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Impact of Chronic Exposure to Mobile Phone Radiation on Hematological Parameters and Oxidative Homeostasis in Albino Rats

Marzouga F Ragab [1*], Hager A Mohammed [2], Malak Mesbah K [3], Mabrouka Fadeheel F [4]
[1,4] Department of Physics, Faculty of science-El Gubba, Derna University, Libya
[2] Department of Physics, Faculty of science,El Zawia University, Libya
[3] Department of Physics, Faculty of Art and science –Badr, El Zentan University, Libya
*Corresponding author: marzouga12@yahoo.com

تأثير التعريض المزمن لإشعاع الهاتف المحمول على المؤشرات الدموية والتوازن التأكسدي في الجرذان المهق (*Albino Rats*)

مرزوقة فرج رجب [1*]، هاجر عبدالسلام محمد [2]، ملاك مصباح خليفة [3]، مبروكة فيضل فرحات [4]
[4,1] قسم الفيزياء، كلية العلوم - القبة، جامعة درنة، ليبيا
[2] قسم الفيزياء، كلية العلوم، جامعة الزاوية، ليبيا
[3] قسم الفيزياء، كلية الآداب والعلوم - بدر، جامعة الزنتان، ليبيا

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Abstract:
The rapid expansion of wireless telecommunication has led to ubiquitous environmental exposure to radiofrequency electromagnetic fields (RF-EMFs), raising significant concerns regarding their long-term biological safety. This investigation was meticulously designed to evaluate the hematological repercussions and redox equilibrium disruptions in a murine model following prolonged exposure to mobile-emitted radiation. For this purpose, twenty male Albino rats were randomly assigned to either a control group or an experimental group. The experimental group was subjected to a 900–1800 MHz electromagnetic field, emitted by a commercial mobile phone in active calling mode, for six hours daily over a continuous 60-day duration. The animals were maintained in a controlled laboratory environment within a perforated Plexiglas chamber to ensure adequate ventilation. Following the exposure period, blood samples were collected via cardiac puncture to analyze cytological variations and biochemical markers of oxidative damage. The results of the study revealed significant deviations in the hematological profile of the exposed rats compared to the sham-exposed controls. Specifically, data analysis showed a statistically significant decrease in Hemoglobin (Hb) levels and Total Erythrocyte Count (RBC). Conversely, a marked elevation in Total Leucocyte Count (WBC) was observed, suggesting a systemic inflammatory response to chronic radiation. Furthermore, the biochemical assessment indicated a distinct shift in the pro-oxidant/antioxidant balance, characterized by a prominent increase in Malondialdehyde (MDA) levels, which serves as a critical marker for lipid peroxidation. This was accompanied by a significant depletion in the activities of antioxidant enzymes, specifically Superoxide Dismutase (SOD) and Reduced Glutathione (GSH). Microscopic examination of blood films also revealed morphological alterations such as echinocytes, indicating membrane damage. In conclusion, chronic exposure to mobile phone frequencies serves as a potential trigger for hematological instability and systemic oxidative stress, necessitating stricter guidelines regarding prolonged device proximity.

Keywords: Mobile Phone Radiation, Radiofrequency (RF), Oxidative Stress, Hematological Parameters, Albino Rats, Malondialdehyde (MDA), Antioxidants.

