Exploring the Effects of Glutathione Supplementation on Liver Enzymes and Serum Electrolyte Levels in Mice Exposed to 850-1900 MHz Mobile Phone Radiation: An Investigation into Radiative Stress and Potential Protective Measures

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ABSTRACT

The pervasive presence of electromagnetic fields (EMF) generated by modern technologies poses a significant threat to human health, with ionizing radiation, a byproduct of EMF, potentially contributing to cancer development. This study explores the impact of chronic exposure to GSM-EMFs and 900-1800 MHz-induced electromagnetic radiation (EMR) on liver enzymes, and serum electrolytes in mice and potential mitigating effect of exogenous glutathione administration. Thirty-five adult male mice were randomly divided into seven groups and exposed to various modes of mobile phone radiation for five weeks, with or without glutathione administration. Liver enzymes (ALP, ALT, AST) and serum electrolytes (sodium, potassium, bicarbonate) were analyzed. Results showed significant increases in ALP levels in the Silent, Ringtone + GSH, and Silent + GSH groups compared to controls, while ALT and AST levels remained largely unchanged. Serum electrolyte concentrations did not significantly differ across experimental groups.

Keywords: Mobile phone radiation, Glutathione, Liver enzymes, Serum electrolytes, Physiology

INTRODUCTION

The widespread presence of electromagnetic fields (EMF) generated by contemporary technologies, encompassing common household appliances and mobile devices, presents a palpable threat to human health. Research indicates that ionizing radiation, a byproduct of EMF, may serve as a precursor to future cancer development, as evidenced by studies linking elevated rates of chromosome abnormalities and micronuclei occurrence in populations exposed to radiation from various sources such as nuclear incidents, environmental contaminants, and medical diagnostic procedures like CT scans and x-rays [1]. Such exposure to radiation triggers oxidative stress (OS) within bodily tissues [2], emphasize the potential health consequences associated with prolonged EMF exposure. This phenomenon arises from an imbalance between the levels of reactive oxygen species (ROS) and the capacity of the antioxidant system to mitigate their effects [3]. Moreover, oxidative stress levels can escalate during different stages of development [4]. Various physiopathological and physiological conditions, nutritional factors [7], and exposure to external pollutants like electromagnetic radiation [5] can contribute to heightened oxidative stress status.

Moreover, studies highlight that electromagnetic radiation intensifies the production of ROS, culminating in various physiological repercussions, such as DNA damage. Ionizing radiation, with its rapid ability to ionize cellular structures, presents a significant peril to both human and animal well-being, capable of inflicting harm in an instant. Conversely, non-ionizing radiation from device such as mobile phones, although lacking ionizing capabilities, can still pose risks with prolonged exposure, a critical consideration in its interaction with the human body [8]. Many researchers concur that non-ionizing radiation poses significant health hazards [9]. The

potential health impacts of electromagnetic pollution and the increasing recognition of EMF exposure spotlight the need for heightened awareness [10].

Non-ionizing radiation spans from extremely low frequency (ELF) to visible light, while ionizing radiation encompasses higher frequencies [11]. These radiations primarily impact the liver, kidneys, and brain due to their proximity to mobile phones during daily use [2]. The increasing use of multi-slice CTs also further amplifies concerns, especially for children, who are at a higher risk of radiation-induced malignancies due to their longer lifespan [12]. Additionally, research reveals the potential adverse effects of electromagnetic frequencies emitted by mobile phones, including DNA damage, increased cancer susceptibility, oxidative stress, chromosomal abnormalities [13, 14, 15, 16, 17, 18], and hormonal and physiological imbalances.

The liver, the body's largest internal organ, plays a pivotal role in detoxification, ridding the body of harmful toxins [19]. Yet, the detrimental effects of free radicals generated during hepatic metabolism can largely be counteracted by various antioxidant enzymes and non-enzymatic mechanisms [20, 3]. Nevertheless, a decline in the antioxidant system's response, coupled with an overproduction of reactive oxygen species from radiation, may escalate hepatic oxidative stress, leading to liver injury. Electromagnetic radiation emitted by 900 MHz cell phones has been shown to impact the expression of Nrf2 protein, trigger oxidative damage, and alter the morphology of liver cells [21].

