FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 8 No. 3, June, (Special Issue) 2024, pp 148 - 153
DOI: https://doi.org/10.33003/fjs-2024-0803-2390

IMPACT OF MAGNETIC RESONANCE IMAGING ON HEMATOLOGICAL PARAMETERS ON ALBINO MICE

[1,2]Amuda, D. B, *[1]Babalola, B. O, [1]Oni, E. A., [1]Oguntunji, D. B, [2]Oyedepo, V. O, [2]Bello, T. O, [3]Gilbert, C. E, [1]Oni O. M, and [4]Olarinoye I. O.

[1]Department of Pure and Applied Physics, Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.
[2]Department of Radiology, Ladoke Akintola University of Technology Teaching Hospital, Ogbomoso, Oyo State, Nigeria.
[3]Medical Laboratory Unit, Health Center, Ladoke Akintola of Technology, Ogbomoso, Oyo State, Nigeria.
[4]Department of Physics, Federal University of Technology, Minna, Niger State, Nigeria.

*Corresponding authors' email: omobolajibabalola29@gmail.com

ABSTRACT

Magnetic resonance imaging (MRI) is a non-invasive technique that uses strong magnetic fields and radiofrequency radiation, to measures behaviour of atomic nuclei inside the body, producing signals that are used to create images. The interactions between the biological systems and magnetic fields present in MRI, concerning changes in hematological parameters are not understood. This research investigated the effects of MRI on hematological parameters in albino mice. 30 male albino mice were divided into two groups, A (control) and B (exposed), each consisting of 15 mice. Mice in group B were exposed to a 1.5 T MRI scanner once a week for 30 minutes for 3 weeks. After the first exposure 5 mice from the exposed and 5 mice from the control were deeply sedated. This was repeated in the second and third exposure. Ministry of Health in Oyo State approved all protocols for animal experimentation. Data were expressed in mean ± standard error (S.E.) and analyzed using GraphPad Prism. First week of exposure indicated a significant increase in packed cell volume, neutrophils, lymphocytes, monocytes of the exposed group except for white blood cells which decreased. There was significant decrease in packed cell volume and lymphocytes of the exposed group except for white blood cells and Neutrophil which increased, monocytes were not significant in the second week. Third week indicated significant increase in white blood cell, lymphocytes, monocytes except for packed cell volume and Neutrophil which decreased. Thus, the hematological parameters of albino mice are negatively impacted by MRI exposure.

Keywords: MRI, Magnetic fields, Radiofrequency, Hematological parameters, Albino mice

INTRODUCTION

Magnetic resonance imaging (MRI) is a non-invasive technique for mapping the internal anatomy and some aspects of bodily function. It uses highly calibrated magnetic fields in conjunction with radio frequency (RF) radiation to create high-quality cross-sectional pictures of the body in any plane (Fardela *et al.*, 2023). These magnetic fields (MF) are significantly stronger than the Earth's magnetic field (Franco, 2020). The patient is placed inside a sizable magnet, which creates a somewhat strong external magnetic field, to create the MR image. As a result, many atoms in the body, including hydrogen, align their nuclei with the magnetic field. When an RF signal is applied later, energy is released from the body, recognized, and utilized by a computer to create an MR image (Manso *et al*., 2023).

The stray field around the scanner causes MRI-related exposure, the static magnetic field in the MRI suite is constantly on, regardless of whether the scanner is operating or not. The field rapidly diminishes as one moves away from the scanner because of the static magnetic field (SMF's) active shielding, creating a broad gradient that becomes noticeable at 0.5 meters from the bore opening. Personnel moving within the SMF's spatial gradient are exposed to induce time varying magnetic field (McRobbie *et al.*, 2020). MRI personnel are subjected to a static magnetic field for the duration of their shifts. MRI staff traveling around the scanner will be exposed to time-varying, extremely low frequency magnetic fields, which cause electric fields and currents to be induced in their bodies. This is because the static magnetic field of an MRI scanner is always on. Additionally, switching gradient fields used for image encoding are only used during patient examinations, exposing MRI workers to radiofrequency radiation at work (Ghadimi-Moghadam *et al*., 2018).