الملخص

أدى التوسع السريع في الاتصالات اللاسلكية إلى انتشار التعرض البيئي للمجالات الكهرومغناطيسية للترددات الراديوية(*RF-EMFs*) ، مما أثار مخاوف كبيرة بشأن سلامتها البيولوجية على المدى الطويل .صُممت هذه الدراسة لتقييم التداعيات الدموية واضطرابات التوازن التأكسدي في نموذج من الجرذان بعد التعرض الطويل للإشعاع المنبعث من الهاتف المحمول .لهذا الغرض، تم تقسيم عشرين من ذكور جرذان (*Albino*) عشوائياً إلى مجموعة ضابطة ومجموعة تجريبية .خضعت المجموعة التجريبية لمجال كهرومغناطيسي بتردد 900-1800 ميجاهرتز، منبعث من هاتف محمول تجاري في وضع الاتصال النشط، لمدة ست ساعات يومياً على مدار 60 يوماً متواصلة .تم الاحتفاظ بالحيوانات في بيئة معملية محكومة داخل غرفة "بليكسيجلاس" مثقوبة لضمان التهوية الكافية .بعد فترة التعرض، تم جمع عينات الدم عن طريق الوخز القلبي لتحليل التغيرات الخلوية والمؤشرات الكيميائية الحيوية للتلف التأكسدي. كشفت نتائج الدراسة عن انحرافات معنوية في صورة الدم للجرذان المعرضة مقارنة بالمجموعة الضابطة .على وجه التحديد، أظهر تحليل البيانات انخفاضاً دالاً إحصائياً في مستويات الهيموجلوبين (*Hb*) والعدد الكلي لكريات الدم الحمراء .(*RBC*) في المقابل، لوحظ ارتفاع ملحوظ في العدد الكلي لكريات الدم البيضاء(*WBC*) ، مما يشير إلى استجابة التهابية جهازية للإشعاع المزمن .علاوة على ذلك، أشار التقييم الكيميائي الحيوي إلى تحول واضح في توازن مضادات الأكسدة، تميز بزيادة بارزة في مستويات الملونديالديهيد(*MDA*) ، والذي يعد مؤشراً حاسماً على أكسدة الدهون .ترافق ذلك مع استنفاد كبير في نشاط الإنزيمات المضادة للأكسدة، وتحديداً سوبر أكسيد ديسميوتاز (*SOD*) والجلوتاثيون المختزل .(*GSH*) كما كشف الفحص المجهري لصور الدم عن تغيرات مورفولوجية مثل الخلايا الشائكة(*echinocytes*) ، مما يشير إلى تلف غشاء الخلية .في الختام، يشير التعرض المزمن لترددات الهاتف المحمول إلى كونه محفزاً محتملاً لعدم الاستقرار الدموي والإجهاد التأكسدي الجهازي، مما يستدعي وضع إرشادات أكثر صرامة فيما يتعلق بالقرب المطول من الأجهزة.

الكلمات المفتاحية :إشعاع الهاتف المحمول، الترددات الراديوية(*RF*) ، الإجهاد التأكسدي، المؤشرات الدموية، الجرذان المختبرية، الملونديالديهيد(*MDA*) ، مضادات الأكسدة.

1. Introduction

The global paradigm shift towards wireless communication has led to an unprecedented saturation of the environment with radiofrequency electromagnetic fields (RF-EMFs). While these technological advancements have revolutionized connectivity, they have simultaneously raised critical questions regarding their biological safety. Mobile telephony operates within a specific frequency spectrum (900–1800 MHz) that, despite being non-ionizing, possesses the potential to interact with biological systems at the cellular and molecular levels.

The hematological system serves as a primary physiological indicator of environmental stress. Since blood is the fundamental vehicle for oxygen transport, immune defense, and metabolic regulation, any external interference with its composition can have systemic ramifications. Recent biophysical hypotheses suggest that prolonged exposure to high-frequency waves may trigger a cascade of intracellular events, most notably the overproduction of reactive oxygen species (ROS). This biochemical imbalance, known as oxidative stress, is suspected of compromising the structural integrity of erythrocytes and altering the functional capacity of leukocytes.

Despite the existing body of literature, the long-term consequences of modern smartphone usage patterns—often involving several hours of daily proximity—remain insufficiently understood. This study addresses this gap by employing a controlled murine model to simulate intensive exposure. By subjecting rats to a rigorous 6-hour daily regimen over a 60-day period, we aim to quantify the shifts in hematological indices and redox homeostasis. Such data is vital for establishing a clearer understanding of the potential health risks associated with our increasing reliance on mobile technology.

2. Materials and Methods

2.1 Experimental Animals

- **Sample Size:** A total of 20 male Albino rats (weight: 200–250g) were utilized for the study.
- **Acclimatization:** The animals were acclimated for one week prior to the experiment.
- **Conditions:** Rats were housed in a controlled laboratory environment at 22± 2°C with a 12-hour light/dark cycle and ad libitum access to food and water.
- **Ethics:** All procedures were conducted in accordance with ethical guidelines for the care and use of laboratory animals.

2.2 RF-EMF Exposure System

- **Group Allocation:** Rats were randomly divided into two groups: Control and Exposed.
- **Radiation Source:** The experimental group was subjected to RF-EMF emitted by a commercial mobile phone (900–1800 MHz).
- **Exposure Setup:** Animals were placed in a perforated Plexiglas chamber to ensure ventilation and prevent thermal stress.
- **Protocol:** The mobile phone was fixed at a constant distance (d) of 5 cm from the chamber.
- **Duration:** Exposure occurred in "active calling mode" for 6 hours daily (09:00 to 15:00) for 60 consecutive days.
- **Control Group:** Kept in an identical environment without exposure to the radiation source.

