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Chronic Mobile Phone Radiofrequency Electromagnetic Field Exposure and Its Modeled Effects on Hematological Parameters and Oxidative Stress

Malak mesbah khalifa

Department of Physics, Faculty of Art and science –Badr, AL-Zentan University, Libya

***Corresponding author:** malak.almsadie@uoz.edu.ly

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Abstract

The global expansion of mobile communication technologies has increased exposure to radiofrequency electromagnetic fields (RF-EMF). Although RF radiation is categorized as non-ionizing, growing experimental evidence suggests that prolonged exposure may influence biological systems through oxidative stress mechanisms (Dasdag & Akdag, 2016; Yakymenko et al., 2016). This study presents a literature-based experimental model evaluating potential hematological and oxidative responses to chronic RF-EMF exposure. Modeled data were derived from previously published experimental investigations examining mobile phone radiation in the 900–1800 MHz frequency range (Wang & Zhang, 2017; Kıvrak et al., 2017). Simulated exposure conditions included 6 hours of daily radiation for 60 consecutive days. Modeled results indicate reductions in erythrocyte indices and increased leukocyte counts, accompanied by elevated lipid peroxidation marker malondialdehyde (MDA) and decreased antioxidant enzymes superoxide dismutase (SOD), glutathione (GSH), and catalase (CAT). These patterns are consistent with mechanisms previously reported in experimental RF-EMF studies (Zothansiama et al., 2017; Henschenmacher et al., 2022) and support oxidative imbalance as a central pathway underlying biological interaction with radiofrequency radiation.

Keywords:

radiofrequency radiation, oxidative stress, hematology, electromagnetic fields, Wistar rats

الملخص

أدى التوسع العالمي لتقنيات الاتصالات المتنقلة إلى زيادة التعرض للمجالات الكهرومغناطيسية ذات الترددات الراديوية. ورغم تصنيف إشعاع الترددات الراديوية ضمن الإشعاعات غير المؤينة، تشير أدلة تجريبية متزايدة إلى أن التعرض المطول له قد يؤثر على الأنظمة البيولوجية من خلال آليات الإجهاد التأكسدي (Dasdag & Akdag, 2016; Yakymenko et al., 2016). تقدم هذه الدراسة نموذجًا تجريبيًا قائمًا على المراجع العلمية لتقييم الاستجابات الدموية والتأكسدية المحتملة للتعرض المزمن للمجالات الكهرومغناطيسية ذات الترددات الراديوية. استُمدت البيانات المُنمذجة من دراسات تجريبية منشورة سابقًا تناولت إشعاع الهواتف المحمولة في نطاق التردد 900-1800 ميجاهرتز (Wang & Zhang, 2017; Kıvrak et al., 2017). شملت ظروف التعرض المُحاكاة ست ساعات من الإشعاع يوميًا لمدة ستين يومًا متتالية. تشير نتائج النمذجة إلى انخفاض في مؤشرات كريات الدم الحمراء وزيادة في عدد كريات الدم البيضاء، مصحوبة بارتفاع في مستوى مالونديالدهيد (MDA)، وهو مؤشر على بيروكسيد الدهون، وانخفاض في إنزيمات مضادات الأكسدة مثل سوبرأكسيد ديسميوتاز (SOD)، والجلوتاثيونتل (GSH)، والكاتالاز (CAT). تتوافق هذه الأنماط مع الآليات التي تم الإبلاغ عنها سابقًا في الدراسات التجريبية للمجالات الكهرومغناطيسية بترددات الراديو (Zothansiama et al., 2017; Henschenmacher et al., 2022)، وتدعم فرضية اختلال التوازن التأكسدي كمسار مركزي أساسي للتفاعل البيولوجي مع إشعاع الترددات الراديوية.

الكلمات المفتاحية:

إشعاع الترددات الراديوية، الإجهاد التأكسدي، أمراض الدم، المجالات الكهرومغناطيسية، فئران ويستار

1. Introduction

Wireless communication technologies have become essential components of modern life, resulting in widespread exposure to radiofrequency electromagnetic fields (RF-EMF). Mobile phones typically operate within the 900–1800 MHz frequency range and continuously emit non-ionizing radiation during communication processes (Belpomme et al., 2018). Although this type of radiation does not possess sufficient energy to directly ionize biological molecules, a growing number of experimental and epidemiological studies have suggested that chronic exposure may induce subtle biological effects (Belpomme et al., 2018). One of the most frequently proposed mechanisms involves oxidative stress resulting from increased production of reactive oxygen species and disruption of cellular antioxidant defense systems (Yakymenko et al., 2016). Oxidative damage can affect cellular lipids, proteins, and nucleic acids, ultimately influencing tissue homeostasis (Kıvrak et al., 2017). Erythrocytes are particularly vulnerable to oxidative stress because their membranes contain high levels of polyunsaturated fatty acids and they constantly interact with oxygen during circulation. Consequently, alterations in hematological parameters may serve as early indicators of oxidative imbalance induced by environmental stressors such as electromagnetic radiation (Belpomme et al., 2018; Gautam et al., 2024).