To evaluate the possible hazardous biological effects connected with MRI environment and procedures, numerous researches have been done over the past thirty years. Most of these studies are comparative to the biological effects of a specific electromagnetic source utilized in MRI, while there is a lack of knowledge about the combination of three MFs components. There is a need to fit in the current findings to better understand the interactions between EMF connected to MRI and biological systems (Hartwig et al. 2021).

A researcher investigated the effect of magnetic resonance on some blood parameters of smoking addicts of all kinds, the result showed a statistically significant decrease in the measurements of (smoke + shisha) exposed to the field at a dose of (3 T) by (11%) for all blood parameters, with the exception of white cells, which increased by 10.3% (Serwaan et al. 2023). Another researcher also reported that the low-frequency static magnetic field had an impact on certain blood parameters in cancer patients, particularly at low intensities (0.1 T, 0.7 T). The number of red blood cells and platelets significantly decreased ($P < 0.05$), but the number of white blood cells increased significantly for the same doses administered (Al-Qadi *et al.*, 2023). Hani and Mohammed, (2018) highlighted the influence of exposure to different applied magnetic fields on some hematological parameters. After the mice were exposed to magnetic field, significant variations were seen in the majority of the hematological blood parameters. Prior studies showed contrary results of SMF effects on behaviour, hematopoietic organs and hematological parameters. Mice exposed for 28 days to static magnetic field in the 2–12 T range did not see any changes in body weight, blood indices, organ coefficients, or the histomorphology of the main organs (Wang *et al*., 2019). Most of these studies are relative to the biological effects of a particular electromagnetic source utilized in MRI, while there is a lack of knowledge in the understanding of the precise modifications in hematological parameters brought about by MRI techniques because the majority of the research that has been done so far has concentrated on heat effects and more general physiological responses. Therefore, the objectives of this study are to investigate the effects of magnetic resonance imaging (MRI) on hematological parameters on albino mice.

MATERIALS AND METHOD

Study Area

This research was done at the MRI Unit, Ladoke Akintola University of Technology (LAUTECH) Teaching Hospital, Ogbomoso, Oyo State where the mice were exposed to 1.5 Tesla MRI machine.

Animal Preparation and Exposure

Thirty (30) male albino mice were acquired from Ladoke Akintola University of Technology (LAUTECH)'s Department of Pharmacology. To aid with acclimatization, mice were housed for a week in plastic cages, exposed to standard room temperature and lighting, and given access to animal feeds and water ad libithum. The Ministry of Health in Oyo State approved all protocols for animal experimentation with the assigned NREC number (NHREC/OYOSHRIEC/10/11/22). All procedures were carried out within the parameters of European Council Directive (EU 2010/63) on scientific procedures involving living animals and in accordance with the institutional protocols that have been authorized.

Thirty male albino mice were divided into two groups, A (control) and B (exposed), each consisting of 15 mice. Group A did not receive any MRI exposure, whereas group B was exposed to a 1.5T MRI with RF range of 64MHz for 30 minutes once a week for three weeks. After the first week of exposure five five (5) mice from the exposed group and five (5) mice from the control group were deeply sedated. This was repeated in the second and third week of the exposure. At the end of each week after exposure, blood samples were taken for hematological analysis. After the mice were deeply sedated the operation used to draw blood samples was a midline laparotomy in order to draw blood samples from the heart into the plain EDTA bottles. The MRI scanner (Siemens Co., MAGNETOM ESSENZA) with field strength of 1.5 Tesla and RF range of 64 MHz to emit waves was used for the exposure.

Hematological Parameters

For a hematological test, after the animals has been deeply sedated, blood was drawn from the heart through midline laparotomy and placed in EDTA bottles. Blood samples were kept at 4˚C until the further laboratory analysis. Complete blood count (CBC) was efficiently and accurately analysed using the automated hematology analyser. The CBC test includes the determination of total white blood cell counts, differential white blood cells (Neutrophils, Lymphocytes, Monocytes, Eosinophils) and packed cell volume.

