

# **Comparative Evaluation of Haematological Parameters in Malaria Infected Children and Teens Age Group Attending State Hospital, Ijebu-Ode, Ogun State**

**AJILEYE, Ayodeji Blessing , ODUKOYA, Julius Sunday ESAN, Ebenezer Olubunmi**

Department of Biomedical Laboratory Science, College of Medicine, University of Ibadan.

Department of Medical Laboratory Science, Lead City University, Ibadan.

Department of Medical Laboratory Science, University of Medical Sciences, Ondo City,  
Ondo State.

**All Corresponding to:**[ab.ajileye@ui.edu.ng](mailto:ab.ajileye@ui.edu.ng)

**Cell Phone:** +2348030445624 **ORCID NUMBER:** 0000-0002-1576-6207

## **ABSTRACT**

*Bthrough the bites of infected female Anopheles mosquitoes. Plasmodium falciparum and Plasmodium vivax are two of the five parasite species that cause malaria in humans and are also the two most hazardous*

*Methods: A total of 200 subjects were recruited for this study and were grouped into pre-teen age group (1-12 years) and teen age group (13-19 years), among which 50 were control and 50 were malaria infected subjects for each group. Standard laboratory procedure was employed for blood collection and analysis. Parasitological and haematological parameters such as malaria parasite, pack cell volume (PCV), white blood cell (WBC) total and differential count and platelet counts were carried out from the blood samples.*

*Results: From the 200 subjects recruited for this study, 88 (44%) were males and 112 (56%) were females. The analysis of the haematological parameters between the two groups (preteens and teen) revealed that there was no statistical significant difference among some of the examined haematological parameters except PCV ( $p < 0.01$ ), total WBC ( $p < 0.01$ ), platelet ( $p < 0.01$ ) and haemoglobin ( $p < 0.05$ ). While for other parameters, the differences are not statistically significant; neutrophil ( $p > 0.05$ ), lymphocyte ( $p > 0.05$ ), monocyte ( $p > 0.05$ ), eosinophil ( $p > 0.05$ ), basophil ( $p > 0.05$ ) and platelet ( $p > 0.05$ ) between the preteen and teen age group.*

*Discussion These changes in haematological parameters can become profound as the infection's severity rises. As a result, early diagnosis of malaria infection is necessary for proper treatment*

**Keywords:** Plasmodium falciparum, Malaria Parasite, Haemoglobin, Platelet, Monocyte.

## INTRODUCTION

Plasmodium parasites, which cause the acute fever sickness known as malaria, are transmitted to people through the bites of infected female Anopheles mosquitoes. Plasmodium falciparum is the deadliest malaria parasite and the most frequent on the African continent. There are five parasitic species that cause malaria in humans and two of these species, Plasmodium vivax and Plasmodium falciparum, pose the greatest threat. The most common malaria parasite outside of sub-Saharan Africa is Plasmodium vivax. The initial signs of malaria, including fever, headache, and chills, can be mild and challenging to diagnose. They typically show 10 to 15 days after the infecting insect bite. Plasmodium falciparum malaria can develop to severe disease and death in less than 2,3 24 hours if untreated. Plasmodium knowlesi, a type of malaria that naturally affects macaques in Southeast Asia, also infects people, resulting in "zoonotic" malaria.

Malaria is a serious public health concern. Families are caught in a cycle of illness, pain, and poverty due to the condition and the price of its treatment. Nearly 50% of the world's population, the majority of whom reside in sub-Saharan Africa, are currently at risk of contracting malaria and dealing with associated economic difficulties. Malaria kills a child under the age of five almost every day. Numerous of these deaths can be avoided or treated. There were 247 million cases of malaria worldwide in 2021, which resulted in 619,000 fatalities. Children under the age of five made up 77% of these fatalities. This equates to a daily toll of more than 1,000 children under the age of five.

