EVALUATION OF THE EFFECT OF ELECTROMAGNETIC RADIATION FROM CELL PHONES ON BLOOD PARAMETERS ON WISTAR RATS

BY

AKANGBOU EBI

BMS2001082

A PROJECT SUBMITTED TO

DEPARTMENT OF RADIOGRAPHY,

SCHOOL OF BASIC MEDICAL SCIENCES,

UNIVERSITY OF BENIN,

SUPERVISED BY: ELDER DR U.I NWADIKE

October 2025

CERTIFICATION

This is to certify that this research work **'Evaluation of the Effect of Electromagnetic Radiation from Cell Phones on Blood Parameters on Wistar Rats'** written by **AKANGBOU EBI** with matriculation number **BMS2001082 and was** carried out under my and **ELDER DR U.I NWADIKE** supervision.

_____ _____

ELDER DR U.I NWADIKE **DATE**

(PROJECT SUPERVISOR)

_____

_____

MRS F. O. IGBINEDION **DATE**

(HEAD OF DEPARTMENT)

DEDICATION

This research work is dedicated to my late Dad Mr. Anthony Akangbou

ACKNOWLEDGEMENT

Firstly, I am grateful to God Almighty for His grace, strength, motivations and provisions throughout my academic journey. Without His help

Then to my beloved sibling Timi Akangbou, my Mum and my other siblings thank you for your wavering support, encouragement, and sacrifices for me.

Lastly, I am grateful to my mentor (Dr Uzzi), friends, course mates, and loved ones who stood by me with their words of encouragement, prayers, and help in one way or another.

God bless you all.

TABLE OF CONTENT

ABSTRACT

This study investigates the electromagnetic radiation from cell phones on the blood parameters on Wister rats. With cell phones present in every aspect of daily life, both humans and by extension laboratory rats are exposed to RF radiation which may affect their hematological parameters and biological systems. The main aim of this study is to evaluate the hematological effects of radiofrequency electromagnetic radiation from cell phones on female Wistar rats under controlled exposure conditions. The specific objectives are to; (1) measure and compare red blood cell count, hemoglobin concentration, hematocrit, and white blood cell count between Wistar rat exposed to cell phone RF-EMR and unexposed control rat, (2) measure and compare the weight differences between Wistar rats exposed to cell phone RF-EMR and unexposed control rats and (3) assess the relationship between exposure duration and the magnitude of changes in these hematological parameters. A randomized controlled experimental design was used, and involving 8 healthy adults female Wistar rats, aged 6–9 weeks and weighing 45– 65 g. A minimum of 4 rats were equally divided into 2 groups, i.e. 4 rats in the control group and 4 rats in the EMR exposed group. Rats were acclimatized for 9 days, with ad libitum food and water. Then each rat in the exposure group was placed individually in the chamber for 2 min/day during which the cell phone emitting the radiation was placed around the rat. Exposure is from the auto-answer mode cell phone which occurred for 2 minutes per day over 4 weeks. Post-exposure blood samples were compared within and between the two groups. The findings of this study showed that the exposed and control group were comparable in baseline characteristics and the analysis of White Blood Cell (WBC) parameters revealed no statistically significant impact of EMR exposure on

the rats, but a significant rise in red blood cell count and hemoglobin concentration was observed in the exposed rats when compared to the WBC findings. Also, the findings of the Platelet count and most platelet indices did not change significantly. The research concluded that specific and measurable significant alterations in the Red Blood Cell (RBC) profiles, while other parameters, notably White Blood Cells (WBCs) and Platelets, showed numerical trends but no statistically significant differences. It recommends that future studies should Increase the exposure duration per rat from 2 minutes up to 30 minutes and the experimental period should be extended from 4 weeks to 8 or 12 weeks to obtain more robust and reliable data.

Keywords: Electromagnetic radiation**, Cell phones, Wister rats, Blood parameters, H**ematology

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

The use of cell phones has gradually risen throughout the globe with increasing public health concerns affecting the ecosystem; this has also raised the need for scientific research into these effects. This effect became extremely serious with the rapid development of the new generation of wireless networks, built for communication purposes, and mainly for cell phones.

These cell phones emit radiofrequency (RF) electromagnetic radiation (EMR) during communication. In fact, the World Health Organization has classified RF-EMF (radiofrequency electromagnetic fields) as possibly carcinogenic to humans, showing uncertain but worrisome risks. With cell phones present in nearly every aspect of daily life, humans and by extension laboratory rats are exposed to RF radiation that may affect hematological parameters and biological systems.

The electromagnetic radiation discovered by James Clerk Maxwell in 1864 laid to the foundation in wireless communication. In 1895 Guglielmo Marconi help in the development of wireless telegraph. Since then, EMR including radiofrequency has become a main component of present modern communication system.

Hasan et al. (2021) reported that Swiss albino rats exposed to 4G cell phone radiation for several weeks showed a significant decrease in total red blood cell (RBC) count and body weight, along with increases in total white blood cell (WBC) count and hemoglobin percentage.

In Wistar rats, Hasan, Amin, Alam, and Islam (2021) demonstrated that 28 days of RF-EMR exposure significantly reduced red blood cell count, hemoglobin, hematocrit, and other red cell indices, while raising platelet and white blood cell counts relative to unexposed controls. To compare result, a recent study by Gautam et al. (2024) found that male Wistar rats exposed chronically 4G-band radiation showed higher RBC count, hemoglobin, and packed cell volume than controls.

Also, Li et al. (2023) exposed Wistar rats to high power S band microwaves and observed physiological stress responses. The result of this study shows that the exposed rats gained weight more slowly than controls and exhibited increased stress hormones and affect heart rate. Taken together, these studies indicate that prolonged cell phone EMR can affect hematological parameters and related physiology in rats, although findings vary with exposure frequency, duration, and intensity.

Despite all these studies done, the effects of cell phone RF-EMR on blood parameters are few in terms of literature review and have not been well characterized in the Nigerian context or point of view and there is no published study that has systematically examined and show how GSM cell phone radiation affects standard hematological indices in local Nigerian rats alone.

Due to the high use of cell phone usage in Nigeria and public ignorance in EMR health risks, it is important to understand if chronic RF exposure might alter blood cell counts or other blood parameters. Therefore, this study builds mainly on rat research to focus specifically on the hematological effects of GSM-frequency EMR in Wistar rats under controlled conditions.

1.2 Statement of Problem

Ezemelue et al. (2021) experimental research used 16 albino rats, which consist of 8 females and 8 male's rats, which were randomly categorizes into to 2 groups only. Group A contained 8 rats which were exposed to cell phone simulators, while Group C was the control group. The experimental work lasted for 6 weeks. During the experimental period, the rats were observed for blood parameters, physical changes and serum oxidative stress markers.