Statistical Analysis

The expression of the results obtained in this work was in mean ± standard error of the mean (S.E.M). The difference between the control and the exposed group were revealed by using the unpaired t-test. $P<0.05$ was considered to indicate a statistically significant difference. These tests of significance were done on GraphPad Prism version 5 for windows.

RESULT AND DISCUSSION

Hematological Studies

Packed Cell Volume (PCV)

The effect of MRI exposure on PCV of the mice in the first week of exposure indicated a significant increase in the PCV of the exposed mice when compared to the control group. The exposed group showed (34.50 ± 0.29%) while the control group showed (28.50 ± 0.87%). There was a significant decrease in the PCV of the exposed group (26.50 ± 0.87%) compared to the control group (40.00 ± 0.58%) in the second week. The third week of exposure also indicated a decrease in the PCV of the exposed group. The control group showed (28.50 ± 0.87%) while the exposed group showed (24.50 ± 0.87%). The increase in PCV in the first week might be as a result of quick physiological reaction to MRI exposure that aims to improve oxygen transport and enable quick adaption and survival (Suppan *et al.*, 2022). Reduced PCV levels in the second and third week are the result of the body's gradual response to chronic stress through regulatory systems that regulate and optimize physiological functioning for long-term survival. Also, with days of exposure, PCV will decrease to the point of hemolysis and anemia. Table 1 shows the effect of MRI on PCV (%) in control and exposed groups of mice from the first week to the third week of exposure. Values were given as mean ±SE. ***=Significant at ($p<0.001$) level of probability. *=Significant at ($p<0.05$) level of probability

Table 1: Effect of MRI on PCV (%) in control and exposed group of mice from the first week to the third week of exposure

Mice group	Mean ± S.E.M	T-test (p-values)
First week		
Control	28.50 ± 0.8660	
Exposed	34.50 ± 0.2887***	0.0006
Second week		
Control	40.00 ± 0.5774	
Exposed	26.50 ± 0.8660***	0.0001
Third week		
Control	28.50 ± 0.8660	
Exposed	24.50 ± 0.8660 *	0.0171

White Blood Cells (WBC)

The effect of MRI exposure on WBC of the mice in the first week of exposure indicated a significant decrease in WBC of the exposed group The control group showed (3600 ± 57.74 mm^3/L) while the exposed group showed (2300 ± 57.74 mm^3/L). The second week of exposure indicated a significant increase in the WBC of the exposed group. The exposed group showed (6200 ± 115.5 mm^3/L) while the control group showed (4850 ± 86.60 mm^3/L). The third week of exposure also indicated an increase in the WBC of the exposed group.

The exposed group showed (8500 ± 57.74 mm^3/L) while the control group showed (6600 ± 57.74 mm^3/L). An acute stress response was probably brought on by the first MRI exposure. Stress hormones like cortisol can be released when the hypothalamic-pituitary-adrenal (HPA) axis is activated as a result of acute stress. A reduction in the number of circulating WBCs can result from the transient transfer of white blood cells from the bloodstream to other tissues, such as the spleen and lymph nodes, when cortisol levels are raised (Dhabhar *et al.,* 2012). The immune system may start to recover after the initial acute stress reaction and the subsequent decline in WBC numbers. The HPA axis activity may stabilize as the mice adjust to the MRI exposure, resulting in a drop in cortisol levels and enabling WBC recovery and proliferation (Dantzer, 2018). Also, the increase might be as a result of the body seeing the MRI exposure as a foreign agent, thereby triggering the production of antibodies. Table 2 shows the effect of MRI on WBC count in control and exposed groups of mice from the first week to the third week of exposure. Values were given as mean ±SE. ***=Significant at ($p<0.001$) level of probability.