Electrolytes are electrically charged molecules that play pivotal roles in regulating acid-base balance, blood clotting, and the contraction of muscles and body fluids. Within the body, several common electrolytes serve specific and vital functions, collectively maintaining the balance of fluids between intracellular and extracellular environments. This equilibrium is crucial for hydration, nerve impulses, muscle function, and pH levels. Among the major electrolytes are

Potassium, Sodium, Magnesium, Calcium, and Chloride. Notably, Serum Sodium, Potassium, and Chloride are fundamental determinants of the electrophysiological properties of myocardial membranes [22, 23]. In the body, serum electrolytes perform essential roles in numerous physiological and metabolic processes. Particularly among acutely ill individuals, including children, adolescents, and animals, fluctuations in serum sodium and potassium concentrations are prevalent, often leading to heightened morbidity and mortality [25]. Serum electrolyte concentrations constitute key tests for evaluating a patient's clinical condition and are closely linked to morbidity and mortality. Any deviations from the normal range of electrolyte levels in the body are termed electrolyte disorders [26]. Despite their critical importance, electrolyte disorders in the context of electromagnetic field (EMF) exposure, encompassing both ionizing and non-ionizing radiation, have received scant attention. However, these disorders hold significant potential in influencing the initiation, diagnosis, and prognosis of diseases [24].

As technology becomes increasingly integrated into our daily lives, there's a notable gap in research concerning the effects of radiation on liver enzymes and electrolyte balance, both of which are closely linked to elevated mortality and morbidity rates. Specifically, there's a lack of understanding in addressing and managing the potential health implications associated with these critical bodily parameters. Therefore, this study dig into investigating the repercussions of electromagnetic radiation exposure on liver enzymes and serum electrolytes.

The research focuses on exploring the impact of daily exposure to GSM-EMFs and 900-1800 MHz-induced electromagnetic radiation (EMR) on oxidative stress levels in mice. By examining these specific frequencies commonly encountered in modern technology, the study aims to shed light on the potential physiological consequences and implications for human health.

METHODS

Animals and grouping

The animals involved in the study were maintained and used in accordance with the Animal Welfare Act and the Guide for the Care and Use of Laboratory animals prepared by the Ahmadu Bello University Committee on Animal Use and Care (ABUCAUC), and ethical approval was obtained from the ABUCAUC with the approval number of ABUCAUC/2021/005.

At the start of the experiment, thirty five (35) apparently healthy adult male Mice between the ages of 8-12 weeks were obtained from the animal house facility of the Department of Human Physiology, College of Medical Sciences, Ahmadu Bello University, Zaria, Nigeria. They were housed in standard polypropylene cages and were maintained and allowed free access to feed and water 24/7 and 12h alternate day light and darkness. The animals were allowed to acclimatize to the environment of the behavioral laboratory for two weeks before the commencement of the experiment.

The animals were randomly selected and divided into seven (7) groups of five (n=5) mice per group as shown in the table below:

Table 1: Showing different irradiated group

GROUP	CATEGORY
I	Normal control group
II	Group exposed to mobile phone radiation in ringtone mode
III	Group exposed to mobile phone radiation in vibration mode
IV	Group exposed to mobile phone radiation in silent mode
V	Group exposed to mobile phone radiation in ringtone mode plus glutathione (GSH)
VI	Group exposed to mobile phone radiation in vibration mode plus glutathione and the last group
VII	Group VII were exposed to mobile phone radiation in silent mode plus glutathione

128 ***Radiation exposure***

129 Using Itel mobile phone (it2160) with specific absorption rate (SAR) of 2W/kg and 2G Network
130 Bands, of frequency 850-1900 MHz, the animals in groups II to VII were all exposed to 4 hours
131 mobile phone radiation of an average of 300 missed calls per day for six (6) weeks. Animals in
132 groups V, VI and VII were administered glutathione (250 mg/kg) thirty minutes prior to mobile
133 phone radiation daily.

134 ***Determination of Alkaline Phospahtase***

135 Alkaline phosphatase (ALP) activity was analyzed using the method described by Bassey *et al.*
136 (1946) [47] and modified by Wright *et al.* (1972) [46], with Randox kits. In this procedure, 10 µl
137 of the sample was mixed with 500 µl of the ALP reagent in a cuvette. The initial absorbance at
138 405 nm was recorded, and additional readings were taken over 3 minutes. The mean absorbance
139 per minute was then used to calculate ALP activity (IU/l) using the formula 2742 × ΔA 405
140 nm/min, where 2742 is the extinction coefficient, and ΔA 405 nm/min represents the change in
141 absorbance per minute for the sample.

