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REVIEW ARTICLE

Effect of Electromagnetic Radiations on Anxiety Related Behavior: A Review

Balwant P. Salunke*, Sudhir N. Umathe, Jagatpalsingh G. Chavan

Department of Pharmaceutical Sciences, Rashtrasant Tukadoji Maharaj Nagpur University, Mahatma Jyotiba Fuley Shaikshanik Parisar, Amravati Road, Nagpur (MS), India-440 033

ABSTRACT

Electromagnetic radiation (EM radiation or EMR) is a form of energy emitted and absorbed by charged particles, which exhibits wave-like behavior as it travels through space. Anxiety is a normal human emotion that everyone experiences at times. Many people feel anxious, or nervous, when faced with a problem at work, before taking a test, or making an important decision. They can cause such distress that it interferes with a person's ability to lead a normal life. Over the past decades, continual evidence has demonstrated that extremely low frequency magnetic field (ELF MF) and Radiofrequency (RF) radiations produced effects on cognition, nervous system function, and brain activity. However, studies have been carried out at various strengths and some of the results are not promising. Therefore, further studies are warranted to critically evaluate the ELF MF and RF exposure on anxiety related behaviors and mechanisms involved therein.

KEYWORDS: Anxiety, Electromagnetic Radiations, Extremely Low Frequency Magnetic Field, Microwaves

INTRODUCTION

In today's society, at least some degree of stress and anxiety have become a normal part of our lives as we struggle with financial troubles, the death of a loved one or friend, demanding jobs, strained relationships, or other difficult situations (1).

An anxiety disorder is a serious mental illness. For people with anxiety disorders, worry and fear are constant and overwhelming, and can be crippling. Anxiety disorder is a blanket term covering several different forms of a type of common psychiatric disorder characterized by excessive rumination, worrying, uneasiness, apprehension and fear about future uncertainties either based on real or imagined events, which may affect both physical and psychological health. There are numerous psychiatric and medical syndromes which may mimic the symptoms of an anxiety disorder such as hyperthyroidism which is frequently misdiagnosed as generalized anxiety disorder (2). Symptoms of an anxiety disorder include chest pain, heart palpitations, feelings of suffocation, muscle tension, headaches, back pain, muscle spasms and tics, excessive sweating, dizziness, digestive disturbances, dry mouth, and insomnia. Attacks can be triggered by caffeine, alcohol, sugar, B vitamin deficiency, calcium or magnesium deficiencies, food allergies, certain other drugs, and the infusion of lactate (lactic acid) into the blood (1, 2).

ELECTROMAGNETIC SPECTRUM:

Electromagnetic radiation (EMR) has both electric and magnetic field components, which stand in a fixed ratio of intensity to each other, and which oscillate in phase perpendicular to each other and perpendicular to the direction of energy and wave propagation. In a vacuum, electromagnetic radiation propagates at a characteristic speed, the speed of light.

EMR is a particular form of the more general electromagnetic field (EMF), which is produced by moving charges. EMR is associated with EMFs that are far enough away from the moving charges that produced them that absorption of the EM radiation no longer affects the behavior of these moving charges. These two types or behaviors of EMF are sometimes referred to as the near and far field. In this language, EMR is merely another name for the far-field. Charges and currents directly produce the near-field. However, charges and currents produce EMR only indirectly—rather, in EMR, both the magnetic and electric fields are produced by changes in the other type of field, not directly by charges and currents. This close relationship causes the electric and magnetic fields in EMR to stand in a fixed ratio of strengths to each other, and to be found in phase, with maxima and nodes in each found at the same places in space.

EMR is classified according to the frequency of its wave. The electromagnetic spectrum, in order of increasing frequency and decreasing wavelength, consists of radio wave, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays (3).

