A Critical Assessment of Electromagnetic Radiation from Telecommunication System and the Magnitude of Its Health Related Issues

BY

OMOJUNIKANBI, Ngozi C., *Ph.D*
Department of Linguistics and Communication Studies
Faculty of Humanities
University of Port Harcourt
CHOBA, Rivers State
Nigeria;

ARIMIE, Christopher O., *Ph.D*
Head Radiography/Image Science Unit
Radiology Department
University of Port Harcourt Teaching Hospital
Rivers State, Nigeria

AND

OMOJUNIKANBI, Alfred O.
Head of Physiotherapy Department
University of Port Harcourt Teaching Hospital
Rivers State, Nigeria

ABSTRACT

With improving technology and affordability, the number of cell phone users increases continuously. Thus, this study extends the boundary conditions of existing literature by noting that increasing the risk of being exposed to more cell phone radiation increases the risk of being exposed to more cellular radiation, which in turn endangers human health or puts the human body at a greater risk of contaminated sickness or disease. Long-term exposure to low-frequency EMR from home appliances like microwave ovens, TV sets, cell phones, etc. can cause health problems such as hyperactivity, sleep disorders, and emotional instability. Furthermore, the paper reviewed the concept of health communication, biological hazards associated with cell phones, risk to pregnant women and children, biological effects of cell phones and cell phone tower radiation, effects of electromagnetic radiation from telecommunication systems on their users, etc. As a result, previous studies have shown that continuous usage of cell phones or wireless internet causes oxidative stress due to an influx of free radicals in the body as the body's antioxidant capacity is overwhelmed. Oxidative damage occurs in cells and DNA due to free radicals, which have also been strongly linked to heart disease, cancer, dementia, and other issues. Thus, the paper concluded that the number of cell phone users is increasing daily and there is a proliferation of wireless transmitting devices all over the world. Yet, there is limited awareness and knowledge about the public health and environmental effects of this form of radiation. As a result, the paper recommended, among others, that the government should develop public information materials and promote dialogue among scientists, industry and the public on the potential adverse health risks of mobile phones.

KEYWORDS: Health Communication, Biological Hazards, Cell Phone, Cell Phone Tower Radiations, Biological Effects and Electromagnetic Radiation

Introduction

Every cell phone has a Specific Absorption Rate (SAR) rating which has a limit of 1.6w/kg and it is calculated to be 360 seconds, which means 6 minutes per day of usage for a person. In order to produce the latest smartphones capable of receiving the full bandwidth power of 4G networks, manufacturers of smartphone handsets are furnishing them with a number of antennas in one handset. Health experts say this further increases the risk of being exposed to more radiation, which in turn endangers human health or puts the human body at a greater risk of contaminated sickness or disease. 4G phones are believed to be capable of producing and transferring more radiation as a series of antennas in a handset can receive and transmit from different sources. Cell towers transmit radiation, and people residing 10 meters within the radius of the tower are bound to receive 10000 to 10000000 times stronger signals than required for mobile communication (Girish, 2010). Constant exposure to low-intensity microwave radiation can have a negative impact on the systems of human beings. A person is advised not to use a cell phone for more than 24 minutes per day following the safety standards, which have put into consideration the SAR limit. The majority of cell phone users are not aware of the negative impact or implications of long and continuous use of cell phones per day. They are unaware of the risk and health hazards of the constant and continuous use of cell phones per day to their health and their biological body systems due to the exposure. However, as a result of this unawareness, this research focuses on raising public awareness, which is important not only for disease control but also for disease prevention.

The Concept of Health Communication

Individuals, communities, society, and organizations communicate information through various media or channels. Simply put, it is the transmission of data from one source to another. Changes in behavior and attitude, as well as cognitive and physical changes, may result from the sharing of knowledge. As a result, health knowledge and education, which are both forms of communication, lead to actions, decisions, beliefs, and behaviors that invariably result in improved health. Thus, researchers in behavioral sciences have correctly noticed that favorable health outcomes in society may not be effectively realized without the involvement or input of the communication factor. The utilization of communication activities in the health sector is critical in addressing the variables that impact health concerns that medical sciences may not address (Parrot, 2004).

