interested in this subject (OSHA, 2004). However, these organizations have classified the radiation emitted from cell phones as a potential cause of cancer for humans.

1.2 Electromagnetic Spectrum and its Sources

Radiation can simply be described as energy moving through space. Any thermal material with temperature above absolute zero (-273.15 ^{o}C) is a source of electromagnetic radiation (EMR) (Herbert, 1985).

EMR has several natural and artificial sources. The visible light, X-rays and gamma rays are natural sources. On the other hand, artificial sources, such as radios and televisions emit radio frequency (RF), microwave ovens, antennas, radar emit microwave (MW), (Podgorsak, 2005). Cell phones and communication towers are major sources of EMR nowadays. They emit microwave radiation that spreads outwards in the form of concentric spheres (Krewski *et al.*, 2007).

The electromagnetic spectrum starts from short wavelengths such as gamma ray and X-ray, and ends with very long wave length of extremely low frequency (ELF) (Joseph, 2001). Radio frequency (RF) wavelength extends from 1m to 10^{3} m, while microwave (MW) extends from 10^{-3} m to 1 m. The electromagnetic spectrum with all its regions is shown in Fig. 1.1.

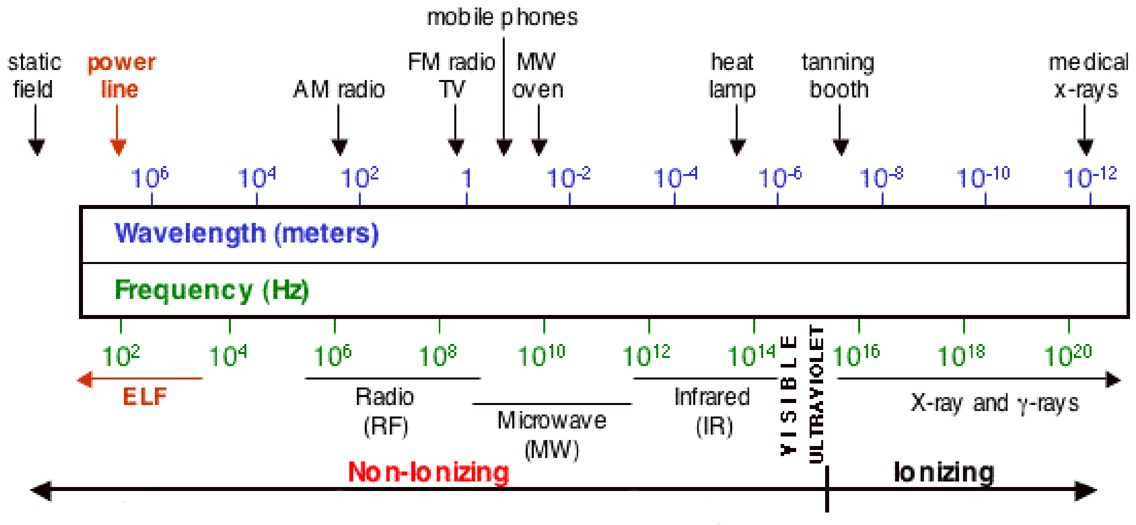

Fig. 1.1: The electromagnetic spectrum (Wenbin, 2012)

Cell phone towers should be bounded with standards in order to reduce the potential effects on human health. International commission for non-ionizing radiation protection (ICNIRP) sets standards for general public maximum exposure to time varying electric and magnetic field. Some of the standard levels of electric field strength (E), magnetic field strength (H) and magnetic flux density (B) are tabulated in Table 1.1.

Table 1.1 Standard levels of electric field strength (E), magnetic field strength (H) and magnetic flux density (B) for exposure between 1MHz and 300 GHz (ICNIRP, 2010)

Frequency range	E-field strength (V/m)	H-field strength (A/m)	B-field (Tesla)
1 - 10MHz	$87/f^{1/2}$	0.73/f	0.92/f
10 - 400MHz	28	0.073	0.092
400 - 2000 MHz	$1.375\ f^{1/2}$	$0.0037\ f^{1/2}$	$0.046 \times 10^{-4} f^{1/2}$
2 - 300GHz	61	0.16	0.20

(Where f is the frequency in MHz)

However, the maximum permissible exposure limits of power flux density for uncontrolled environments are shown in Table 1.2.

Table 1.2 The maximum permissible exposure limits of power flux density for uncontrolled environments (IEEE, 1999)

Frequency range (MHz)	Power flux density (W/m^2)
0.10 - 1.34	1000
1.34 – 30	$1800/f^2$
30 - 400	2
400 – 2000	f/200

(Where f is the frequency in MHz)

1.3 Biological Effects of Electromagnetic Radiation on Human

EMR can be classified in terms of its impact on the human tissue into ionizing radiation (IR) and non-ionizing radiation (NIR). However, the ionizing radiation carries enough energy to induce the formation of ions, which changes the chemical properties of human tissues. Gamma ray, X-ray, ultraviolet, and all particle radiation from radioactive decay processes are examples of ionizing radiation (Podgorsak, 2005). On the other hand, the non-ionizing radiation does not have sufficient energy to ionize atoms and molecules, so it does not cause any chemical change in the properties of the tissue. Visible light, infrared, near ultraviolet, microwave, radio waves, very low frequency (VLF) and extremely low frequency (ELF) are examples of non-ionizing radiation (Podgorsak, 2005).

The exposure to the electromagnetic radiations may cause changes on the variables of biological system, which are called biological effects. These effects can be physiological, biochemical or behavioral changes. The effects depend on the radiation frequency, radiation intensity and the distance from the radiation source. One major effect of radiation is the increase of temperature in a similar manner to heating food in a microwave oven. Because the human body contains three-quarters of water, its temperature might be affected in several manners (Patricia *et al.*, 1980).

Electromagnetic spectrum can be divided according to their biological effects into several categories:

- Chemical effects: in which the chemical bonds are broken due to radiation. For example, the deoxyribonucleic acid (DNA) is damaged by ultraviolet (UV) radiation and X-rays (Foster, 2000).
- Optical effects: the visible light is part of the electromagnetic spectrum that can be absorbed or emitted during the excitation processes. The visible light is essential to the process of the vision in humans and photosynthesis in plants (Carmichael, 2009).
- Thermal effects: the thermal effect of radio waves and microwave appears in raising the temperature of water molecules in the body. If the body cannot dispose high temperature, permanent damage might occur (Shani *et al.*, 1995).
- Non thermal effects: the temperature of cells and tissues of organisms does not rise if they are exposed to extremely low frequency. However, other symptons might occur. These non-thermal effects are the subjects of several studies to discuss the impact of the low frequency radiation on humans (Ahlbom *et al.*, 2004).

1.4 Previous Studies

Due to the spread concern among a lot of people from the effect of mobile radiation on human health, many researchers discussed the potential effects of exposure to radiation from cell phones and their towers. These studies carried out by researchers not only on human volunteers, but also on plant, animal, vitro studies and epidemiological studies. However, when using excessive doses of radiation animals and laboratory studies where done away from humans due to their effects (Michael, 2001).

The effects of EMR on the growth of the children, on their feelings, on their behaviors and leukemia were studied (Rezk *et al.*, 2008), (Guxens *et al.*, 2013) (Schüz *et al.*, 2007) and (Merzenich, 2008). Rezk showed in his study that is a significant increase in heart pulse rate (HPR) in infants and newborns, and a significant reduction in brain volume (Rezk *et al.*, 2008). The results of Guxens's study (Guxens *et al.*, 2013); showed an increase in behavioral problems for the children, their mothers were using mobiles during pregnancy. Two other studies have shown that there is no relationship between RF exposure from mobile phones and leukemia in children (Schüz *et al.*, 2007 and Merzenich, 2008).

Several studies have focused on the relationship between exposures of EMR with different types of cancer. One of these studies concerning the risk of brain tumor showed that there is no significant risk of glioma or meningioma from occupational RF exposure. The study built its results on data self-reported exposure. However, it found a significant increase in the risk for a period of 10 years of high exposure (Berg *et al.*, 2006). Other studies have shown a clear relationship between different kinds of cancer and mobile phone use. These Studies have shown an increase in the risk of glioma and acoustic neuromas with the use of mobile phones (Hardell, 2008). The risk increases with increasing the duration of use. Using the phone on one side of the head increases the risk of malignant brain tumors (Hardell *et al.*, 2009) and (Hardell *et al.*, 2010). Adilza found that the people who live within 500 m from the cell phone towers are at risk of neoplasia cancer (Adilza *et al.*, 2011).

The increase in the temperature of the human head when exposed to 900 MHz frequency was also studied (Ibrahim *et al.*, 2005). The results showed a clear increase in the temperature of the head influenced by the radiation of 250 (mW) and 900 MHz frequency of cell phone towers. The results showed that the increase in the temperature of internal tissue is less than 0.01 ^{0}C, while the increase of the temperature in skin is 1.6 ^{0}C (Ibrahim *et al.*, 2005). On the other hand, an Australian study showed there is no significant risk of exposure to power frequency (50-60 Hz). The study indicated the existence of large worries of the risk of the exposure to high frequencies (Karipidis *et al.*, 2007).

Other studies have focused on the effects of EMR on the nervous system and mental state. Nervous system studies have shown that the cell phone have an impact on the nervous system disorders such as Alzheimer's disease, migraine headaches and dizziness (Schüz *et al.*, 2009). Mobile phones effects on the physical and mental state have been studied (Santini *et al.*, 2002). Santini found in his study that the people who live within

300m of the phone towers are feeling tired, headaches and sleep disturbance. The same study showed that the people who live within 100 m of the phone towers feel irritability, depression, memory loss, dizziness, and loss of libido (Santini *et al.*, 2002).

A study indicated that there is some positive evidence of a non-thermal effect of exposure on calcium dynamics in stem cell derived neuronal cells. The one of the most important results is a significant increase in the percentage of calcium ions (Rao *et al.*, 2008).

Vitro studies suggested that mobile phone radiation might alter cell physiology e.g. by triggering cellular stress response, causing DNA damage, altering gene and protein expression (Hardell *et al.*, 2008). Another study showed that people who live near phone towers are at risk for developing neuropsychiatric problems and changes in the performance of neurobehavioral functions (Abdel-Rassoul *et al.*, 2007).

Many researchers discussed the risk of long-term exposure to radiation from the base stations on natural immunity, health status, reproduction, and fertility problems. It was found that the microwave and radio waves pollution constitutes a potential cause for the decline in animal populations and deterioration of health of plants living near cell phone towers (Balmori, 2009).

High radio frequency radiation (RFR) has significant effects on the activity of the pituitary-adrenal gland that appears in the reduction of adrenocorticotropic hormone (ACTH) and thus impaired cortisol levels. Exposures to RFR also cause low secretion of thyroid hormones. The study showed that all of prolactin in the blood in young females, and testosterone levels in males dropped significantly due to long-term exposure to RFR (Eskander *et al.*, 2012). Burch concluded that the use of cellular phones lead to reduced melatonin production, which has an effect in many biological processes (Burch *et al.*, 2002).

The effect of exposure to RFR on changes in sperm cells was studied (Erogul *et al.*, 2006). Erogul in his study observed that long-term exposure to radiation emitted from cell phone adversely affect sperm; it also leads to structural changes in the male biological cell. Wdowiak (Wdowiak *et al.*, 2007) had emphasized this effect when he studied the impact of global system for mobile (GSM) on male fertility. He found an increase in the ratio of abnormal sperm, and a decrease in sperm activity.

The effects of the signals emitted by cell phone on the circulatory system, show that there were significant changes on blood components and its viscosity which effects on a blood circulation due to many body problems. Red blood cells, white blood cells, and platelets are broken after exposure to electromagnetic radiation produced by cell phone. In addition, blood viscosity and plasma viscosity values were increased (El-Bediwi *et al.*, 2013). Another study on the effect of antennas was done on blood variables in rats. The results were an increase in white blood cells (WBC), mean corpuscular hemoglobin concentration (MCHC) and blood platelets count (PLT). In addition, it was a decrease in red blood cells (RBC), hemoglobin incidence (HB), hematocrit value and the mean corpuscular volume

(MCV). The electromagnetic field exposure causes a significant decrease in a growth rate (Abdul Aziz *et al.*, 2010).

Aruna showed that cell phone serving global system for mobile (GSM) has the largest effect on brain compared to cell phone serving code division multiple accesses (CDMA) (Aruna *et al.*, 2011).