142

143 ***Determination of Alanine Transaminase***

144 Alanine transaminase (ALT) activity was measured using the method described by Shaw *et al.*
145 (1978) [45] with Randox kits. In this process, 50 µl of the sample and 500 µl of the ALT reagent
146 were mixed in a test tube. The initial absorbance at 340 nm was recorded after 1 minute, and the
147 timer was started simultaneously. Further absorbance readings were taken at 1, 2, and 3 minutes.
148 ALT activity (nm/min) was calculated using the formula 1746 × ΔA 340 nm/min, where ΔA 340
149 nm/min is the change in absorbance per minute for the sample, and 1746 is the extinction
150 coefficient.

151

152 ***Determination of Aspartate Aminotransferase***

153 Aspartate transaminase (AST) activity was also measured using the method described by Shaw
154 *et al.* (1978) [45] with Randox kits. In this procedure, 50 µl of the sample and 500 µl of the AST
155 reagent were combined in a test tube. The initial absorbance at 340 nm was recorded after 1
156 minute. The timer was then started, and additional absorbance readings were taken at 1, 2, and 3
157 minutes. AST activity (nm/min) was calculated using the formula 1746 × ΔA 340 nm/min, where
158 ΔA 340 nm/min represents the change in absorbance per minute for the sample, and 1746 is the
159 extinction coefficient.

160

161 ***Determination of Sodium and Potassium ion concentration***

162 Serum sodium and potassium concentrations were measured using the flame emission
163 photometry method described by Magoshes and Vallee in 1956 [49]. This technique involves the
164 desolvation of a solution containing these elements by a flame, which leaves behind solid salts.
165 These salts dissociate into neutral ground state atoms, which then become excited by the flame,
166 moving to a higher energy state. As the excited atoms return to the ground state, they emit light
167 at characteristic wavelengths (590 nm for sodium and 770 nm for potassium). This emitted light
168 passes through a suitable filter onto a photosensitive element, and the resulting current produced
169 is measured, corresponding to the amount of sodium or potassium in the original sample.

170

171 ***Determination of Bicarbonate Concentration***

172 The concentration of bicarbonate ions in serum samples was determined using the titration
173 method described by Van Slyke and Neil in 1924 [48]. The method involves releasing carbon

dioxide from bicarbonate ions in the serum by adding dilute hydrochloric acid. The remaining acid is then titrated with sodium hydroxide, using phenol red as an indicator.

RESULTS

LIVER ENZYMES

Serum Alkaline Phosphate (ALP)

The impact of chronic exposure to mobile phone radiation, coupled with glutathione administration, on serum liver enzyme (ALP) levels in mice was examined, yielding the following outcomes [Figure 1]: Control (25.97 ±3.09), Ringtone (23.37±2.04), Vibration (35.76±4.95), Silent (141.13±12.87), Ringtone + GSH (71.09±6.38), Vibration + GSH (39.09± 6.13), Silent + GSH (80.73±17.21). Statistical analysis revealed no significant differences ($p>0.05$) between the control group and other experimental groups, except for the Silent, Ringtone + GSH, and Silent + GSH groups, which exhibited notable increases compared to the control group.