Health communication is defined in the Healthy People 2010 as:

> The art and technique of informing, influencing and motivating individual, institutional, and public audiences about important health issues. The scope of health communication includes disease prevention, health promotion, health care policy, and the business of health care as well as enhancement of the quality of life and health of individuals within the community (U.S. Department of Health and Human Services, 2000).

Over the years, interest in health communication has grown tremendously. It is obvious that challenges in health conditions globally today cannot be handled by health professionals and scientists alone. No wonder, when in the Healthy People 2010 objectives published in 2000 by the U.S. Department of Health and Human Services, for the first time, a chapter on health communication appeared to provide a national prevention agenda for the American people. Health communication, therefore, involves the exchange, transmission, perception and internalization of health-related information, within varying social and physical environments, regarding factors that influence health and health-related behaviors (Witte, Meyer, Bidol, Casey, Kopfman, Maduschke, Marshal, Kelly, Kurt and Robbins, 1996). This exchange usually takes place between individuals, among groups, organizations and the mass media.

Biological Hazards Associated with Cell Phone and Cell Phone Tower Radiations

About 70% of the human body consists of fluid which absorbs electromagnetic radiation readily and the human body is highly susceptible to the radiation. Body parts containing fluid are more susceptible to radiation as the microwave absorption effect is more significant (Kanimozhi et al., 2018). The brain, eyes, heart and abdomen where the fluid is almost stagnant are affected more severely by RF radiation (Kanimozhi et al., 2018).

Long-term exposure to low-frequency EMR from home appliances like microwave ovens, TV sets, cell phones, etc. can cause health problems such as hyperactivity, sleep disorders, and emotional instability (Batool et al., 2019). Other harmful biological effects reported in the literature include memory disruptions, brain disorders, hormonal imbalances, genetic mutations, infertility, hindered learning, dementia, heart complications, insomnia, cancer, etc. Low-frequency EMR from cell phones and cell phone towers has been reported to have the ability to cause Type 2 Diabetes Mellitus (Sultan et al., 2015). Miller et al. (2019) reported that three large-scale carcinogenicity studies in rodents exposed to some doses of RF radiation (RFR) estimated to be equivalent to a lifetime radiation dose to humans exposed to RFR, showed significantly increased rates of Schwannomas and malignant gliomas, as well as chromosomal DNA damage. Kanimozhi et al. (2018) stated that a study conducted in 2015 showed that continuous usage of cell phones or wireless internet causes oxidative stress due to an influx of free radicals in the body as the body's antioxidant capacity is overwhelmed. Oxidative damage occurs in cells and DNA due to free radicals, which have also been strongly linked to heart disease, cancer, dementia, and other issues.

Risk to Pregnant Women and Children

It is well established in radiobiology that the sensitivity of a body tissue to radiation is directly proportional to the rate of mitotic cell division. This implies that developing embryos and children whose cells are still undergoing rapid mitoses are more susceptible to radiation effects. In the same vein, certain body parts in adults, e.g. the gonads, the lens of the eyes, bone marrow, etc., are also undergoing rapid mitosis and are equally susceptible to the harmful effects of RFR. On account of this, there is a higher risk of EMR hazards to growing children and pregnant women as the developing embryos/fetuses undergo rapid cell division from the time of conception to delivery at term. The rapid rate of mitosis continues in growing children until adulthood, though the rate of mitotic cell division reduces progressively as the child grows older until adulthood, when no more significant growth is expected.

It is worthy of note that although numerous studies have reported the harmful effect of EMR on the reproductive system, only a few studies have focused on radiation effects from the SW band. Several studies found no significant correlation between congenital malformations of fetuses and SW radiation with non-thermal intensity (Oliveira et al., 2015; Yu and Peng, 2017). An empirical study conducted by Oliveira et al. (2015) using pregnant rats showed that SW electromagnetic a-thermal radiation had no significant effect on the offspring. "Compared with control fetuses, no cases of teratogenesis, stillbirth, or malformation of internal organs occurred in the exposure group". However, SW electromagnetic hyper-thermic exposure may induce teratogenicity (Lary et al., 1986). In other empirical studies with pregnant rats, Brown-Woodman et al. (1989) showed that the exposed rats, with a temperature elevation of 5°C in the rectum induced by radiation, had fetal malformations including microphthalmia, encephalocele, facial clefting, and maxillary hypoplasia.