The findings show that radiofrequency electromagnetic exposure affected the body weight of the rats when compared to their initial and final weights with those of the control group. A similar pattern was observed between male and female rats, although the difference between the groups was not statistically significant ($P > 0.05$).

Cell phones are now ever present and their RF-EMR emissions can cause possible public health concern and the specific hematological effects of chronic RF exposure still remain poorly understood.

Previous studies on rats experiments shows that long term exposure to cell phone radiation can alter blood parameters, but results have been inconsistent and show some level of variations.

In Nigeria, large GSM phone network and high subscription rates with no exact data are factors on how typical cell phone radiation affects the blood of Wistar rats.

This research addresses that gap by investigating whether daily exposure to GSM-range cell phone EMR actually produces measurable changes in the complete blood count of female Wistar rats.

1.3 Aim and General Objectives

The primary aim of this study is to evaluate the hematological effects of radiofrequency electromagnetic radiation from GSM cell phones on female Wistar rats under simulated long term exposure conditions.

The general objectives of this study are:

Generally, this research will determine whether chronic exposure to typical cell phone radiation alters key blood parameters.

1.4 Specific Objectives

The specific objectives are to:

1. Measure and compare red blood cell count, hemoglobin concentration, hematocrit, and white blood cell count between Wistar rat exposed to cell-phone RF-EMR and unexposed control rat.
2. Measure and compare the weight between Wistar rats exposed to cell-phone RF-EMR and unexposed control rats.

3. Assess the relationship between exposure duration and the magnitude of changes in these hematological parameters.

4. Note EMR effects symptoms that may happen when the Wister female rat is exposed to radiation.

1.5 Significance of Study

This study is significant both locally and to the global. However, public awareness of possible RF-EMR health effect still remains low. By focusing on blood parameters effects in a controlled rat style, this research study will contribute new knowledge which will be relevant to the Nigerian context or point of view.

The results could inform the national guidelines on RF exposure limits and encourage or ensure further research study in Nigeria on EMR safety. More broadly, the results will add to the global literature on biological effects of cell phone radiation. Since changes in blood parameters may indicate emerging health effects (e.g., on oxygen

transport or immune function), understanding these changes is very important for knowing any long-term risks of common cell phone usage.

In summary, this study will provide empirical evidence of possible physiological effects of everyday RF-EMR exposure, thereby filling this differences in scientific understanding and supporting evidence-based policy and public education on electromagnetic safety.

1.6 Research Hypothesis

1. Null hypothesis (H_0): Exposure to GSM cell-phone RF-EMR has no significant effect on the hematological parameters of male Wistar rat; i.e., there will be no difference between exposed and control groups.

2. Alternative hypothesis (H_1): Exposure to GSM cell-phone RF-EMR causes significant changes in the blood parameters of male Wistar rats; i.e., exposed rat will differ from controls in one or more blood indices.

1.7 Scope of the Study

This study is limited to an experimental model using male Wistar rats. Exposures will be conducted using commercially available cell phones. Rats will be exposed under controlled laboratory conditions for a fixed daily duration over several weeks. The measured outcomes will include standard blood parameters: red blood cell count, white blood cell count, hemoglobin, hematocrit, platelets, and related indices. No other species, frequency bands (such as 5G), or physiological systems (e.g., neurological or endocrine) are included.

Environmental variables (temperature, diet) will be held constant to isolate the effect of RF-EMR. Thus, the scope is strictly the hematological impact of GSM-band cell-phone radiation in Wistar rats, not the full spectrum of possible biological effects or other exposures.

1.8 Operational definition of terms

Electromagnetic radiation (EMR): Energy propagated through space or matter as oscillating electric and magnetic fields. In this study, EMR refers specifically to radiofrequency fields emitted by cell phones (microwave-range frequencies, typically hundreds of megahertz to a few gigahertz).

Wistar rats: A common strain of albino laboratory rats (Rattus norvegicus) originally developed at the Wistar Institute. Wistar rats are widely used in biomedical research due to their well-characterized physiology and reproducible responses; adult males typically weigh about 200–300 g.

Blood parameters: Quantitative measures of blood composition used to assess health status. These include red blood cell (RBC) count, white blood cell (WBC) count, hemoglobin concentration (Hb), hematocrit (packed cell volume), platelet count, and related indices (e.g., mean corpuscular volume). Changes in these parameters can indicate hematological or systemic effects.

GSM frequency: Global System for Mobile communications (GSM) frequency bands used by 2G cellular networks. In Nigeria, GSM phones commonly operate around 900

MHz and 1800 MHz. These frequencies fall within the radiofrequency portion of the electromagnetic spectrum and are the source of cell-phone RF-EMR in this study.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter gives a review of literature which is relevant and currently available in relation to the evaluation of the effect of electromagnetic radiation (EMR) from cell phones on blood parameters of Wistar rats. This literature will be reviewed under the subject, focusing on conceptual, empirical, and theoretical perspectives.

2.2 Conceptual Review

Electromagnetic waves are common in modern technology and broadly used in civilian and military applications. Prolonged exposure t from cell phones has raised public health concerns because it pose a health hazard under long term exposure conditions.

Studies shows that laypeople are wary of these risks: for example, university students generally have negative attitudes toward mobile phone and wireless radiation, viewing it as dangerous to living organisms, even while admitting they have incomplete knowledge of the topic. (Hasan, Amin, Alam, & Islam, 2021)

This differences between concern and understanding affect systematic biological studies of EMR.

Indeed, research notes that findings of biological effects should provide greater public awareness on cell phone radiation effect.

2.3 Empirical Review

Wister rat's experiments have begun to illuminate how cell phone frequency EMR affects physiology.

Ezemelue et al. (2021) experimental research used 16 albino rats, which consist of 8 females and 8 male's rats, which were randomly categorizes into to 2 groups only. Group A contained 8 rats which were exposed to cell phone simulators, while Group C was the control group. The experimental work lasted for 6 weeks. During the experimental period, the rats were observed for blood parameters, physical changes and serum oxidative stress markers.

The findings show that radiofrequency electromagnetic exposure affected the body weight of the rats when compared to their initial and final weights with those of the control group. A similar pattern was observed between male and female rats, although the difference between the groups was not statistically significant ($P > 0.05$). The blood parameter tests show that only granulocytes, including basophils, neutrophils and eosinophils, showed a significant difference ($P = 0.04$). Also, the oxidative stress biomarkers superoxide dismutase and catalase exhibited significant differences ($P = 0.02$) between the exposed and control groups (Ezemelue et al., 2021).

Coskun, Turk, and Comlekci (2022) experimental research used 90 rats categorizes into to 3 groups: which are a cage control group, a pseudo-exposure group, and a group which was exposed to 2.45 GHz electromagnetic radiation. The exposed rats received EMF at a frequency of 2.45 GHz and power of 1 mW/cm² for two hours daily over a 2-week period. Blood parameters analysis showed that lymphocyte levels were low, while monocyte counts were higher in the exposed group when compared to the control. Platelet counts were also noticeably increased among the exposed rats.