Ala'a Aldine found that the sources of radiation pollution in the West Bank, includes FM radio, TV broadcasting and cell phone towers. FM radio contributes the largest part of the dose that the personnel are exposed to in the West Bank (Hammash, 2004). Al-Faqeeh studied the effect of the EMR from high voltage transformers on student's health in Hebron district. She found that the measured values of power flux density were within slight concern limit. In addition, there was increasing in tympanic temperature, heart pulse rate, arterial blood pressure, on the other hand the blood oxygen saturation was decreased (Al-Faqeeh, 2013).

1.5 Research Objectives

There are many questions that worry most of people's minds on the impact of electromagnetic radiation from different communication devices on their health and their bodies. There is a lack of information about the exposure effect of the signals of cell phone towers in Palestine

The goal of this research is studying the exposure effects of the signals of cell phones on the health variables of the employees in Nablus and Jenin municipalities. The study consists of the following:

- Measuring the power flux density of electromagnetic radiation emitted by cell phone towers.

- The values of the electromagnetic field emitted by the cell phone towers have to be calculated from the measured power flux density.
- Measuring tympanic temperature, blood pressure, heart pulse rate, and the percentage of blood oxygen saturation, of the employees of Nablus and Jenin municipalities.
- Comparing the results of this work with other studies and with the international standards.

Chapter Two

Theoretical Background

This chapter consists of five sections. The first section includes an overview of the electromagnetic field (EMF) and its measurements. The second section discusses the power density calculations emitted from the towers of mobile phones. The third section explains absorption of electromagnetic waves. Section four discusses the specific absorption rate (SAR) measurements and universally standard values. The fifth section explains some basic information about cellular network, cell phone towers, and cell phone types.

2.1 Electromagnetic Field

Electromagnetic field (EMF) is a physical output of electrically charged objects. EMF spreads around the source in all directions and extends to infinity. The electromagnetic force is one of the four forces of nature along with gravity, the weak interaction and the strong interaction (Michelini, 2008).

The electric field and the magnetic field are the components of the electromagnetic field. Where the static charged particles give the electric field, and if they are moving, they produce the magnetic field. The Lorentz force ($\vec{F}$), shows the effect of the electric field ($\vec{E}$) and the magnetic field ($\vec{B}$) on the particle of charge (q) moving with velocity $\vec{v}$, as given in following equation, (Jackson, 1998):

$$\vec{F} = q\ (\vec{E} + \vec{v}\ X\ \vec{B}\ )\ , \tag{2.1}$$

The magnetic field can be expressed in two ways, the magnetic flux densities ($\vec{B}$) and the magnetic field strength ($\vec{H}$). The two quantities are related by the expression (Jackson, 1998):

$$\vec{B} = \mu_0 \vec{H}, \qquad (2.2)$$

where, μ_0 is the magnetic permeability in vacuum, and is equal to $4\pi \times 10^{-7}$ Tesla.m/A. Similarly, the electric field can be expressed in terms of the electric flux densities ($\vec{D}$) and the electric field strength ($\vec{E}$). Both quantities $\vec{D}$ and $\vec{E}$ are related by the expression (Jackson, 1998):

$$\vec{D} = \varepsilon_0 \vec{E}, \qquad (2.3)$$

where ε_0 is the electric permittivity in vacuum, and is equal to 8.854×10^{-12} farad/m.

2.2 Power Flux Density

Power flux density of an electromagnetic wave is the power passing per unit area in units of watts per square meter (W/m^2). A vector multiplication between the electric field strength ($\vec{E}$) and the magnetic field strength ($\vec{H}$), gives the Poynting vector ($\overrightarrow{P_d}$) (Simon, 2007)**:**

$$\overrightarrow{P_d} = \vec{E} \times \vec{H} = \frac{1}{\mu_0} \vec{E} \times \vec{B} \qquad (2.4)$$

where the Poynting vector here is the power density in W/m^2. But, $E = c\,B$, c: the speed of light; then Eq. (2.4) becomes:

$$P_d = \frac{E^2}{c\mu_0}, \qquad (2.5)$$

hence $c\mu_0 = \eta$ so,

$$P_d = \frac{E^2}{\eta}, \quad (2.6)$$

where η is the intrinsic impedance taken to be 377Ω for free space. Eq. (2.6) shows the relationship between the electric field strength and the power density (Bexhet *et al.*, 2012).

The power density of cell phone tower is inversely proportional to the square of the distance from the tower as shown in the following formula (Joseph, 2001):

$$P_d = \left(\frac{P_t\, G_t}{4\pi r^2}\right) \text{Watt/m}^2 \quad (2.7)$$

where,

P_d (w/m^2) is the power density at distance r,

P_t (w) is the power radiated by the antenna,

G_t is the Gain of the antenna,

r (m) is distance from the antenna.

2.3 Absorption of Electromagnetic Waves

Absorption of electromagnetic radiation is the way in which the photon energy is taken by the material raising the internal energy of the material. The materials absorb one part of the electromagnetic radiation passing through it, and the other part is transmitted.

The intensity of electromagnetic radiation is the power transferred per unit area (W/m^2) (Christopher, 2004). Therefore, it is related to power by:

$$P = \int I\, dA \quad (2.8)$$

However, if the intensity I is uniform, then

$$I = \frac{P}{4\pi r^2} \quad (2.9)$$

When the electromagnetic radiation is transmitted through a thickness (x) of homogeneous material, it can be described by Lambert's Law (Christopher, 2004):

$$\mathrm{I} = \mathrm{I}_0 e^{-\alpha x} , \quad (2.10)$$

where,

I_0: is the intensity of the incident wave,

α: is linear absorption coefficient of the absorbing material.

2.4 Specific Absorption Rate

Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed by the body when exposed to radio frequency (RF) electromagnetic field. It is defined as the power absorbed per mass of the absorbing tissue and has units of watts per kilogram (W/kg) (Karunarathna *et al.*, 2006).

SAR value of each tissue is calculated by using the following formula, (Angelone *et al.*, 2004):

$$SAR = \frac{\sigma E^2}{2\rho} \quad (2.11)$$

Where,

σ: the tissue electrical conductivity ($\Omega^{-1}m^{-1}$) ,

ρ: the mass density of the tissue (kg/m^3),

E: the peak electric field strength (V/m).

SAR measures exposure to the electromagnetic frequencies, including radio frequency between 100 kHz and 10 MHz. It measures the power absorbed from cell phones and cell phone towers. The differences in the values of SAR between the organs of the body are caused by the differences in the geometry of the organs and their tissue composition. In addition, SAR values vary according to location, geometry of the sources, type of cellular network, and type of cell phone (Seddik *et al.*, 2011).

Radio frequency radiation causes heating of tissue, the change in temperature can be calculated by the equation (Bernardi *et al.*, 2003):

$$SAR = c_p \frac{\delta T}{\delta t} \tag{2.12}$$

Where

c_p: is the specific heat at constant pressure in J/ (kg·K).

δT: is the change in tissue temperature over a time δt.

In various countries, governments set safety limits for exposure to signals of cell phone towers. For example, the Federal Communications Commission (FCC) in United States of America (USA) set that 1.6 W/Kg is the maximum level of SAR permissible. While the European Union Council and the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in Europe set that the suggested SAR value is from 0.0 to 2.0 W/Kg, (ICNIRP, 1998).

2.5 Cellular Network

Wireless communication is based on the cellular network. The area around the tower providing coverage is known as a cell. The cellular network is based on following major things discussed in the following subsections:

* The type of cell phone technology (Sec. 2.5.1).

* The kind of the used cell phone towers (Sec. 2.5.2).

* The type, weight, and size of the available Cell phones (Sec. 2.5.3).

2.5.1 Types of Cell Phone Technology

There are several kinds of cell phone technology. These types are Global System for Mobile Communications (GSM) and Code Division Multiple Accesses (CDMA). However, about 73% of the global mobile communications market uses GSM, whereas about 14% uses CDMA. The remaining telecommunication markets are covered by other mobile phone technology (Amit *et al.*, 2010).

2.5.1.1 Global System for Mobile Communications (GSM)

GSM is the world's most popular standard for mobile telephone systems. It is a cellular network, which means that mobile phones connect to it by searching for cells in the immediate vicinity. GSM networks operate in a number of different carrier frequency ranges, such as 850 MHz and 1900 MHz, (Amit *et al.*, 2010).

In Palestine, Jawwal Company and Wataniya mobile use the 900 MHz band in GSM digital technology. The 900 MHz band is divided into two regions (Sempere, 1999):

- The uplink band (890 MHz to 915 MHz) which is used by the cell phones.
- The downlink band (935 MHz to 960 MHz) which is used by cell phone towers.

2.5.1.2 Code Division Multiple Accesses (CDMA)

In CDMA technology, each device is assigned a specific code, allowing multiple users to share access to the subscriber network. CDMA wireless technology offers a wide coverage, allows for a larger cell area and receives better coverage in areas with weak signal. Also it provides a better ability to voice and data communications. The CDMA network operates in the frequency spectrum of CDMA 800 MHz and 1900 MHz (Amit *et al.*, 2010).

2.5.2 Cell Phone Towers

Cell phone towers spread on the roofs of the buildings and hilltops. Companies that own these towers are using different types of towers. In general, the cell phone towers are composed of the following parts (Joseph, 2001):

1. The Tower: there are three types of towers,
    a. Lattice Tower: it provides maximum flexibility and is often used in the heavy load conditions. It has usually three or four sided, with similar shaped bases.
    b. Monopole Tower: is a single steel or concrete tube tower. It does not exceed a height of 50 m, the antenna placed on the outside of the tower.
    c. Guyed Tower: needs more space for its construction. It is the highest types of towers, placed on the mast fixed by wire with the land. Most radio and television stations use this type.
2. Base Transceiver Station (BTS): contains transceivers and supporting equipment installed in cabinets.

3. The Antennas: the technology, antenna performance, coverage and the required capacity are factors which determine the number of antennas on the tower. Usually three to fifteen antennas on each tower are installed.
4. The utilities: installed at the site of the tower for use by the carriers. Each initial carrier has power run to the site as well as phone service. The transmission requirement may be handled by fiber run to the site depending on the carrier.
5. Access: each site requires access carriers, both for the initial installation and continuous maintenance activities. These arrangements may require a separately path to the site of mobile tower (Joseph, 2001).

The transmitting power of a cell phone varies, depending on the type of network and its distance from the base station. The power generally increases when you move away from the base station. This increment occurs between 50 m and 300m. It irradiates the whole body and exposes the entire community (Kamil, 2013).

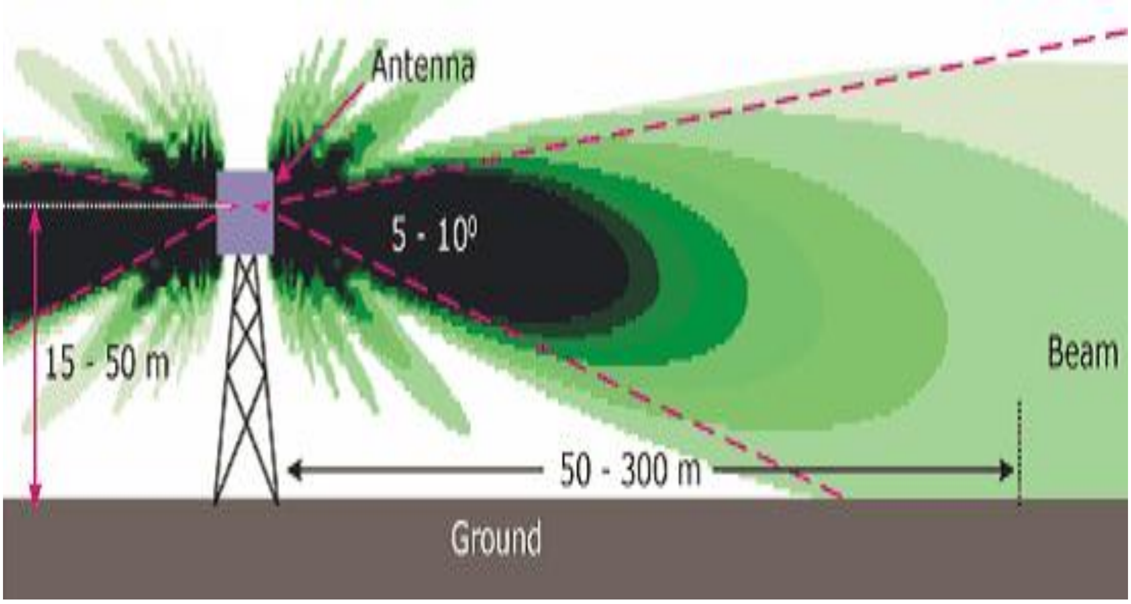

Fig.2.1: Shape of the beam produced by cell phone tower

Cell phone towers produce radiofrequency (RF) wave beams that are spread around cell phone towers. These beams are narrow in the level of elevation and are titled slightly downwards, so the top edge of the main beam is approximately horizontal and the lower edge is directed 50 to 100 below horizontal. The main beam is extending from 50m to 300m from tower, (Abdelati, 2005) as shown Fig. 2.1.