There is ample evidence linking impairment of brain development in children to the effects of RFR exposure. Compared with an adult, a cell phone held against a child's head exposes deeper brain structures to greater radiation doses per unit volume, and the young, thin skull's bone marrow absorbs roughly 10-fold higher local dose of radiation (Florence et al., 2017; Fernandez et al., 2018; Miller et al., 2019; Ju et al., 2019). According to Kanimozhi et al. (2018), children are more vulnerable to cell phone radiation due to the fact that they easily absorb more radiation energy than adults because of their thinner skin and cranial bones, smaller brain and head size, lower blood cell volume, thin and elastic ears, higher cell reproduction rate, underdeveloped immune systems and greater conductivity in nerve cells. Children are likely to have a longer duration of exposure on account of their young age, as they will be exposed to this radiant energy till old age. As a result, in some developed countries of the world, e.g. Germany, Russia, Israel, France, Finland, and Belgium, children are discouraged from using cell phones (Kanimozhi et al., 2018). A number of studies have associated the increasing use of cell phones by children with emotional and behavioral disorders, and cognition (Walsh et al., 2018; Foerster et al., 2018). Foerster et al. (2018) "suggested a potential adverse effect of RFR on cognitive functions that involve brain regions mostly exposed during mobile phone use". Sage and Burgio et al. (2018) "posit that epigenetic drivers and DNA damage underlie the adverse effects of wireless devices on childhood development".

Risk of Irreversible Infertility

In recent time, the rising cases of male infertility have prompted a series of research which has pointed to EMR as being a possible environmental cause of male infertility. Although many studies have indicated ionizing radiation as a cause of irreversible infertility in both males and females, there are still controversies regarding the effect of RF and SW radiation on reproductive functioning as many studies have reported contradictory findings (Kim et al., 2007). "Experimental and observational studies suggest that men who keep cell phones in their trouser pockets have significantly lower sperm counts and significantly impaired sperm motility and morphology, including mitochondrial DNA damage" (Miller et al., 2019). RFR, given intermittently to male rats over a given period of time, was reported to cause significant histopathological alterations like focal tubular atrophy, necrosis, and seminiferous epithelial erosion in the rat testis (Singh and Kapoor, 2014). Another epidemiological study revealed a significantly higher incidence of abnormal male reproduction symptoms in SW radio men (Ding et al., 2002).

Hazard to the Blood-Brain Barrier

The impact of radiation on the central nervous system (CNS) has been extensively reported in the literature. Of particular importance are findings on the impact of RF-EMF radiation on the brain and nerves. Ju et al. (2019) reported that absorption of EMF radiation by the CNS causes heat, changes of ion channels, demyelination, autophagy, etc. as depicted in Figure 1. Salford et al. (2003) reported nerve cell damage in the mammalian brain after exposure to microwaves from GSM mobile phones. Also, exposure to RF-EMF radiation has been reported to induce stress and anxiety (Bouji et al., 2016). Damage to the blood-brain barrier has also been reported.

