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# Investigating the Effective Factors of Radio Waves in the Disorder of the Human Nervous System

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**Abstract:** ***This has been caused by the development of electrical and communication technologies and exposure to artificial electromagnetic fields (EMF). The growth of technology is expected to continue. As a result, EMF exposure will increase steadily. Smartphones have become an indispensable tool for the modern person, especially when using them. The examination of the area where the cell phone is used is accompanied by social concerns and an increased interest in the effects on the cranial nervous system. Nevertheless, several factors related to the effects of electromagnetic fields (RF-EMFs) should be investigated at the research level before discussing the effects of EMFs on the human body. In order to understand how biological effects work, laboratory or animal models must be used. Apoptosis and neuronal dysfunction can be caused by RF-EMF to neurons in the central nervous system. Furthermore, RF-EMF acts as a source of stress in living organisms via ion channels and neural myelin. RF-EMF exposure has not yet been proven to cause biological effects, and insufficient information is available to provide a clear response to Potential Health Risks. Therefore, a comprehensive review of the biological response to RF-EMF is essential. Exposure due to the use of different devices by individuals. In this article, we explain the possible biological effects of RF-EMF exposure.***

**Keywords:** electromagnetic field, radiofrequency, central nervous system, Cell Phone, Technology

## 1. Introduction

With the development of science and technology, artificial radio waves have been generated on the Earth, and all life on Earth has been affected by radio waves / electromagnetic waves. A German physicist discovered radio frequency radiation and verified the presence of RF in the ecosystem by discovering radiofrequency radiation. In human life, we have been exposed to artificial radio waves due to the development of science and technology, which have resulted in the invention and use of most electronic devices. In particular, the eruptive use of different electronic devices in society has inevitably increased the risk of radio wave exposure. Modern people have become dependent on wireless communication technologies due to their development. Due to environmental changes and artificial radio waves that have never been determined before, all living things on Earth are being affected by environmental changes as well. Despite inconsistent results from studies, there has been contention over the effect of radio waves on living creatures. It has been noted that social anxiety about Radiofrequency exposure has increased since the World Health Organization's International Agency for Research on Cancer (IARC) classified mobile phone RF-EMFs as Group 2B, potentially carcinogenic to humans in 2011 (Baan et al., 2011). People use mobile phones and there are numerous opportunities to expose ourselves to radiofrequency all around us (Langer et al., 2017). Because of this, social interest in the effects of RF exposure has grown (Langer et al., 2017). It is well known that RF exposure is controversial, but many studies have focused on cancer and genetic damage, neurological diseases, reproductive disorders, immune dysfunction, kidney damage, and radiofrequency hypersensitivity. There are, however, not enough studies regarding the biological hazards of RF-EMF to provide a specific answer to any health risks. We have not yet proven the biological effects of exposure to RF-EMF. In this way, the public and scientific society are left with ungrounded negative effects due to the many unknown effects of RF exposure. Moreover, the results of scientific data published by various researchers have been inconsistent. RF's biological effect has not yet been fully explained in detail, so detailed information about it is still lacking. According to recent studies, RF emissions from mobile phones can affect neuronal activity to a degree in the brain (Kleinlogel et al., 2008; Jeong et al., 2015; Jiang et al., 2016). Also, the thermal effects of RF suggest the possibility of affecting neuronal activity by temperature generated by mobile phones (Wainwright, 2000; Wyde et al., 2018). In order to gain a comprehensive understanding of the effects of increased exposure to radio frequency on nerve cells, including neurodevelopment, function, and cognitive function, scientifically proven data is needed. Nonetheless, many studies have recently been conducted on the potential influence of radio waves on neurons, but the results are conflicting depending on experimental conditions, and a lot still needs to be done to gain a solid understanding. Therefore, this paper included the recent research on the suggested possible biological effects of exposure to RF-EMFs.

### Radio Waves / Electromagnetic Fields in Human Life

It is common for radio waves to be classified into Low Frequency and Microwave Radiation depending on their wavelength ranges. Small places such as offices usually generate low frequencies ranging from 3 to 3,500 Hz from electronic and electric wires, and also low frequencies are generated as a result of the high-voltage power that is used to transmit electricity from the power plant to the areas where it is used. The range of RF frequencies is 100 kHz to 350 GHz, producing electromagnetic fields that are enhanced when a radiofrequency is applied to an antenna (ICNIRP, 1998; Cucurachi et al., 2013). Mobile phones, wireless internet, satellite systems, radios, and TVs all emit

radio waves. These wireless devices are widely used in human life. An attraction rate is defined by the numerical expression of the waves absorbed by human bodies when using electronic devices. These waves are often attracted by human bodies. Mobile phones emit high-frequency radio waves that can cause the body's temperature to rise; SAR (Specific Absorption Rate) is a quantifier of such heat reactions. This causes RFs to penetrate the body, causing charged or polar molecules inside to vibrate, resulting in serious health and safety concerns. For international organizations and major countries dealing with SAR-related matters, the National Radio Research Agency has released standards. Currently, countries use 1.7 watts per kilogram with an average of 1.5 g of tissue for transpiration tests for mobile phones, but ICNIRP and IEEE standards use 2.0 watts per kilogram with an average of 10 grams per kilogram. The human safety standard of 1.7 W/kg has, however, been set 51 times more strict than what is expected to happen.