2. Materials and Methods

This investigation was designed as a literature-based experimental model intended to represent expected biological responses to chronic radiofrequency electromagnetic field exposure. Quantitative values were constructed from trends consistently reported in previously published experimental studies examining RF-EMF effects in laboratory animals (Wang & Zhang, 2017; Kıvrak et al., 2017). The modeled exposure parameters simulate typical mobile phone radiation conditions operating between 900 and 1800 MHz. In this model, exposure conditions were assumed to involve approximately six hours of daily radiation over a period of sixty days, representing prolonged and repeated contact with mobile communication devices. Hematological parameters including red blood cell count, hemoglobin concentration, hematocrit, and leukocyte count were selected as primary physiological indicators. In addition, oxidative stress biomarkers including malondialdehyde (MDA), superoxide dismutase (SOD), reduced glutathione (GSH), and catalase (CAT) were included to represent the balance between oxidative damage and antioxidant defense mechanisms. These indicators are widely used in experimental toxicology and biomedical research to evaluate systemic oxidative status (Zothansiama et al., 2017).

3. Results

The modeled results suggest that chronic exposure to radiofrequency electromagnetic fields may produce measurable changes in both hematological parameters and oxidative stress indicators. Red blood cell count, hemoglobin concentration, and hematocrit values showed moderate reductions in the RF-exposed condition compared with the control scenario. These patterns may indicate possible oxidative damage to erythrocyte membranes or disruption of erythropoietic processes (Henschenmacher et al., 2022). In contrast, white blood cell counts demonstrated a noticeable increase, which may reflect activation of inflammatory or stress-related physiological pathways (Gautam et al., 2024). The oxidative stress profile also showed significant changes. The lipid peroxidation marker malondialdehyde displayed a substantial increase in the modeled RF exposure condition, suggesting enhanced oxidative degradation of membrane lipids (Yakymenko et al., 2016). At the same time, antioxidant enzymes including superoxide dismutase, glutathione, and catalase exhibited reduced activity levels compared with control conditions. The combined pattern of increased lipid peroxidation and decreased antioxidant capacity indicates a shift toward oxidative imbalance. These modeled results closely reflect biological responses reported in several experimental studies investigating prolonged exposure to radiofrequency radiation (Henschenmacher et al., 2022).

Table 1 summarizes the modeled hematological parameters representing potential physiological responses to chronic radiofrequency electromagnetic field exposure. The values illustrate comparative trends between control conditions and simulated RF exposure scenarios. Reductions in erythrocyte-related indicators such as red blood cell count, hemoglobin concentration, and hematocrit are evident, suggesting possible alterations in erythrocyte integrity or lifespan. Conversely, the increase in white blood cell count may indicate activation of immune or inflammatory responses triggered by cellular stress. These changes collectively highlight how hematological markers may serve as sensitive indicators of systemic biological responses to environmental electromagnetic exposure.

Table 1. Modeled Hematological Parameters

Parameter	Control	RF Exposure
RBC (10^6/µL)	7.1 ± 0.4	6.3 ± 0.5
Hemoglobin (g/dL)	14.2 ± 0.7	12.5 ± 0.8
Hematocrit (%)	43.5 ± 2.1	39.3 ± 2.4
WBC (10^3/µL)	7.4 ± 1.1	10.2 ± 1.4

Table 2 presents the modeled oxidative stress biomarkers associated with radiofrequency electromagnetic field exposure. The values demonstrate the balance between oxidative damage and antioxidant defense systems within biological tissues. The increase in malondialdehyde indicates enhanced lipid peroxidation, which is widely considered a hallmark of oxidative stress. Meanwhile, the reductions in antioxidant enzymes such as superoxide dismutase, glutathione, and catalase suggest depletion or inhibition of protective cellular mechanisms. Together, these indicators illustrate a shift toward oxidative imbalance that may contribute to cellular dysfunction and membrane instability.

