



Circulating platelets and malaria severity: two sides of the same coin among inhabitants of a tropical savannah region, Nigeria

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Abstract

Changes in circulating platelets during different grades of malaria are of major concerns, and its etiology is poorly understood. We appraised and evaluated the role of circulating platelets in the determination of the severity of malaria among a cohort of outpatients living in Ilorin, Nigeria. A hospital-based case-control study of outpatients visiting public health facilities within the locality voluntarily enrolled for this study. Blood samples from 1162 malaise patients were screened using routine microscopy for *Plasmodium* parasite species identification, and their respective circulating platelet levels were determined. Seven hundred and seventy-five individuals (775, 66.7%, $p < 0.001$) were malaria-positive. Samples from 387 (33.3%) uninfected healthy individuals were used as controls. Individuals with uncomplicated malaria (UCM) and complicated malaria (CM) across age group were notable ($p < 0.05$). Children ≤ 5 years had the highest number of individuals with CM (103, 45.2%) with a relative risk ratio of 4.005 (95% CI: 2.964–5.413). UCM (471, 40.5%) occurred more than CM (304, 26.2%) ($p > 0.05$) across the groups. The geometric mean, 95% CI, median, and IQR of populations with malaria thrombocytopenia were higher (181, 110.94 ± 2.207 , 106.59–115.30, 118.00, and 39.00) than thrombocytosis (78, 624.64 ± 13.131 , 598.49–650.79, 623.00, and 208). Seemingly, health controls recorded insignificant morbidity with respect to platelet counts. High *P. falciparum* parasitemia is inversely correlated with platelet count, and its morbidity is associated with the manifestation of several malaria pathogenesis. Thrombocytopenia is a silent pathophysiological attribute that can trigger other cofactors during severe malaria disease. Although further studies are pertinent in order to specifically clarify its relevance to clinical disease spectrum.

Keywords Circulating platelets · Malaria · Thrombocytopenia · Morbidity · Nigeria

Background

In parts of tropical sub-Sahara Africa where malaria is hyperendemic, fluctuating platelet counts are a recurring decimal (Watson et al. 2021). An increase or decrease in platelet production as a result of malaria-related thrombocytopenia may occur due to different mechanisms of red blood cell (RBC) destruction. The aforementioned is usually exhibited by these manifestations: peripheral destruction,

bone marrow alterations, excessive removal of platelets by the spleen, platelet consumption by the process of disseminated intravascular coagulopathy, and pseudo-thrombocytopenia (Punnath et al. 2019; Dos-Santos et al. 2020; Gebreweld et al. 2021). On the other hand, the pathophysiological mechanisms that lead to platelet homeostasis during malaria appear more predominant than other blood cell abnormalities which most often result in the following: the destruction of platelets by IgG antibodies, release of adenosine diphosphate (ADP) by hemolyzed and parasitized RBCs, dysmegakaryopoiesis, direct lytic effect of the parasite on the platelets, platelet phagocytosis, platelet adhesion to erythrocytes, and oxidative stress (Gupta et al. 2019; Kumbhar et al. 2019). With the administration of appropriate artemisinin combination therapies (ACTs) to malaria patients, thrombocytopenia seems to improve within 7 days of therapy (Muwonge et al. 2013). Furthermore, acute malaria also presents with additional changes in

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platelet function and such changes are not limited to increase in the plasma concentration of specific proteins like the beta-thromboglobulin (PTG) and platelet factor 4 (PF4) together with loss of lactate dehydrogenase (LDH) activity (Farhana and Lappin 2020; Aninagyei et al. 2021). Thrombopoiesis involves platelet production by the megakaryocytes, the platelet precursor domiciled in the bone marrow. Thrombopoietin (TPO), the principal physiologic regulator of platelet production, induces the growth of colony-forming units-megakaryocyte and the generation of mature polyploid megakaryocytes (proplatelets) (Morrell 2014). Platelets are thrombogenic cells with specific chemokines that act on infected erythrocytes (iRBC) in order to reduce host-parasite load (Miyazaki and Kato 1999). Most often malaria infection results in an increase in thrombopoietin as a feedback process to counter the loss of circulating platelets, although not sufficient to abate this loss because the destruction of platelets in malaria thrombocytopenia is often accompanied by simultaneous suppression of thrombopoiesis (Kreil et al. 2000; Makar et al. 2013). Several studies have enunciated the diagnostic implications of the changes in hematological parameters of patients with severe *P. falciparum* malaria, yet

there is a dearth of evidence with respect to platelet activities and its diagnostic relevance in health controls and uncomplicated *P. falciparum* malaria. In view of the foregoing, the study sought, determined, and examined the relationship between the circulating platelet count among malaria-positive with respect to varying degrees of parasitemia and correlate it with seemingly malaria-negative population in a tropical savannah region of North-Central, Nigeria.