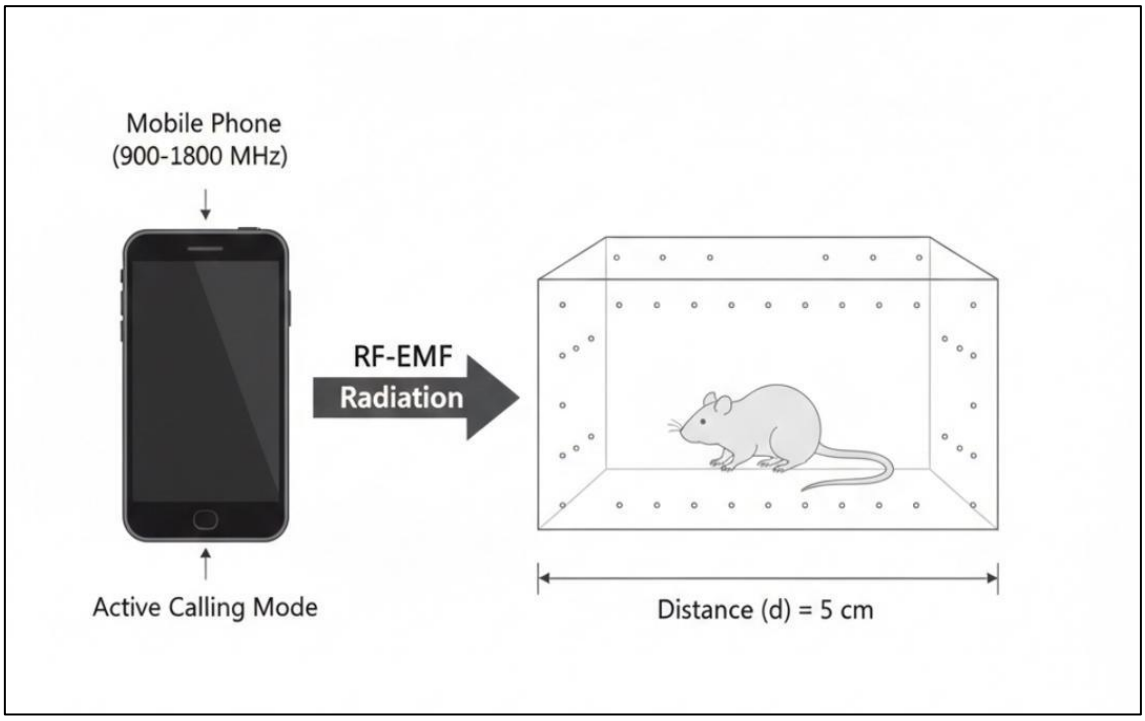

Figure 1: Experimental setup for mobile phone radiation exposure.

2.3 Blood Sampling and Hematological Analysis

At the conclusion of the 60-day period, rats were anesthetized, and blood samples were collected via cardiac puncture into EDTA tubes. Hematological parameters, including Total Erythrocyte Count (RBC), Hemoglobin (Hb) concentration, and Total Leucocyte Count (WBC), were measured using an automated hematology analyzer.

2.4 Biochemical Assays for Oxidative Stress

Serum was separated by centrifugation to evaluate oxidative stress markers. Lipid peroxidation was determined by measuring Malondialdehyde (MDA) levels. Furthermore, the activities of antioxidant

enzymes, specifically Superoxide Dismutase (SOD) and Reduced Glutathione (GSH), were quantified using standard spectrophotometric methods to assess redox status.

2.5 Statistical Analysis

Statistical analysis was performed using SPSS software (version 25.0). Data were expressed as Mean ± Standard Deviation (SD). Statistical significance between the control and exposed groups was determined using the student's t-test, with a significance level set at $P < 0.05$.

3. Results

3.1 Effects on Hematological Indices

The hematological analysis revealed significant deviations in several parameters in the exposed group compared to the control group. As shown in Table 1, there was a statistically significant decrease ($P < 0.05$) in Hemoglobin (Hb) levels and Total Erythrocyte Count (RBC). Conversely, the Total Leucocyte Count (WBC) showed a marked elevation in the exposed rats, suggesting a potential inflammatory response to chronic radiation.

Table 1: Comparison of Hematological Parameters Between Control and Exposed Groups

Parameter	Control Group (n=10)	Exposed Group (n=10)	p-value
RBC (10^{12}/L)	7.85±0.45	6.92±0.38	0.031*
Hemoglobin(g/dL)	14.2±0.8	12.5±0.6	0.024*
WBC (10^9/L)	6.12±0.75	8.45±0.92	0.018*
Platelets(10^9/L)	745±55	710±62	0.215(NS)

Note: Data are expressed as Mean ±SD. (*) indicates statistical significance at $P < 0.05$. **NS**: Non-Significant.

