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Original Article

Effects of 4G 2100 MHz Radiation on Lymphocyte Levels: An Experimental Study in Wistar Rats

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Abstract

Background : Electromagnetic radiation (EMR) from mobile phones has become a global concern due to its potential impact on the immune system. However, the effects of EMR on lymphocyte levels remain inconsistent across studies. This study aimed to evaluate the effects of 4G 2100 MHz EMR exposure on lymphocyte levels in Wistar rats.
Methods : This research employed a true experimental design with a Post Test Only Controlled Group Design. Four groups of male Wistar rats were used: a control group (G1) and three exposure groups subjected to EMR for 15 (G2), 30 (G3), and 45 days (G4). The exposed groups were subjected to 2 hours per day of 4G 2100 MHz EMR using a Redmi A2 mobile phone in WhatsApp call mode. Lymphocyte levels were analyzed using ANOVA to determine differences among the groups.
Results : The average lymphocyte levels in groups G1, G2, G3, and G4 were 68.92 ± 4.78%, 63.37 ± 6.29%, 67.00 ± 11.51%, and 64.35 ± 13.58%, respectively. Statistical analysis revealed no significant differences among the groups ($p = 0.703$).
Conclusion : Exposure to 4G 2100 MHz EMR for 1545 days did not significantly change lymphocyte levels in Wistar rats. These findings support the need for further studies to evaluate other immunological parameters and the long-term effects of EMR exposure.

Keywords : Electromagnetic radiation; Lymphocyte levels; Wistar rats; Mobile phones; Immune system

INTRODUCTION

The rapid advancement of technology has led to a surge in the use of wireless communication devices, especially smartphones. As of 2024, there are more than 7.2 billion smartphone users globally––around 90% of the world's population. In Indonesia, smartphone use is also widespread. According to APJII, 196.71 million Indonesians were smartphone users in 2019, placing the country fourth globally. By 2023, smartphone penetration among adolescents aged 13–18 had reached 98.20%, making them the highest-using age group.[1,2]

This widespread smartphone use raises public health concerns, particularly due to exposure to electromagnetic radiation (EMR), which has been linked to oxidative stress and various health issues, including effects on the immune system.[3,4] Lymphocytes, key players in the adaptive immune response, are susceptible to environmental changes. EMR exposure may reduce lymphocyte levels through mechanisms such as oxidative stress, chronic inflammation, and impaired proliferation.[4]

Exposure to low to high levels of EMR (900 MHz and 1.3 GHz for 15 hours/day) from mobile phones in male albino rats over 28 days showed a trend of decreased lymphocyte levels.[5] Other studies have also reported that exposure to 900 MHz EMF for 2 hours/day in albino rats resulted in a significant decrease in lymphocyte count after two weeks of exposure.[6] Given the increasing public exposure to newer-generation mobile network frequencies, such as 4G operating at 2100 MHz, it is crucial to investigate their potential health impacts. Therefore, this study aims to examine the effects of 4G 2100 MHz electromagnetic radiation on lymphocyte levels in Wistar rats.

METHODS

This study was conducted from August to October 2024 at the Experimental Animal Laboratory, Faculty of Medicine, Universitas Jenderal Soedirman, and the Clinical Pathology Laboratory, Faculty of Medicine, Universitas Muhammadiyah Purwokerto.

The research employed a true experimental design with a Post Test Only Controlled Group Design using Wistar strain rats *(Rattus norvegicus)* as test subjects. Inclusion criteria included healthy and active male Wistar rats aged 24 weeks, weighing 150200 grams.[7] Exclusion criteria included sick or dying rats during acclimatization or the research process.

The study consisted of four groups: the control group (G1), a group exposed to electromagnetic radiation (EMR) for 15 days (G2), a group exposed for 30 days (G3), and a group exposed for 45 days (G4).[7] Each group included seven rats. Before the study began, the rats were acclimatized for seven days under standard animal care conditions. The rats were housed in cages of identical size. All protocols involving animal subjects were approved by the Research Ethics Committee of the Faculty of Medicine, Universitas Jenderal Soedirman, under approval number 041/KEPK/PE/VI/2024.