2.5.3 Cell Phone Types

Cell phones allow communicating from anywhere through mobile towers. The information is exchanged between Cell phones and towers by electromagnetic frequencies. The power density depends on the distance of the cell phone from the tower and the status of the transmitter. There are multiple of cell phones spreading in the market. These cell phones take different shapes and sizes. The most importantly, they differ in the SAR values. Manufacturers are usually pretty excited to see the SAR of their cell phones are less than the standard levels, Table 2.1 shows the maximum SAR values for some models of cell phones.

Table 2.1 The maximum SAR values for some models of cell phones, (CENT, 2013)

Manufacturer	Model	SAR (W/kg)
Apple	iPhone 5	1.25
LG	Chocolate Touch	1.47
Motorola	Droid X	1.43
Nokia	Lumia 928	1.40
Samsung	Galaxy S4	1.03
Siemens	ME45	0.98
Sony Ericsson	Xperia X10	1.43

Chapter Three

Methodology

This chapter consists of five sections. The first section includes choosing the population sample. The second section shows the study steps. Timetable of the study will be discussed in the third section. The fourth section contains some information about experimental apparatus. In the last section, statistical analysis will be discussed.

3.1 Population Sample

The population sample consists of 136 employees (80 males and 56 females) from two municipalities of Jenin and Nablus in the north of Palestine. The heart diseases and blood vessels diseases were the most important factors that led to the exclusion of some employees. The least duration of the work of the study sample was one year and the maximum duration was 40 years. The employees were asked to stay away from eating salty food, in order to reduce the impact of high salt concentration on the measurement variables.

Cochran's formula (Cochran, 1977), has been used to select the best sample:

$$n_0 = \frac{Z^2 p\, q}{e^2} \tag{3.1}$$

where

n_0 is the best value to select a random sample of employees in each municipality according to Cochran's formula.

Z= 1.96, which is the value for the selected alpha level,

p is the estimated proportion of an attribute that is present in the population.

(p) (q) are the estimate of variance, p = 0.9, and q = 1 - p, q = 0.1,

e is the acceptable margin of error for proportion being estimated to be 0.055. Substituting the values of Z, p, q and e in Eq. (3.1) then n_0 is 114.3.

The correction formula (Cochran, 1977), is:

$$m = \frac{n_0}{1+\frac{n_0}{N}} \quad (3.2)$$

where m is the correction sample size that should be used, N is the actual number of employees.

Using Eq. (3.2), the number of employees that should be the examined sample (m) is given in Table 3.1.

Table 3.1 The sex of employees, actual number, sample number, average ages and average durations of employment in Nablus and Jenin municipalities

Municipality	Sex	Actual number	sample number	Average age (year)	Average duration of employment (year)
Nablus	Female	78	46	38.9	13.5
Nablus	Male	75	45	42.6	15.3
Jenin	Female	11	10	36.4	9.2
Jenin	Male	50	35	44.8	14.5

3.2 Study Steps

During this study, the following steps were done:

1. Selecting Nablus and Jenin municipalities in the north of Palestine. Nablus municipality is located at 70 m south of monopole towers, while Jenin municipality is located at 50 m west of monopole

towers. The number of employees in these municipalities is suitable for this study

2. Neglecting employees of health problems.
3. Collecting the necessary information of the study concerning age, and employment duration.
4. Measuring the power density of towers.
5. Measuring the following health parameters of the employees in the selected municipalities:
   a. blood oxygen saturation
   b. blood pressure
   c. heart pulse rate
   d. tympanic temperature.

3.3 Timetable

The measurements of the blood pressure, heart pulse rate, tympanic temperature and the percentage of blood oxygen saturation were done before and after exposure to the signals of phone towers. They were measured during (8:15 – 8:45) a.m. before (b) exposure to the signals of phone towers. The measurements were repeated during (13:15– 13:45) p.m after (a) exposure to the signals of phone towers. During each time interval the mentioned health parameters were measured three times, and the average value was registered.

The study was carried out in February; 2013. The measurements on the employees of Jenin municipality were done in two days, whereas four days were required to complete measurements on the employees of Nablus municipality.

3.4 Experimental Apparatus

3.4.1 Spectran of Radio Frequency (RF) 6080

The Spectran of radio frequency (RF) 6080, Fig. (3.1) was used to measure the frequency, and the power density of EMR. The frequency range is from 10MHz to 8GHz and the power density range is from -90dBm to +30dBm, and of accuracy ±2dB. The maximum power at RF input is +10dBm. The resolution is from 1 kHz to 50MHz (Instruction Manual for Spectran of radio frequency (RF) 6080, 2010).

Fig. 3.1: Spectran of radio frequency (RF) 6080

3.4.2 Lux Hitester

The Lux Hitester model 3423 is a digital device, used to measure the intensity of light brightness Fig. (3.2). It is used widely to measure the levels of lighting in various areas such as hospitals, science rooms, laboratories, hallways, and the media production areas. The measurement range is from 19.99 to199999 lx full-scale. It has 5 ranges and accuracy ±4 % (Instruction Manual for the Lux Hitester 3423, 2012).

Fig. 3.2: Lux Hitester 3423

3.4.3 Automatic Blood Pressure Monitor

Automatic Blood Pressure Monitor model BP 2BHO, Fig. (3.3). It is used for measuring arterial blood pressure (systolic, diastolic) and pulse rate. The measuring range is from 30 to 280 mmHg, with accuracy ± 2% mm-Hg, and ± 2% for reading heart pulse rate. The operating temperature ranges from +10 °C to +40 °C. (Instruction for the Automatic Blood pressure Monitor, 2011).

Fig. 3.3: Automatic Blood Pressure Monitor micro life AG, BP 2BHO

3.4.4 Pulse Oximeter

The China technology Pulse Oximeter model CMS50DL is used to measure the blood oxygen saturation, Fig. (3.4). The accuracy of its measurement is ± 1% (Instruction Manual of Pulse Oximeter CMS50DL, 2011).

Fig. 3.4: Pulse Oximeter CMS50DL

3.4.5 Tempscan Ear Thermometer

The U.S.A technology thermometer model GT-302, Fig.(3.5) is used to measure human body temperature through the tympanic temperature of the ear. The display temperature range is 32.0°C to 42.9 °C. The accuracy of its measurement is ± 0.01°C (Instruction manual GT- 302 of TempScan, 2003).

Fig. 3.5: The GT-302 Thermometer

3.4.6 Sound Level Meter

The U.S.A technology sound level meter model 2900 is a device for measuring the noise level in decibels (dB), Fig. (3.6). The accuracy of its measurement is ± 0.5 dB at 25 °C. This device gives the reading with a precision of 0.1dB. The measurement range is from 0 to 140 dB, (Instruction manual of Sound Level Meter, 1998).

Fig. 3.6: Sound level meter model 2900

3.5 The Permissible Exposure Limits

According to standard levels in Table 1.1 and the permissible exposure limits in Table 1.2, and taking into consideration the cell phone towers operating at 935 MHz, which are used by the cell phone companies in Palestine. The electric field strength, magnetic field strength, magnetic flux density and power flux density can be calculated according to the formulas in the Table 1.1 and Table 1.2 to be given in Table 3.2.

Table 3.2 The permissible exposure limits of electric field strength, magnetic field strength, magnetic flux density and power flux density for the cell phone towers operating at 935 MHz (ICNIRP, 2010; IEEE, 1999).

E-field strength (V/m)	H-field strength (A/m)	B-field (Tesla)	Power flux density (W/m^2)
42.04	0.11	1.4×10^{-4}	4.68

3.6 Statistical Analysis

Microsoft Excel and SPSS programs were used to analyze data. The measurements were analyzed statistically as the following:

1. Pearson correlation coefficient (R) and the Probability (P) were used to measure the strength correlation between power flux density and the dependent variables, before and after exposure signals from cell phone towers.
2. The (R) values ranged from zero to one as follows (Brown *et al.*, 1998):
   a. $0.00 \leq R \leq 0.39$, weak correlation
   b. $0.40 \leq R \leq 0.59$, moderate correlation
   c. $0.60 \leq R \leq 0.79$, strong correlation
   d. $0.80 \leq R \leq 1.0$, very strong correlation.
3. The P-values ranged from zero to one as follows (William *et al.*, 2007):
   a. $0.000 \leq P \leq 0.050$, strong significant relationship.
   b. $0.050 \leq P \leq 1.000$, no significance.

Chapter Four

Measurements and Results

Several measurements were conducted to achieve the objectives of this research. This chapter shows these measurements carried out on a sample of the municipalities of Nablus and Jenin cities. The following physical quantities were measured in both municipalities:

1. Power density (P_d)
2. Sound pressure level (SPL)
3. Light intensity level (LI)
4. Diastolic blood pressure (DBP)
5. Systolic blood pressure (SBP)
6. Heart pulse rate (HPR)
7. Blood oxygen saturation (SPO_2%)
8. Tympanic temperature (T).

4.1 Measurements of the Light Intensity and Sound Pressure Level

The light intensity and sound pressure level were measured more than ten times in different places in both municipalities at (8:15 a.m. - 13:45 p.m.) in each municipality. The average for each of the previous variables has been taken. The light intensity was measured by the Lux Hitester and the sound pressure level was measured by Sound Pressure Level Meter.

The result of measurement of the light intensity and sound pressure level are given in the Table 4.1.

Table 4.1 The mean values of intensity of light and sound pressure level for two municipalities before and after the employees start and finish their work

Municipality	Nablus	Jenin
SPL(dB) before	63.4	57.7
SPL(dB) after	55.8	61.7
LI(Lx) before	465	483
LI(Lx) after	490	501

The intensity of light (LI) and sound pressure level (SPL) were measured in Nablus and Jenin municipalities before and after the employees start and finish their work in order to minimize their effects on the results of this study. Some studies showed that there are health effects from light intensity (> 500) Lux. In the other hand, some studies found that the noise pollution over 60 dB has effects on health parameter (Qamhieh *et al*., 2000; Abdel-Raziq *et al*., 2003; Abdel-Ali *et al.*, 2003; Sadeq *et al.*, 2012; Ibrahim *et al*., 2013; Al-Sheikh *et al*., 2013).

4.2 Measurements of Power Flux Density

Spectran RF 6080 was used to measure the power flux density. In Nablus municipality the mean value was 52.58 $\mu W/m^2$; however in Jenin municipality the mean value was 31.76 $\mu W/m^2$. The measured values of power flux density were used to calculate the electric fields, magnetic fields and magnetic flux density by using equations (2.2), (2.4) and (2.6). The calculated values of the electric fields, magnetic fields and magnetic flux density are shown in the Table 4.2. These values will be used to calculate the specific absorption rate (SAR) in the next section, and compared it with international standards.

Table 4.2 The mean values of power flux density, electric fields, magnetic fields and magnetic flux density for municipality

Measured and calculated values	Nablus municipality	Jenin municipality
Tower location (m)	70	50
P (μW/m²) measured	52.58	31.76
E (mV/m) calculated	140.79	109.42
H (mA/m) calculated	0.37	0.29
B (nT) calculated	0.47	0.37

4.3 Calculations of SAR

Specific absorption rate (SAR) is important to know the rate of energy absorbed by the human body or any tissue. The calculated electric fields in Table 4.2 were used to calculate SAR values for some tissues of the employee's body. The calculation was done by using equation (2.11) which is

$$SAR = \frac{\sigma E^2}{2\rho}$$

According to mass density (ρ) and the tissue electrical conductivity (σ), (Gabriel, 1996), the results of SAR values are shown in Table 4.3.