*Corresponding author: Balwant P. Salunke (Ph.D. Research scholar), / Email: balwantsalunke@yahoo.com,

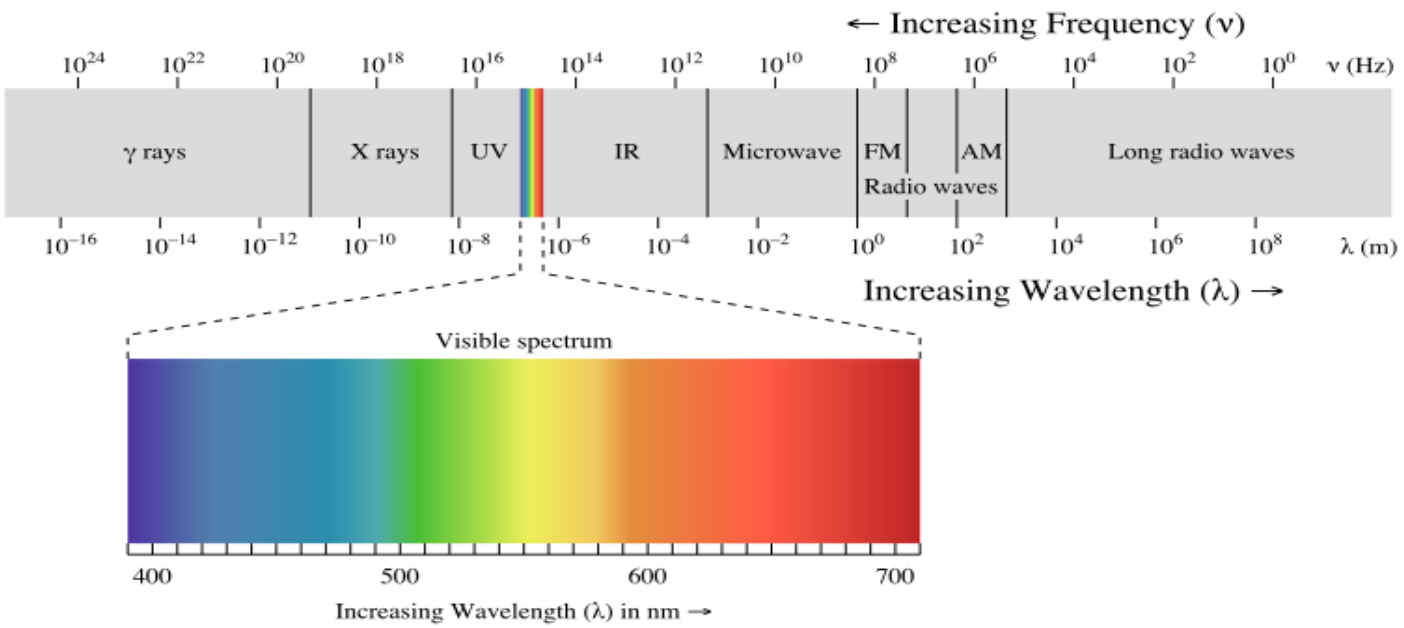

Figure 1: Electromagnetic Spectrum (4)

The effects of EMR upon biological systems depend both upon the radiation's power and frequency. For lower frequencies of EMR up to those of visible light (i.e., radio, microwave, infrared), the damage done to cells and also too many ordinary materials under such conditions is determined mainly by heating effects, and thus by the radiation power. By contrast, for higher frequency radiations at ultraviolet frequencies and above (i.e., X-rays and gamma rays) the damage to chemical materials and living cells by EMR is far larger than that done by simple heating, due to the ability of single photons in such high frequency EMR to damage individual molecules chemically (3).

TYPES OF ANXIETY DISORDERS:

There are several recognized types of anxiety disorders, including:

1. **Panic disorder:** People with this condition have feelings of terror that strike suddenly and repeatedly with no warning. Other symptoms of a panic attack include sweating, chest pain, palpitations (irregular heartbeats), and a feeling of choking, which may make the person feel like he or she is having a heart attack or "going crazy."
2. **Post-traumatic stress disorder (PTSD):** PTSD is a condition that can develop following a traumatic and/or terrifying event, such as a sexual or physical assault, the unexpected death of a loved one, or a natural disaster. People with PTSD often have lasting and frightening thoughts and memories of the event and tend to be emotionally numb.
3. **Obsessive-compulsive disorder (OCD):** People with OCD are plagued by constant thoughts or fears that cause them to perform certain rituals or routines. The disturbing thoughts are called obsessions, and the rituals are called compulsions. An example is a person with an unreasonable fear of germs who constantly washes his or her hands.
4. **Specific phobias:** A specific phobia is an intense fear of a specific object or situation, such as snakes, heights, or flying. The level of fear is usually inappropriate to the situation and may cause the person to avoid common, everyday situations.
5. **Social anxiety disorder:** Also called social phobia, social anxiety disorder involves overwhelming worry and self-consciousness about everyday social situations. The worry often centers on a fear of being judged by others, or behaving in a way that might cause embarrassment or lead to ridicule.
6. **Generalized anxiety disorder:** This disorder involves excessive, unrealistic worry and tension, even if there is little or nothing to provoke the anxiety (5).