Materials and methods

Study area

Kwara State is situated between parallels 8° and 10° North latitudes and 3° and 6° East longitudes (Fig. 1). It expands from west to east, covering an area of about 32,500 km². The state has River Niger as its natural boundary along its northern and eastern margins. Ilorin is the state capital and comprises three local government areas (LGAs) (Sawyer et al. 2016).

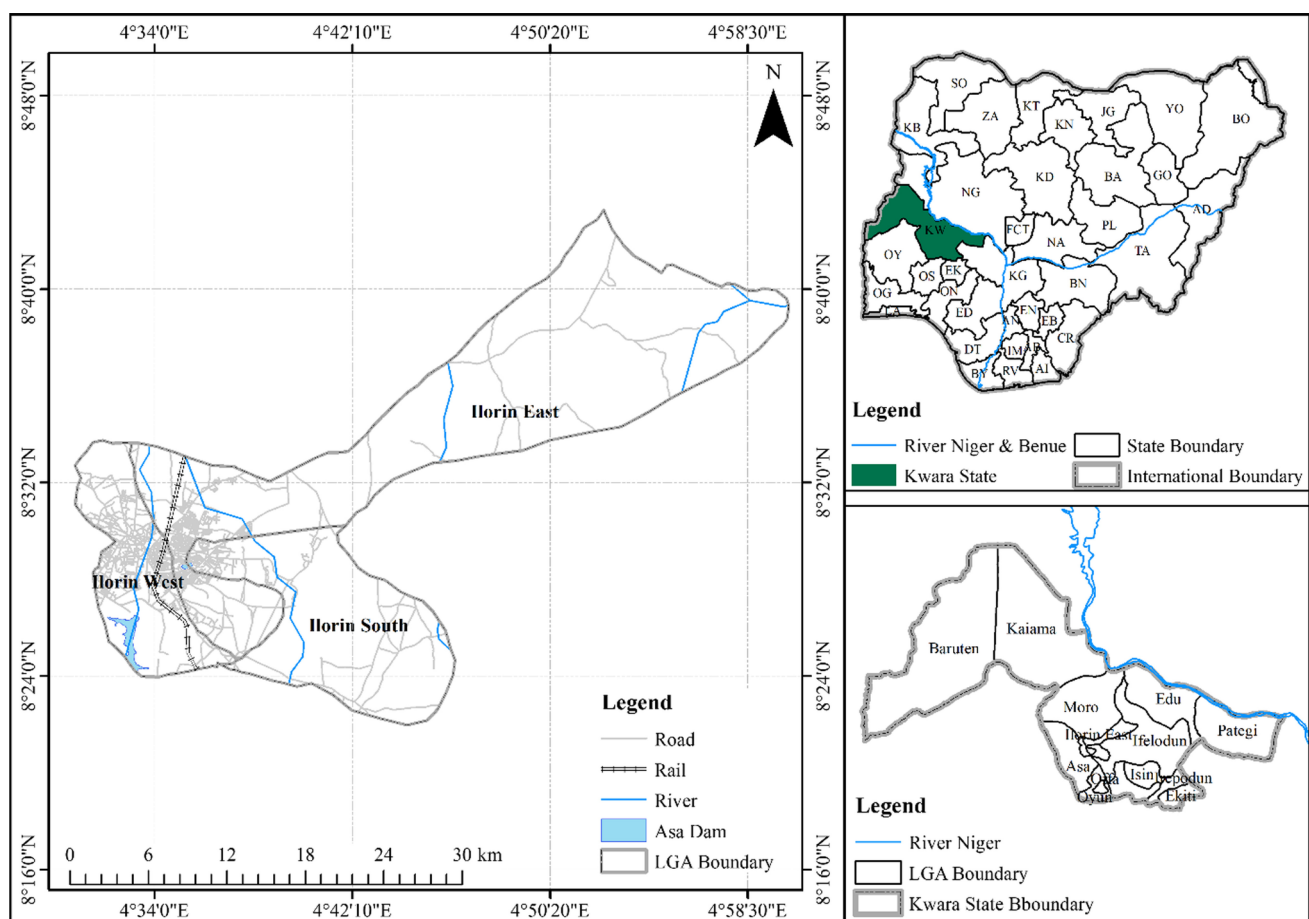


Fig. 1 Map of Ilorin showing the three main LGA where the study was conducted

Study design

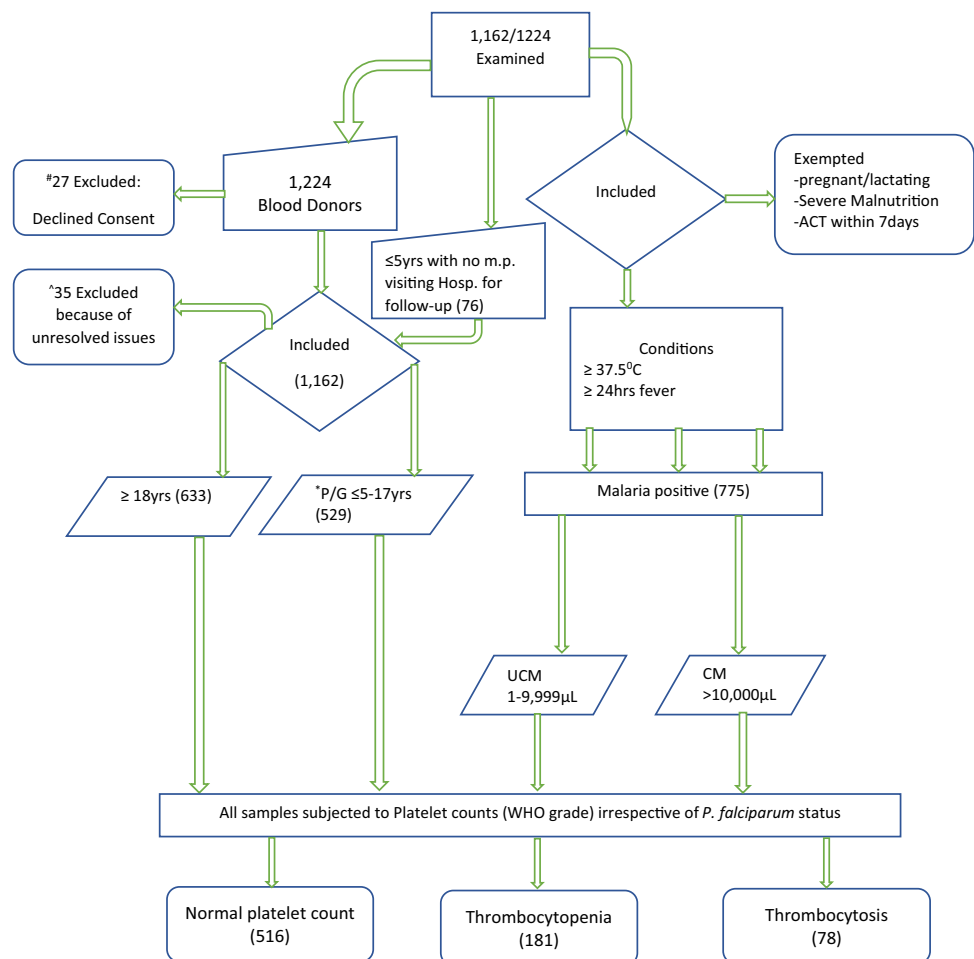
This was a hospital-based study involving case-control of patients visiting public health centers across the three LGAs. The sampling was conducted all year round (2018–2019) covering both dry season (October–March) and malaria peak periods (i.e., April–September). Prior to the commencement of this study, the ethical review committees of both the Kwara State Ministry of Health and the University of Ilorin approved the study protocols (UERC/ASN/2021/221). A category of the volunteers were outpatients with classical malarial symptoms such as malaise, intermittent fever, chills, and rigors. Adults (i.e., ≥ 18 years) and minors (≥ 16 years, with parental consent) attending blood bank for blood donations and who tested negative for malaria were enrolled as health controls (HCs). Children ≤ 5 years visiting the hospital for routine check-up and without malaria were used as HCs. Inclusion criteria for the case-control study involve volunteers of age ≤ 5 years and ≥ 16 years, with an axillary temperature of ≥ 37.5 °C and/or a history of fever in the previous 24 h, *P. falciparum* mono-infection with a parasite density (≥ 1 and 100,000/ μ l) by light microscopy (LM), and