Hasan et al. (2021) exposed male Swiss albino rats to 2400 MHz (4G) cell phone radiation for 40 or 60 minutes daily over 60 days

Compared to unexposed controls, irradiated mice showed significant hematological alterations: body weight and total erythrocyte (red blood cell) count both decreased, while total leukocyte (white blood cell) count, hemoglobin percentage, and serum creatinine increased.

High-exposure rats also developed marked tissue damage: kidney sections exhibited interstitial inflammation with mononuclear cell infiltration, and tests showed irregular, dilated seminiferous tubules with reduced germ cell layers. Hasan et al. concluded that 4G radiation “may affect blood hemostasis and inflammation” in these rodents, implying systemic stress on blood parameters and organ health.

Similarly, Li et al. (2023) examined the effects of intense microwave (S-band) exposure on adult rats. Rats subjected to 30 mW/cm² S-band radiation for 35 minutes showed severe cardiac and systemic effects. Histologically, their myocardial fibers

were “disorganized, fragmented, and showed severe mitochondrial cavitation” compared to controls.

These rats also displayed biochemical signs of stress: oxidative-stress markers in the heart were elevated and stress-related hormones in serum were significantly increased. Behaviorally, irradiated rats exhibited anxiety- and depression-like symptoms with reduced exercise capacity after exposure. Molecular assays revealed upregulation of stress-response proteins (JNK, p-JNK, HSF1, NFATc4) in heart tissue, indicating activation of intracellular stress pathways.

Arjilli Vamsy, Lakshmi, and Venkatachalam (2021) research reported the disappearance of certain bird species, mostly linked to 2G and 3G radiation, while limited information existed on the impact of 4G radiation. In this study, male Wistar rats were exposed to 4G mobile phone radiation within a frequency range of 800–2700 MHz for 96 minutes daily over six months through WhatsApp video calls. The findings show low to moderate, blood vessel congestion, liver inflammation and the presence of Kupffer cell granulomas under microscopic examination. These results show that long term exposure to 4G mobile radiation can affect liver health negatively.

Ibraheim and Amin (2020), research study shows that 40 adult male albino rats weighing between 25 and 30 grams were categorizes into 4 exactly equal groups, which are A, B, C, and D. Group A was the negative control, Group B was the control for the vitamin E solution. Group C was the group that was exposed to electromagnetic radiation for at least 2 hours daily for over 3 weeks period without vitamin E treatment, and while Group D received vitamin E while still being exposed

to the same electromagnetic radiation conditions. The results of this study showed that Group C experienced significant changes in blood parameters, with also red and white blood cells, hemoglobin, hematocrit, mean corpuscular volume, mean corpuscular hemoglobin concentration, and platelets. Furthermore, histopathological changes were noted in the liver, kidney, lungs, heart, spleen, and brain due to the radiation exposure. Treatment with vitamin E in this study was found to reduce these harmful effects by reducing tissue damage and improving the affected blood parameters. Therefore, vitamin E demonstrated a protective role in reducing the adverse effects of cell phone radiation on blood and organ tissues.

Attah et al. (2022) study made use of Wistar rats which were exposed to radiofrequency radiation of 2.45 GHz or even higher within the last five years. Most studies showed good quality, scoring above 60%. The review showed that exposure to high radiofrequency radiation caused several biological changes in Wistar rats, affecting biochemical, genetic, histological, psychological, optical, and skin-related functions. Changes were observed in protein and liver enzyme levels, with evidence of oxidative stress and cellular damage when compared to unexposed rats. Changes were also seen in gene expression, neurotransmitter balance, and hormone levels. Structural damage to cells, tissues, and organs suggested apoptosis and cell death. The Behavioral tests showed fear and memory decline, while some studies also showed visual and skin changes in the exposed rats.

Krivova et al. (2023) study used male Wistar rats at 3 life stages: juvenile, adult, and presenile. The exposure conditions obeyed the ICNIRP guidelines for radiofrequency electromagnetic fields, using a 2.4 GHz frequency with an average specific absorption rate of 0.0076 W/kg and 0.0059 W/kg across the rats' bodies. Body weight was

checked every week to track growth, and both rectal and skin temperatures on the right hind limb were measured weekly. In the final week of exposure, Week 5, the rats were tested in the Morris water maze. After euthanasia, organ weights were compared between exposed and control groups. The results showed no significant differences in any measured parameters between the exposed and control rats of the same age group.

Hasan, Amin, Alam, and Islam (2021) used thirty male Swiss albino mice weighing between 45 and 65 grams were randomly assigned into three groups of ten. Group A served as the control, Group B was exposed to mobile phone radiation for 40 minutes daily, and Group C was exposed for 60 minutes daily using two 2400 MHz 4G mobile phones over a 60-day period. The electromagnetic radiation emitted from the phones was measured with a frequency radiometer, and the specific absorption rate was determined to be 0.087 W/kg. The control mice were kept under similar conditions without radiation exposure for the same duration. At the end of the experiment, all mice were sacrificed, and blood samples were collected for hematological and biochemical analyses. Kidney and testis tissues were also taken for histopathological examination.

The findings revealed a significant ($p < 0.05$) reduction in body weight and total erythrocyte count, while total leukocyte count, hemoglobin concentration, and serum creatinine levels significantly ($p < 0.05$) increased in both radiation-exposed groups compared with the control group. Histological analysis of the kidneys in the 60-minute exposure group showed interstitial inflammation with pronounced mononuclear cell infiltration compared to the 40-minute and control groups. Examination of testicular tissues from exposed mice revealed irregularly shaped

seminiferous tubules, uneven sizes, and reduced layers of spermatogenic cells, resulting in larger tubular lumens compared with the control mice (Hasan et al., 2021).

Gavrilas, Kotsis, and Papanikolaou (2022) research focused on exploring university students' knowledge, attitudes, and behaviours concerning electromagnetic radiation from mobile phones and wireless networks. It also examined how their academic programmes influenced these perspectives. A total of 619 students from six university departments participated, and data were gathered through a structured questionnaire. The findings indicated that most students had limited understanding of electromagnetic radiation and generally viewed it as harmful to living organisms. Despite this concern, their personal health protection practices did not reflect their stated attitudes. Additionally, the study found that students' behaviors were strongly associated with the specific department in which they studied.

In Akakın et al. (2021) study, electromagnetic waves (EMW) from mobile phones were applied for two hours daily until birth in both stand-by fetal and EMW fetal groups, and continued until the 60th postnatal day in the stand-by and EMW groups. The control group was not exposed to mobile phone radiation. On the 60th postnatal day, brain samples were collected to measure malondialdehyde (MDA) and glutathione (GSH) levels, while western blot analysis was used to assess glial fibrillary acidic protein (GFAP) expression. Histological examination was conducted using hematoxylin and eosin staining and GFAP immunohistochemistry, and the trigeminal nerves were evaluated under a transmission electron microscope.