Nearly half of the world's population was susceptible to malaria in 2020. Infants, children under five, pregnant women, persons with HIV/AIDS, and anyone migrating to places with high malaria transmission but low immunity, such as migrant workers, mobile communities, and travelers, are at significantly increased risk of contracting malaria and developing severe disease. Any disease condition, including endemic illnesses like malaria that might have an impact on human health and appear in a variety of clinical manifestations, is likely to have an impact on changes in haematological parameters. In the tropics, malaria is one of the leading causes of death. In 2010, there were around 219,000,000 cases recorded worldwide. One of the most typical malarial consequences is hemorrhaging, and this plays a significant part in the pathogenesis of malaria. The main cell types that are affected by these alterations include leucocytes, thrombocytes, and red

blood 6, 7 cells (RBCs) . Patients with malaria typically have significantly higher monocyte and neutrophil counts 8 compared to non-malaria infected patients , while patients with malaria typically have significantly lower platelets, 8,9 WBCs, lymphocytes, eosinophils, RBCs, and Hb levels . Thrombocytopenia is the most typical consequence from 10,11,12 malaria infection . People with platelet counts below 150,000/L are 12–15 times more likely to contract malaria 12 than people with platelet counts above 150,000/L . Findings have demonstrated a correlation between the ratio of monocytes to lymphocytes and the probability of 13 developing clinical malaria over time . The majority of the five million people in Thailand who live in high malaria 14 transmission areas reside around the border with Burma . Clinical diagnosis is widely performed to determine the presence of malaria, especially in these areas. Fever and other signs and symptoms are known to be sensitive indicators of malaria infection, but they lack specificity and positive predictive values, particularly in regions where 15 malaria is less common . Additionally, it may be challenging to differentiate between the signs and symptoms of the disease from other viral or bacterial 16 infections . The most frequent test and gold standard for identifying malaria infection is often microscopic slide 17 examination of peripheral blood . In smear examinations, it is time-consuming and demands technical knowledge. It is widely known that malaria infection causes haematological abnormalities such as leucocytosis and thrombocytopenia. People who live in malaria-endemic areas may find it simple and helpful to obtain these haematological changes, which have diagnostic value. The enormous burden of sickness in early children has largely eclipsed the issue of malaria in adolescents. Although a large number of teenagers are at risk of contracting malaria, little is known about the disease's prevalence and effects in this age range. According to studies, even in regions with steady malaria transmission, malaria is a common cause of clinical disease in adolescents and a preventable cause of mortality. Due to immunological and hormonal variables, younger adolescents may be more 1 8 at risk than older adolescents .Comparing the haematological parameters in malaria patients of the children and adolescent age groups at State Hospital, IjebuOde, Ogun State, was the aim of this study.

## **Materials and Methods**

### **Study Area**

This study was conducted in Ijebu-Ode, Ogun State, Nigeria.

### **Study Population**

This study was carried out among children between the ages of 1 year to 12 years and teens who are between the ages of 13 years to 19 years in Ijebu-Ode, children with malaria infected were recruited from State Hospital, IjebuOde, while control samples (malaria non-

infected) were recruited randomly from subjects outside the hospital who were tested to be negative to malaria. 200 sample size of participants of children were selected. The participants were divided into two; preteen (age 1-12) and teen (13-19). 50 participants were selected for control in each group of the participant. The participants were selected within the target population.

### **Research Design**

This is a cross-sectional descriptive study of comparative assessment of haematological parameters in malaria patients of children and teens age group attending State Hospital, Ijebu-Ode Ogun State.

### **Ethical Consideration**

The protocol for this study was sought and approved by the ethics and research committee of Lead City University, Ibadan, Oyo State, with the approval number LCUREC/22/072 dated 31st January, 2022

### **Inclusion criteria**

- Children and teens attending State Hospital, Ijebu Ode, Ogun State.
- Children between the ages of 1 year to 12 years and teens between the ages of 13-19 years
- Both male and female subjects
- Those that consented to participate in the study.

### **Exclusion criteria**

- Subjects younger than 1 year old and older than 19 years old
- Those that did not consent to this study
- Sickle cell patients

### **Sampling Technique**

The blood samples from children and teens attending State Hospital Ijebu-Ode, were selectively collected for laboratory tests to determine malaria infection as the evidence of infection before proceeding to aematological parameters.

### **Sample Collection, Processing and Analysis for malaria parasite**

A venous blood sample of 2mls was collected into EDTA bottle from each of the children/teens using needle and syringe. Standard and careful laboratory procedures were

adopted in collecting blood samples from the subjects. Thick and thin blood films of the blood samples were made on clean dry grease free slides, labelled and allowed to dry. The thin films were fixed with methanol to avoid lysis, allowed to dry for 30 seconds. The thin and thick films were stained with freshly prepared 10% working solution of Giemsa stain for 8-10 minutes. The stain is gently flushed by dropping clean water over it and allowed to dry. The films were examined under the light binocular microscope using x100 objective lens, with a drop of oil immersion. The presence of malaria parasite in either of the films is regarded as positive, either with scanty, one plus (+), two pluses (++) or three pluses (+++).