Table 4.3 SAR values for some organs of chosen employees in both Nablus municipality and in Jenin municipality

Tissue	σ ($\Omega^{-1}m^{-1}$)	ρ (kg/m³)	SAR_N (μW/kg)	SAR_J (μW/kg)
Skin	0.872	1100	7. 86	4.75
Dura	0.966	1100	8.70	5.26
Brain	0.77	1030	7.41	4.48
Muscle	0.948	1040	9.03	5.46
Cartilage	0.789	1100	7.12	4.30
Lens	0.798	1100	7.20	4.34
Eye sclera	1.173	1100	10.57	6.38
Cerebellum	1.269	1030	12.21	7.38

4.4 Measurements of Health Effects of EMR

The sample was consisted of 136 employees, 56 females and 80 males. The employees were ages between 19 to 60 years and durations of their employment were ranged between 1- 40 years. The employees were classified into eight groups in each municipality according to age and sex, as shown in Table 4.4.

Table 4.4 The employees groups, average age, average duration, sex, and numbers in Nablus and Jenin municipalities

		Sex	Average age (year)	Average duration (year)	Numbers
Nablus Municipality	< 40	Female	34.48	12.44	25
		Male	33.22	9.89	18
	> 40	Female	44.10	14.67	21
		Male	48.89	18.89	27
Jenin Municipality	< 40	Female	30.67	7.83	6
		Male	33.79	11.26	19
	> 40	Female	45.00	11.30	4
		Male	44.75	14.50	16

Diastolic blood pressure (DBP), systolic blood pressure (SBP), heart pulse rate (HPR), blood oxygen saturation (SPO_2%) and tympanic temperature were measured three times between 8:15 – 8:45 a.m. before (b) exposure to the signals of cell phone towers , and the measurement was repeated between 13:15 – 13:45 p.m. after (a) exposure to the signals of cell phone towers. The results of these measurements will be presenting in this section.

The normal, minimum (Min.), maximum (Max.), mean, and standard deviation (S.D.) values of the blood oxygen saturation (SPO_2%), heart pulse rate (HPR), systolic pressure (SBP), diastolic pressure (DBP), and tympanic temperature before (b) and after (a) exposure to the signals of cell phone towers are presented in (Tables 4.5 and 4.12).

Tables 4.5 The normal values, Min., Max., mean and S.D. values of studied variables for female employees in Nablus municipality with age < 40 years

Nablus Municipality – Female		Average power density 52.58 µW/m^2				
Variables		Normal	Min.	Max.	Mean	S.D.
T (^{o}C)	(b)	35.4-37.8[1]	34.10	36.20	35.46	0.49
T (^{o}C)	(a)		35.30	36.70	36.00	0.46
SPO_2%	(b)	95-100[2]	98.00	99.00	98.84	0.37
SPO_2%	(a)		94.00	99.00	97.48	0.96
HPR beats /min	(b)	60 -100[3]	69.00	103.00	79.00	7.66
HPR beats /min	(a)		76.00	108.00	85.44	8.00
DBP mmHg	(b)	60 - 90[4]	63.00	91.00	75.16	7.29
DBP mmHg	(a)		68.00	92.00	79.20	6.19
SBP mmHg	(b)	100 -139[4]	106.00	129.00	115.80	5.85
SBP mmHg	(a)		112.00	140.00	125.76	7.20

Tables 4.6 The normal values, Min., Max., mean and S.D. values of studied variables for female employees in Nablus municipality with age > 40 years

Nablus Municipality – Female		Average power density 52.58 µW/m^2				
Variables		Normal	Min.	Max.	Mean	S.D.
T (^{o}C)	(b)	35.4-37.8[1]	33.70	36.10	35.29	0.63
T (^{o}C)	(a)		35.10	36.50	35.97	0.45
SPO_2%	(b)	95-100[2]	98.00	99.00	98.62	0.50
SPO_2%	(a)		95.00	99.00	96.91	1.00
HPR beats /min	(b)	60 -100[3]	67.00	96.00	80.52	7.98
HPR beats /min	(a)		74.00	98.00	84.81	7.68
DBP mmHg	(b)	60 - 90[4]	64.00	93.00	76.10	8.60
DBP mmHg	(a)		65.00	96.00	80.52	8.50
SBP mmHg	(b)	100 -139[4]	105.00	146.00	123.67	12.63
SBP mmHg	(a)		114.00	157.00	133.19	13.01

Tables 4.7 The normal values, Min., Max., mean and S.D. values of studied variables for male employees in Nablus municipality with age < 40 years

Nablus Municipality – male Average power density 52.58 µW/m^2					
Variables	Normal	Min.	Max.	Mean	S.D.
T(°C) (b)	35.4-37.8(1)	33.30	35.50	34.38	0.54
T(°C) (a)		34.00	36.10	35.02	0.58
SPO_2% (b)	95-100(2)	97.00	99.00	98.72	0.57
SPO_2% (a)		95.00	99.00	97.39	1.29
HPR beats /min (b)	60 -100(3)	65.00	89.00	75.67	6.28
HPR beats /min (a)		68.00	104.00	81.61	9.21
DBP mmHg (b)	60 - 90(4)	60.00	93.00	69.11	8.30
DBP mmHg (a)		66.00	95.00	75.83	8.56
SBP mmHg (b)	100 -139(4)	103.00	133.00	115.78	8.07
SBP mmHg (a)		107.00	143.00	124.28	11.08

Tables 4.8 The normal values, Min., Max., mean and S.D. values of studied variables for male employees in Nablus municipality with age > 40 years

Nablus Municipality – male Average power density 52.58 µW/m^2					
Variables	Normal	Min.	Max.	Mean	S.D.
T (°C) (b)	35.4-37.8(1)	33.30	35.30	34.41	0.56
T (°C) (a)		33.80	35.80	34.98	0.52
SPO_2% (b)	95-100(2)	97.00	99.00	98.22	0.64
SPO_2% (a)		93.00	98.00	96.67	1.30
HPR beats /min (b)	60 -100(3)	67.00	92.00	79.93	7.35
HPR beats /min (a)		65.00	96.00	85.19	7.37
DBP mmHg (b)	60 - 90(4)	56.00	97.00	76.26	8.54
DBP mmHg (a)		62.00	101.00	81.59	8.64
SBP mmHg (b)	100 -139(4)	100.00	154.00	127.15	12.91
SBP mmHg (a)		108.00	171.00	137.22	14.12

(1- Sund-Levander *et al.*, 2002; 2- Grap M., 1998; 3- Fuster *et al.*, 2001; 4- Chobanian *et al.*, 2003).

Tables 4.9 The normal values, Min., Max., mean and S.D. values of studied variables for female employees in Jenin municipality with age < 40 years

Jenin Municipality – Female	Average power density 31.76 µW/m^2				
Variables	Normal	Min.	Max.	Mean	S.D.
T(°C) (b)	35.4-37.8(1)	34.40	36.20	35.25	0.58
T(°C) (a)		35.40	36.50	35.78	0.39
SPO_2% (b)	95-100(2)	99.00	99.00	99.00	0.00
SPO_2% (a)		97.00	99.00	98.17	0.75
HPR beats /min (b)	60 -100(3)	68.00	98.00	80.67	11.31
HPR beats /min (a)		68.00	88.00	80.33	7.42
DBP mmHg (b)	60 - 90(4)	56.00	80.00	69.33	9.07
DBP mmHg (a)		62.00	86.00	71.67	8.91
SBP mmHg (b)	100 -139(4)	105.00	134.00	115.17	11.16
SBP mmHg (a)		108.00	135.00	122.17	10.46

Tables 4.10 The normal values, Min., Max., mean and S.D. values of studied variables for female employees in Jenin municipality with age > 40 years

Jenin Municipality – Female	Average power density 31.76 µW/m^2				
Variables	Normal	Min.	Max.	Mean	S.D.
T(°C) (b)	35.4-37.8(1)	35.30	35.80	35.60	0.22
T(°C) (a)		35.50	36.20	35.83	0.30
SPO_2% (b)	95-100(2)	98.00	99.00	98.25	0.50
SPO_2% (a)		96.00	97.00	96.75	0.50
HPR beats /min (b)	60 -100(3)	65.00	86.00	76.00	8.83
HPR beats /min (a)		75.00	93.00	86.25	7.89
DBP mmHg (b)	60 - 90(4)	65.00	85.00	73.75	8.54
DBP mmHg (a)		73.00	86.00	79.25	6.70
SBP mmHg (b)	100 -139(4)	117.00	136.00	123.75	8.42
SBP mmHg (a)		122.00	140.00	132.75	7.63

Tables 4.11 The normal values, Min., Max., mean and S.D. values of studied variables for male employees in Jenin municipality with age < 40 years

Jenin Municipality – male	Average power density 31.76 µW/m^2					
Variables		Normal	Min.	Max.	Mean	S.D.
T(°C)	(b)	35.4-37.8(1)	33.50	35.60	34.10	0.52
T(°C)	(a)		33.50	36.20	34.55	0.71
SPO_2%	(b)	95-100(2)	97.00	99.00	98.42	0.69
SPO_2%	(a)		95.00	98.00	97.05	0.91
HPR beats /min	(b)	60 -100(3)	68.00	87.00	79.16	5.60
HPR beats /min	(a)		65.00	90.00	82.58	6.51
DBP mmHg	(b)	60 - 90(4)	61.00	83.00	72.90	6.34
DBP mmHg	(a)		57.00	92.00	78.31	10.14
SBP mmHg	(b)	100 -139(4)	99.00	137.00	119.79	12.45
SBP mmHg	(a)		103.00	147.00	128.84	11.63

Tables 4.12 The normal values, Min., Max., mean and S.D. values of studied variables for male employees in Jenin municipality with age > 40 years

Jenin Municipality – male	Average power density 31.76 µW/m^2					
Variables		Normal	Min.	Max.	Mean	S.D.
T(°C)	(b)	35.4-37.8(1)	33.20	35.80	34.40	0.64
T(°C)	(a)		33.90	35.40	34.76	0.48
SPO_2%	(b)	95-100(2)	97.00	99.00	98.38	0.62
SPO_2%	(a)		96.00	99.00	97.25	1.00
HPR beats /min	(b)	60 -100(3)	57.00	92.00	77.13	9.65
HPR beats /min	(a)		62.00	94.00	82.38	9.07
DBP mmHg	(b)	60 - 90(4)	63.00	87.00	74.88	6.23
DBP mmHg	(a)		63.00	95.00	79.88	8.37
SBP mmHg	(b)	100 -139(4)	109.00	153.00	125.94	11.51
SBP mmHg	(a)		117.00	147.00	134.00	8.79

(1- Sund-Levander *et al*., 2002; 2- Grap M., 1998; 3- Fuster *et al.*, 2001; 4- Chobanian *et al.*, 2003).

The final outcome of the net change of tympanic temperature, blood oxygen saturation, heart pulse rate, systolic blood pressure and diastolic blood pressure, after exposure to the signals of cell phone towers for all employees, male, and female, in two municipalities are calculated and shown in Tables 4. 13 and 4.14.

Table4.13 The net change of tympanic temperature, blood oxygen saturation, heart pulse rate, diastolic blood pressure and systolic blood pressure after exposure to signals of cell phone towers for employees with age < 40 years in Nablus and Jenin municipalities

Health parameter	Nablus municipality		Jenin municipality	
	Female	Male	Female	Male
ΔT (^{0}C)	0.54	0.64	0.53	0.45
ΔSPO_2%	1.36	1.33	0.83	1.37
ΔHPR beats/min	6.44	5.94	0.34	3.42
ΔDBP mmHg	4.04	6.72	2.34	5.41
ΔSBP mmHg	9.96	8.5	7.00	9.05

Table4.14 The net change of tympanic temperature, blood oxygen saturation, heart pulse rate, diastolic blood pressure and systolic blood pressure after exposure to signals of cell phone towers for employees with age > 40 years in Nablus and Jenin municipalities

Health parameter	Nablus municipality		Jenin municipality	
	Female	Male	Female	Male
ΔT (^{0}C)	0.68	0.57	0.23	0.36
ΔSPO_2%	1.71	1.55	1.50	1.13
ΔHPR beats/min	4. 29	5.26	10.25	5. 25
ΔDBP mmHg	4.42	5.33	5.50	5.00
ΔSBP mmHg	9.52	10.07	9.00	8.06

4.4.1 Tympanic Temperature Results

Ear Thermometers is a device was used to measure the tympanic temperature of employees. The effect of the signals of cell phone towers on the tympanic temperature of employees in Nablus and Jenin municipalities are shown in Fig. (4.1).