Table 2: Effect of MRI on WBC (mm^3/L) count in control and exposed group of mice from the first week to the third week of exposure

Mice group	Mean ± S.E.M	T-test (p-values)
First week		
Control	3600 ± 57.74	
Exposed	2300 ± 57.74***	0.0001
Second week		
Control	4850 ± 86.60	
Exposed	6200 ± 115.5***	0.0001
Third week		
Control	6600 ± 57.74	
Exposed	8500 ± 57.74 ***	0.0001

Neutrophils count

The effect of MRI exposure on neutrophil counts of the mice in the first week of exposure indicates an increase in neutrophils count of the exposed group. The exposed group showed (52.00 ± 0.58 %) and the control group showed (48.00 ± 0.58 %). The second week of exposure also showed an increase in the neutrophils count of the exposed group. The exposed group showed (54.00 ± 1.16 %) while the control group showed (48.50 ± 0.87 %). The effect of MRI exposure on neutrophil count of the mice in the third week of exposure showed that there was decrease in the neutrophil count of the exposed group The control group showed (56.50 ± 0.87 %) and the exposed group showed (51.50 ± 0.87 %). As part of the body's defense mechanism, the initial MRI exposure may have been interpreted by the body as a mild threat or novel stressor, triggering an innate immune response and raising neutrophil numbers. The prolonged stress may keep the immune system stimulated and neutrophil counts high throughout the second week of exposure (Lauridsen, 2019). The mice might have grown accustomed to the recurrent MRI exposure by the third week. Neutrophil numbers may drop as a result of this adaptation as the body gets used to the new baseline.

Table 3 shows the effect of MRI on neutrophil counts in control and exposed groups of mice from the first week to the third week of exposure. Values were given as mean ±SE. **=Significant at ($p<0.01$) level of probability.

Table 3: Effect of MRI on neutrophil (%) counts in control and exposed group of mice from the first week to the third week of exposure

Mice group	Mean ± S.E.M	T-test (p-values)
First week		
Control	48.00 ± 0.58	
Exposed	49.50 ± 0.58**	0.0027
Second week		
Control	48.50 ± 0.87	
Exposed	54.00 ± 1.16**	0.0089
Third week		
Control	56.50 ± 0.87	
Exposed	51.50 ± 0.87**	0.0065

Lymphocytes counts

The effect of MRI exposure on lymphocytes count of the mice in the first week of exposure showed an increase in the lymphocytes count of the exposed group. The exposed group showed (47.50 ± 0.87 %) while the control group showed (43.50 ± 0.87 %). The second week of exposure indicated a decrease in the lymphocytes count of the exposed group (32.50 ± 1.44 %) compared to the control group (43.50 ± 1.44 %) The third week of exposure indicated an increase in the lymphocytes of the exposed group. The exposed group showed (38.00 ± 0.58 %) and the control group showed (36.00 ± 0.58%). Dynamic variations in the number of lymphocytes can result from the interaction of various immune cells with cytokines. When the immune system recalibrates in the third week, pro-inflammatory cytokines generated during the first stress reaction may promote lymphocyte proliferation, while regulatory T cells and anti-inflammatory cytokines may decrease in quantity in the second week (Simpson *et al.,* 2020). Table 4 shows the effect of MRI on lymphocytes counts in control and exposed groups of mice from the first to the third week of exposure. Values were given as mean ±SE. **=Significant at ($p<0.01$) level of probability. *=Significant at ($p<0.05$) level of probability.