### **Procedure for Packed Cell Volume Estimation**

Micro-haematocrit method for packed cell volume estimation: this involves the use of micro haematocrit centrifuge to spin blood in a capillary tube at 12,000rpm for 5 minutes and read using the micro-haematocrit reader

The capillary tube was filled to about three

quarters ( $\frac{3}{4}$ ) with well mixed EDTA

anticoagulated blood. The unfilled end was sealed using a sealant material. The capillary tube was carefully placed in one of the numbered slots of the microhaematocrit centrifuge with the sealed end against the rim gasket (to prevent breakage). The inner lid was carefully positioned to avoid dislodging of the tube and centrifuged at 12,000rpm for 5 minutes. Immediately after centrifuging, the packed cell volume was read.

The PCV was read using micro-haematocrit reader with the base of the red cell column (above the sealant) on the 0 line and the top of the plasma column on the 100 line. The PCV was read from scale. The reading point was the top of the red cell columns just below the buffy coat layer (consisting of white blood cell and platelet)

### **Procedure for Total White Blood Cell Counts**

The method for total white blood cell counts involved the use of Neubauer counting chamber and Turk's solution using the microscope which is the manual method of counting. About 0.38ml of diluting fluid was measured and dispensed into a small container or tube, 0.02ml of well mixed EDTA anticoagulated venous blood was added and mixed. The counting chamber was assembled, the center grid area of the chamber and the haemocytometer cover glass was completely clean and dry. The cover glass was slide into position over the grid area and it was pressed down on each side until rainbow colors (Newton's rings) are seen. The solution was remixed by using capillary tube. At an angle of about  $45^\circ$ , the grid area of the chamber was filled with the solution, the filled chamber was left undisturbed for 2 minutes to allow the white cells to settle. To prevent drying of the

fluid, the chamber was placed in a Petri-dish on dampen tissue and it was covered with a lid. The underside of the chamber was dried and it was placed on the microscope stage using x10 objective lens with condenser iris closed, the ruling was focused and the white cell. It was focus until the white blood cells appear as small black dot. The cells were counted in the four large corner squares of the chamber

### Statistical Analysis

Statistical analysis for Social Sciences (SPSS) version 25 was the statistical package used in analyzing all data obtained. Frequency table, Bar chart and Pearson Chi-Square were used to compare the means of the different analytes at  $p < 0.05$  statistical significance.

### RESULT

**Table 1.0: frequency distribution according to gender and malaria status.**

		<i>Frequency (%)</i>
<i>Gender</i>	Male	88 (44)
	Female	112 (56)
	Total	200 (100)
<i>Malaria status</i>	Negative	100 (50)
	Positive	100 (50)
	Total	200 (100)

This shows the frequency and the percentage frequency of the study subjects based on gender and the malaria status. From the 200 participant, it is seen that females constituted the larger percentage of the study (Table 1.0).

Table 2.0: Mean value and standard deviation of haematological parameters across groups

Parameters	Preteen (1-12yrs) (mp -ve) n=50	Preteen (1-12yrs) (mp +ve) n=50	Teen (13- 19yrs) (mp -ve) n=50	Teen (13- 19yrs) (mp +ve) n=50	p-value
Age	6.48 ±3.530	6.12 ±2.974	15.92 ±1.627	15.74 ±1.736	0.023
Mn±SD					
haemoglobin	10.84 ±1.9104	10.59 ±2.2439	11.84 ±1.616	11.20 ±1.8066	0.031
Mn±SD					
PCV	32.52 ±5.726	31.78 ±6.741	35.50 ±4.841	33.58 ±5.406	0.001
Mn±SD					
Total WBC	8683.80	10152.80	7156.40	8157.80	0.001
Mn±SD	±4728.266	±5873.058	±3104.843	±6495.080	
Neutrophil	57.78 ±14.966	53.68 ±10.374	53.18 ±12.676	55.94 ±10.135	0.678
Mn±SD					
Lymphocyte	33.50 ±12.981	37.20 ±10.319	38.02 ±11.741	34.00 ±11.308	0.878
Mn±SD					
Monocytes	6.74 ±3.294	6.74 ±3.932	6.58 ±2.726	6.70 ±3.358	0.678
Mn±SD					
Eosinophil	1.96 ±2.040	2.36 ±2.164	2.16 ±2.132	2.44 ±2.681	0.455
Mn±SD					
Basophil	0.02 ±0.141	0.02 ±0.141	0.04 ±0.283	0.10 ±0.364	0.344
Mn±SD					
Platelet	256.64	211.96	243.10	180.22	0.001
Mn±SD	±129.332	±123.757	±124.215	±80.394	