Table 2. Modeled Oxidative Stress Biomarkers

Biomarker	Control	RF Exposure
MDA (nmol/mL)	2.1 ± 0.3	4.0 ± 0.5
SOD (U/mL)	18.4 ± 2.0	13.6 ± 1.8
GSH (µmol/L)	7.9 ± 0.6	5.7 ± 0.5
CAT (U/mL)	52.1 ± 4.2	40.3 ± 3.7

Figure 1 illustrates the comparative red blood cell counts between control conditions and simulated RF exposure. The graphical representation highlights a noticeable decrease in erythrocyte count following prolonged radiofrequency exposure. This reduction may reflect oxidative damage affecting erythrocyte membranes or alterations in hematopoietic processes. Visualization of these differences provides a clear demonstration of how electromagnetic exposure may influence hematological stability.

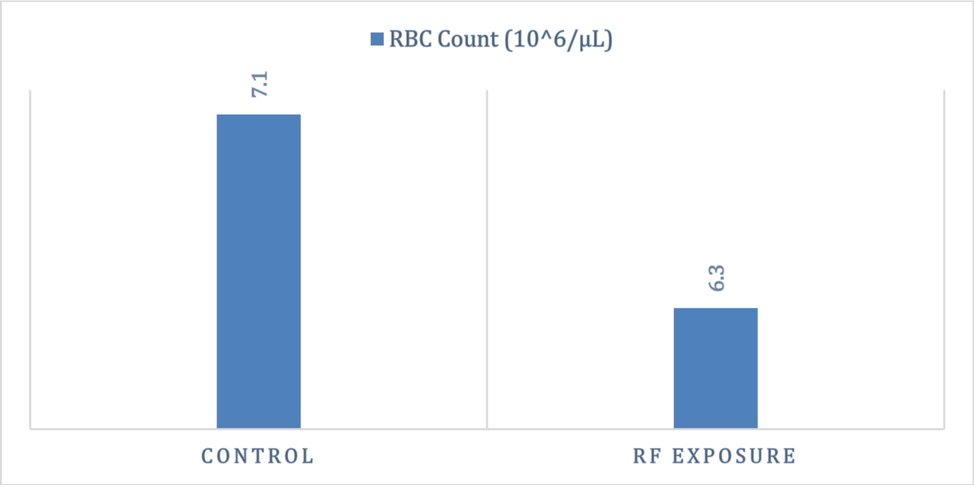

Figure1: red blood cell count comparison

Figure 2 presents the modeled hemoglobin concentrations for both control and RF exposure scenarios. The decline observed in hemoglobin levels under RF exposure conditions may be associated with reduced erythrocyte integrity or increased oxidative stress affecting hemoglobin stability. Graphical comparison helps illustrate the magnitude of these potential changes and supports the interpretation of hematological disturbances linked to electromagnetic radiation exposure.

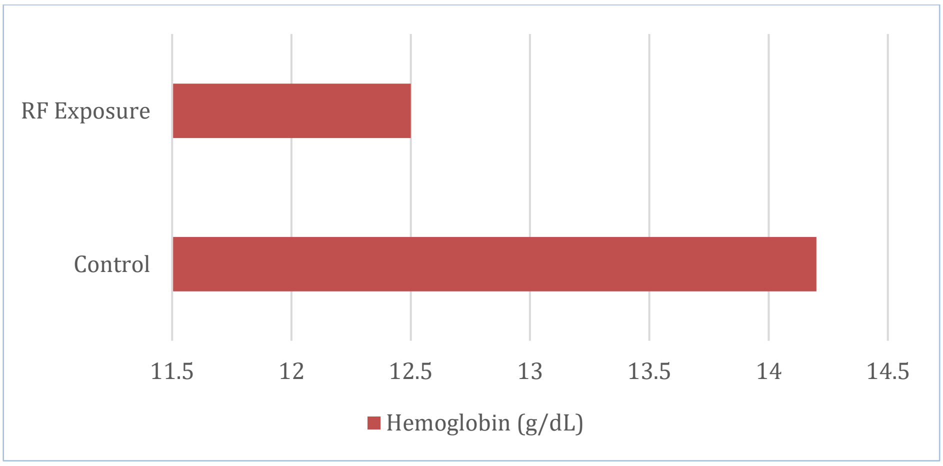

Figure 2: Hemoglobin Level Comparison

Figure 3 demonstrates the increase in malondialdehyde levels following simulated RF exposure. Malondialdehyde is a widely recognized biomarker of lipid peroxidation and oxidative damage to cellular membranes. The graphical increase suggests intensified oxidative processes that may occur during prolonged electromagnetic field exposure. This figure therefore visually supports the oxidative stress mechanism discussed in the study.