The results revealed that rats exposed to mobile phone radiation, whether in stand-by or active talk mode, exhibited significantly greater neuronal damage in the cortex and hippocampus compared to the control group. The EMW-exposed rats showed

elevated MDA levels and reduced GSH concentrations in the stand-by, EMW fetal, and EMW groups relative to controls. Additionally, GFAP levels and immunostaining were markedly higher in the EMW and EMW fetal groups. The number of myelinated axons was also significantly lower in the EMW group compared with control animals, indicating structural nerve damage linked to radiation exposure (Akakın et al., 2021).

Yaseen (2022) study examined, twenty-four mice were divided into three groups of eight. The first group served as the control and was exposed to a switched-off mobile phone for two hours daily. The second group was exposed to a mobile phone in non-talking mode for the same duration, while the third group was exposed to a phone in talking mode for twenty minutes daily. After six weeks, sperm shape and count were evaluated. The results showed that mice in the talking-mode group exhibited significant abnormalities in sperm shape and a reduction in sperm count compared to the control group. In contrast, exposure to a non-talking mobile phone for two hours per day did not produce any noticeable effects on sperm structure or concentration.

In summary, the authors reported that this exposure "could cause both physiological and psychological stress damage in rats". Together, these rodent studies demonstrate that chronic cell phone–frequency exposure can perturb hematological parameters and induce tissue pathology and stress responses.

2.3 Theoretical Review

GSM is an acronym which means Global System for Mobile Communication. It is a digital mobile network which is being used by cell phone users around the globe. It is one of the most popular of the 3 digital wireless telephony systems which are; , GSM, TDMA and CDMA and make use of the combination of TDMA and FDMA. Four different frequency bands are used which are 1900 MHz, 1800 MHz, 900 MHz and 850 MHz

Global System for Mobile Communication converts and reduces data before sending it along a route with two other streams of user data, each with its own time slot. GSM have 4 different kinds of sizes of cells:

1. Umbrella: It covers the spaces between cells
2. Pico: It has a small cell diameter of a few meters long.
3. Micro: Here, the antenna height is less than the average roof level.
4. Macro: This is a Base Station antenna which is installed

Electromagnetic radiation is a non-ionizing radiation which causes biological effects that arise through thermal and stress related mechanisms. key mechanistic themes come from:

Changed hematology and homeostasis: Cell phone radiation has been known to disrupt blood parameters counts. E.g., 4G exposure to rats led to lower red blood cells and higher white blood cells and hemoglobin. Such changes show that disturbed blood homeostasis and potential inflammatory responses.

Oxidative and mitochondrial stress: Li et al. (2023) observed that severe mitochondrial cavitation and other signs of oxidative-stress injury in exposed rat hearts is due to high frequency microwaves which can generate reactive oxygen species and damage mitochondria. Mitochondrial dysfunction can support many other effects, such as reduced energy production to cell death.

Activation of stress-signaling pathways: EMR exposure upregulates stress-related proteins. In irradiated rat myocardium, the expressions of JNK (c-Jun N-terminal kinase), p-JNK, HSF1, and NFATc4 were all increased. JNK signaling is known to mediate inflammatory and apoptotic responses, so its activation provides a molecular link between radiation exposure and cellular injury.

Systemic stress responses: Beyond local tissue damage, intense RF exposure triggers whole-body stress. The studies above reported increased serum stress hormones and anxiety/depression-like behavior in exposed animals. Such neuroendocrine changes could feedback to alter immune and hematological parameters (e.g. stress hormones can influence leukocyte counts).

These conceptual and empirical insights suggest that cellphone EMR can perturb blood parameters in rats through a combination of oxidative stress, inflammation, and neurohormonal stress pathways.

While direct data on Wistar rats' blood parameters are limited in these sources, the mechanisms identified – oxidative damage, stress kinase signaling, and altered hemostasis – are likely relevant. Further research on Wistar rats is warranted to directly link these processes to specific hematological outcomes.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter describes the systematic approach used to evaluate the effect of electromagnetic radiation (EMR) from cell phones on blood parameters of Wister rats. It details where and how data were collected, who the participants were, the tools used, procedures for ensuring data quality (validity and reliability), methods of analysis, and ethical safeguards.

Sreekumar (2023) explains research methodology as the techniques and procedures used by researchers to identify and analyses information regarding a specific research topic. It is a process by which researchers design their study so that they can achieve their objectives using the selected research instruments. Therefore, this methodology of this study was selected to evaluate the effect electromagnetic radiation (EMR) from cell phones on blood parameters of Wister rats

3.2 Research Setting

This study will be conducted in the Department of Anatomy and Physiology, Faculty of Basic Medical Sciences of University of Benin during the period from July 25 to August 30 to evaluate the impacts of cell phone of electromagnetic radiation on blood parameters of Wistar rats. All blood analyses will be performed in the Departmental Physiological and Hematology Laboratory of University of Benin, which maintains calibrated clinical analyzers and centrifuges.

3.3 Study Design

This study used a randomized controlled experimental design to evaluate the effects of electromagnetic radiation from cell phones on blood parameters of Wistar rats. 8 female Wistar rats will be used:

1. Control female rat: not exposed I.e. no cell phone is around the rat.

2. Exposure female rat: exposed to cell phone radiation I.e. a cell phone is around the rat.

Exposure will occur for 2 minutes per day over 4 weeks. Post-exposure blood samples will be compared within and between the 8 rats.

3.4 Target Population

The target population for this study comprises healthy adult female Wistar rats, aged 6–9 weeks and weighing 45– 65 g will be chosen for this study. The rats will be kept in a temperature-controlled environment. Daily diet and drinking of water will be given.

1. Inclusion criteria.

- Adults female Wistar rat

- Adults Wistar rat aged 6–9 weeks
- Adults Wistar rat weighing 45– 65g

2. Exclusion criteria.

- Adults male Wistar rat
- Non adults Wistar rat aged 6 weeks below
- Adults Wistar rat weighing below 45– 65g

3.5 Sampling techniques/ Sample size

First, each individual weight of these 8 rats were documented before radiation exposure. Using power analysis ($\alpha = 0.05$, power = 0.80) and expected effect sizes from pilot studies, a minimum of 4 rats in each group is required to detect a 10% change in hematological indices. A total of 8 rats will be procured to allow for possible attrition as also used in the research studies of (Hasan, Amin, Alam, & Islam, 2021).

3.6 Instrument for Data Collection

1. For Radiation Source: Standard GSM cell phone with auto-answer mode was centrally tied to the exposed rat to deliver a uniform field strength inside the mouse cage. This is similar to the exposure method used in previous studies of (Hasan, Amin, Alam, & Islam, 2021).