This shows the mean value and standard deviation of haematological parameters across groups. The groups include Preteen 1-12 years (mp -ve), Preteen 1-12 years (mp +ve), Teen 13-19 years (mp -ve), Teen 13-19 years (mp +ve). Each group consist of 50 subjects (N) (Table 2.0).

Mn±SD					
Eosinophil	1.96 ±2.040	2.36 ±2.164	2.16 ±2.132	2.44 ±2.681	0.455
Mn±SD					
Basophil	0.02 ±0.141	0.02 ±0.141	0.04 ±0.283	0.10 ±0.364	0.344
Mn±SD					
Platelet	256.64	211.96	243.10	180.22	0.001
Mn±SD	±129.332	±123.757	±124.215	±80.394	

This shows the mean value and standard deviation of haematological parameters across groups. The groups include Preteen 1-12 years (mp -ve), Preteen 1-12 years (mp +ve), Teen 13-19 years (mp -ve), Teen 13-19 years (mp +ve). Each group consist of 50 subjects (N) (Table 2.0).

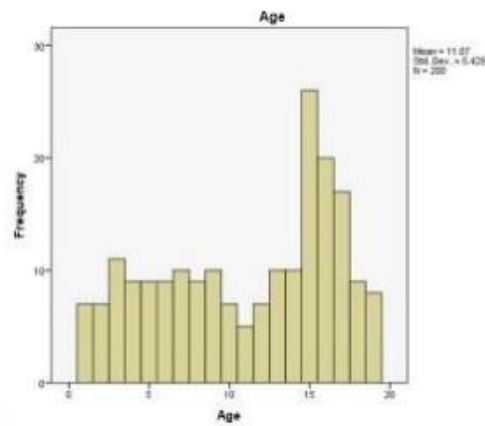


Figure 1.0: Age Frequency of the study

The above chart shows the age frequency of the subjects with age 15 occurring most.

### Comparative Evaluation of Haematological Parameters

Table 3.0: Mean and standard deviation of haematological parameters for preteen subjects with malaria parasite.

Malaria parasite	Packed cell volume	Total WBC	Neutrophil	Lymphocyte	Monocyte	Eosinophil	Basophil	Platelet	p-value
N	38	38	38	38	38	38	38	38	
% of Total N	76.0%	76.0%	76.0%	76.0%	76.0%	76.0%	76.0%	76.0%	0.677
1+ Mean	31.61	11665.79	55.55	35.34	6.21	2.05	.00	141.13	
Std. Deviation	6.352	9003.769	15.076	14.964	3.042	1.845	.000	44.734	
N	10	10	10	10	10	10	10	10	
% of Total N	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	20.0%	
2+ Mean	17.30	18480.00	55.10	36.40	8.50	1.00	.00	147.40	
Std. Deviation	8.795	11200.74	19.105	15.650	6.096	1.247	.000	61.815	
N	2	2	2	2	2	2	2	2	
% of Total N	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	
3+ Mean	23.00	9200.00	64.00	24.50	10.00	1.50	.00	114.00	
Std. Deviation	8.485	2828.427	4.243	3.536	7.071	.707	.000	36.770	

This shows the mean and standard deviation of haematological parameters for preteen subjects that are positive to malaria parasite (1+, 2+ and 3+). There are changes in the haematological values of 1+ parasitemia, 2+ parasitemia and 3+ parasitemia. Although the changes were not statistically significant ( $p>0.05$ ). Out of the 50 subjects that are malaria positive in the age group of 1-12 years, 38 of the subjects were certified with 1+ parasitemia, 10 were certified with 2+ parasitemia and 2 were certified with 3+ parasitemia. (Table 3.0).