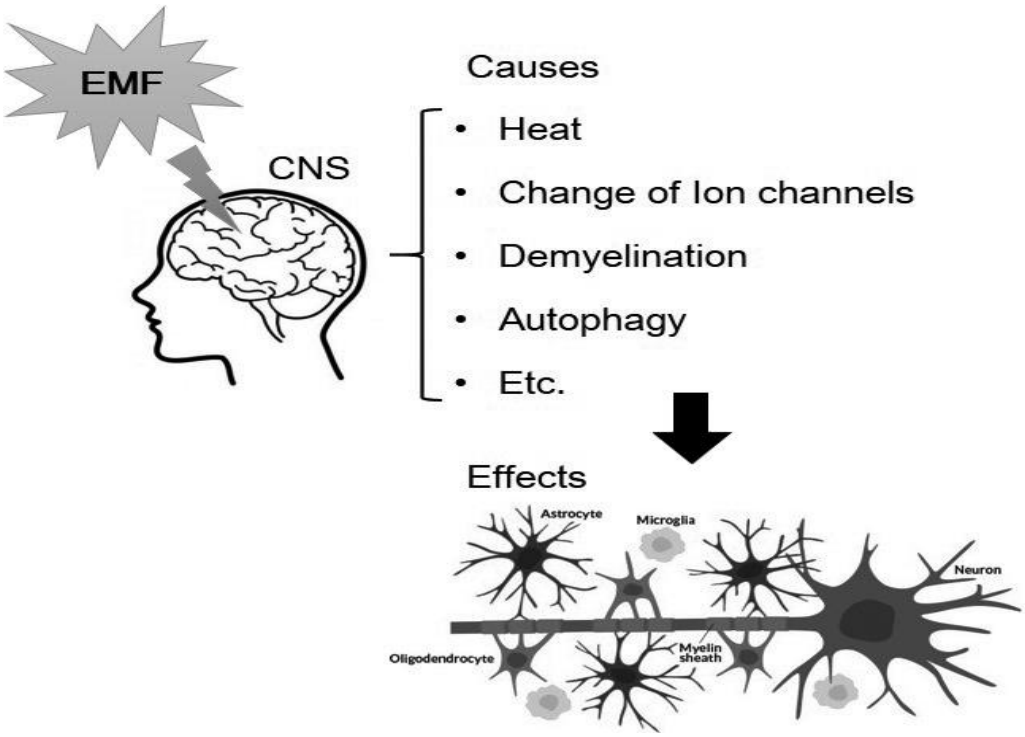

Figure 1: Schematic summary of the possible mechanisms of RF-EMF exposure in central nerve system (Source: Ju *et al.,* 2019).

The blood-brain barrier (BBB) is a structure within the brain, made up of highly specialized endothelial cells and acts as an additional boundary between the circulating blood and the extracellular space of the brain. The BBB maintains homeostasis of the brain microenvironment, which is necessary for its normal function. That is to say, it restricts the paracellular diffusion of hydrophilic molecules. Research has shown that ionizing radiation and heat can alter BBB permeability (Nittby et al., 2009). Stam (2010) states that "exposure to levels of radiofrequency electromagnetic fields (EMF) that increase brain temperature by more than 1°C can reversibly increase the permeability of the BBB for macromolecules." Exposure to radiofrequency fields (RF) at high specific absorption rates (SAR) has also been reported to induce BBB leakage and is known to induce hyperthermia and heat stress (Florence et al., 2017). It should be noted that there is still no general agreement among researchers on the claim of RF-EMF radiation-induced BBB leakage. Franke et al. (2005) and Kuribayashi et al. (2005), in their separate studies using rat and in vitro studies, did not observe leakages via the BBB.

Effects on Skin, Ear and Eye

RF-EMF radiation has been reported to cause electromagnetic hypersensitivity, a symptom of Morgellons disease, which is associated with numerous skin symptoms including sensations of crawling, stinging, biting, etc., which can also result in rashes and sores (Kanimozhi et al., 2018). Cell tower radiation can increase mast cells, which can cause itching, pain, edema and erythema (Kanimozhi et al., 2018). Radiation can also reduce immunity in humans and make them more susceptible to allergic and inflammatory reactions. It has been observed (Kanimozhi et al., 2018) that many cell phone users suffer from tinnitus, a psychological disease in which the sufferer experiences hallucinations of the sound of a cell phone ringing. Tinnitus, depending on its severity, can cause hearing problems as well as disrupt working and sleeping patterns. Cell phones may cause damage to the inner ear (Hutter et al., 2010), and long-term usage, say, for more than half an hour daily for about 4 years and above, may result in irreversible hearing loss (Kanimozhi et al., 2018).

A study has connected the cause of cancer and tumours in the eyes (also known as uveal melanoma) to the increase in the use of mobile phones. 98% of the tumours are found in the choroid region, 1% in the iris and 1% in the uveal tract (Schmidt-Pokrzywniak et al., 2004). Studies conducted on animals revealed that microwave radiation corresponding to the mobile phone frequency can cause cataracts and affect corneal epithelial cells in the eye, causing chromosomal breaks (Kanimozhi et al., 2018).

Risk to Patients Carrying Pace Makers

RF radiation from cell phones and towers can cause electromagnetic interference with some devices, e.g. pacemakers, impulse generators, and implantable cardiovascular defibrillators (ICDs), thus disrupting their functioning (Nathan and Damien, 2004). This could affect patients carrying any of these devices. The pace maker will malfunction if cell phones are operated very close to it. In their empirical study involving 980 patients using heart pacemakers and who used five types of cell phones, Hayes et al. (1997) observed that cell phones can interfere with the functioning of a heart pacemaker. However, the pacemaker interference was intense only when the phones were held over the pacemakers and not near the ears.