2. For Blood Sampling: Approximately 1 ml of blood from the syringe will be collected for hematological tests in the test tube containing anticoagulant Ethylene

diamine tetra acetic acid (EDTA). The remaining amount of syringe blood will be used to obtain the serum as also used in the research studies of (Hasan, Amin, Alam, & Islam, 2021).

3. Analysis: Hematological variables will be tested using Automated hematology analyzer e.g Sysmex automated CBC analyzers, these variables are; Total erythrocyte count (TEC), Hemoglobin (Hb) percentage (%), and Total leukocyte count (TLC) similar to instrument used in previous studies of (Hasan, Amin, Alam, & Islam, 2021).

3.7 Validity of the Instrument

The validity of the instrument like the GSM cell phone will be calibrated against manufacturer standards before use. Hematology and biochemistry analyzers will undergo quality control checks.

3.8 Reliability of the Instrument

The coefficients of variation for blood parameters are maintained below 5% by:

1. Running duplicate measurements on 10% of samples.

2. Having the same trained technician perform all analyses.

3. Re-analyzing any outlying values.

3.9 Method of Data Collection

Rats were acclimatized for 9 days, with ad libitum food and water. Then each rat in the exposure group will be placed individually in the chamber for 2 min/day; controls undergo the same handling without radiation, then within 24 hours of the final exposure, blood will be collected via cardiac puncture under light anesthesia. Then the whole blood will be analyzed immediately; serum will be separated by centrifugation and stored at –20 °C until biochemical assays.

3.10 Method of Data Analysis

The statistical data analysis will be entered into SPSS v28.0. Descriptive statistics (mean ± SD) will summarize each parameter. Between-group comparisons will use unpaired Student's t-tests (or Mann–Whitney U if non-normal). Within-group (pre- vs. post-) changes will be assessed by paired t-tests. A two-way ANOVA may be applied if multiple time-points are added. Statistical significance is set at $p < 0.05$.

3.11 Ethical Consideration

Based on the standardized instruction, all of the rats received human care. These study interventions will be permitted and carried out in compliance with the researcher ethics committee of the College of Medical Sciences University of Benin, Benin city Nigeria.

CHAPTER 4

RESULTS FINDINGS

4.1 Presentation of Results

This chapter presents the analysis and discussion of findings from the study on the evaluation of the effect of electromagnetic radiation from cell phones on blood parameters on Wistar rats. The findings are discussed in relation to the research objectives and relevant literature. The findings are presented below as follows:

4.2 Study Design Parameters

Table 4.2: Baseline Characteristics of Study Groups

Parameter	**Control Group (n=4)**	**Exposed Group (n=4)**	**t-value**	**p-value**
Body Weight (grams)	208.25±15.20	204.33±10.86	0.210	0.841

The baseline body weights between the control and electromagnetic radiation (EMR) exposed groups showed no statistically significant difference (p=0.841), indicating successful randomization and comparable baseline characteristics.

4.3 White Blood Cell Parameters

Table 4.3: White Blood Cell Count and Differential Analysis

Parameter	**Control Group**	**EMR Exposed Group**	**t-value**	**p-value**
Total WBC Count				
White Blood Cell Count ($\times 10^3/\mu L$)	5.48±0.68	4.33±0.45	1.421	0.205
Differential Percentages				
Lymphocyte (%)	87.68±1.16	89.08±2.58	-0.496	0.638
Mid-range Cell (%)	9.58±0.79	8.50±2.03	0.494	0.639
Granulocyte (%)	2.75±0.39	2.43±0.55	0.478	0.649
Absolute Counts				
Lymphocyte Count ($\times 10^3/\mu L$)	4.80±0.56	3.80±0.31	1.562	0.169
Mid-range Cell Count ($\times 10^3/\mu L$)	0.55±0.09	0.40±0.12	1.000	0.356
Granulocyte Count ($\times 10^3/\mu L$)	0.13±0.05	0.13±0.05	0.000	1.000

The white blood cell analysis revealed no statistically significant differences between control and EMR-exposed groups across all measured parameters (all $p>0.05$). The total WBC count in the control group was 5.48±0.68 $\times 10^3/\mu L$ compared to 4.33±0.45 $\times 10^3/\mu L$ in the EMR-exposed group ($t=1.421$, $p=0.205$), representing a 21% reduction. Lymphocyte percentages were comparable between groups (87.68±1.16% vs 89.08±2.58%, $t=-0.496$, $p=0.638$). Mid-range cell percentages showed minimal variation (9.58±0.79% vs 8.50±2.03%, $t=0.494$, $p=0.639$), while granulocyte

percentages remained similar (2.75±0.39% vs 2.43±0.55%, t=0.478, p=0.649). The absolute lymphocyte count decreased by 21% in the EMR group (4.80±0.56 vs 3.80±0.31 $\times 10^3/\mu L$, t=1.562, p=0.169). Mid-range cell absolute count was 0.55±0.09 $\times 10^3/\mu L$ in controls versus 0.40±0.12 $\times 10^3/\mu L$ in exposed animals (t=1.000, p=0.356), while granulocyte counts were identical at 0.13±0.05 $\times 10^3/\mu L$ (t=0.000, p=1.000).

4.4 Red Blood Cell Parameters

Table 4.4: Red Blood Cell Count and Hemoglobin Analysis

Parameter	**Control Group**	**EMR Exposed Group**	**t-value**	**p-value**
Basic RBC Measures				
Red Blood Cell Count ($\times 10^6/\mu L$)	5.60±0.16	6.19±0.03	-3.603	**0.011***
Hemoglobin (g/dL)	12.98±0.26	14.30±0.23	-3.815	**0.009***
Hematocrit (%)	36.93±1.04	38.10±0.58	-0.986	0.362

*p<0.05; **p<0.01

The red blood cell analysis showed significant alterations in the EMR-exposed group compared to controls. Red blood cell count was significantly elevated from 5.60±0.16 $\times 10^6/\mu L$ in controls to 6.19±0.03 $\times 10^6/\mu L$ in the exposed group (t=-3.603, p=0.011), representing a 10.5% increase. Hemoglobin concentration increased significantly from 12.98±0.26 g/dL in controls to 14.30±0.23 g/dL in exposed animals (t=-3.815, p=0.009), constituting a 10.2% elevation. Hematocrit values showed a non-significant trend from 36.93±1.04% in controls to 38.10±0.58% in exposed animals (t=-0.986, p=0.362), representing a 3.2% increase.