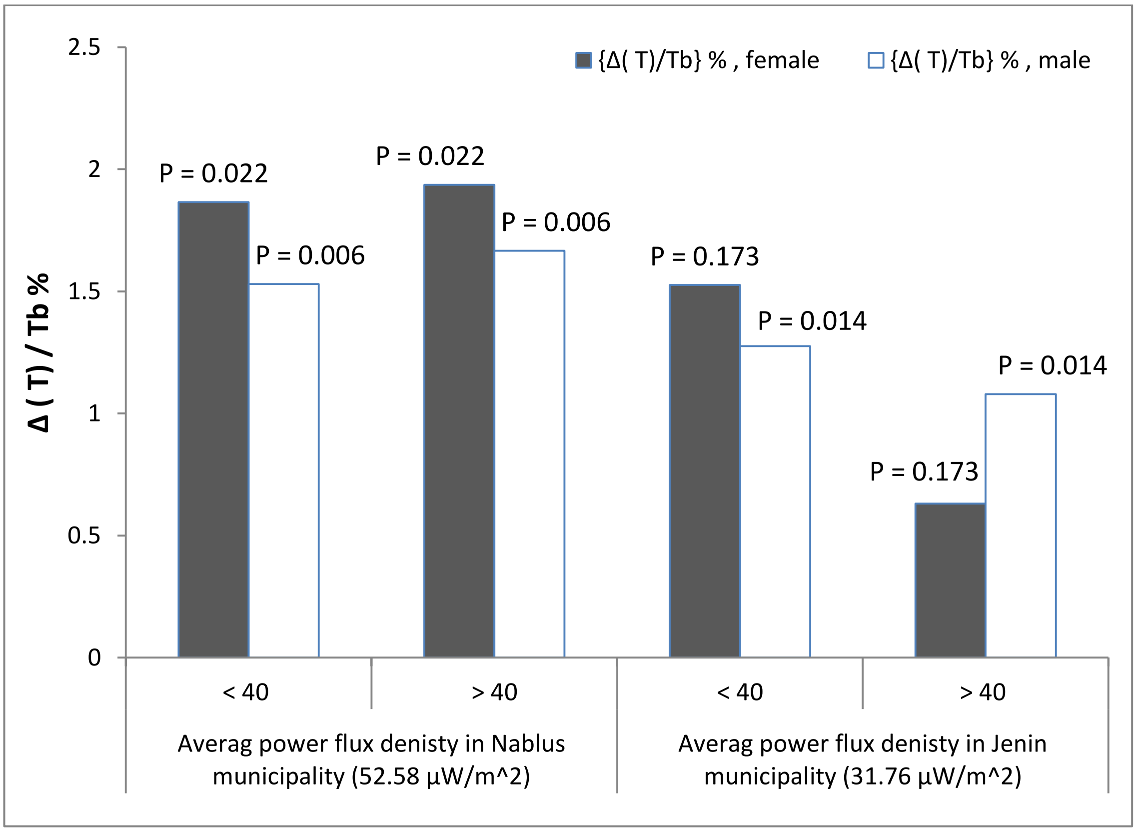

Fig. 4.1 The percentage changes of tympanic temperature of female and male employees in Nablus and Jenin municipalities after (a) exposure to the signals of cell phone towers

Fig. 4.1 shows that there is significant shift of employee's percentage changes of tympanic temperature after exposure to the signals of cell phone towers.

4.4.2 Blood Oxygen Saturation Results

Blood oxygen saturation was measured for each employee in both municipalities by using Pulse Oximeter LM-800. The effect of the signals of cell phone towers on the blood oxygen saturation of employees in Nablus and Jenin municipalities are shown in Fig. (4.2).

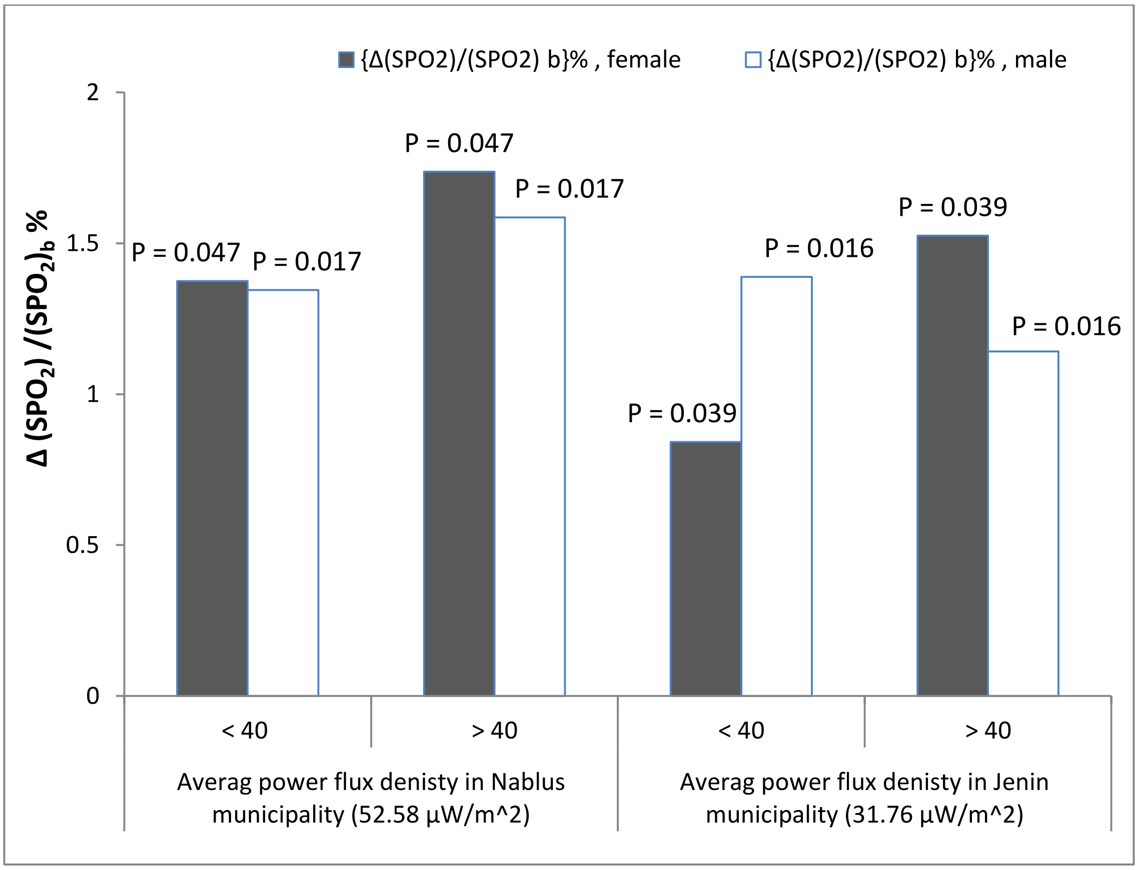

Fig. 4.2: The percentage changes of blood oxygen saturation of female and male employees in Nablus and Jenin municipalities after (a) exposure to the signals of cell phone towers

Fig. (4.2) shows that the percentage changes of blood oxygen saturation of selected employees are decreased in Nablus and Jenin municipalities after exposure to the signals of cell phone towers.

4.4.3 Heart Pulse Rate Results

The measurements of heart pulse rate were taken by using Automatic Blood Pressure Monitor.The effect of the signals of cell phone towers on the heart pulse rate of employees in Nablus and Jenin municipalities are shown in Fig. (4.3).

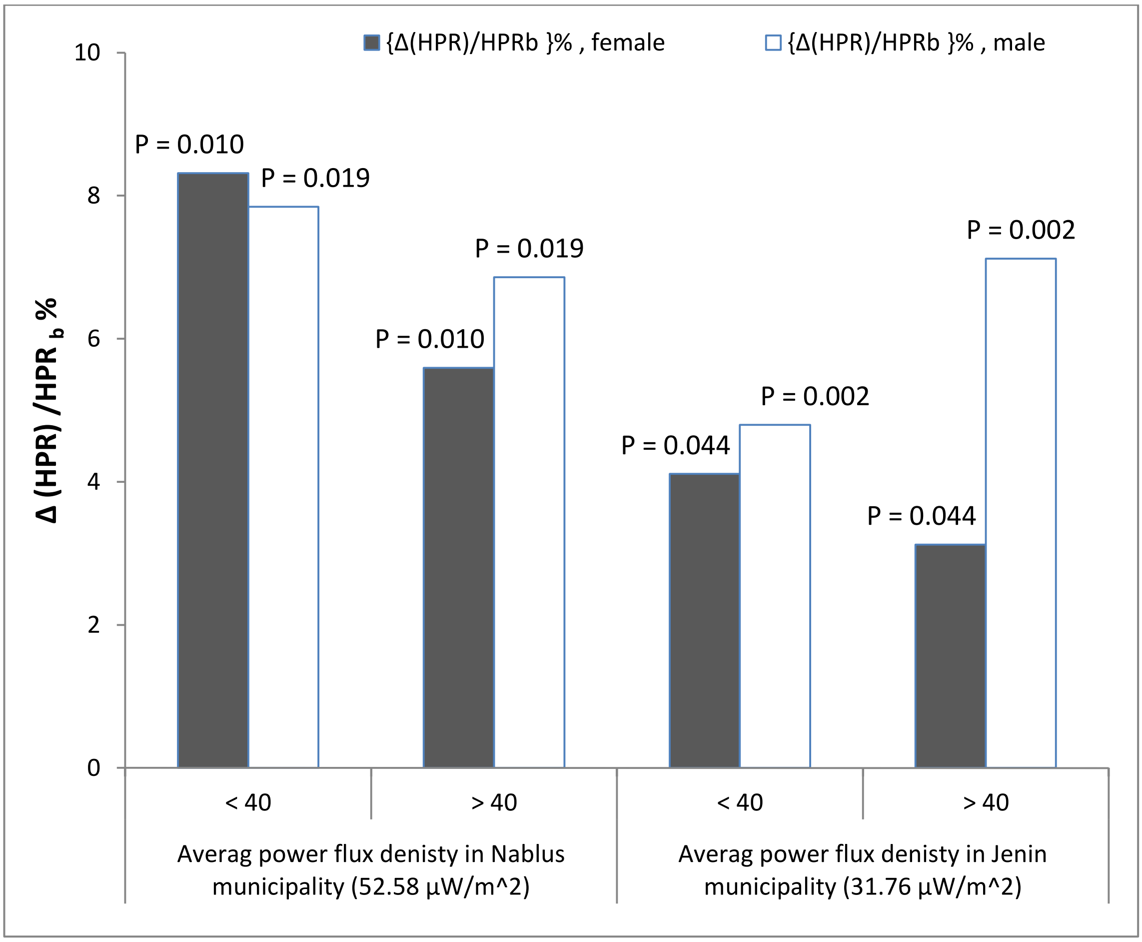

Fig. 4.3: The percentage changes of heart pulse rate of female and male employees in Nablus and Jenin municipalities after (a) exposure the signals of cell phone towers

Fig. (4.3) indicates that the percentage changes of heart pulse rate of all employees in Nablus and Jenin municipalities are increased after (a) exposure to the signals of cell phone towers.

4.4.4 Systolic Blood Pressure Results

Systolic blood pressure was measured for each employee in both municipalities by using Automatic Blood Pressure Monitor. The effect of the signals of cell phone towers on the systolic blood pressure of employees in Nablus and Jenin municipalities are shown in Fig. (4.4).