Biological Effects of Cell Phone and Cell Phone Tower Radiations

RF and MW (Shortwave) radiation from cell phones and cell phone towers is generally low-energy radiation and is non-ionizing. The strength of the radiation decreases the farther away one is from the radiation source because it loses energy as it travels from the source through air. Hence, the farther away one is from a cell phone tower, the less radiation one gets from it, and the farther away one keeps the cell phone from the body, the less radiation one receives from the device. Studies abound in the literature to support the fact that shortwave (SW) radiation has some beneficial as well as harmful effects. Studies in basic medical sciences and clinical evidence have reported the beneficial effects of SW-EMF on cancer treatment, wound repair, and pain control (Munabi et al., 2015; Kubat, Moffett, and Fray, 2015).

RF radiation has also been successfully harnessed for medical diagnostic purposes. Magnetic Resonance Imaging (MRI) is an example. Here, RF pulses are delivered to the human body, causing the hydrogen nuclei (protons) in the body to realign themselves with the magnetic field

in the MR scanner, a process called precession. When the RF pulse is switched off, the energy acquired by the aligned hydrogen nuclei is given up through a complex system of microcomputers to form the MR image (Reddy and Prasad, 2005).

Like RF radiation, microwave (MV) radiation is potentially hazardous. Experiments conducted using a microwave oven show that EMR from microwave oven heating destroyed garlic's anti-carcinogenesis property, which is related to active allyl sulfur compounds (Song and Milner, 2001). Batool et al. (2019) posit that EMR from microwave ovens has the ability to penetrate water, ice, smog, etc. It affects the nutrient capability of vegetables, making them unhealthy for human use as the RF-EMF radiation destroys the anti-cancer ability of different vegetables. Generally, low levels of EMF exposure, which were hitherto considered insignificant and harmless to humans, are now known to be a source of potential hazard to the health and wellbeing of humans. They can damage the DNA strands, magnetize iron in blood cells, and disrupt the entire processes of one's body, causing sleeping problems such as insomnia, heated cells, etc. Damage to DNA can lead to reproductive effects, such as DNA fragmentation, fertility issues, brain cancer, cognitive effects, behavioral effects including electromagnetic hypersensitivity syndrome.

Effects of Electromagnetic Radiation from Telecommunication System on its Users

The use of telecommunication devices (mobile phones, Wi-Fi, computers, televisions, etc.) has effects that are both beneficial and harmful. The ease of communication provided by these devices has enhanced the rapid growth and development of society. But the use of these devices is believed, in most quarters, to be accompanied by electromagnetic radiation (EMR) hazards.

The human body has the ability to absorb radiation from these devices, which might be harmful and can cause different diseases such as cancers, mental disorders, neurologic illnesses, fetal abnormalities, cardiovascular diseases, etc. (Batool et al., 2019). When RF radiation is absorbed in large amounts, it can produce heat. This can lead to skin burns and body tissue damage (Ju et al., 2019; American Cancer Society, 2020). "Although RF radiation is not thought to cause cancer by damaging the DNA in cells the way ionizing radiation does, there has been concern that in some circumstances, some forms of non-ionizing radiation might still have other effects on cells that might somehow result in cancer" (American Cancer Society, 2020).

Conclusion

It is obvious, going by this review, that the number of cell phone users is increasing daily and there is a proliferation of wireless transmitting devices all over the world. Yet, there is limited awareness and knowledge about the public health and environmental effects of this form of radiation. There are several critical questions to be answered regarding mobile phone radiation today, but the truth is that the vast majority of those who should know do not. As a result, the paper recommends that the government develop public information materials and promote dialogue among scientists, industry, and the public on the potential adverse health risks of mobile phones. Also, that cell towers should be distanced from homes, daycare centers, schools, and places frequented by pregnant women, men who wish to father healthy children, and the young.

Recommendations

1. Users of mobile phones should endeavour to limit the closeness of the phone to their ears, or they should limit the time spent using a cell (mobile) phone, or reduce the time of calls.

2. They should also limit time spent near appliances, equipment, and other devices (such as WiFi routers) that give off RF radiation.