Table 4.0: Mean and standard deviation of haematological parameters for teen subjects with malaria parasite.

Malaria parasite	Packed cell volume	Total WBC	Neutrophil	Monocyte	Lymphocyte	Eosinophil	Basophil	Platelet	p-value
N	44	44	44	44	44	44	44	44	
% of Total N	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%	88.0%	0.455
1+ Mean	32.93	10315.45	65.95	6.20	25.84	2.23	.00	123.48	
Std. Deviation	6.711	7645.991	14.338	3.651	13.362	2.133	.000	32.205	
N	6	6	6	6	6	6	6	6	
% of Total N	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%	12.0%	
2+ Mean	35.17	7050.00	69.50	8.50	21.33	.67	.00	98.33	
Std. Deviation	4.215	4332.090	15.110	5.541	12.770	.816	.000	38.229	

This shows the mean and standard deviation of haematological parameters for teen subjects with malaria parasite (1+ and 2+). There are changes in the haematological value of 1+ parasitemia and 2+ parasitemia. Although the change was not statistically significant ( $p>0.05$ ). out of the 50 subjects that are malaria positive in the age group of 13-19, 44(88%) of the subjects were certified with 1+ parasitemia while 6(12%) of the subjects were certified with 2+ parasitemia (Table 4.0).

## Discussion

In sub-Saharan Africa, particularly Nigeria, malaria is a major health concern that can be prevented and treated. *Plasmodium falciparum* is the most prevalent malaria parasite in the WHO African region, accounting for 99.7% of estimated malaria cases in 2017, *Plasmodium vivax* is the predominant (74.1%) parasite in the WHO region of the Americas. *Plasmodium vivax* contributed 4% of the total global cases in 2015, but outside Africa the proportion was 41% among all malaria infections. Its high burden of disease is maintained in part due to dormant liver stage parasite forms known as hypnozoites which can induce clinical relapse episodes.

In this study, 200 subjects were recruited, out of which 88 (44%) were males and 112 (56%) were females. The females constituted the larger percentage of the study. The subjects were divided into pre-teen age group (1-12 years) with a mean age of 6.3 years (SD=3.25 years) and teen age group (13-19 years) with a mean age of 15.83 years (SD=1.68 years), among which 50 were control and 50 were malaria infected subjects for each of the two groups. The analysis of the haematological parameters between the two groups (preteens and teen) revealed that there was no statistical significant difference among some of the examined haematological parameters except haemoglobin ( $p<0.05$ ), platelet ( $p<0.01$ ), PCV ( $p<0.01$ ), and total WBC ( $p<0.01$ ). While for other parameters, the differences are not statistically significant; neutrophil ( $p>0.05$ ), lymphocyte ( $p>0.05$ ), monocyte ( $p>0.05$ ), eosinophil ( $p>0.05$ ), basophil ( $p>0.05$ ) and platelet ( $p>0.05$ ) between the preteen and teen age group (table 2.0).

Thrombocytopenia was the most common haematological abnormality observed in malaria subjects, both pre-teen and teen age groups (Table 2.0). This is in tandem with Abro et al., who carried out a study on malaria and "haematological changes, the results indicated that 83% of the subjects recruited for the study had thrombocytopenia. Malaria, which is frequently accompanied by palpable splenomegaly and circulating immune complexes, is thought to promote platelet destruction and shorten the lifespan of the cells, which is thought to be the cause of thrombocytopenia. Reduced platelet synthesis due to an increase in megakaryocytes in the bone marrow may result in thrombocytopenia in malaria patients.

Due to its considerable decrease when compared to the control, anemia was the second most often seen haematological abnormality in malaria-infected participants. This suggests that anaemia and *P. falciparum* infection are more frequently linked. This is in line

with 22 research by Jain et al., , in which anaemia was found in 66 patients (94.28%), of which 37 (56.06%) had Plasmodium 23 falciparum infection. According to Abro et al., who carried out a study on malaria and “haematological changes, the results indicated that 64% of the subjects recruited for the study had anaemia, 24% lymphopenia and 10% 24 monocytosis. Also, the findings of Bawal et al., which observed a reduced PCV among children infected with malaria parasite in Kisumu, western Kenya. Anaemia is brought on by high parasitaemia, especially when *P. falciparum* is present. *P. falciparum* causes increased red blood cell death. This could be the result of parasitized red blood cells being hemolyzed, the clearance of parasitized red 25 blood cells being expedited, or inefficient erythropoiesis . A number of variables, including mechanical destruction of the parasitized red blood cells, decreased RBC synthesis in the bone marrow, and phagocytosis of parasite-infected RBC, have been proposed to play a role in the complex and poorly understood pathophysiology of anemia in malaria<sup>21</sup>. One of the most frequent side effects of malaria, particularly in young children and pregnant women in areas with high 26 transmission rates, is anemia