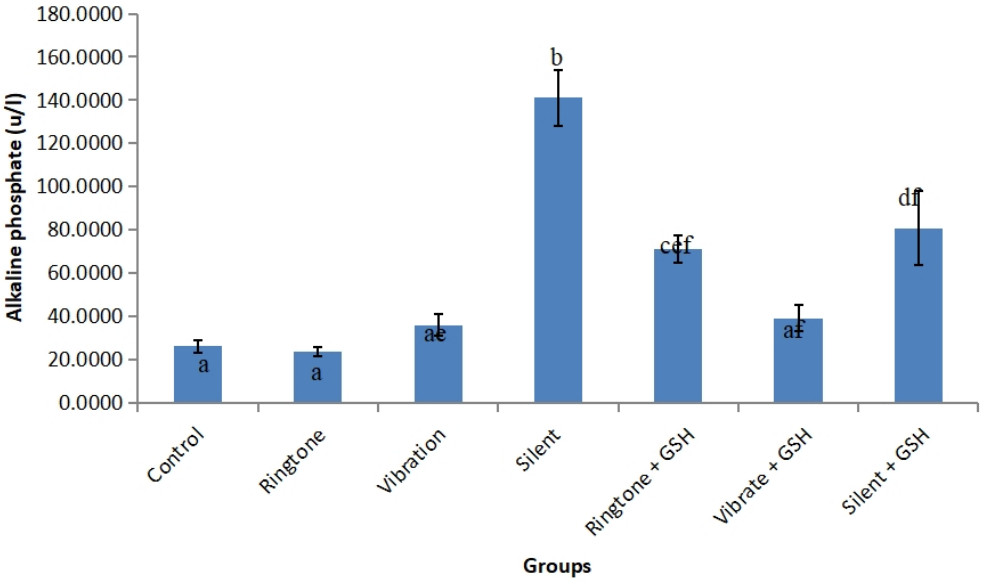
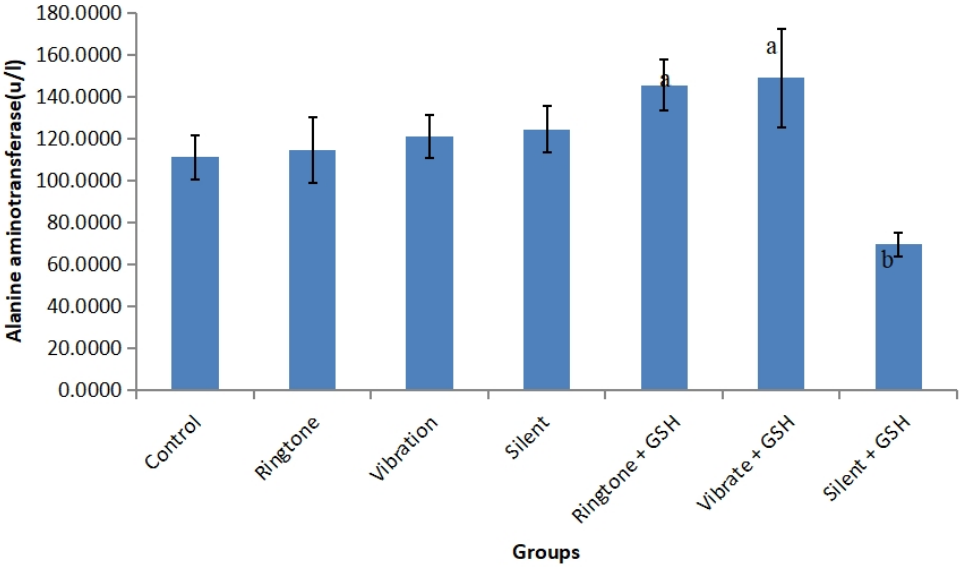


Figure 1: Effect of chronic exposure to mobile phone radiation and glutathione administration on serum alkaline phosphate in mice.

Serum Alanine Aminotransferase (ALT)

208 The impact of chronic exposure to mobile phone radiation, alongside glutathione administration,
209 on serum liver enzyme levels (ALT) in mice was investigated, yielding the following outcomes
210 [Figure 2]: Control (111.0±10.47), Ringtone (114.5±15.57), Vibration (121.0±10.08), Silent
211 (124.25±11.0), Ringtone + GSH (145.5±12.10), Vibration + GSH (148.75±23.57), Silent + GSH
212 (69.5±5.7). Statistical analysis revealed no significant differences (p>0.05) between the control
213 group and the other experimental groups, except for the Ringtone + GSH and Vibration + GSH
214 groups, which demonstrated a notable increase.



215

216 **Figure 2:** Effect of Chronic Exposure to Mobile Phone Radiation and Glutathione
217 Administration on Serum Alanine aminotransferase in mice.

218 ***Serum Aspartate Aminotransferase (AST)***

219 The effect of chronic exposure to mobile phone radiation and glutathione administration on
220 serum liver enzymes (AST) in mice gave the following results [Figure 3]; Control
221 (262.25±17.79), ringtone (221.0±11.08), vibration (234.25±31.497), silent (217.5±24.75),
222 ringtone + GSH (272.75±23.62), vibration + GSH (392.25±58.41), silent + GSH (227.5±28.0).
223 There was no statistical significance (p>0.05) when control group was compared to other groups.

But when the other groups are compared to each other there was statistical significance as shown on the graph.