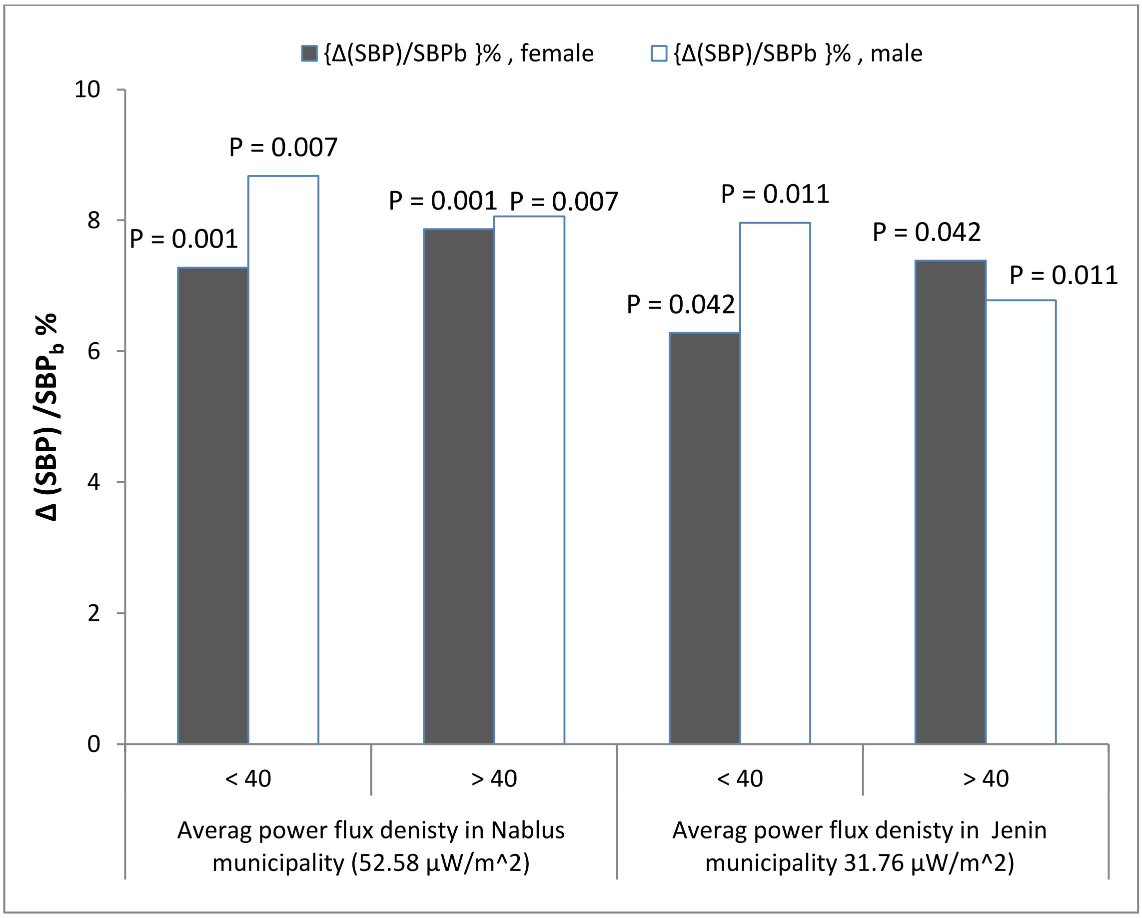

Fig. 4.4: The percentage changes of systolic blood pressure of female and male employees in Nablus and Jenin municipalities after (a) exposure to the signals of cell phone towers

The systolic blood pressure of the employees are increased in Nablus and Jenin municipalities after exposure to the signals of cell phone towers as shown in Fig. (4.4).

4.4.5 Diastolic Blood Pressure Results

Diastolic blood pressure was measured for each employee in both municipalities by using Automatic Blood Pressure Monitor. The effect of the signals of cell phone towers on the diastolic blood pressure of employees in Nablus and Jenin municipalities are shown in Fig. (4.5).

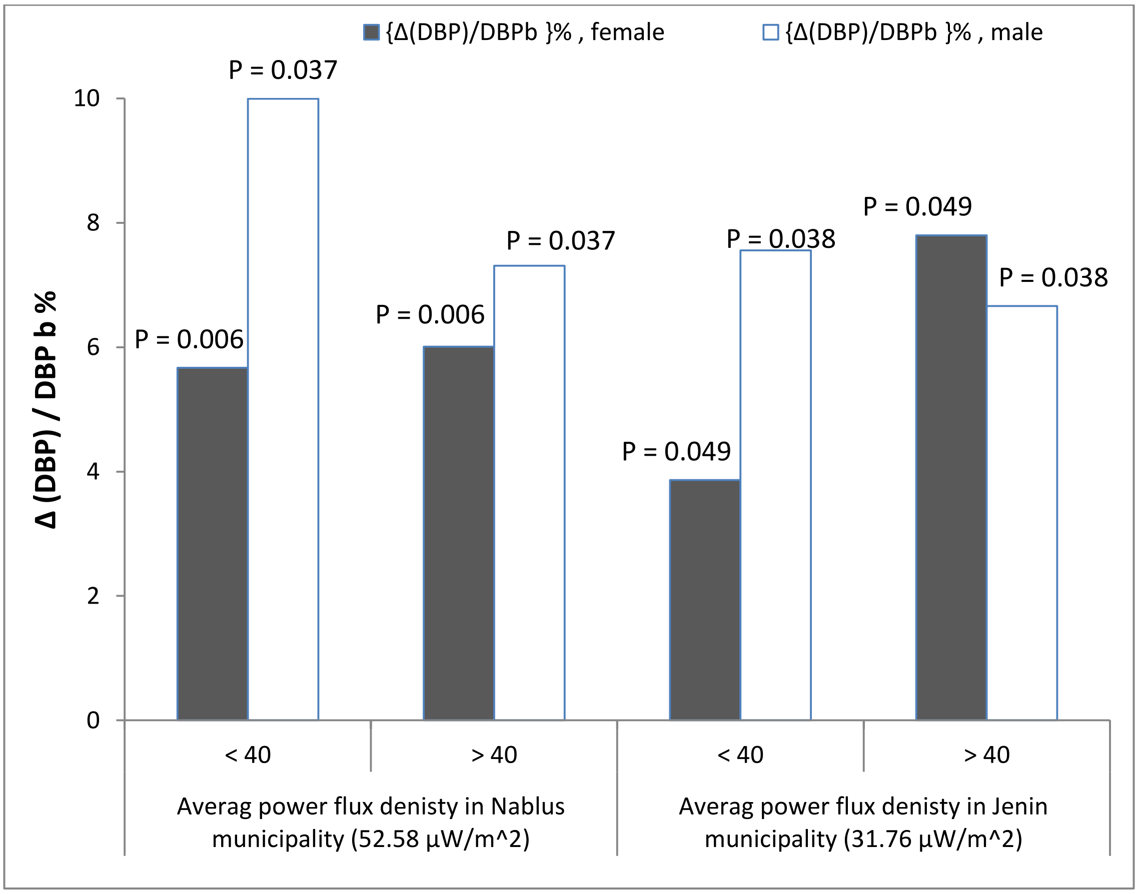

Fig. 4.5: The percentage changes of diastolic blood pressure of female and male employees in Nablus and Jenin municipalities after (a) exposure to the signals of cell phone towers

Fig. (4.5) shows that the diastolic blood pressure of the employees increased in Nablus and Jenin municipalities after exposure to the signals of cell phone towers.

4.5 Age Effect

The dependence of the rate changes of tympanic temperature, blood oxygen saturation, heart pulse rate, blood pressure (systolic and diastolic) on the age of the employees in the studied municipalities before (b) and after (a) exposure to the signals of cell phone towers are represented in Figs. (4.6 - 4.10).

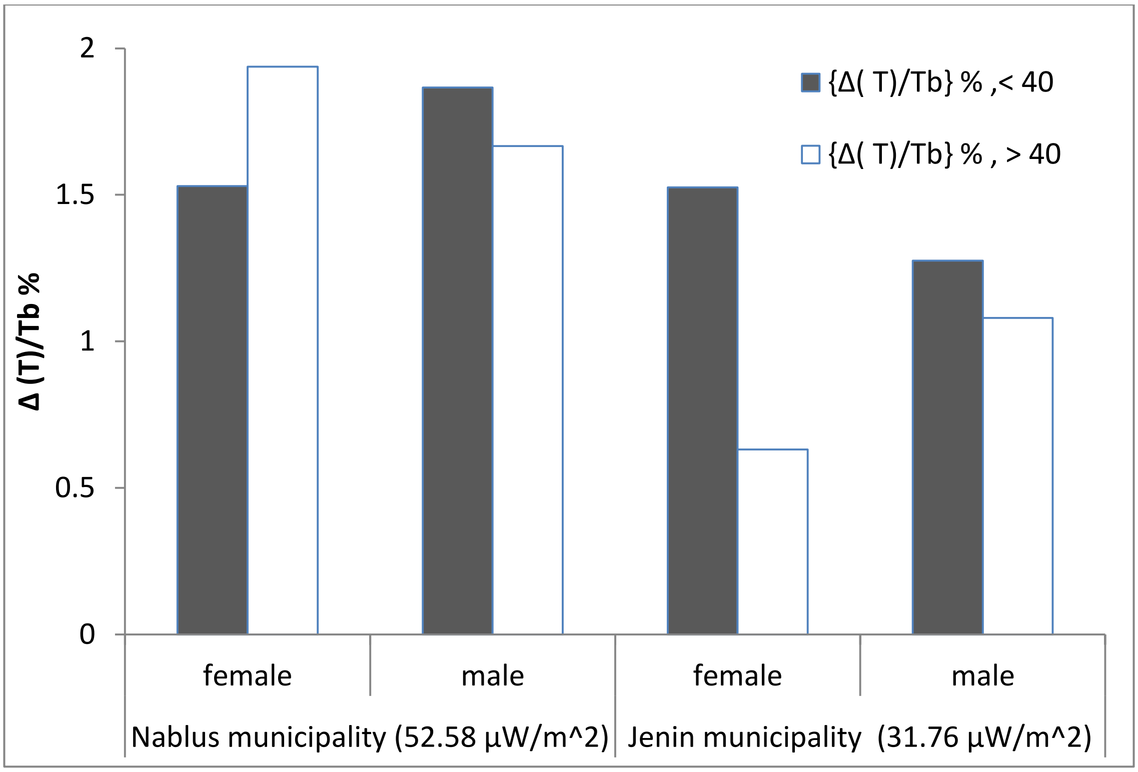

Fig. 4.6: The percentage changes of tympanic temperature as a function of age employees in Nablus and Jenin municipalities after (a) exposure to the signals of cell phone towers

Fig. 4.6 shows a clear change in the percentage changes of tympanic temperature with the age employees in two municipalities after (a) exposure to the signals of cell phone towers.

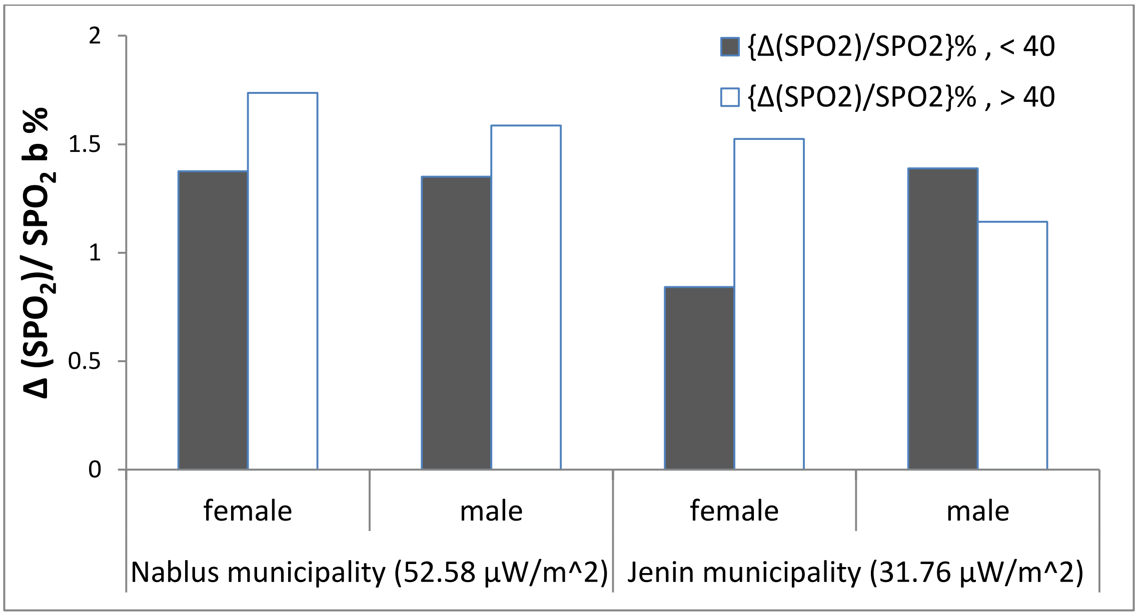

Fig. 4.7: The percentage changes of blood oxygen saturation as a function of age employees in Nablus and Jenin municipalities after (a) exposure to the signals of cell phone towers

It can be observed that there is significant shift of the percentage changes of blood oxygen saturation as well as age of employees are increased.