Table 4.4: Red Blood Cell Indices

Parameter	**Control Group**	**EMR Exposed Group**	**t-value**	**p-value**
RBC Indices				
Mean Corpuscular Volume (fL)	66.18±2.01	61.73±1.15	1.926	0.102
Mean Corpuscular Hemoglobin (pg)	23.18±0.41	23.05±0.43	0.211	0.840
Mean Corpuscular Hemoglobin Concentration (g/dL)	35.10±0.54	37.50±0.93	-2.232	0.067
RBC Distribution				
Red Cell Distribution Width-SD (fL)	33.10±1.38	32.58±1.03	0.305	0.771
Red Cell Distribution Width-CV (%)	14.90±0.49	15.13±0.45	-0.339	0.746

The RBC indices revealed notable morphological changes in EMR-exposed animals. Mean Corpuscular Volume decreased from 66.18±2.01 fL in controls to 61.73±1.15 fL in exposed animals (t=1.926, p=0.102), representing a 6.7% reduction indicating smaller red blood cells. Mean Corpuscular Hemoglobin remained relatively stable (23.18±0.41 pg vs 23.05±0.43 pg, t=0.211, p=0.840), showing only a 0.6% decrease. Mean Corpuscular Hemoglobin Concentration showed a trending increase from 35.10±0.54 g/dL in controls to 37.50±0.93 g/dL in exposed animals (t=-2.232, p=0.067), constituting a 6.8% elevation. Red Cell Distribution Width-SD was comparable between groups (33.10±1.38 fL vs 32.58±1.03 fL, t=0.305, p=0.771), as was Red Cell Distribution Width-CV (14.90±0.49% vs 15.13±0.45%, t=-0.339, p=0.746). The differences were not statistically significant (p>0.05).

4.5 Platelet Parameters

Table 4.5: Platelet Count and Indices Analysis

Parameter	Control Group	Exposed Group	t-value	p-value
Basic Platelet Measures				
Platelet Count (×10³/μL)	424.00±52.28	352.00±15.88	1.318	0.236
Plateletcrit (%)	0.32±0.06	0.26±0.01	1.187	0.280
Platelet Indices				
Mean Platelet Volume (fL)	7.55±0.36	7.43±0.20	0.305	0.771
Platelet Distribution Width (fL)	9.28±0.43	9.28±0.30	0.000	1.000
Platelet Large Cell Ratio (%)	8.68±3.47	3.93±1.36	1.274	0.250

Platelet parameters showed no statistically significant differences between control and EMR-exposed groups (all $p>0.05$). Platelet count decreased from 424.00±52.28 ×10³/μL in controls to 352.00±15.88 ×10³/μL in exposed animals ($t=1.318$, $p=0.236$), representing a 17% reduction. Platelets values declined from 0.32±0.06% in controls to 0.26±0.01% in exposed animals ($t=1.187$, $p=0.280$), constituting an 18.8% decrease. Mean Platelet Volume remained essentially unchanged (7.55±0.36 fL vs 7.43±0.20 fL, $t=0.305$, $p=0.771$), showing only a 1.6% reduction. Platelet Distribution Width was identical between groups at 9.28±0.43 fL and 9.28±0.30 fL respectively ($t=0.000$, $p=1.000$). The Platelet Large Cell Ratio showed the most substantial change, decreasing from 8.68±3.47% in controls to 3.93±1.36% in exposed animals ($t=1.274$, $p=0.250$), representing a 55% reduction in the proportion of large platelets.

CHAPTER 5

DISCUSSION OF FINDINGS, RECOMMENDATION, LIMITATION, CONCLUSION, AND SUGGESTED AREA OF FURTHER STUDY

5.1 Discussion of Findings

This experimental study used 8 Wister rats randomly grouped into exposed and control, with four female rats in each group. In line with the first specific objective, which is measure and compare red blood cell count, hemoglobin concentration, hematocrit, and white blood cell count between Wistar rat exposed to cell phone RF-EMR and unexposed control rat. The result of the study shows that the hematological analysis result showed only significant alterations in the Red Blood Cell (RBC) profile, while other parameters, especially White Blood Cells (WBCs) and Platelets, showed numerical trends across the two groups.

In line with the second specific objective, which is to measure and compare the weight between Wistar rats exposed to cell-phone RF-EMR and unexposed control rats. The result of the study shows that in the exposed group; the weight of the animals was not affected when compared to the control group.

Also, In line with the other two objectives, the exposed rats appear to look less healthy when compared to the control group this might be the of oxidative-stress injury in the exposed rats due to the radio frequency waves which can generate reactive oxygen species and damage mitochondria. such as reduced energy production to cell death.

This study was set out to determine whether electromagnetic radiation from mobile phones affects blood parameters in Wistar rats. It evaluated the effects of Electromagnetic Radiation from cell phones on the key blood parameters in Wistar rats. The analysis of the blood results, which is actually detailed in the previous section above, shows or highlights specific and measurable changs or alterations in the Red Blood Cell (RBC) profile, while other parameters, especially or notably White Blood Cells (WBCs) and Platelets, showed numerical values or trends but no statistically significant differences. Also, these results are analyzed in conjunction with current research to establish their importance.

5.1.1 Baseline comparability and White Blood Cell Profile

The initial result confirmed that the Exposed and Control group were comparable in baseline characteristics, as evidenced by the lack of a significant difference in body weight ($p=0.841$), which supports the validity of a successful randomization.

The analysis of White Blood Cell (WBC) parameters revealed no statistically significant impact of EMR exposure on the rats' overall immune profile. Although the Total WBC Count decreased by 21% in the exposed group, this difference was not statistically significant ($p=0.205$). Similarly, the absolute and differential counts for Lymphocytes, Mid-range Cells, and Granulocytes remained statistically

indistinguishable between the groups especially with the Lymphocytes showing minimal variation between the two groups.

This minimal variation suggests agrees that rats to RF-EMF would lead to an increased number of

neutrophils. This increase in the level of neutrophils has been attributed to the compensation for the impairment of neutrophils caused by cell phone radiation (Ezemelue et al., 2021).

Significant Alterations in Red blood cell Parameters

The most robust finding was the rise in red blood cell count and hemoglobin concentration in the exposed rats when compared to the WBC findings. Both RBC Count and Hemoglobin (Hb) concentrations were statistically and significantly elevated in the exposed group. RBC count increased by about 10.5% and hemoglobin by about 10.2%, both statistically significant. Hematocrit showed a small nonsignificant rise. Taken together, these results point toward an increase in erythropoietic activity or a change in red cell turnover in response to EMR exposure.

This significant alteration of RBC agrees with previous studies that the results revealed that electromagnetic radiation from cell phones causes statistically significant changes in RBCs, Hb, HCT, MCV, MCHC, and PLT (Ibraheim & Amin, 2020).

Electromagnetic radiation from cell phones has damaging effects on the blood cells and produces an imbalance in blood enzymes and increased cell apoptosis and functional disorders in many cell types. Additionally, the detected alterations in the hematological parameters could also be attributed to the ability of radiation from

mobile phones to induce stimulation of haemopoietic activity in the bone marrows and oxidative stress that resulting in anemia due to uncontrolled hemopoiesis as confirmed by the obtained results in the current research (Ibraheim & Amin, 2020).