The impact of chronic exposure to mobile phone radiation, coupled with glutathione administration, on serum liver enzyme levels (AST) in mice was explored, yielding the following observations [Figure 3]: Control (262.25±17.79), Ringtone (221.0±11.08), Vibration (234.25±31.497), Silent (217.5±24.75), Ringtone + GSH (272.75±23.62), Vibration + GSH (392.25±58.41), Silent + GSH (227.5±28.0). Statistical analysis revealed no significant differences ($p>0.05$) when comparing the control group to the other experimental groups except the vibration+GSH group.

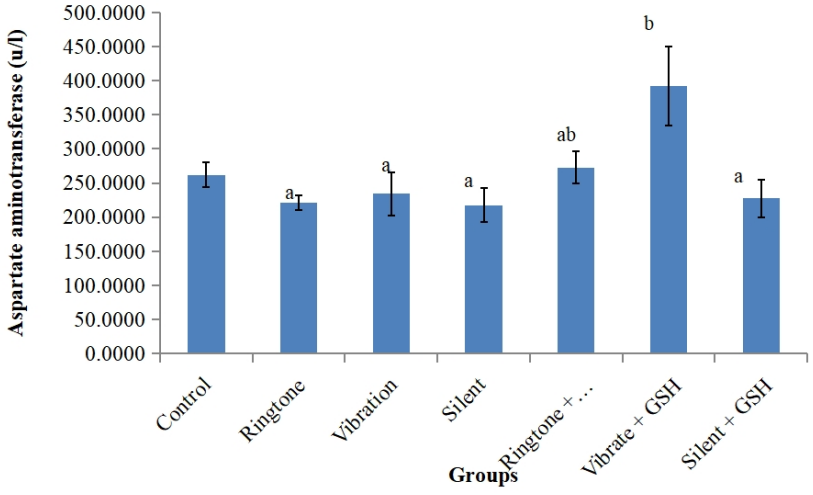


Figure 3: Effect of Chronic Exposure to Mobile Phone Radiation and Glutathione Administration on Serum Aspartate aminotransferase in Mice.

240 **Table 2:** Detailed the difference of chronic exposure to mobile phone radiation and glutathione
241 administration on notable liver enzymes.

Liver Enzymes	Control	Ringtone	Vibration	Silent	Ringtone+GSH	Vibration+GSH	Silent+GSH
Alkaline Phosphate	25.97 ±3.09	23.37±2.04	35.76±4.95	**141.13±12.87**	**71.09±6.38**	39.09± 6.13	**80.73±17.21**
Alanine Aminotransferase	111.0±10.47	114.5±15.57	121.0±10.08	124.25±11.0	**145.5±12.10**	**148.75±23.57**	69.5±5.7
Aspartate Aminotransferase	262.25±17.79	221.0±11.08	234.25±31.497	217.5±24.75	272.75±23.62	**392.25±58.41**	227.5±28.0

242

243 **SERUM ELECTROLYTES**

244 ***Serum Sodium ion Concentration***

245 The impact of chronic exposure to mobile phone radiation, alongside glutathione administration,
246 on serum sodium ion concentration was investigated, yielding the following outcomes [Figure
247 4]: Control (103.0 ± 4.26), Ringtone (104.94 ± 3.83), Vibration (111.28 ± 2.87), Silent (108.30 ±
248 2.19), Ringtone + GSH (109.60 ± 2.79), Vibration + GSH (103.10 ± 2.79), Silent + GSH (105.0
249 ± 3.88). Upon analysis, no significant differences were observed ($p > 0.05$) when comparing the
250 control group with the entire experimental cohort. These findings suggest that chronic exposure
251 to mobile phone radiation, in conjunction with glutathione administration, does not exert a
252 substantial influence on serum sodium ion concentration. Further exploration is warranted to
253 comprehensively understand the interplay between these factors and their potential implications
254 for health.

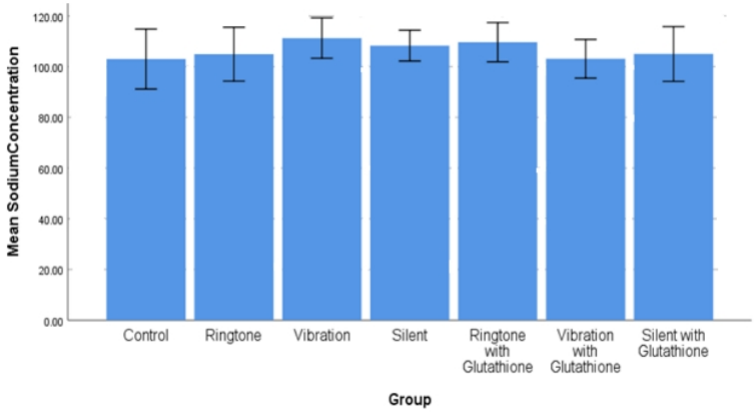


Figure 4: Effect of Chronic Exposure to Mobile Radiation and Glutathione Administration on Serum Sodium Ion Concentration in Mice.