According to this study, both *P. falciparum* infected groups had a little lower Hb level than those who weren't infected (Table 2). This is in line with the findings of Maina et al., 2009, who noted a decrease in the level of hemoglobin among *P. falciparum*-infected kids residing in western 24 Kenya. This is also consistent with a study by , which discovered a substantial rise in the haemoglobin and WBC count in children under five who had malaria compared to the control in a cross-sectional study at the HO Municipality of Ghana.

This study revealed that there was significant difference in total white blood cell count in malaria-infected children (teen and preteen age group) when compared with their controls. This is in tandem with the findings of Maina et al., who revealed significant increase in WBC count in children infected with malaria when compared to the control in a cross-sectional study among children in Kisumu, western Kenya, also with the study of Francis et al., 2014 who observed a significant difference the WBC counts of malaria infected subjects when compared with the control. White blood cell alterations caused by malaria can vary based on host immunity, parasitemia, and co-infection levels. Neutrophils, macrophages, and natural killer (NK) cells are examples of effector cells that are stimulated as part of the body's immunological response to infections<sup>27</sup>

## **Conclusion**

This study established that there are changes in haematological profile of malaria infected children (pre-teen and teen age group) when compared with non-infected children. Although some of the haematological profile changes are not statistically significant, while

some are significant such as the platelet. The common thing that was noticed are thrombocytopenia, reduced packed cell volume and reduced total white blood cell.

Therefore this study concluded that malaria tends to cause reduce platelet, packed cell volume and total white blood cell count

## References

1. World Health Organization (WHO). World malaria report 2022. Geneva: <https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2022#:~:text=Despite%20continued%20impact%20of%20COVID,further%20setbacks%20to%20malaria%20control>. Accessed 22 May, 2023.
2. WHO. World malaria report 2018. Geneva: World Health Organization; 2018. <https://apps.who.int/iris/bitstream/handle/10665/275867/9789241565653-eng.pdf>. Accessed 20 May, 2023.
3. Dhangadamajhi G., Panigrahi S., Roy S. and Tripathy S. (2019). Effect of Plasmodium falciparum infection on blood parameters and their association with clinical severity in children and adults of Odisha, India. *Acta Tropica.* ;190:1–8
4. World Health Organization (WHO). World malaria report 2016. Geneva:2016. <https://apps.who.int/iris/bitstream/handle/10665/252038/9789241511711-eng.pdf?sequence=1>. Accessed 15 May, 2023.
5. Bakhubaira S. (2013). haematological parameters in severe complicated Plasmodium falciparum malaria among adults in Aden. *The Turkish Journal of Hematology*;30(4):394–399.
6. Van Wolfswinkel, M. E., Vliegthart-Jongbloed, K., de Mendonça Melo, M., Wever, P. C., McCall, M. B., Koelewijn, R., and van Genderen, P. J. (2013). Predictive value of lymphocytopenia and the neutrophil-lymphocyte count ratio for severe imported malaria. *Malaria journal*, 12(1), 1-8
7. Naing, C., and Whittaker, M. A. (2018). Severe thrombocytopaenia in patients with vivax malaria compared to falciparum malaria: a systematic review and meta-analysis. *Infectious diseases of poverty*, 7(1), 1-10.
8. Sakzabre, D., Asiamah, E. A., Akorsu, E. E., AbakaYawson, A., Dika, N. D., Kwasi, D. A. and Osei, G. Y. (2020). Haematological profile of adults with malaria parasitaemia visiting the Volta Regional Hospital, Ghana. *Advances in Hematology*.