RBC indices show a reduction in mean corpuscular volume and a trend toward higher mean corpuscular hemoglobin concentration in the exposed group.

Mean Corpuscular Volume (MCV) showed a 6.7% reduction in the EMR group though this trend was not statistically significant (p=0.102).

Mean Corpuscular Hemoglobin Concentration (MCHC) showed a non-significant elevation trend of 6.8% in the exposed group.

Platelet Profile

Platelet count and most platelet indices did not change significantly, though platelet count and platelet Rit were lower in the exposed group (about 17% and 19% reductions, respectively). The platelet large cell ratio showed a large relative decrease but with wide variability and no statistical significance.

Coskun, Turk, and Comlekci (2022) result disagrees with this, that the Mean Platelet Count was observed in the experimental group was more intense or high than the control group.

Recommendations

For the experiment work or practical point of view we would recommend that;

1. Exposure Duration: Increase the exposure duration per rat from 2 minutes up to 30 minutes to assess dose response and time dependent effects.
2. Experimental periods: The experimental period should be extended from 4 weeks to 8 or 12 weeks to obtain more robust and reliable data.
3. Groups: More additional groups are needed by having four to five EMR exposed groups with and four to five matched control groups for better comparison.
4. Cell Phones: Increase the number of mobile phones used to generate and emit radiation to the exposed group and categorize them by network technology, for example 2G, 3G, 4G and 5G.
5. Collaborative Work: Consider organizing the study as a collaborative group project to improve data collection and management.
6. Measure functional outcomes such as bleeding time and responses to immune challenge to determine whether hematological changes have meaningful physiological consequences.

Limitations

1. A number of limitations restrict how far these findings can be generalized. The most important is the small group size (n = 4 per group), which reduces statistical power and raises the chance of type II errors; some real effects may have gone undetected.

2. Only female rats were used in this study, which limits the ability to generalize results across sexes.
3. Key exposure parameters such as frequency, specific absorption rate, distance from the phone and cumulative exposure time were not reported in detail. These details are very important to assess biological acceptability and to compare results with other research studies.
4. The experimental duration was relatively short, which may limit detection of longer-term effects.
5. The funding of this study was done alone.

CONCLUSIONS

This study provides evidence that Electromagnetic Radiation from cell phones exert a significant alteration specific effect on the Red Blood Cell component of the blood in Wistar rats, causing a statistically significant elevation in RBC count and modest shifts in hematological concentration. To compare with the effects on White Blood Cells and Platelets were not statistically significant, though numerical trends for reduced counts and an altered platelet morphology warrant further investigation.

SUGGESTED AREA OF FURTHER STUDY

future studies should:

1. Increase sample size and include both sexes to explore sex specific responses.
2. Provide detailed reporting of exposure metrics (frequency, SAR, distance, duration) and, if possible, use dosimetry to quantify absorbed energy.

3. Include time course sampling to determine whether changes are transient or progressive.

REFERENCE

Akakın, D., Tok, O. E., Anıl, D., Akakın, A., Sırvancı, S., Şener, G., & Ercan, F. (2021). Electromagnetic waves from mobile phones may affect rat brain during development. *Turkish Neurosurgery, 31*(3), 412–421. https://doi.org/10.5137/1019-5149.JTN.31665-20.2

Arjilli Vamsy, A., Lakshmi, V. S., & Venkatachalam, T. S. P. (2021). A study on the histological and biochemical effects of long-term exposure of 4G LTE radiation emitted by mobile phone on the liver of Wistar rats. *Asian Journal of Pharmaceutical Research and Health Care, 13*(2), 132–138. https://pdfs.semanticscholar.org/dfda/5dccc2b65c84fa078b1a45f50191e2a86bd3.pdf

Attah, T. A., Ayantunji, B., Adamu, A., Omede, A., Leleji, J., Hussiani, S., Enemali, J.-P., Suleiman, Z. I., Dumbiri, C., Bwala, I., & Polok, C. (2022). Biological effects of high radiofrequency radiation on Wistar rats: A literature review. *Journal of Public Health International, 5*(2), 1–31. https://doi.org/10.14302/issn.2641-4538.jphi-22-4197

Coskun, O., Turk, S., & Comlekci, S. (2022). Effects of the wireless (2.45 GHz) electromagnetic fields on blood cells in rat. *Techno-Science, Scientific Journal of Mehmet Akif Ersoy University, 5*(2), 18–25. https://dergipark.org.tr/en/pub/sjmakeu/issue/74842/1185700

Ezemelue, P. N., Onyegbule, D. U., Okoli, L. C., Kareem, K. O., Awodele, O., & Otitoloju, A. A. (2021). Evaluation of haematological parameters and oxidative stress-induced in rats exposed to radio-frequency radiation from mobile phones. *Nigerian Journal of Experimental and Clinical Biosciences, 9*(3), 165–171. https://journals.lww.com/necp/Fulltext/2021/09030/Evaluation_of_Haematological_Parameters_and_Oxidative.5.aspx

Gavrilas, L., Kotsis, K. T., & Papanikolaou, M.–S. (2022). Attitudes and behaviors of university students towards electromagnetic radiation of cell phones and wireless networks. *Aquademia, 6*(2), ep22009. https://doi.org/10.30935/aquademia/12393

Hasan, I., Amin, T., Alam, M. R., & Islam, M. R. (2021). Hematobiochemical and histopathological alterations of kidney and testis due to exposure of 4G cell phone radiation in mice. *Saudi Journal of Biological Sciences, 28*(5), 2933–2942. https://doi.org/10.1016/j.sjbs.2021.02.028

Ibraheim, M. H., & Amin, A. (2020). Ameliorative effect of vitamin E against radiofrequency radiation emitted from mobile phone-induced hematological and histopathological alterations in male albino mice. *Arab Journal of Nuclear Sciences and Applications, 53*(4), 26–38. https://doi.org/10.21608/ajnsa.2020.25996.1339

Krivova, N. A., Kudabaeva, M. S., Zaeva, O. B., Borodina, S. V., Lepekhina, T. B., Pavlenko, O. A., Makhmanazarov, R. M., Kokin, D. S., & Shipilov, S. E. (2024). The effect of exposure to RF-EMF from the laboratory simulator of 5G NR base station on physiological parameters and cognitive abilities of male Wistar rats of different ages. *Scientific Reports, 14*, 10283. https://doi.org/10.1038/s41598-024-60862-5

Li, D., Xu, X., Yin, Y., Yao, B., Dong, J., Zhao, L., Wang, H., Wang, H., Zhang, J., & Peng, R. (2023). Physiological and psychological stress of microwave radiation-induced cardiac injury in rats. *International Journal of Molecular Sciences, 24*(7), 6237. https://doi.org/10.3390/ijms24076237

Sreekumar, D. (2023). What is research methodology? Definition, types and examples. *Paperpal Blog.* https://paperpal.com/blog/academic-writing-guides/what-is-research-methodology

Yaseen, N. J. (2022). Effects of radiofrequency electromagnetic radiation of mobile phones on sperms shape and number in male albino mice. *ZANCO Journal of Pure and Applied Sciences, 34*(4), 108–115. https://doi.org/10.21271/ZJPAS.34.4.12

APPENDIX I: Ethical approval request

Department of Radiography,

School of Basic Medical Sciences,

University of Benin,

Edo State.