Table 4: Effect of MRI on lymphocytes counts (%) in control and exposed group of mice from the first to the third week of exposure

Mice group	Mean ± S.E.M	T-test (p-values)
First week		
Control	43.50 ± 0.87	
Exposed	44.25 ± 0.87*	0.0171
Second week		
Control	43.50 ± 1.44	
Exposed	38.00 ± 1.44**	0.0017
Third week		
Control	37.50 ± 0.58	
Exposed	40.50 ± 0.58 *	0.0498

Monocytes Count

The effect of MRI exposure on monocytes counts of the mice in the first week of exposure showed a significant increase in the monocytes count of the exposed group of mice (6.500 ± 0.28 %) compared to the control group (5.500 ± 0.28 %). There was no significant difference in the monocytes count of the exposed group of mice (6.500 ± 0.28 %) and the control group (6.000 ± 0.57 %). The third week of exposure also showed an increase in the exposed group of mice. The exposed group showed (6.500 ± 0.28 %) while the control group showed (4.500 ± 0.28 %). The immune system naturally fluctuates in response to both external stimuli and internal regulation mechanisms (Ding *et al.*, 2024). These normal oscillations that occur naturally when the body dynamically reacts to continuous MRI exposure may be reflected in the observed pattern of early increase, stabilization, and subsequent increase in monocyte counts. Table 5 shows the effect of MRI on monocytes counts in control and exposed groups of mice from the first to the third week of exposure. Values were given as mean ±SE. *=Significant at ($p<0.05$) level of probability. **=Significant at ($p<0.01$) level of probability. Week 2 was non-significant.

Table 5: Effect of MRI on monocytes counts (%) in control and exposed group of mice from the first to the third week of exposure

Mice group	Mean ± S.E.M	T-test (p-values)
First week		
Control	5.500 ± 0.28	
Exposed	6.500 ± 0.28*	0.0498
Second week		
Control	6.250 ± 0.57	
Exposed	6.500 ± 0.28	0.4680
Third week		
Control	4.500 ± 0.28	
Exposed	6.500 ± 0.28**	0.0027

Eosinophil Count

The effect of MRI exposure on eosinophil count of the mice in the first week of exposure showed no significant difference between the exposed group (1.500 ± 0.28 %) of mice and the control group (1.250 ± 0.25 %). Second week indicated no significant difference in the control group (1.750 ± 0.25 %) and the exposed group (1.500 ± 0.28 %). and third week of exposure indicated no significant difference between the exposed group (1.500 ± 0.28 %) of mice and the control (1.750 ± 0.25 %). MRI exposure might not provide the specific triggers necessary to significantly alter eosinophil counts. Eosinophils are typically mobilized and activated in response to parasitic infections, allergic reactions, or specific cytokines like interleukin-5 (IL-5) (Nagase *et al.*, 2020). In the context of MRI exposure, these specific triggers are likely absent, leading to non-significant changes in eosinophil levels. Table 6 shows the effect of MRI on eosinophil counts in control and exposed groups of mice from the first to the third week of exposure. Values were given as mean ±SE. Non-Significant at ($p<0.001$) level of probability.

Table 6: Effect of MRI on eosinophil counts (%) in control and exposed group of mice from the first to the third week of exposure

Mice group	Mean ± S.E.M	T-test (p-values)
First week		
Control	1.500 ± 0.28	
Exposed	1.250 ± 0.25	0.5370
Second week		
Control	1.750 ± 0.25	
Exposed	1.500 ± 0.28	0.5370
Third week		
Control	1.500 ± 0.28	
Exposed	1.500 ± 0.28	1.0000

A wide range of indicators are included in the hematological parameters, such as packed cell volume, white blood cell counts, red blood cell counts, and different biochemical markers. These metrics are essential markers of general health, and any disruptions in their equilibrium may point to underlying physiological changes (Maulood, 2018). The findings revealed that there were significant effects in the hematological parameters exposed group of mice. In the first