Serum Potassium ion Concentration

The impact of chronic exposure to mobile phone radiation, coupled with glutathione administration, on serum potassium ion concentration was explored, yielding the following observations [Figure 5]: Control (36.40 ± 4.26), Ringtone (34.46 ± 3.83), Vibration (28.12 ± 2.87), Silent (31.10 ± 2.19), Ringtone + GSH (29.74 ± 2.79), Vibration + GSH (36.30 ± 2.79), Silent + GSH (34.40 ± 3.88). Result revealed no statistically significant differences ($p > 0.05$) when comparing the control group with the various experimental conditions, including Ringtone mode, Silent Mode, Vibration mode, as well as their corresponding combinations with glutathione administration. These findings suggest that chronic exposure to mobile phone radiation, in tandem with glutathione administration, does not significantly influence serum potassium ion concentration. Further investigations are warranted to elucidate the nuanced interplay between these variables and their potential implications for health.

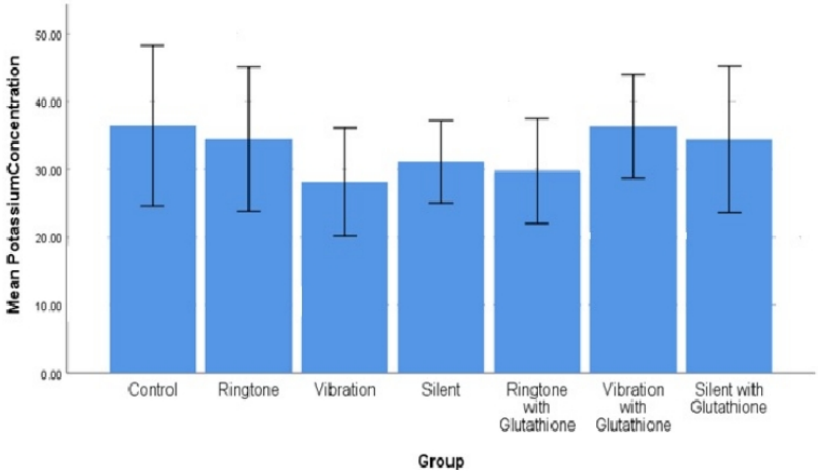


Figure 5: Effect of Chronic Exposure to Mobile Radiation and Glutathione Administration on Serum Potassium Ion Concentration in Mice

Serum Bicarbonate Concentration

The impact of chronic exposure to mobile phone radiation, alongside glutathione administration, on serum bicarbonate concentration was assessed, yielding the following findings [Figure 6]: Control (24.82 ± 3.60), Ringtone (24.78 ± 3.31), Vibration (19.08 ± 2.47), Silent (24.18 ± 2.29), Ringtone + GSH (23.32 ± 3.94), Vibration + GSH (21.98 ± 4.38), Silent + GSH (27.42 ± 8.18). Statistical analysis revealed no significant differences ($p > 0.05$) when comparing the control group with the various experimental conditions. These results suggest that chronic exposure to mobile phone radiation, in conjunction with glutathione administration, does not notably alter serum bicarbonate concentration. However, further investigations are warranted to comprehensively understand the intricate relationship between these variables and their potential implications for physiological health.