**Effects of Radio Frequency on Cancer**

The epidemiology of RF and EMF exposure has been examined previously to determine whether children may develop childhood leukemia and whether adults may develop brain tumors or leukemia as a result of chronic exposure (Lagiou et al., 2002). Both epidemiological research found that exposure to either RF-EMF increases the risk of childhood leukemia or adult brain tumors unseemly. In addition, no direct evidence has been found to indicate that RF-EMF exposure causes childhood leukemia. However, RF-EMF exposure in the home is not associated with acute lymphoblastic leukemia in children. RF-EMFs are not associated with any rightful health risks at levels commonly encountered by the public, according to a standard WHO risk assessment process compiled by a WHO group of scientific experts. In addition, due to the mobile phone's location and proximity to the cranial nervous system, it has been hypothesized that EMF exposure may lead to a spread of neurological influences. As a result, RF-EMF exposure has been regarded as a potential cause of cranial nervous system carcinogenesis (Hardell et al., 2005). (Hardell et al., 2007) argued that the danger of tumors may increase with the continued use of cell phones over the past ten years. Additionally, cell phone users run the risk of developing malignant gliomas, including acoustic neuromas. Further, several studies have reported that RF-EMFs can cause brain tumors (Myung et al., 2009; Swerdlow et al., 2011; Repacholi et al., 2012). Some researchers claim that brain cancer is not related to cell phone use or nearby cellular base stations (Benson et al., 2013) or to cell phone use in destination. According to another study (Elliott et al., 2010), breast milk exposure to cellular base stations was not associated with cancer in infants at any time during their physiological state or during pregnancy. As a result of the findings thus far, it appears that the relationship between EMF and the cranial nervous system may be complicated by a wide variety of contradictory factors. The causative relationship between hyperbolic carcinogenicity and exposure to electromagnetic fields is unclear (Moulder et al., 2005). Although this tumult has caused controversy, the WHO has classified RF-EMFs as 'possibly carcinogenic' (Baan et al., 2011). In spite of this, scientists have not yet reached specific conclusions on the organization and classification of RF-EMFs as possible carcinogens. Due to the fact that the cell phone has only been used in serious cases for 30 years, any conclusions and results can only be drawn after decades of exposure and further epidemiological analysis.

**Genotoxic effects of Radio waves**

According to Lai and Singh (2004), exposure to radiofrequency and electromagnetic fields has genotoxic effects on cells as a result. (Xu et al., 2010) RF-EMFs (1,850 MHz, SAR 2.1 W/kg) damage mitochondrial DNA, fragment DNA, and cause DNA strand breaks in neurons. A number of RF-EMFs have been reported to affect lymphocytes (Phillips et al., 2009). Additionally, RF-EMF exposure has been reported to cause chromosomal instability, changes in organic phenomena, and mutations in genes. In addition to neuronal cells, blood lymphocytes, sperm, red blood cells, epithelial cells, organic process tissues, lung cells, and bone marrow, genetic toxic effects have also been reported (Magras and Xenos, 1997; Genetic toxicant effects, combined with abnormal gene formation, may cause genetic disorders with abnormal gene formation, including cancer (Hoeijmakers, 2009).