week of exposure PCV, Neutrophil, Lymphocytes and Monocytes increased in the exposed group when compared to the control group except WBC which decreased The obtained result in this work negates Serwaan *et al.* (2023) that investigated the effect of magnetic resonance on some blood parameters of smoking addicts of all kinds, the findings showed a statistically significant reduction in the measurements of (smoke + shisha) exposed to the field at a dose of (3 T) by (11%) for all blood parameters, with the exception of white cells, which increased by 10.3%.
In the second week of exposure there was increase in the WBC and Neutrophil of the exposed group when compared to the control group and there was decrease in the PCV and Lymphocytes of the exposed compared to the control group. This result agrees with a study by Hani and Mohammed (2018) highlighted the influence of exposure to different applied magnetic fields on some haematological parameters of mice. The WBC count of the exposed group was significantly increased after exposure to magnetic fields, with percentage differences of 50.86%. There was an increase in the WBC, Lymphocytes and Monocytes of the exposed group when compared to the control group in the third week of exposure and there was a decrease in the PCV and Neutrophil count of the exposed group. This result also revealed in accordance with a study by Al-Qadi *et al*. (2023) reported that the low-frequency static magnetic field had an impact on certain blood parameters in cancer patients, particularly at low intensities (0.1 T, 0.7 T). The number of red blood cells and platelets significantly decreased (0.05≤P), but the number of white blood cells increased significantly for the same doses administered.

CONCLUSION

In conclusion, results showed that MRI exposure can cause notable changes in the hematological parameters of albino mice. White blood cell counts and PCV significantly changed after MRI exposure. The statistical analysis indicated a significant impact of MRI on hematological health, revealing substantial variations in parameters between the MRI-exposed and control groups. One of the primary mechanisms likely responsible for the hematological alterations is the activation of the stress response, specifically the hypothalamic-pituitary-adrenal axis. The mice may experience stress from the MRI setting, which includes noise and confinement. Also, strong magnetic fields and radiofrequency (RF) pulses, which can interact with biological tissues at the cellular and molecular levels, are used in MRI the observed hematological changes may be a result of these interactions. Thus, the hematological parameters of albino mice are negatively impacted by MRI exposure. Only albino mice were used in the research. Although mice are frequently used as model organisms, their immune systems and physiologies can differ greatly from those of other species, including humans. To find out if the effects reported are constant across multiple organisms, further study should be done using different animal models, such as rats or even non-human primates.

REFERENCES

Al-Qadi, S. H. Z., Al_Dulamey, Q. K., Abed, M. A. and Mehuaiden, A. K. (2023). Effect of Static Magnetic Field on some Hematological Parameters of Human AML Leukemia: in vitro. *Rafidain Journal of Science,* 32(3):32-40. DOI: 10.33899/rjs.2023.180274

Dantzer, R. (2018). Neuroimmune interactions: from the brain to the immune system and vice versa. *Physiological reviews*, 98(1), 477-504. https://doi.org/10.1152/physrev.00039.2016

Dhabhar, F. S., Malarkey, W. B., Neri, E., and McEwen, B. S. (2012). Stress-induced redistribution of immune cells—From barracks to boulevards to battlefields: A tale of three hormones–Curt Richter Award Winner. *Psychoneuroendocrinology*, 37(9), 1345-1368. https://doi.org/10.1016/j.psyneuen.2012.05.008

Ding, J., Chen, P., and Qi, C. (2024). Circadian rhythm regulation in the immune system. *Immunology*, 171(4), 525-533. https://doi.org/10.1111/imm.13747

Fardela, R., Rena, S. R., Maulida, A., and Diyona, F. (2023). Magnetic Resonance Imaging (MRI) Safety in Pregnant (A Literature Review). *Jurnal Ilmiah Fisika FMIPA Universitas Lambung Mangkurat*, 19(3), 236-246 https://doi.org/10.1016/j.ecoenv.2020.111085

Franco, J. (2020). Magnetic resonance imaging safety. *Journal of Radiology Technology*, 91(4): 343-356 https://doi.org/10.1016/j.05.070

Ghadimi-Moghadam, A., Mortazavi, S.M.J., Hosseini-Moghadam, A., Haghani, M., Taeb, S., Hosseini, M.A., Rastegariyan, N., Arian, F., Sanipour, L. and Aghajari, S. (2018). Does Exposure to Static Magnetic Fields Generated by Magnetic Resonance Imaging Scanners Raise Safety Problems for Personnel? *Journal of Biomedical Physics Engineering.* 8, 333–336. DOI: 10.22086/jbpe. v0i0.653