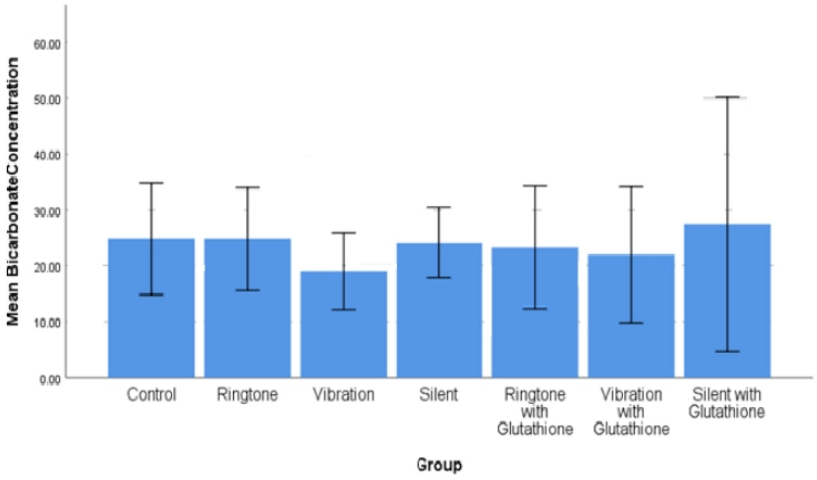


Figure 6: Effect of Chronic Exposure to Mobile Radiation and Glutathione Administration on Serum Bicarbonate Ion Concentration in Mice

Table 3: Detailed the difference of chronic exposure to mobile phone radiation and glutathione administration on different serum electrolytes.

Serum Electrolytes	Control	Ringtone	Vibration	Silent	Ringtone+GSH	Vibration+GSH	Silent+GSH
Na+	103.0 ± 4.26	104.94 ± 3.83	111.28 ± 2.87	108.30 ± 2.19	109.60 ± 2.79	103.10 ± 2.79	105.0 ± 3.88
K+	36.40 ± 4.26	34.46 ± 3.83	28.12 ± 2.87	31.10 ± 2.19	29.74 ± 2.79	36.30 ± 2.79	34.40 ± 3.88
$NaHCO_3$	24.82 ± 3.60	24.78 ± 3.31	19.08 ± 2.47	24.18 ± 2.29	23.32 ± 3.94	21.98 ± 4.38	27.42 ± 8.18

296 **DISCUSSION**

297 The utilization of mobile phones stands as one of the most rapidly advancing technological
298 fronts, prompting concerns regarding the interplay between electromagnetic radiation (EMR) and
299 liver function [27]. Amidst the different applications of low-intensity, extremely low-frequency
300 electromagnetic fields (EMF) in combatting ailments like malaria and cancer [28], the utilization
301 of radiofrequency radiation (RFR) is emerging as a promising noninvasive strategy for tumor
302 therapy, capitalizing on its ability to induce shock responses and apoptosis in human cancer cells
303 [29]. Nonetheless, findings by Costa et al. [31] suggest that even minute levels of EMF,
304 modulated at specific frequencies, might disrupt the growth of Hep G2 cells. However, their
305 study delves into the in vitro mechanisms elucidating the antiproliferative impact of such low-
306 intensity EMF on Hep G2 cells [30, 31]. Moreover, various studies have explored the
307 repercussions of EMF exposure on the delicate balance of antioxidants and oxidants in vital
308 organs and tissues such as the liver, heart, and lens [32, 33, 34]. Despite this wealth of research,
309 scant literature exists on the influence of EMF radiation on physiological parameters exposure
310 [35] (Unpublished report) such as serum electrolytes and liver enzymes, particularly regarding
311 the interplay with glutathione.

312 A previous study conducted by Kosanic *et al.* (2001) [38] reported the effects of vitamin C, a
313 potent antioxidant, on individuals exposed to Wi-Fi radiation for one day. Their findings
314 unveiled a significant rise in blood glucose levels and a concurrent decrease in triglyceride levels
315 compared to the control group. However, no notable impact was observed on cholesterol levels,
316 low-density lipoprotein (LDL), high-density lipoprotein (HDL), or hepatic enzyme activities
317 such as ALP, AST, and ALT relative to the control group. Interestingly, in the extended 5-day
318 tests, contrasting outcomes emerged, showcasing a significant reduction in blood sugar levels

319 and an elevation in cholesterol and lipoproteins among various groups compared to the control.
320 Nevertheless, triglyceride levels and hepatic enzyme activities remained unaffected.

321 This discrepancy suggests that the observed effects could potentially stem from the antioxidant
322 properties of vitamin C. In our study, where we investigated the influence of glutathione (GSH),
323 a compound closely related to vitamin C in its role as an antioxidant, on radiation exposure from
324 different modes of phone activity, distinct patterns were noted. Notably, a significant increase in
325 ALP was only noted in the Silent, Ringtone+GSH, and Silent+GSH modes, while other modes
326 exhibited no significant increase, as detailed in [Table 2].