Groups 2, 3, and 4 were exposed to 4G 2100 MHz EMR using WhatsApp call mode on a Redmi A2 mobile phone for 2 hours daily in treatment cages measuring 7x20x5 cm^2. The phone was positioned at a distance of 3 cm from the cage wall.[7] After maintenance and treatment, the rats were fasted for 8–12 hours, and blood samples were collected via the retro-orbital sinus for lymphocyte level analysis. Blood samples were collected via the retro-orbital sinus and analyzed using an automated Hematoanalyzer Sysmex KX-21 at the Clinical Pathology Laboratory, Faculty of Medicine, Universitas Muhammadiyah Purwokerto. The rats were then terminated using the cervical dislocation technique.

The data obtained were tested for normality using the Shapiro-Wilk test and for homogeneity using Levene's test. The results indicated that the data were normally distributed and homogeneous. Subsequently, the data were analyzed using One-Way ANOVA.

RESULTS

The results of the study showed a *p-value* of 0.703 ($p > 0.05$), indicating that there was no statistically significant differences among the treatment groups. Therefore, exposure to EMR at a frequency of 2100 MHz for 2 hours per day over 15, 30, and 45 days did not result in significant changes in lymphocyte levels in rats.

Body weight was also recorded before and after treatment. The analysis showed no significant differences in body weight among groups ($p > 0.05$), indicating that EMR exposure did not significantly affect the animals' weight.

DISCUSSION

The findings of this study indicate that exposure to 4G 2100 MHz (EMR for 15, 30, and 45 days did not result in significant changes in rat lymphocyte levels ($p = 0.703$). These results contradict the initial hypothesis that prolonged EMR exposure would significantly affect lymphocyte levels. Previous studies have mentioned that exposure to radiofrequency electromagnetic fields did not significantly alter T cell populations or functions in developing rats, suggesting that the immune system may tolerate certain levels of EMR without dysregulation.[8] Another study also mentioned that no significant changes in circulating lymphocyte counts following EMR exposure from a 915 MHz RFID system in healthy adult rats.[9]

Minor fluctuations in lymphocyte levels among the exposed groups (G2, G3, and G4) may reflect adaptive responses of the immune system to EMR exposure.