ANXIETY SYMPTOMS:

The following list is an example of some of the symptoms associated with anxiety. They involve our body, mind and behavior.

1. **Physical Symptoms:**
    - Fast and shallow breathing.
    - Palpitations (Rapid / strong / irregular heartbeat).
    - Trembling and shaking.

- Excessive sweating.
- Blushing.
- Legs feel like jelly.
- Dry throat and difficulty swallowing.
- Dizziness and feeling light-headed.
- Tightness across the chest.
- Nausea.
- Generally feeling 'on-edge'.
- Needing the toilet.

2. **Mental Symptoms:**
   - Feelings of apprehension and dread.
   - Being 'mildly scared' for much of the time.
   - Trouble concentrating.
   - Starting to worry more.
   - Irritability.
   - Anger.
   - Increased self-consciousness.
   - Thoughts about illness.
   - Restlessness.
3. **Long-term Behavioral Symptoms:**
   - Extreme anxiety and panic around other people.
   - Excessive Worrying
   - Avoidance behavior
   - Obsessions and compulsions
   - Hypochondria
   - Depression
   - Sexual problems
   - Others include: Aggression, sleep disorders and eating disorders.
4. **Psychological Symptoms:**

These can be expressed in the way we think, feel and behave, and may include:

- Perfectionism
- Constantly making comparisons
- Excessive self-consciousness
- Child-like thoughts and behaviors
- Fantasizing
- Excessive Tidiness
- Symmetry
- Ending sentences with questions
- Mild paranoia
- Obsessed with body image
- Poor posture
- Others include: Persistent negative thoughts and images, constantly looking back for reasons and answers, and feelings of having no control over our mind or body (6).

ELECTROMAGNETIC RADIATIONS:

Electromagnetic Field refers to the two types of fields associated with any kind of electricity – electric fields and magnetic fields. Electric and magnetic fields are produced by both natural and man-made sources that surround us in our daily lives. They occur throughout nature and in our own bodies. The earth itself produces a magnetic field, which is used for compass navigation.

Electric fields are related to voltage. Voltage is analogous to pressure in a water pipe. Higher voltages produce stronger electric fields.

Magnetic fields are related to the amount of current that is flowing. Current is analogous to the rate of fluid flow in a water pipe. Higher currents produce stronger magnetic fields.

Extremely low frequency magnetic field (ELF MF) are electromagnetic oscillating fields defined as having frequencies below 300 Hz, generated by various household appliances and industrial devices including electrical power lines (50/60 Hz) (15).

Mobile phones, mobile phone base stations and other wireless communication devices emit RF (radiofrequency) radiations. 3G mobile phones operate at lower power levels than both Global System for Mobile Communication (GSM) and Code division multiple access (CDMA) handsets. The maximum power from a 3G phone (2100 MHz) is 0.125 watts produced over a 5 MHz bandwidth, whereas GSM phones (900 and 1800 MHz) emit an average power of 0.25 and 0.125 watts over a 0.2 MHz bandwidth and CDMA handsets (800 MHz) have a maximum power of 1 watt.

Microwaves are a specific category of radio waves that can be defined as radiofrequency radiation where frequencies range upward from several hundred megahertz (MHz) to several gigahertz (GHz). One of the most familiar and widespread uses of microwave energy is found in household microwave ovens, which operate at a frequency of 2450 MHz (2.45 GHz).

EMR AND ANXIETY:

Laboratory studies showed that the nervous system of both human as well as animal is sensitive to both ELF MF and radiofrequency (RF) fields. Assessable changes in brain function and behavior occur at level associated with new technologies including cell phone use. Relatively limited study has been done on the effect of ELF MF and RF on the emotional status.