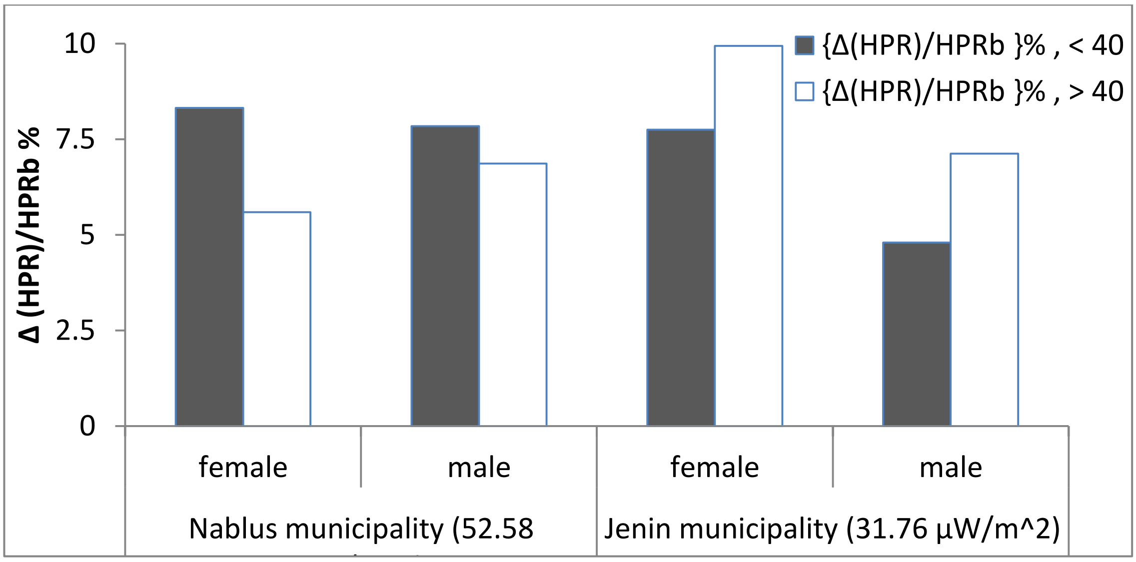

Fig. 4.8: The percentage changes of heart pulse rate as a function of age employees in Nablus and Jenin municipalities after (a) exposure to the signals of cell phone towers

Fig. 4.8 shows that the change in the heart pulse rate increases with the age of employees in Nablus and Jenin municipalities.

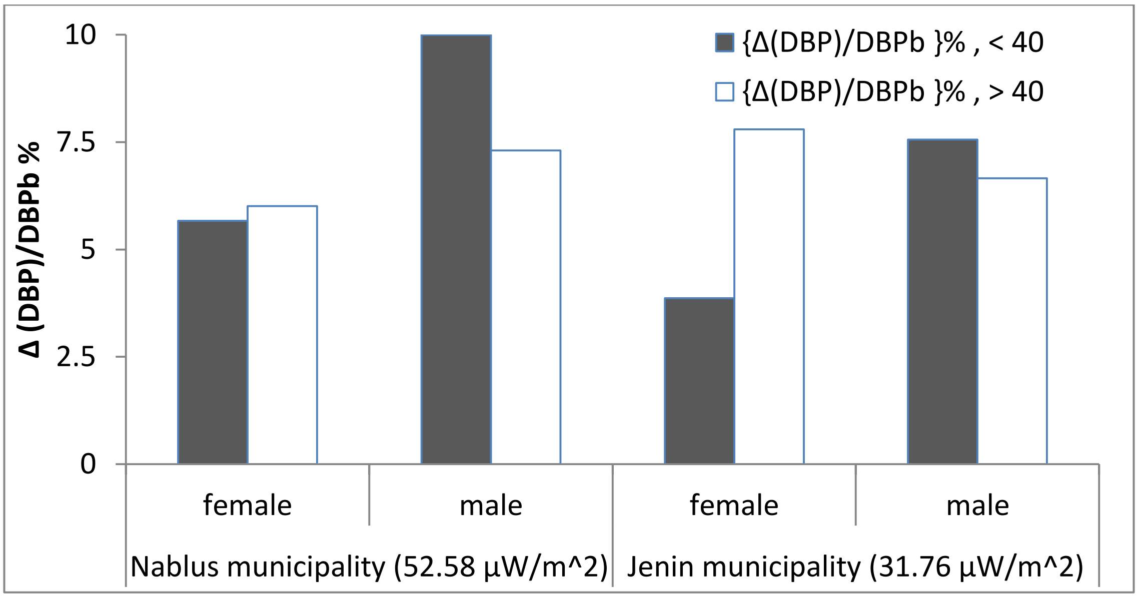

Fig. 4.9: The percentage changes of diastolic blood pressure as a function of age of employees in Nablus and Jenin municipalities after (a) exposure to the signals of cell phone towers

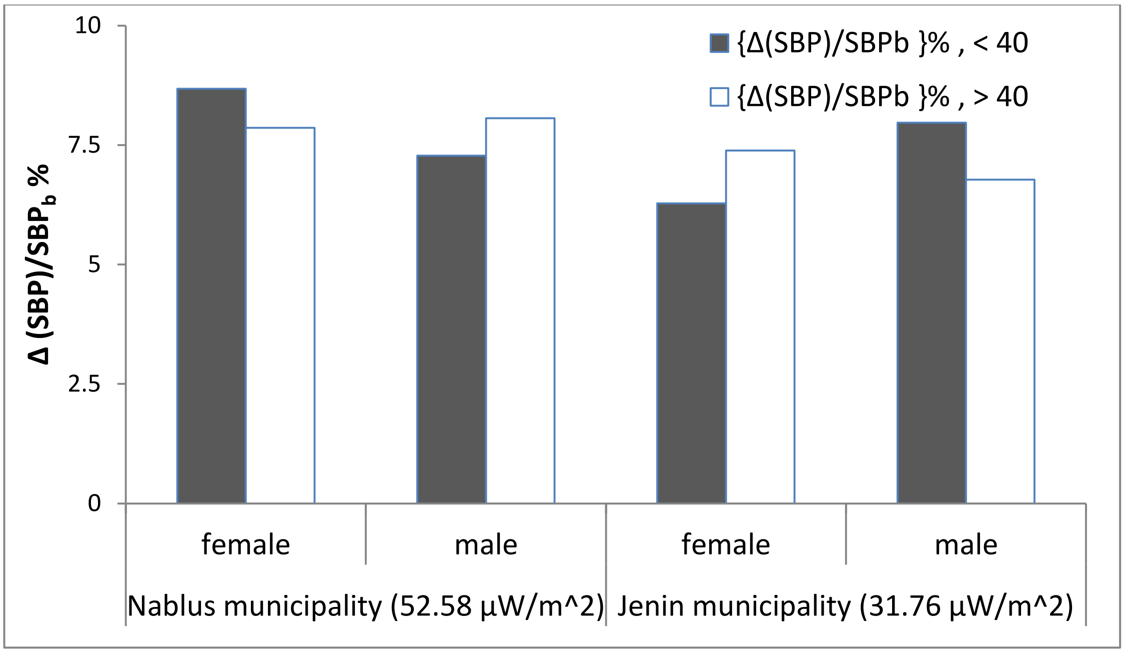

Fig. 4.10: The percentage changes of systolic blood pressure as a function of age employees in Nablus and Jenin municipalities after (a) exposure to the signals of cell phone towers

Figs. (4.9 - 4.10) show that there is a significant increment of diastolic and systolic blood pressure with age of employees in Nablus and Jenin municipalities after (a) exposure the signals of cell phone towers.

4.6 Statistical Analysis

The previous results in the fourth chapter for the power flux density, pulse rate, tympanic temperature, blood oxygen saturation, and blood pressure (systolic and diastolic pressure), showed that there is shifting of these measurements after exposure to signals of cell phone towers. It is found that there is a correlation (Pearson correlation coefficient) between these variables and power flux density of cell phone towers.

The following Tables (4.14 - 4.17) show the dependent variables, the correlation coefficient (R) and the probability (P-value) in Nablus and Jenin municipalities.

Table 4.14 Person correlation coefficient (R) and the probability (P) for females in Nablus municipalities

Paired Variables	Correlation Pearson (R)	Probability (P)
P (µW/m^2) and T (^oC)	0.337	0.022
P(µW/m^2) and SPO_2 %	0.294	0.047
P (µW/m2) and HPR beats/min	0.377	0.010
P (µW/m^2) and DBP mmHg	0.401	0.006
P (µW/m^2) and SBP mmHg	0.477	0.001

Table 4.15 Person correlation coefficient (R) and the probability (P) for males in Nablus municipalities

Paired Variables	Correlation Pearson (R)	Probability (P)
P (µW/m^2) and T (^oC)	0.405	0.006
P(µW/m^2) and SPO_2 %	0.355	0.017
P (µW/m2) and HPR beats/min	0.348	0.019
P (µW/m^2) and DBP mmHg	0.312	0.037
P (µW/m^2) and SBP mmHg	0.394	0.007

Table 4.16 Person correlation coefficient (R) and the probability (P) for females in Jenin municipality

Paired Variables	Correlation Pearson (R)	Probability (P)
P ($\mu W/m^2$) and T (^oC)	0.468	0.173
P($\mu W/m^2$) and SPO_2 %	0.657	0.039
P (μW/m2) and HPR beats/min	0.645	0.044
P ($\mu W/m^2$) and DBP mmHg	0.634	0.049
P ($\mu W/m^2$) and SBP mmHg	0.649	0.042

Table 4.17 Person correlation coefficient (R) and the probability (P) for males in Jenin municipality

Paired Variables	Correlation Pearson (R)	Probability (P)
P ($\mu W/m^2$) and T (^oC)	0.411	0.014
P($\mu W/m^2$) and SPO_2 %	0.403	0.016
P (μW/m2) and HPR beats/min	0.505	0.002
P ($\mu W/m^2$) and DBP mmHg	0.351	0.038
P ($\mu W/m^2$) and SBP mmHg	0.423	0.011

Chapter Five

Discussion

In this study, the power flux densities were measured. The measured values of power flux density were used to calculate the values of electric fields, magnetic fields strength, magnetic flux density and specific absorption rate (SAR). Tympanic temperature, heart pulse rate, blood oxygen saturation, and diastolic and systolic blood pressure, were measured for selected employees as a function of power flux density. The obtained results are discussed in the following sections.

5.1 Power Flux Density and International Standards

The permissible exposure limit and the measured values in this study of power flux densities of cell phone towers operating at 935MHz are shown in Table 5.1, (IEEE, 1999).

Table 5.1 The permissible limit (IEEE, 1999) and measured values for power flux density of cell phone towers operating at 935MHz

Power flux density (W/m^2)	Permissible limit	Measured values	
		Nablus municipality	Jenin municipality
	4.68	52.58×10^{-6}	31.76×10^{-6}

The measured power flux density in Nablus municipality was 52.58 $\mu W/m^2$, while the measured value in Jenin municipality was 31.76 $\mu W/m^2$. This difference is due to that the distance between cell phone towers and Nablus municipality (70 m) is more than the distance from Jenin municipality (50 m); this increment is applicable between 50 m and 300 m(Kamil, 2013). Comparing these two values with international standard indicates that both values are less than the permissible limit which is 4.68 W/m^2 for cell phone towers working at 935 MHz, (IEEE, 1999).

The standard levels of the electric field strength, the magnetic field strength and the magnetic flux density and their calculated values are summarized in Table 5.2 (ICNIRP, 2010).

Table 5.2 Standard levels (ICNIRP, 2010) and calculated values for electric field strength, magnetic field strength and magnetic flux density for the cell phone towers operating at 935MHz

	Standard levels	Calculated values	
		Nablus municipality	Jenin municipality
E-field strength (V/m)	42.04	140.79×10^{-3}	109.42×10^{-3}
H-field strength (A/m)	0.11	0.37×10^{-3}	0.29×10^{-3}
B-field (Tesla)	1.4×10^{-4}	0.47×10^{-9}	0.37×10^{-9}

The calculated electric fields were 140.79 $\times10^{-3}$ V/m and 109.42×10^{-3} V/m in Nablus and Jenin municipalities, respectively. These values are less than the international standards value which is 42.04 V/m (ICNIRP, 2010). The calculated magnetic fields strength in Nablus was 0.37×10^{-3} A/m and in Jenin was 0.29 $\times10^{-3}$ A/m. These values are less than the international standards which is 0.11 A/m (ICNIRP, 2010). The calculated magnetic flux density was 0.47×10^{-9} Tesla in Nablus municipality and 0.37×10^{-9} Tesla in Jenin municipality. These values are less than the international standards which is 1.4×10^{-4} Tesla (ICNIRP, 2010).

Table 5.3 shows a comparison between the calculated values of SAR for some organs of the employees in Nablus (SAR_N) and Jenin (SAR_J) municipalities and the accepted values in European and USA standards for SAR (ICNIRP, 1998).