REFERENCES

American Cancer Society (2020). *Radiofrequency (RF) Radiation*. (www.cancer.org).

Batool, S., Bibi, A., Frezza, F., Mangini F. (2019). Benefits and Hazards of Electromagnetic Waves, Telecommunication, Physical and Biomedical: A Review. *European Review for Medical and Pharmacological Sciences*; 23: 3121-3128.

Bouji, M., Lecomte, A., Gamez, C., Blazy, K. and Villegier, A. S. (2016). Neurobiological effects of repeated radiofrequency exposures in male senescent rats. *Biogerontology*; 17: 841–857.

Brown-Woodman, P. D. C., Hadley, J. A., Richardson, L., Bright, D. and Porter, D. (1989). Evaluation of reproductive function of female rats exposed to radiofrequency fields (27.12 MHz) near a shortwave diathermy device. *Health Phys.*;56(4):521–525.

Ding, X. P., Yan, S. W. and Zhang, N. (2002). Effect of short-wave radiation on male reproductive function evaluated by DNA strand breakage analysis. *Ind Hlth Occup Dis.*; 28(2):74–76.

Fernandez, C., de Salles, A. A., Sears, M. E., Morris, R. D. and Davis, D. L. (2018). Absorption of wireless radiation in the child versus adult brain and eye from cell phone conversation or virtual reality. *Environ Res*.; 167:694–699.

Florence Poulletier de Gannes, Hiroshi Masuda, Bernard Billaudel, Emmanuelle Poque-Haro, Annabelle Hurtier, Philippe Leveque *et al.* (2017). *Effects of GSM and UMTS mobile telephony signals on neuron degeneration and blood-brain barrier permeation in the rat brain*. (www.nature.com/scientificreports).

Foerster, M., Thielens, A., Joseph, W., Eeftens, M. and Roosli, M. (2018). A prospective cohort study of adolescents' memory performance and individual brain dose of microwave radiation from wireless communication. *Environ Health Perspect*.; 126:077007.

Franke, H., Ringelstein, E. B. and Stogbauer, F. (2005). Electromagnetic fields (GSM 1800) do not alter blood-brain barrier permeability to sucrose in models in vitro with high barrier tightness. *Bioelectromagnetics*; 26: 529-535.

Girish, K. (2010). *Report on Cell Tower Radiation*: Submitted to Secretary DOT, Delhi.

Hayes, D. L., Wang, P. J., Reynolds, D. W., Estes, M. *et al*. (1997). Interference with Cardiac Pacemakers by Cellular Telephones, *New England Journal of Medicine*; 336(21):1473–1479.

Hutter, H. P., Moshammer, H., Wallner, P., Cartellieri, M., Denk-Linnert, D. M., Katzinger, M., Ehrenberger, K. and Kundi, M. (2010). Tinnitus and mobile phone use. *Occup Environ Med*; 67(12): 804-808.

Ju Hwan Kim, Jin-Koo Lee, Hyung-Gun Kim, Kyu-Bong Kim and Hak Rim Kim (2019). Possible Effects of Radiofrequency Electromagnetic Field Exposure on Central Nerve System. *Biomol Ther* 27(3), 265-275.

Kanimozhi, G., Hema Shruthi. G. and Xiao-Zhi Gao (2018). Mobile Tower Radiation Impact on Biological Impairment. *International Journal of Civil Engineering and Technology (IJCIET);* 9(11): 443-454.

Kim, J. Y., Kim, H. T., Moon, K. H. and Shin, H. J. (2007). Long-term exposure of rats to a 2.45GHz electromagnetic field: effects on reproductive function. *Korean Journal of Urology*; 48(12): 1308–1314.

Kubat, N. J., Moffett, J. and Fray, L. M. (2015). Effect of pulsed electromagnetic field treatment on programmed resolution of inflammation pathway markers in human cells in culture. *J Inflamm Res*.; 8:59–69.

Kuribayashi, M., Wang, J., Fujiwara, O., Doi, Y., Nabae, K., Tamano, S., Ogiso, T., Asamoto, M. and Shirai, T. (2005). Lack of effects of 1439 MHz electromagnetic near field exposure on the blood-brain barrier in immature and young rats. *Bioelectromagnetics*; 26: 578–588.