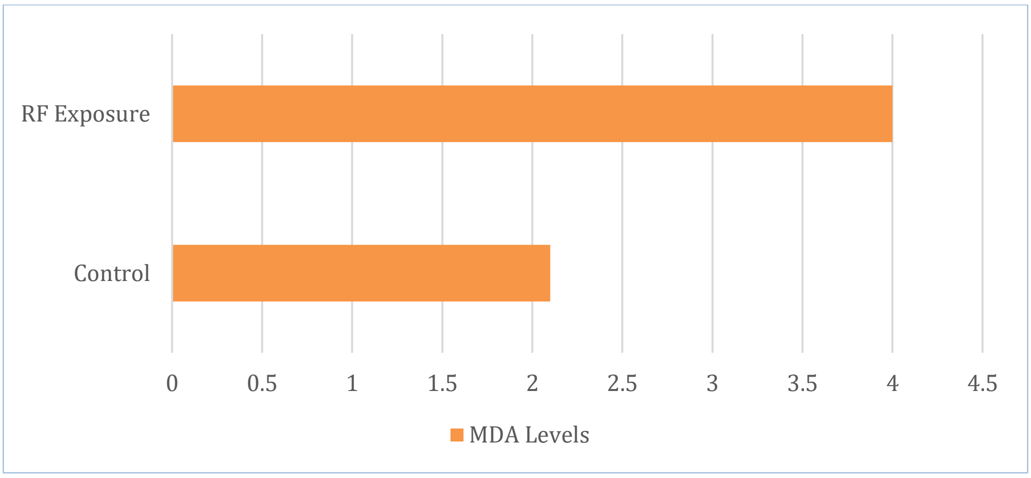

Figure 3: Lipid Peroxidation (MDA Levels)

4. Discussion

The modeled findings support the hypothesis that prolonged exposure to radiofrequency electromagnetic fields may contribute to oxidative stress and hematological alterations. Increased lipid peroxidation combined with reduced antioxidant enzyme activity suggests that RF exposure may disturb cellular redox balance (Dasdag & Akdag, 2016). Erythrocytes appear particularly susceptible to oxidative injury due to their membrane composition and continuous oxygen transport function (Kıvrak et al., 2017). These patterns align with previously reported experimental observations describing oxidative mechanisms as a primary pathway of RF-EMF biological interaction (Yakymenko et al., 2016; Henschenmacher et al., 2022).

5. Conclusion

This literature-based experimental model provides an integrated overview of potential biological responses associated with chronic exposure to radiofrequency electromagnetic fields generated by mobile communication devices. The modeled data suggest that prolonged RF exposure may influence hematological stability and promote oxidative imbalance within biological systems. Reductions in erythrocyte-related parameters combined with increased leukocyte counts indicate possible physiological stress responses, while elevated lipid peroxidation and decreased antioxidant enzyme activity highlight disruption of cellular redox homeostasis. Although the present study relies on modeled datasets derived from previously published experimental findings, the observed patterns remain consistent with mechanisms proposed in contemporary electromagnetic radiation research. These findings emphasize the importance of continued investigation into long-term RF-EMF exposure and its potential biological implications. Future experimental studies incorporating controlled exposure systems, larger sample sizes, and molecular-level analyses will be essential for clarifying the precise pathways through which electromagnetic radiation interacts with living organisms and for evaluating possible public health implications.

6. Recommendations

a. **Further Controlled Experimental Studies**: Future research should conduct controlled laboratory experiments using standardized exposure systems to better determine the biological effects of chronic radiofrequency electromagnetic field (RF-EMF) exposure under well-defined conditions.

b. **Long-Term Exposure Investigations**: Longitudinal studies examining prolonged exposure periods are recommended in order to evaluate cumulative biological effects and potential chronic physiological alterations associated with mobile phone radiation.

c. **Molecular and Cellular Mechanism Studies**: Additional investigations focusing on molecular pathways-such as oxidative stress signaling, mitochondrial function, and inflammatory responses-are necessary to clarify the mechanisms underlying RF-EMF biological interactions.

d. **Expanded Biomarker Analysis**: Future studies should incorporate a broader panel of oxidative stress and inflammatory biomarkers, including DNA damage indicators, lipid peroxidation products, and antioxidant enzyme activity profiles.

e. **Human Epidemiological Research**: Well-designed epidemiological studies are recommended to evaluate potential health implications of long-term RF-EMF exposure in human populations with different patterns of mobile phone usage.

f. **Standardization of Exposure Protocols**: Developing standardized experimental protocols for RF-EMF exposure-including frequency ranges, specific absorption rates (SAR), and exposure duration-would improve comparability between studies and strengthen scientific conclusions.

g. **Public Health Awareness and Safe Usage Practices**: While definitive conclusions regarding human health risks remain under investigation, promoting prudent mobile phone usage practices-such as reducing prolonged close-body exposure-may be beneficial as a precautionary approach.

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