327 Despite GSH's known physiological and metabolic roles and its capacity to shield against
328 radiation-induced damage by scavenging free radicals and converting them into non-radical
329 forms [36, 37], our findings suggest a potential surge in oxidative stress. This could arise from an
330 upsurge in free radical production, a decline in antioxidant defense systems, or a combination of
331 both factors. The lack of significant effects observed in ALP, ALT, and AST across most phone
332 modes may be attributed to prolonged exposure to mobile phone radiation, which has been
333 linked to increased serum ALT and AST levels, as reported by Li (2015) and Rahman (2022)
334 [5,44]. However, insights from Fatima *et al*. (2017) [40] and colleagues shed further light,
335 revealing that rats exposed to radiation over a two-month period, three days per week, exhibited
336 heightened liver enzyme activity, elevated levels of MDA and H202, and decreased antioxidant
337 levels such as GSH and CAT in liver tissue. While this aligns partially with our findings, it's
338 worth noting differences in exposure duration between our study and theirs.

339 Our findings also echo the conclusions drawn by Nersesova *et al.* (2014) [41], who elucidated
340 that despite observing changes in enzyme activity levels of liver-sensitive enzymes in both liver
341 tissue and blood serum upon radiation exposure, no discernible effects on hepatocyte cell

membrane permeability were evident. Instead, they noted alterations in energetic metabolism. However, despite these observations, correlational analysis of post-radiation enzyme activity level changes failed to reveal a clear relationship among them. Our study aligns with the findings of Ma *et al.* (2014) [42], who reported no significant changes in serum levels of ALT, AST, and AST/ALT in the radiated group. Notably, they observed hepatocyte nuclear atrophy and cytoplasmic vacuolar degeneration in histological sections, which was not explored in our study. Additionally, in Cetin *et al.*'s [43] investigation on brain and liver glutathione peroxidase activities, along with liver vitamin A and β-carotene concentrations, they noted a decrease in glutathione peroxidase levels in the EMF radiated groups. Conversely, brain iron, vitamin A, and β-carotene concentrations increased in the EMR groups, a result consistent with some outcomes from our phone model assessments on glutathione's role in mitigating EMF radiation effects on liver enzymes.

Furthermore, our results share similarities with the findings of Nwokocha *et al*. (2012) [44]. In their study, they observed that AST liver enzymes elevated with increasing radiation, which is also observed in some certain phone models in our study, such as vibration+GSH, AST liver enzyme levels elevated with increasing radiation, while others within the same category did not exhibit statistical significance in our study. Similarly, they found that alanine transaminase (ALT) levels increased with radiation, which is also similar with our ringtone+GSH and vibration+GSH models, while others in this same category showed no significant changes. Notably, our study also identified an increase in AST liver enzyme levels, particularly in the vibration+GSH model, an aspect not explored in their research. However, the remaining phone models in our study, including ringtone, vibration, silent, ringtone+GSH, and silent+GSH, did not show any significant increase.

365 Almost similar to our findings, Nwokocha *et al.* (2012) [44] reported that serum electrolyte
366 concentrations remained within normal ranges following total body irradiation, this is also to
367 similar to our results which is detailed in [Table 3]. Specifically, sodium, potassium, and
368 bicarbonate levels were found to be statistically not significant ($p>0.05$) lower than the control
369 group after irradiation.

370 In conclusion, this study sheds light on the impact of chronic mobile phone radiation exposure on
371 liver enzymes and serum electrolytes in a Mice model. While some variations were observed in
372 liver enzyme levels, the overall findings suggest minimal alterations in serum electrolyte
373 concentrations. These results reveal the miscellaneous nature of the biological response to
374 electromagnetic radiation and emphasize the importance of continued research in this field to
375 safeguard public health exposure to mobile phone radiation..

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381 facilities. The authors also acknowledge the indispensable contributions of the Technicians at the
382 Department, whose dedication greatly contributed to the success of the study.

383 **ETHICAL STATEMENT**

384 This study was conducted at the Department of Human Physiology, Faculty of Basic Medical
385 Sciences of Ahmadu Bello University, Zaria. Approval for the project was granted by the
386 Ahmadu Bello University Ethical Committee on Animal Use and Care, with the assigned

approval number ABUCAUC/2021/005. All ethical protocols concerning the handling, care, and welfare of the animals were meticulously observed throughout the study, from its inception to its conclusion.

AUTHOR'S CONTRIBUTIONS

All authors contributed greatly to the success of this work

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CONFLICT OF INTEREST

No conflict of interest to declare in this manuscript

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