Lary, J. M., Conover, D. L., Johnson, P. H. and Hornung, R. W. (1986). Dose-response relationship between body temperature and birth defects in radiofrequency-irradiated rats. *Bioelectromagnetics*;7(2):141–149.

Miller, A. B., Sears, M. E., Morgan, L. L., Davis, D. L., Hardell, L., Oremus, M. and Soskolne, C. L. (2019). Risks to Health and Well-Being from Radio-Frequency Radiation Emitted by Cell Phones and Other Wireless Devices. *Front. Public Health* 7:223.

Munabi, N. C. O., Wu, J. K., Taylor, E. M., Ascherman, J. A., Pilla, A. A., and Rohde, C. H. (2015). PEMF modulates cytokines in the wound milieu to reduce post-operative inflammation: application to autologous breast reconstruction. *Plast. Reconstr. Surg.*; 135(suppl. 5):42.

Nathan, Lawrentschuk and Damien, M Bolton (2004). Mobile phone interference with medical equipment and its clinical relevance: a systematic review. *Med J Aust*.; 181 (3):145-149.

Nittby, H., Brun, A., Eberhardt, J., Malmgren, L., Persson, B. R. and Salford, L. G. (2009). Increased blood-brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone. *Pathophysiology*; 16: 103-112.

Oliveira, A. B. D., Lessa, R. A., dos Santos, C. A., Silva, R. E. S. D., Alonso, A. C., Speciali, D. S. *et al*. (2015). Exposure of pregnant rats to shortwave electromagnetic athermal radiation does not adversely affect their fetuses. *Med Express*; 2(2):1–4.

Parrot, R. (2004). Emphasizing Communication in Health Communication. *Journal of Communication*; 54:751-787.

Reddy, J. J. M. and Prasad, V. (2005). *Step by Step MRI*. JAYPEE BROTHERS Medical Publishers (P) Ltd. New Delhi (www.jaypeebrothers.com).

Sage, C. and Burgio, E. (2018). Electromagnetic fields, pulsed radiofrequency radiation, and epigenetics: how wireless technologies may affect childhood development. *Child Dev.*; 89:129–36.

Salford, L. G., Brun A. E., Eberhardt J. L., Malmgren L., Persson B. R. (2003). Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. *Environ Health Perspect;* 111: 881–883; discussion A408.

Schmidt-Pokrzywniak, A., Jockel, K. H., Bornfeld, N. and Stang, A. (2004). Case-control study on uveal melanoma (RIFA): rational and design. *BMC Ophthalmol*., 4(11), 4-11

Singh, S. and Kapoor, N. (2014). Health Implications of Electromagnetic Fields, Mechanisms of Action, and Research Needs. *Advances in Biology*. (http://dx.doi.org/10.1155/2014/198609)

Song, K., Milner, J. A. (2001). The influence of heating on the anticancer properties of garlic. *Int J Nutr*; 131: 1054-1057.

Stam, R. (2010). Electromagnetic fields and the blood-brain barrier. *Brain Res Rev*.; 65(1): 80–97.

Sultan, A. M., Yazeed, A., Zaid, A., Hisham, A., Yazeed, A., and Rana, M. H. (2015). Association of Exposure to Radio-Frequency Electromagnetic Field Radiation (RF-EMFR) Generated by Mobile Phone Base Stations with Glycated Haemoglobin (HbA1c) and Risk of Type 2 Diabetes Mellitus. *Int. J. Environ Res Public Health*; 12(11): 14519–14528.

U.S. Department of Health and Human Services (2000).

A publication of the US Department of Health and Human Sciences, (www.healthypeople.gov/2010).

Walsh, J. J., Barnes, J. D., Cameron, J. D., Goldfield, G. S., Chaput, J. P., Gunnell, K. E. (2018). Associations between 24-hour movement behaviours and global cognition in US children: a cross-sectional observational study. *Lancet Child Adolesc Health*; 2:783–791.

Witte, K.; Meyer, G.; Bidol, H., Casey, Mary, K; Kopfman, J., Maduschke, K., Marshal, A. M., Kelly, R., Kurt, M and Robbins, S. (1996) "Health Communication Defined: Bringing Order to Chaos*." Communication and Health Communication Studies*, Fall 1996.

Yu, C., and Peng, R. Y. (2017). Biological effects and mechanisms of shortwave radiation: a review. *Military Med Res;* 4, 24.