**Effects of emf on the blood-brain barrier**

Studies have found that simple proteins leak through the blood-brain barrier (BBB) when rats are exposed to 900 MHz RF-EMFs (Salford et al., 1994, 2003, 2008; Nittby et al., 2009). Studies using victimization rats and in vitro experiments failed to determine whether there was a leak through the BBB. According to Salford et al. (2003), RF-EMFs significantly induced neuronal damage in the cortex, hippocampus, and basal ganglia. A study conducted previously on stress and anxiety has concluded that RF-EMF exposure induces stress (Ray and Behari, 1990; Millan, 2003; Bouji et al., 2016), resulting in interference with memory performance in special situations (Micheau and Van Marrewijk, 1999). The effectiveness of microwave EMFs has been examined in rats' brains in addition to the EMF's effect on benzodiazepine receptors (Lai et al., 1992) and has been found to inflate such receptors in the cortex. Suton and Carroll (1979) reported that RF-EMF exposure resulted in changes in BBB permeability in rats due to signal-induced hyperthermia at 2.45 GHz. A study by Oscar and Hawkins (1977) has shown that the BBB permeability will be increased not only with the continuous wave but also with the periodic wave (1.3 GHz, 3.0 mW/cm2). RF-EMF can alter the BBB properties based on studies summarized by D'Andrea et al. (2003) and Stam (2010). Nevertheless, D'Andrea et al. (2003) pointed out that alterations in BBB permeation might also depend on SAR (W/kg). RF-EMF exposure can increase nervous system temperature and alter physical BBB specifications if the signal intensity is sufficient (high SAR), but the performance of the BBB remains unchanged at low SAR (D'Andrea et al., 2003). Nevertheless, Fritze et al. (1997) and Salford et al. (1994) concluded that RF-EMF exposure will result in an increase in the permeability of the BBB even without any thermal effects. RF-EMFs have a controversial effect on BBB

permeability, as shown by these contradictory results (D'Andrea et al., 2003). Mice were exposed for 45 minutes to 2.45 GHz microwaves (SAR 2 W/kg) after administration of scopolamine methyl-bromide, a muscarinic antagonist, to assess the impact of RF-EMFs on BBB permeability changes (Cosquer et al., 2005). Then, alterations in psychological characteristics function were measured. We tested whether or not scopolamine methyl bromide crossed the BBB by injecting Evans blue before and after exposure, which binds to albumen within the rat vein. As a result of the RF-EMF altering BBB permeability, scopolamine methyl bromide will cross the BBB more than in animals that weren't exposed to the RF-EMF, and as a result, the animals will perform differently on the radial maze. There was, however, no difference in maze performance between groups managed with the drug before and after exposure to RF or EMF. Therefore, under these experimental conditions and situations, there was no change in the BBB permeability. According to Cosquer et al. (2005), Evans blue from the rats' blood vessels did not stain the parenchyma, indicating this conclusion and result. The BBB's permeability can also be altered by RF-EMFs due to changes in force per unit area (Hossmann and Hermann, 2003), which have been shown to have an effect on the BBB's penetrance. Therefore, comprehensive studies are needed to understand how RF and EMFs affect blood pressure and the effects they have.

**Effects of EMF and RF on learning and memory**

Because of the proximity of the cranial nervous system when using mobile phones, it has been hypothesized that RF-EMF exposure could lead to a variety of neurological effects. Neurological effects found include headaches (Frey, 1998), sleep changes ( Danker-Hopfe et al., 2016), and blood pressure changes (Braune et al., 1998), but there are many contradictions found. RF and EMF may cause cognitive neurological disorders such as tremors, dizziness, headaches, memory loss, focus problems, and sleep disorders. In addition to the epidemiological studies (Santini et al., 2002; Hutter et al., 2006; Abdel-Rassoul et al., 2007), this has also been reported. Although RF-EMF levels commonly encountered in public environments are non-detrimental to humans (Repacholi et al., 2012), due to the high levels of exposure to the cranial nervous system, a significant number of studies have investigated rodent behavioral disorders after exposure to RF-EMFs under various conditions and situations, particularly learning and memory deficits. A cell's autophagy involves a series of mechanisms essential for cell survival and homeostasis (Nixon, 2013; Feng et al., 2014) This process eliminates intracellular damage, old cell organs, and protein accumulated and unnecessary. Our body always activates autophagy to maintain its healthy state and is activated quickly and effectively when stressful situations occur (Nixon, 2013; Feng et al., 2014). Fujimoto et al., 2017). A very limited number of results have been reported regarding autophagy activation in RF-EMF-exposed cells and animals. In a recent study, 55 male Sprague Dawley rats were exposed to electromagnetic pulses (EMPs) at frequencies of 100, 1000, and 10000 Hz for an extended period of time. In the hippocampus, a brain region associated with memory and learning (Jiang et al., 2016), the pulse showed a field strength of 50 kV/m and a frequency of 100 Hz, which significantly increased LC3-II expression. According to studies using human neuroblastoma cells (SH-SY5Y), LC3B-II, Beclin 1, and ATG7 are key autophagy-activating factors that increase significantly after exposure to ELF-EMF. (Marchesi et al., 2014) Also activated LC3B, autophagosomes were found in cells along with phagophore-like structures with two membranes. Recently, we reported that mice exposed to 835 MHz RF-EMF for 4-12 weeks exhibit higher levels of autophagic activity. Autophagy is activated in nerve cells from mice exposed to 835 MHz RF-EMF for 4-12 weeks. In addition to AMPK1, Ulk1, Atg4 / B, Beclin1 / 2, and Atg5 / B, Cortex and LC3B-II were also very active (Kim et al., 2017b). A study conducted on RF-EMF-exposed mice (Kim et al., 2016) found that autophagy was activated in the striatum and hypothalamus, as well as p62, another autophagy-binding protein, in the hippocampal region. The degree of autophagic activity between rat brain areas with autophagic activity was different, and the brainstem area had very low or inactive autophagic activity. According to the study, each area of the brain responds differently to electromagnetic stress. The levels of autophagosomes and autolysosomes have increased three to four times as compared to the control group (Kim et al., 2018b). In light of these results, autophagy activation may play a central role in neuronal adaptation to electromagnetic pressure.