Hani, M., Abdelsalama, and Mohammed E. (2018). The Influence of Magnetic Fields on Selected Physiological Parameters of Blood and Tissues in Mice. *International Journal of Advanced Research in Biological Sciences.*5(11):149-158. http://dx.doi.org/10.22192/ijarbs.2018.05.11.018

Hartwig, V., Virgili, G., Mattei, F., Biagini, C., Romeo, S.; Zeni, O., Scarfi, M. R., Massa, R., Campanella, F., Landini, L., Gobba, F., Modenese, A. and Giovannetti, G. (2021). Occupational exposure to electromagnetic fields in magnetic resonance environment: an update on regulation, exposure assessment techniques, health risk evaluation, and surveillance. *Medical & biological engineering & computing,* 1-24. DOI:10.1007/s11517-021-02435-6

Lauridsen, C. (2019). From oxidative stress to inflammation: Redox balance and immune system. *Poultry science*, 98(10), 4240-4246. https://doi.org/10.3382/ps/pey407

Manso Jimeno, M., Vaughan, J. T., and Geethanath, S. (2023). Superconducting magnet designs and MRI accessibility: A review. *NMR in Biomedicine*, 36(9)-4921. https://doi.org/10.1002/nbm.4921

Maulood, K. A. (2018). Assessment of some hematological, biochemical parameters and cardiac biomarker levels in patients with ischemic heart disease in Erbil city. *ZANCO Journal of Pure and Applied Sciences,* 30(2): 86-93 DOI: 10.18 869/psj.16.3.67

McRobbie, D.W. (2020). Essentials of MRI safety. *Wiley-Blackwell, Hoboken, New Jersey, US,* 35*: 32-88 https://doi.org/10.1016/j.03.058*

Mustafa, B. T., Yaba, S. P. and Ismail, A. H. (2020). Experimental Evaluation of the Static Magnetic Field Effect on White Blood Cells: In Vivo Study. *Materials Science Forum*, *Trans Tech Publications Ltd*, 1002**:** 412-419. DOI: http://dx.doi.org/10.21271/zjpas

Nagase, H., Ueki, S., and Fujieda, S. (2020). The roles of IL-5 and anti-IL-5 treatment in eosinophilic diseases: Asthma, eosinophilic granulomatosis with polyangiitis, and eosinophilic chronic rhinosinusitis. *AllergologyInternational*, 69(2),178-186. https://doi.org/10.1016/j.alit.2020.02.002

Pai, A., Shetty, R., Hodis, B., and Chowdhury, Y. (2023). Magnetic Resonance Imaging Physics. In: *Stat Pearls Publishing*, *Treasure Island* 33(23)-1990. https://europepmc.org/article/NBK/nbk564320

Serwaan, J., Abdullah, A., Qusay, K., Al-Dulamey, M. and Ahmed, A. (2023). Study of the Effect of Magnetic Resonance on Some Blood Parameters of Smoking Addicts of All Kinds. *International Journal of Scientific Research in Science and Technology*, 10(4):519-530. https://doi.org/10.32628/IJSRST52310454

Simpson, R. J., Campbell, J. P., Gleeson, M., Krüger, K., Nieman, D. C., Pyne, D. B., and Walsh, N. P. (2020). Can exercise affect immune function to increase susceptibility to infection? *Exercise immunology review*, 26,8-22 https://www.ncbi.nlm.nih.gov/pubmed/32139352.

Suppan, E., Pichler, G., Binder-Heschl, C., Schwaberger, B., and Urlesberger, B. (2022). Three physiological components that influence regional cerebral tissue oxygen saturation. *Frontiers in Pediatrics*, 10, 913-223. https://doi.org/10.3389/fped.2022.913223

Wang, S., Luo, J., and Lv, H. (2019). Safety of exposure to high static magnetic fields (2 T–12 T): a study on mice. *European Radiology* 29:6029-6037._DOI:10.1007/s00330-019-06256