Concern about the possible adverse psychological consequences of exposures to EMFs stems from reports in the late 1960's of symptoms such as headache, fatigue and disruption of sleep patterns in occupationally exposed

extra-high voltage switchyard workers (17, 18). Nervous and behavioral effects of RF radiations on humans have been reported for five decades. Behavioral changes due to RF radiations are reported in many scientific studies (19). Silverman, (1973) is an early reviewer of health effects linked to microwave exposure. In an earlier study, Lai et al. (1992) also addressed the effects of electromagnetic fields (EMFs) on benzodiazepine receptors in the rat brain; and found the latter to be increased in the cortex (20). Interestingly, these receptors are involved in stress and anxiety responses (21). Furthermore, exposure to EMFs was occasionally reported to induce stress (22).

Epidemiological study has suggested an association between chronic ELF MF exposure and depression. It was also reported that residential exposure to ELF MF could increase trait anxiety in women. Moreover, a kind of therapeutic magnetic field, repetitive transcranial magnetic stimulation (rTMS), was reported to cause anxiety in normal volunteers (8, 9). In compliance with this , Isogawa et al. (2003, 2005) observed an anxiogenic effect of rTMS in normal rats in elevated plus maze (EPM) (23, 24), in similar way considering animal model reported that magnetic field was found to modify rodent behavior in open field test (OFT) (25, 26, 27). In recent past, the chronic effect of repeated ELF MF exposure on the anxiety state has been studied. Studies on this aspect helped to understand the bio-effects on nervous system and behavioral changes induced by ELF MF. The 50 Hz sinusoidal ELF MF was generated from a pair of Helmholtz coils and the strength of magnetic field was adjusted to 2mT. The ELF MF exposure was conducted repeatedly in every afternoon (2:00–7:00 p.m.) for 25 days. To obtain a more precise and comprehensive assessment of anxiety-related behaviors, authors adopted three classic behavioral paradigms, i.e. OFT, EPM and light/dark box, which were proved to be valid by abundant studies. The combination effects of the three tests were evaluated on the 21^{th}, 23^{th} and 25^{th} exposure day, respectively, as the evidence of the anxiety level. Results demonstrated that EMF exposure 4 h/day increased the anxiety-like behaviors in rats in the OFT and the EPM test. (7).

The frequencies of interest for RF related to mobile phone signals range from approximately 450 to 2600 MHz. The most commonly studied of these frequencies is the 900 MHz GSM, but the number of studies including UMTS phones signals (1800-1900 MHz) has increased over the last years. In recent past the study assessed prevalence of EMF related and EMF nonrelated symptoms in humans, this showed that the mobile phones increased levels of exhaustion and depression but not of anxiety, somatization, and stress (10). On the other hand, recently, Sokolovic et al. (2012) studied the effect of microwave radiation from mobile phone on anxiety behavior and it is reported to produce anxiety related behavior in animals. The rats were exposed to microwave radiation (4 h/day) for 20, 40 and 60 days. Microwave radiation exposed animals showed an anxiety related behavior (agitation, irritability) after 10 days of exposure and, also suggested the involvement of melatonin in its effect. (11). However, another study by using RF radiation has shown that short term exposure to a 1439 MHz time division multiple access (TDMA) EMF does not alter melatonin and serotonin synthesis in rats (12). Furthermore, recent study address possible associations between excessive use of mobile phones and certain psychological variables indicates that chronic stress, low emotional stability, depression are associated with problematic mobile phone use (13) suggesting possible adverse effects on nervous system . In addition, a recent literature on mobile phone use suggests that women with low self-esteem are the most vulnerable group, and the most commonly associated psychopathological symptom in relation to mobile phone use reported was depression (14).

Although numerous studies have been carried out in the epidemiology, cellular biology, and pharmacology and toxicology research fields, the potential adverse effects of EMR exposure on the human central nervous system (CNS) are still controversial (16).

CONCLUSION:

Anxiety disorder is one of the most common psychiatric disorders, which is proved to be associated with a variety of behavioral responses, including cognitive behaviors. Several studies proposed that the mechanism might relate to the involvement of EMR in modulation of opioid system, vestibular function and melatonin. Methodological limitations in available studies, prevents conclusions about causal effects of EMRs on the studied health outcomes in humans and in animals. Further studies on anxiety and other emotion related behaviors, such as depression, including studies on the mechanisms involved therein are needed for fully understanding of the effects of EMR on emotional state.

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