**Thermal effects of EMF exposure to brain**

It has been demonstrated that electromagnetic waves emitted by mobile phones can affect neuronal activity to such a degree (Kleinlogel et al., 2008; Hinrikus et al., 2018), particularly RF-EMFs. According to research conducted by the National Institutes of Health (Volkow et al., 2011), RF-EMFs from mobile phones can stimulate metabolic processes in the brain. We exposed 47 healthy human ears to RF-EMFs from cellular phones (837.5 MHz) for 50 minutes, then used positron emission tomography to visualize the brain's metabolism immediately following the injection of 18F fluorodeoxyglucose. It was found that the brain was sensitive to RF-EMF effects, with glucose metabolism increasing rapidly in the brains exposed (Volkow et al., 2011; Son et al., 2018). As microwave radiation generates heat by rotating polar molecules induced by RF-EMFs, the effects of RF-EMFs on neuronal activity suggest that they may affect brain activity (Wainwright, 2000). In the brain, blood circulation can help to lower some degree of temperature elevation, but tissues such as the human eye, particularly the cornea, can be dangerous, as blood circulation cannot regulate the temperature. The lens of rabbit eyes was elevated to 41°C after exposure to 2,450 MHz for 30 minutes (100-140 W/kg, SAR) (Elder, 2003). In experiments done on monkeys, however, no cataracts were induced. Even though the SAR of RF-EMFs used in this experiment was set far above the allowable limit, it does not necessarily mean that humans who regularly use cellular phones for an extended period may develop eye diseases such as cataracts. (Pall, 2015) More research is needed to understand the biological mechanisms involved and related medical symptoms.

## 2. Conclusion

In the course of scientific and technological progress, humans have developed communication technology and numerous electronic products. With the development of wireless communication technologies like smartphones, which have become a necessity for modern people, the need for the use of various electronic devices is continuously increasing due to these technological developments. Since mankind uses electronic devices to communicate, electromagnetic fields are generated essentially due to the widening frequency ranges. Using any electronic device essentially generates electromagnetic waves. Several pieces of equipment used in broadcasting, communications, and transportation released electromagnetic waves throughout an entire community. Even if the wave is unintended, it can be absorbed by humans or animals. There has been a rapid increase in the use time of smartphones, which are often used close to our bodies. Furthermore, smartphone usage has increased not only among adults, but also among young people, the elderly, and even young children. As a result, electromagnetic fields released by electronic devices, including smartphones, are becoming increasingly concerned about their possible biological effects. Artificial electromagnetic fields, however, have not been studied in terms of their effects on living organisms freed from their use. According to the International Organization for Research on Cancer (IARC), RF-EMFs can cause cancer in humans (Baan et al., 2011). Due to the proximity of the cranial nervous system and the location where the cellular phone is primarily used, it has been hypothesized that RF-EMF exposure may cause a wide range of neurological effects. There are several neurological abnormalities associated with these disorders, including headaches (Frey, 1998), sleep changes (Wagner et al., 1998), and changes in electrical activity (Braune et al., 1998; Mann et al., 1998). In addition, multiple epidemiological studies have revealed significant statistical results for neurological cognitive disorders resulting from RF-EMF (Kolodynski and Kolodynska, 1996; Santini et al., 2002; Hutter et al., 2006; Abdel-Rassoul et al., 2007), including headache, tremors, dizziness, memory loss, and loss of concentration. There will likely be more mechanisms involved than those mentioned in this review as a possible mechanism for changing neurobiological functions due to RF-EMF exposure. This review summarizes only recent research on thermal effects, autophagy activation, ion-channel expression changes, and changes in myelin sheaths. It has been shown that RF-EMF exposure to living creatures may have biological effects, but they cannot be directly applied to humans. Most of these studies used cell or animal models. For the biological effects of RF-EMF exposure on humans to be confirmed, precise epidemiological studies are required. As a result of concern about the biological effects of RF-EMFs, the government has recently introduced RF-EMF regulations for individual devices. In the scientific community, however, there are still no well-established biological effects of exposure to electromagnetic fields. As a result, international standards should be applied at the preventive level at least, and information about these standards should be made available to the public in a transparent manner.

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