August 2025.

The Chairman,

Health Research and Ethics Committee

University of Benin,

Edo State.

Dear Sir/ma,

APPLICATION FOR ETHICAL APPROVAL TO CONDUCT A RESEARCH STUDY

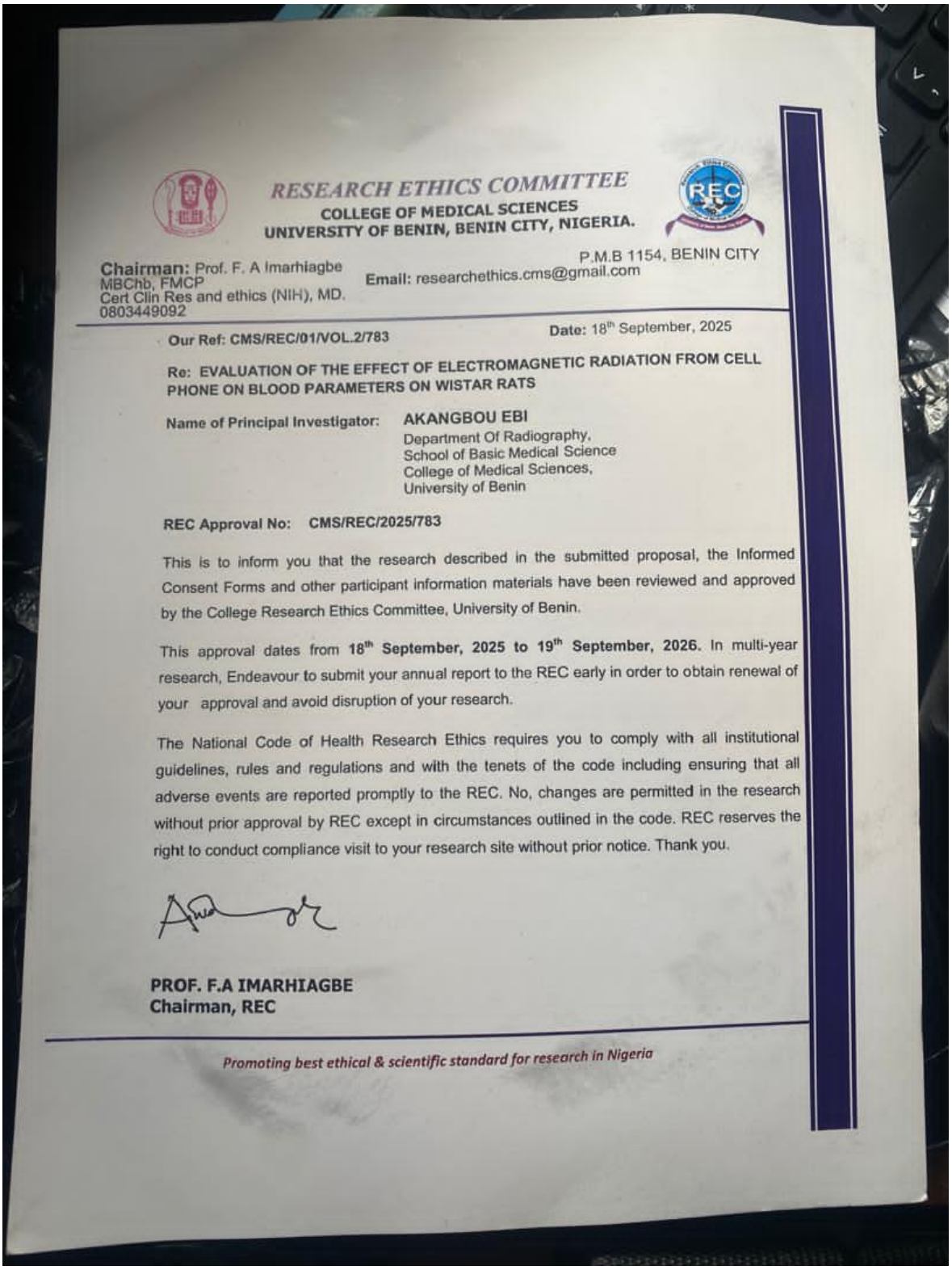
My name Akangbou Ebi a final year student in the Department of Radiography, School of Basic Medical Science, University of Benin with matriculation number BMS2001082 conducting a research study on "Evaluation of the Effect of Electromagnetic Radiation from Cell Phones on Blood Parameters on Wistar Rat, under the supervision of my lecturer Elder DR U.I Nwadike. I am writing to kindly request ethical approval to conduct this research study.

Attached is a copy of my research project proposal. I hope my request will be considered.

Yours Faithfully,

Akangbou Ebi.

09014908259



RESEARCH ETHICS COMMITTEE
COLLEGE OF MEDICAL SCIENCES
UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

Chairman: Prof. F. A Imarhiagbe
MBChb, FMCP
Cert Clin Res and ethics (NIH), MD.
0803449092

P.M.B 1154, BENIN CITY
Email: researchethics.cms@gmail.com

Our Ref: CMS/REC/01/VOL.2/783 **Date:** 18th September, 2025

Re: EVALUATION OF THE EFFECT OF ELECTROMAGNETIC RADIATION FROM CELL PHONE ON BLOOD PARAMETERS ON WISTAR RATS

Name of Principal Investigator: **AKANGBOU EBI**
Department Of Radiography,
School of Basic Medical Science
College of Medical Sciences,
University of Benin

REC Approval No: **CMS/REC/2025/783**

This is to inform you that the research described in the submitted proposal, the Informed Consent Forms and other participant information materials have been reviewed and approved by the College Research Ethics Committee, University of Benin.

This approval dates from **18th September, 2025 to 19th September, 2026.** In multi-year research, Endeavour to submit your annual report to the REC early in order to obtain renewal of your approval and avoid disruption of your research.

The National Code of Health Research Ethics requires you to comply with all institutional guidelines, rules and regulations and with the tenets of the code including ensuring that all adverse events are reported promptly to the REC. No, changes are permitted in the research without prior approval by REC except in circumstances outlined in the code. REC reserves the right to conduct compliance visit to your research site without prior notice. Thank you.

PROF. F.A IMARHIAGBE
Chairman, REC

Promoting best ethical & scientific standard for research in Nigeria

APPENDIX I1: ETHICAL APPROVAL LETTER