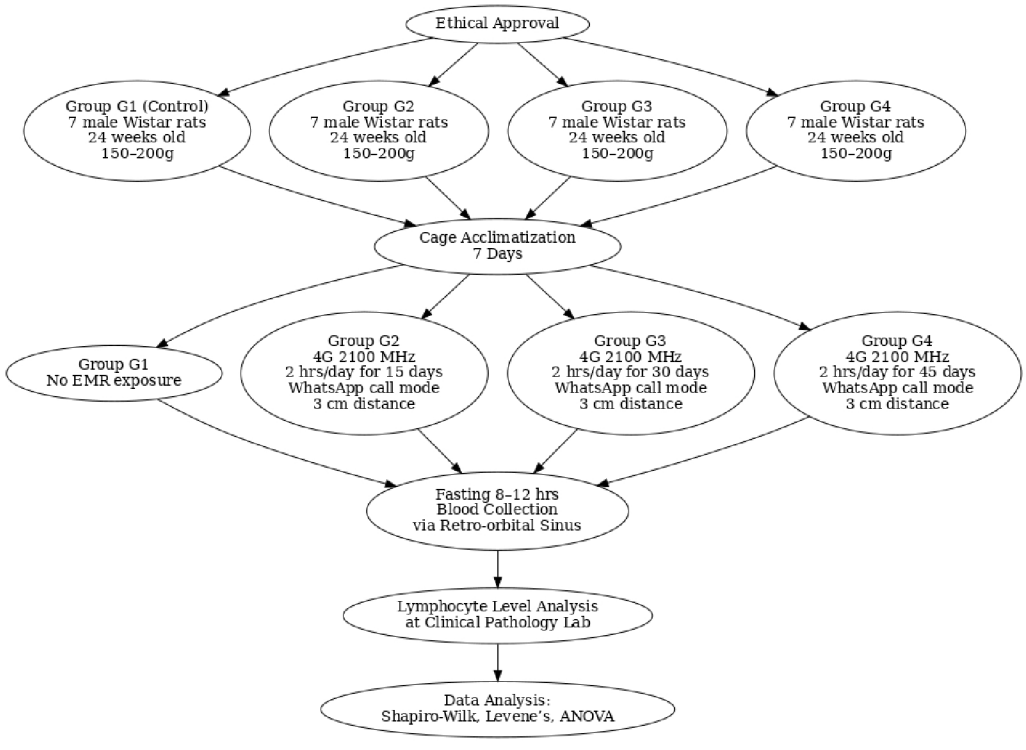

Figure 1. Flowchart of the experimental procedure

TABLE 1
Rat lymphocyte levels

Groups	Mean±SI (%)	*p value*
G1	68.92 ± 4.78	0.703
G2	63.37 ± 6.29	
G3	67.002 ± 11.51	
G4	64.35 ± 13.58	

Lymphocyte homeostasis, a mechanism that regulates cell numbers in response to environmental stimuli, likely contributed to the stable lymphocyte counts observed. Previous studies have mentioned that short-term GSM radiation did not produce measurable physiological effects, suggesting a limited impact of transient EMR exposure on biological systems.[10]

The discrepancy between the results and the initial hypothesis could be attributed to several factors. The cage dimensions may have affected the homogeneity of radiation exposure, potentially leading to variability in EMR absorption among rats. Moreover, biological variation and a relatively small sample size may have limited the statistical power to detect subtle effects. The exposure method––using WhatsApp call mode on a mobile phone––could have resulted in fluctuating signal strengths, which might not have consistently delivered uniform EMR intensity across individuals. Additionally, external factors such as ambient stress or minor environmental inconsistencies could have confounded the results, as also acknowledged in other studies assessing EMR effects.[11]

The frequency used in this study, 2100 MHz for 2 hours daily, may not have reached the threshold necessary to induce significant immunomodulatory effects. Prior research has emphasized that both the dose and duration of EMR exposure are critical in determining biological outcomes. If the exposure is too short or at insufficient intensity, immunological changes may not manifest.[8,9]

Classified as short-term exposure, the 15–45 day EMR treatments in this study might not have elicited cumulative immune effects. No significant alterations in physiological parameters following short-term EMR

exposure, possibly due to the establishment of systemic tolerance mechanisms.[10]

In addition to lymphocyte levels, this study also monitored the animals' body weight before and after treatment. No marked differences were observed across the groups. Body weight stability has also been reported in other EMR-related animal studies as an indicator of minimal systemic stress or metabolic disruption. Other studies, found no significant body weight changes in Wistar and Sprague Dawley rats exposed to 5G or 150 kHz EMR over several weeks.[12,13] These findings reinforce our interpretation that short-term EMR exposure at 2100 MHz does not appear to produce measurable systemic effects, at least as reflected in body weight parameters.

It is important to note that this study exclusively measured lymphocyte levels, without assessing other immunological markers such as lymphocyte activation status or subtype distributions. Future research should consider evaluating broader immune responses––including functional assays and profiling of T-helper and T-cytotoxic subpopulations––to better understand the scope of EMR impact. Increasing sample size, using more controlled EMR exposure setups, and conducting long-term studies will further clarify the potential health effects of mobile-related EMR exposure.

Additionally, this study did not include direct measurement of signal strength or EMR wavelength, which limits the ability to verify the accuracy and uniformity of the radiation exposure. Moreover, no physiological or behavioral stress markers, such as corticosterone levels or observation of stress-related behaviors were assessed. The absence of these parameters may limit the depth of interpretation regarding systemic or stress-mediated responses to EMR exposure.

Furthermore, since this study used an animal model (Wistar rats), the findings may not fully represent immune responses in humans. Physiological and metabolic differences between rats and humans could influence the outcomes. Therefore, the results should be interpreted with caution, and further studies involving human subjects are necessary to validate these findings.

CONCLUSION

This study demonstrated that exposure to 4G 2100 MHz EMR for 15, 30, and 45 days at a duration of 2 hours per day did not result in significant changes in lymphocyte levels in Wistar rats. However, as this study was conducted using an animal model, the findings should be interpreted with caution and not directly generalized to humans.

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