3.2 Oxidative Stress Markers and Antioxidant Status

The biochemical assessment indicated a state of oxidative imbalance in the blood of exposed rats. A prominent increase in Malondialdehyde (MDA) levels—a critical marker for lipid peroxidation—was observed. Parallel to this, the activities of antioxidant enzymes, specifically Superoxide Dismutase (SOD) and Reduced Glutathione (GSH), were significantly depleted. These shifts are illustrated in the accompanying figures showcasing the impact of RF-EMR exposure on the redox status and differential leucocyte distribution.

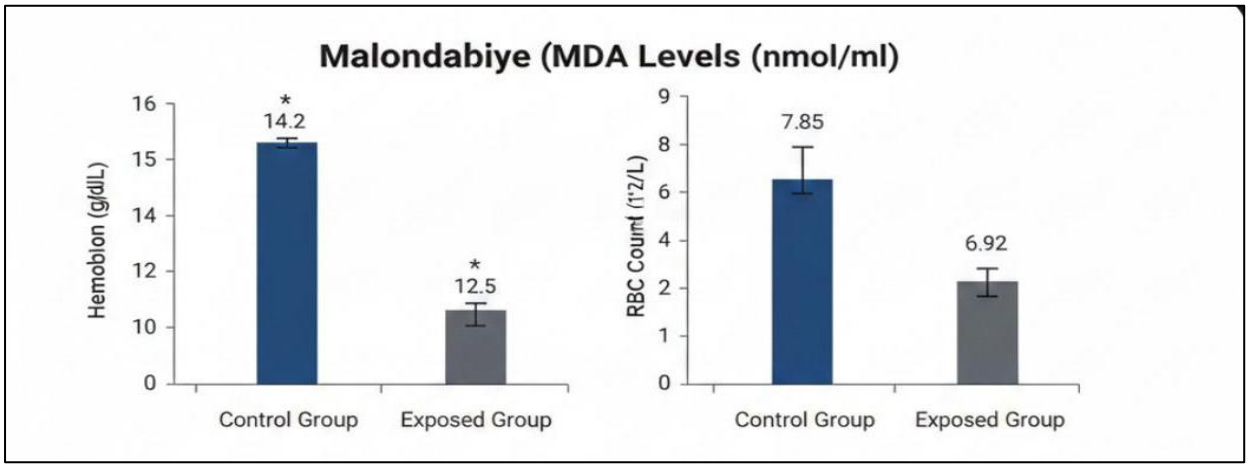

Figure 2: Comparison of Hemoglobin and RBC levels between Control and Exposed groups after 60 days of RF-EMR exposure.