Table 5.3 European and USA standards for SAR (ICNIRP, 1998) and the calculated values of SAR for some organs of the employees in Nablus and Jenin municipalities

Standard SAR (W/Kg)		Organs	SAR_N (W/Kg)	SAR_J (W/Kg)
European	USA			
2	1.6	cerebellum	12.21×10^{-6}	7.38×10^{-6}
		eye sclera	10.57×10^{-6}	6.38×10^{-6}
		Muscle	9.03×10^{-6}	5.46×10^{-6}

All calculated SAR values for organs of employees in Nablus and Jenin municipalities are less than European standard (2 W/Kg) and USA standard (1.6 W/Kg) (ICNIRP, 1998).

The results of this study show that all values of the power flux density, electric fields, magnetic fields strength, magnetic flux density and SAR were much below than the international standard.

5.2 The Effect of Signals of Cell Phone Towers on Tympanic Temperature of Employees

The results of the measurements indicate that the net changes of the tympanic temperature increase for selected employees after they are exposed to signals of cell phone towers for five hours. Comparing the results of percentage changes of tympanic temperature for all employees show that the Pearson correlation coefficients (R) are more than 0.337 and P-values are less than 0.022 as shown in Tables (4.14 - 4.17). These statistical values indicate the existence of significant correlation between power flux density and tympanic temperature, after exposure to cell phone tower signals. The percentage changes of tympanic temperature are increasing after exposure to signals of cell phone towers as shown in Fig. 4.1. The increment is ranged between 0.23 ^{0}C and 0.68 ^{0}C. This result is in good agreement with Ibrahim's study (Ibrahim *et al.*, 2005), which showed that there is an increment of skin temperature of 1.6 ^{0}C, after exposure to 900 MHz, for 50 minutes.

The increasing of tympanic temperature is a consequence of electromagnetic energy absorption that caused the rise in temperature. The charged objects (ions) in human body are under the effects of the force produced by an electromagnetic field. The movement of ions produces an electric current, which led to heating of tissues, because of the electrical resistance of the tissue components. This heat input causes a raise in the temperature of the human body (ICNIRP, 1996). The increment of tympanic temperature in this study is in the normal range (35.4 - 37.8) ^{0}C.

5.3 The Effect of Signals of Cell Phone Towers on Blood Oxygen Saturation of Employees

The percentage change of blood oxygen saturation was decreased as shown in Fig. 4.2 after exposure to signals of cell phone towers for five hours. This decrement is ranged between 0.83% and 1.71% as shown in

Table (4.13). These figures show that females are affected more than males in both municipalities. The Pearson correlation coefficients (R) are from 0.294 to 0.657 and the P-values are < 0.047 as shown in Tables (4.14 - 4.17). R and P-values show significant correlation between power flux density and blood oxygen saturation. The results of this study are in agreement with Abdel Aziz's study (Abdul Aziz *et al.*, 2010). Abdel Aziz found a decrement of 12.2% in red blood cells (RBC) after exposing to frequency of 900 MHz for two weeks.

A decrement of blood oxygen saturation is resulting from a shortage of hemoglobin molecules, because each molecule of hemoglobin carries four oxygen molecules, (Clark et al., 1985). A decrement of blood oxygen saturation in this study is within in the normal range (95 -100) %.

5.4 The Effect of Signals of Cell Phone Towers on Heart Pulse Rate of Employees

Heart pulse rate (HPR) was measured after exposure to signals of cell phone towers for five hours. The results showed that there is an increment in HPR as shown in Fig. 4.3. In addition, males are more affected than females in all samples. The Pearson correlation coefficients (R) are > 0.348 and Probability (P) values are < 0.044 as given in Tables (4.14 - 4.17). The statistical values of R and P show that there are significant interactions between the percentage changes of heart pulse rate and power flux density. The average increment in heart pulse rate was 5.22 beats/min. This is in good agreement with the study conducted by Rezk and his group. The result of their study indicates that the infants and newborns suffered from increase in heart pulse rate (HPR). They found an increment of 7.3 % at a gestational age (30 – 35) weeks and 4.3% in newborns (Rezk *et al.*, 2008).

The human body absorbs EMR according to Lambert's law (Christopher, 2004). The body produces a hormone of melatonin. Melatonin hormone decreases with an increment of power flux density (Burch *et al.*, 2002). The decrement of this hormone causes a rise in heart pulse rate. The increment of heart pulse rate in this study is in the normal range (60 - 100) beats/min.

5.5 The Effect of Signals of Cell Phone Towers on Blood Pressure (Systolic and Diastolic) of Employees

The percentage change of blood pressure (systolic and diastolic) was increased after the employees were exposed to signals of cell phone towers for five hours as shown in Figs. (4.4 - 4.5). The Pearson correlation coefficients (R) are > 0.312 and Probability (P) is < 0.049 for diastolic blood pressure, also, R are > 0.394 and P is < 0.042 for systolic blood pressure as shown in Tables (4.14 - 4.17). The R and P-values show there is a correlation between changes in blood pressure (systolic and diastolic) and power flux density. The net change of systolic blood pressure is between (7 - 10.07) mmHg, and the net change of diastolic blood pressure is between (2.34 - 6.72) mmHg. The results of this study are in agreement with El-Bediwi's study. This study supports that exposure to signals of cell phone towers leads to change blood pressure. El-Bediwi found a significant change (P < 0.05) on blood components and its viscosity, which effects on a blood circulation after exposure to the effect of 900 MHz an hour daily for a week (El-Bediwi *et al.*, 2012).

The decrement of melatonin hormone causes a rise in systolic and diastolic blood pressure. The increment of systolic and diastolic blood pressure in this study is in the normal range (systolic: 100 - 139 mmHg; diastolic: 60 - 90 mmHg). Males are more affected than females in the percentage change of blood pressure (systolic and diastolic). This result is due to that the male's body contains electromagnetic waves more than a female's body (Kumar *et al*., 2008) and the monthly period (Eric *et al*., 2010) for females. Young females have monthly period more active than adult females, so adult females are more affected than young females. Young males are more affected than adult males because of the vital activity for young males.

5.6 Age of Employees Health Effects Dependence

The dependence of health effects of the power flux density on the age of the employees of both gender are shown in Figs. (4.6 - 4.10). The percentage changes of tympanic temperature are shown in Fig. 4.6. It shows that old females are more affected than young females, while young males are more affected than old males, after they are exposed to 52.58 $\mu W/m^2$ for five hours in Nablus municipality. In addition, it can be observed that all young females and males are more affected than old females and males, after they are exposed to 31.76 $\mu W/m^2$ for five hours in Jenin municipality. The old employees are more affected than young employees in the percentage changes of blood oxygen saturation at 52.58 $\mu W/m^2$ and 31.76 $\mu W/m^2$ as shown in Fig. 4.7.

Young employees are more affected than old employees in changes of the heart pulse rates at 52.58 $\mu W/m^2$, while old employees are more affected than young employees at 31.76 $\mu W/m^2$, as observed in Figs. 4.8. Old females are more affected in diastolic and systolic blood pressure than young females, but old males are less affected than young males, at both power flux densities as shown in Figs. (4.9 - 4.10). Old males are more affected than young males in systolic blood pressure, but old females are less affected than young females at 52.58 $\mu W/m^2$ as shown in Fig. 4.10.

As a conclusion, when human being is exposed to power flux density of cell phone towers, the body absorbs EMR. The increment in the percentage changes of the tympanic temperature, blood oxygen saturation, heart pulse rate, and blood pressure (systolic and diastolic) indicate that the risk of exposure to EMR increases in the long term. This increment is remaining within the normal range and international standards.

Chapter Six

Summary and Recommendations

6.1 Summary

The overall results in this study indicate the following:

1. The measured power flux densities in Nablus and Jenin municipalities were 52.58 µW/m^2 and 31.76 µW/m^2, respectively.
2. The calculated electric fields, magnetic fields strength and magnetic flux density in Nablus municipality were 140.79 mV/m, 0.37 mA/m and 0.47×10^{-9} T, respectively.
3. The calculated electric fields, magnetic fields strength and magnetic flux density in Jenin municipality were 109.42 mV/m, 0.29 mA/m and 0.37×10^{-9} T, respectively.
4. The standard levels for electric fields, magnetic fields strength and magnetic flux density are 42 V/m, 0.11 A/m and 1.4×10^{-4} nT, respectively.
5. The specific absorption rates (SAR) of employee's organs in Nablus and Jenin municipalities are less than European and USA standards which are 2 W/Kg and 1.6 W/Kg, respectively.
6. There are significant correlations between power flux density and changes of temperature, blood oxygen saturation, heart pulse rate, systolic blood pressure and diastolic blood pressure.
    a. The tympanic temperature of employees was increased, with maximum net change of 0.68 ^{0}C.

b. Blood oxygen saturation was decreased, with maximum net change of 1.71 %.

c. Heart pulse rate was increased, with maximum net change of 10.25 beats/min.

d. Systolic blood pressure was increased, with maximum net change of 10.07 mmHg.

e. Diastolic blood pressure was increased, with maximum net change of 6.72 mmHg.

7. The age effects on changes of temperature, blood oxygen saturation, heart pulse rate, systolic blood pressure and diastolic blood pressure were as following:

   a. Most of young employees were more affected in change of tympanic temperature than old employees.

   b. Most of old employees were more affected in change of blood oxygen saturation than young employees.

   c. Most of young employees were more affected in change of heart pulse rate than old employees.

   d. Old females were more affected than young females in change of systolic and diastolic blood pressure.

   e. Young males were more affected than old males in change of systolic and diastolic blood pressure.

8. Previous studies indicate that the risk increases with longer exposure to lower intensities. (Berg *et al.,* 2006; Hardell *et al.*, 2009; Hardell *et al.*, 2010 and Erogul *et al.*, 2006).

6.2 Recommendations

The following are some recommendations to reduce the effects of signals of cell phone towers:

1. Comprehensive education should be provided to the citizens of the risks resulting from signals of cell phones and towers.
2. Some of materials can be added to building materials, to increase the absorption of radiation. These materials can be polystyrene or electrolytic manganese dioxide and MnZn-ferrite.
3. Department of Health in the municipalities should be measure the power flux density of cell phone towers regularly, to maintain the safety and health of its employees.
4. More scientific research should be focused on this field to gain more insight of EMR health effects and the means for better and safer human life.

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جامعة النجاح الوطنية

كلية الدراسات العليا

أثر التعرض للإشارات اللاسلكية المنبعثة من ابراج الهواتف المحمولة على موظفي بلديتي نابلس و جنين

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قدمت هذه الاطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في الفيزياء بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس – فلسطين

2014

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الملخص

ركزت هذه الدراسة على تأثير التعرض للإشارات اللاسلكية المنبعثة من ابراج الهواتف الخلوية على درجة الحرارة ونسبة الأكسجين في الدم ومعدل نبض القلب وضغط الدم.

شملت العينة العشوائية التي تم اختيارها لإجراء الدراسة 136 موظفا من كلا الجنسين (56 إناث، 80 ذكور)، وكان متوسط أعمارهم 40 سنة و معدل خدمتهم 14 سنة. اختيرت العينة من بين موظفي بلدية نابلس التي تبعد 70 م عن برج الهواتف المحمولة، وكذلك من بين موظفي بلدية جنين التي تبعد 50 م عن برج الهواتف المحمولة.

تم قياس كثافة تدفق الطاقة في كلا البلدتين ، حيث كانت معدلها في بلدية نابلس 52,58 ميكروواط/م^2، وكان معدلها في بلدية جنين 31,76 ميكروواط/م^2. استخدم معدل كثافة تدفق الطاقة المقاسة لحساب شدة المجال الكهربائي وكذلك شدة المجال المغناطيسي. كانت نتيجة ذلك أن جميع القيم المقاسة والمحسوبة تقع في المدى المسموح به دوليا للتعرض للإشعاع الكهرومغناطيسي المنبعث من ابراج الهواتف المحمولة. تم قياس درجة حرارة الجسم عن طريق طبلة الاذن، ومعدل ضربات القلب ، وضغط الدم الشرياني (الانقباضي والانبساطي) قبل التعرض للإشارات المنبعثة من ابراج الهواتف المحمولة وبعد التعرض بخمس ساعات، حيث تبين اعتماد الاثار الصحية على كثافة تدفق الطاقة.

تم تحليل البيانات بالاعتماد على برنامج SPSS الإحصائي. أظهر التحليل وجود علاقة بين كثافة تدفق الطاقة و كافة المتغيرات المقاسة، حيث أن معامل ارتباط بيرسون R تراوح بين 0,294 و 0,657، في حين أن الاحتمالية P كانت أقل من 0.05.