9. Watson, J. A., Ndila, C. M., Uyoga, S., Macharia, A., Nyutu, G., Mohammed, S. and White, N. J. (2021). Improving statistical power in severe malaria genetic association studies by augmenting phenotypic precision. *Elife*, 10, e69698.
10. Kotepui, M., Kotepui, K. U., De Jesus Milanez, G., and Masangkay, F. R. (2020). *Plasmodium* spp. mixed infection leading to severe malaria: A systematic review and meta-analysis. *Scientific reports*, 10(1), 1-12.
11. Kotepui M, Phunphuech B, Phiwklam N, Chupeerach C, Duangmano S. Effect of malarial infection on haematological parameters in population near Thailand-Myanmar border. *Malaria Journal* 2014;13: 218-223.
12. Kho, S., Barber, B. E., Johar, E., Andries, B., Poespoprodjo, J. R., Kenangalem, E. and McMorran, B. J. (2018). Platelets kill circulating parasites of all major *Plasmodium* species in human malaria. *Blood, The Journal of the American Society of Hematology*, 132(12), 1332-1344.
13. Warimwe, G. M., Murungi, L. M., Kamuyu, G., Nyangweso, G. M., Wambua, J., Naranbhai, V., and Marsh, K. (2013). The ratio of monocytes to lymphocytes in peripheral blood correlates with increased susceptibility to clinical malaria in Kenyan children. *PLoS One*, 8(2), e57320
14. Fuhad, K. M., Tuba, J. F., Sarker, M., Ali, R., Momen, S., Mohammed, N. and Rahman, T. (2020). Deep learning based automatic malaria parasite detection from blood smear and its smartphone based application. *Diagnostics*, 10(5), 329.
15. Awoke, N., and Arota, A. (2019). Profiles of haematological parameters in *Plasmodium falciparum* and *Plasmodium vivax* malaria patients attending Tercha General Hospital, Dawuro Zone, South Ethiopia. *Infection and drug resistance*, 12, 521.
16. World Health Organization. (2013). WHO global malaria programme: world malaria report: 2013. In *Who global malaria programme: world malaria report*: (pp. 255-255).
17. Baird, J. K. (2013). Evidence and implications of mortality associated with acute *Plasmodium vivax* malaria. *Clinical microbiology reviews*, 26(1), 36- 57.
18. Lalloo, D. G., Olukoya, P., and Olliaro, P. (2006). Malaria in adolescence: burden of disease, consequences, and opportunities for intervention. *The Lancet. Infectious diseases*, 6(12), 780–793.
19. Ochei, J. K. and Kolhatkar A. (2005). *Medical Laboratory Science Theory and Practice*. London. Pp.399 – 406

20. Khan, S. J., Abbass, Y. and Marwat, M. A. (2012). Thrombocytopenia as an indicator of malaria in adult population. *Malaria research and treatment*.
21. Maina, R. N., Walsh, D., Gaddy, C., Hongo, G., Waitumbi, J., Otieno, L. and Ogutu, B. R. (2010). Impact of *Plasmodium falciparum* infection on haematological parameters in children living in Western Kenya. *Malaria journal*, 9(3), 1-11.
22. Jain, M., and Kaur, M. (2005). Comparative study of microscopic detection methods and haematological changes in malaria. *Indian Journal of Pathology and Microbiology*, 48(4), 464-467.
23. Abro, A. H., Ustadi, A. M., Younis, N. J., Abdou, A. S., Hamed, D. A., and Saleh, A. A. (2008). Malaria and haematological changes. *Pakistan Journal of Medical Sciences*, 24(2), 287
24. Bawah AT, Nyakpo KT, Ussher FA, Alidu H, Dzogbo JJ, Agbemenya S, Kwasie DA, Seini MM. Haematological profile of children under five years with malaria at the Ho Municipality of Ghana. *Edorium J. Pediatr*. 2018;2:100004P05AB2018.
25. Absar, M. N. (2012). Haemoglobin Level in Children of a Northern District of Bangladesh. *Journal of Bangladesh College of Physicians and Surgeons*, 30(3), 127-131.
26. Ugwu EO, Dim CC, Uzochukwu BS, Iloghalu EI, Ugwu AO. Malaria and anaemia in pregnancy: a cross-sectional study of pregnant women in rural communities of Southeastern Nigeria. *Int Health*. 2014;6:130–7.
27. Vivier E, Raulet DH, Moretta A, et al. Innate or adaptive immunity? The example of natural killer cells. *Science* 2011 Jan 7;331(6013):44–9.