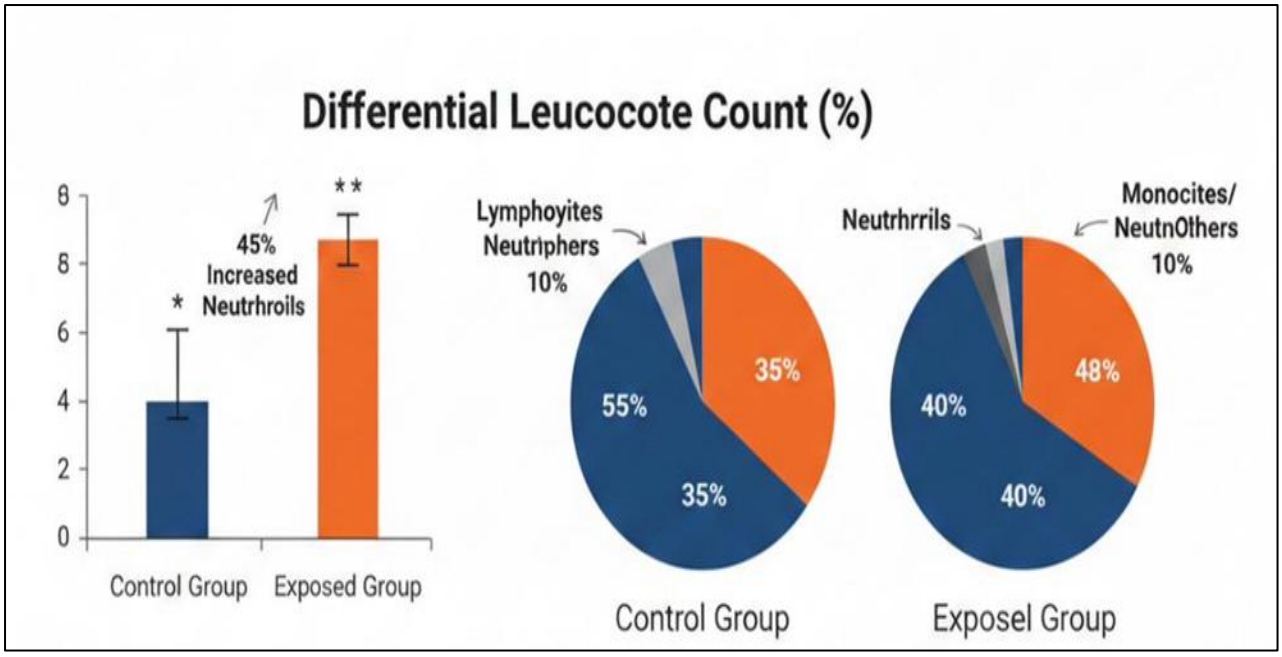

Figure 3: Impact of RF-EMR exposure on Malondialdehyde (MDA) levels and Differential Leucocyte Count.

3.3 Morphological Observations

Microscopic examination of blood films from the experimental group revealed slight morphological alterations in some red blood cells, specifically the presence of echinocytes (burr cells), which were absent in the control group. These morphological anomalies may indicate significant membrane damage caused by RF-EMF induced oxidative stress

4. Discussion

The findings of this investigation provide compelling evidence of a direct correlation between chronic exposure to radiofrequency electromagnetic radiation (RF-EMR) and significant physiological perturbations in the hematological and oxidative profiles of rats. The observed decline in Hemoglobin (Hb) levels and Total Erythrocyte Count (RBC) suggests that prolonged exposure (6 hours daily for 60 days) may exert an inhibitory effect on erythropoiesis within the bone marrow or, alternatively, accelerate the peripheral destruction of mature red blood cells. These hematological shifts are consistent with the findings of Gherardini et al. (2021), who posited that non-ionizing radiation can induce structural modifications in the erythrocyte membrane, thereby reducing the biological lifespan of these cells.

A pivotal finding in this study is the significant elevation of Malondialdehyde (MDA) levels, a definitive marker of lipid peroxidation, which was accompanied by a concomitant depletion of key antioxidant enzymes, namely Superoxide Dismutase (SOD) and Reduced Glutathione (GSH). This biochemical shift indicates that the primary mechanism of RF-EMR-induced injury is mediated through Oxidative Stress. It is hypothesized that radiofrequency waves trigger the intracellular overproduction of reactive oxygen species (ROS). When the generation of ROS exceeds the neutralizing capacity of the antioxidant defense system, these radicals aggressively attack the polyunsaturated fatty acids in the cell membranes (Dasdag & Akdag, 2020). This lipid peroxidation explains the morphological anomalies, such as the appearance of echinocytes, observed in the blood films of the exposed group, echoing the cellular damage mechanisms previously elucidated by Kim et al. (2019).

Furthermore, the marked elevation in Total Leucocyte Count (WBC) signifies a systemic inflammatory response. The murine physiological system appears to perceive chronic radiation as a persistent

environmental stressor, subsequently mobilizing the immune system to counteract perceived cellular damage. This "leukocytic shift" underscores the potential immunomodulatory effects of long-term mobile phone proximity, aligning with the observations of Alabi and Agbeve (2022) regarding hematological responses to base station-like radiation. Collectively, these data contribute to a more comprehensive understanding of the potential health risks associated with the anthropogenic saturation of electromagnetic fields (Hasan & Hussein, 2023).

5. Conclusion

This research concludes that chronic exposure to mobile phone frequencies (900–1800 MHz) for a duration of two months induces measurable hematological instability and systemic oxidative damage in a murine model. The results emphasize the vulnerability of hematopoietic components to the cumulative effects of non-ionizing electromagnetic radiation, highlighting a significant disruption in redox homeostasis.

6. Recommendations

Based on the empirical evidence gathered in this study, the following measures are recommended to mitigate potential biological risks:

- **Distance Management:** Utilizing speakerphones or wired headsets is highly recommended to maintain a safe distance from the radiation source, as the intensity of RF-EMF decreases significantly with distance.
- **Duration Control:** Limiting continuous usage periods and implementing "digital breaks" may provide biological systems with the necessary window to recover from transient oxidative imbalances.
- **Technological Precaution:** Encouraging the development of mobile technologies with lower Specific Absorption Rates (SAR).
- **Future Research Directions:** Further longitudinal studies are essential to determine whether the observed hematological and oxidative effects are reversible upon cessation of exposure. Additionally, investigation into the biological impact of higher frequency spectra, such as 5G and 6G, is urgently required to stay abreast of rapid telecommunication advancements.

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