provision of written informed consent to participate in the trial. For patients aged ≤ 18 years, informed consent was obtained from the parents/guardians. The following set of individuals were excluded from this study: pregnant/lactating women, patients with concomitant acute or chronic severe illness, severe malnutrition, and patients who had received any antimalarial therapy in the last 7 days (Fig. 2).

Identification and assessment of *Plasmodium falciparum* species

Routine microscopy was used to make both thick and thin films on the same slide after the methods of Gilles (Gilles 1993). The parasite species was identified using standard procedures as specified by Cheesbrough (Cheesbrough 2006). *Plasmodium falciparum* was identified in the prepared slides by the presence of Maurer's clefts (membrane-limited vacuoles or sack-like structures in the cytosol) and visible blue dots in Giemsa-stained blood smears) and the presence of a high-grade parasitemia in iRBCs and rarely crescent-shaped gametocytes. *P. falciparum* densities were determined as parasites/ μ l of blood (number of parasites

Fig. 2 Flowchart illustrating the data collection strategy. Key: m.p., malaria positive; *P/G, parent/guardian consent (minor); UCM, uncomplicated malaria; CM, complicated malaria. Caret and number sign symbols were not included in the total number examined for the study



counted/number of white blood cells (WBCs), counted $\times$ total number of WBCs per μl of blood). Parasite density was determined following the guidelines in WHO, 2001 as the number of parasites per 200 leukocytes (WBC).

Determination of platelet count

Approximately 2 ml of blood via vials were introduced into the auto-hematology analyzer (Sysmex KX-21N). The machine counted the platelets within a few minutes, and the results obtained alongside other blood indices were printed out. For the purpose of validation of results obtained from the auto-hematology analyzer, the manual method of platelet counting was performed by smearing EDTA blood on slides, air dried, and stained with Leishman stain. Under the oil immersion lens ($\times 100$) (Olympus Cx 21i microscope), the slides were examined, and wherever the RBCs slightly touched one another, platelets were counted in at least 10 fields and multiplied by a platelet count of 20,000 in thin Leishman stained-smears, i.e., $=20,000 \times \text{Average platelet count (10 oil immersion fields)}$ (Bhasker et al. 2022; Mishra et al. 2022).

Classification of study enrollee

The study enrollees were grouped into the following: (i.) malaria-positives, (ii.) HC—individuals that tested negative for the presence of *Plasmodium falciparum* parasites, (iii.) uncomplicated malaria (UCM)—the patients who had low-grade parasitemia ((i.e., 1–9,999 μl asexual parasites), marked by fever, headache, axillary temperature ($\geq 37.5^\circ\text{C}$)), (iv.) complicated malaria (CM)—high-grade parasitemia/hyperparasitaemia ($>10,000 \mu\text{l}$ asexual parasites), severe anemia ($\text{Hb} < 5 \text{ g/dl}$), serum creatinine ($>3 \text{ mg/dl}$), serum bilirubin ($>3 \text{ mg/dl}$), and plasma glucose $<40 \text{ mg/dl}$) (WHO. 2015). Mean platelet count was considered among the study enrollee with respect to the WHO grade with the following categorization: normal platelet count (150,000–450,000), thrombocytosis ($>450,000$), and thrombocytopenia ($<150,000$) ($10^9/\text{L}$).

Estimation of sample size

The sample size for this study was estimated by pulling the current population of the inhabitants residing in the three LGAs of Ilorin, the Kwara from the National Population website: <https://nationalpopulation.gov.ng/>. The population size (761, 700) was entered into the sampling size estimator bearing in mind the confidence level (95%), margin of error (5%), and population proportion (50%) at www.calculator.net/sample-size-calculator.

Statistical analysis

All data analyses were performed using IBM SPSS 20.0 Statistics and Graphpad Prism 7 version 7.04 (Graphpad Prism software Inc., San Diego, CA, USA). The categorical data are presented as frequency (percentages), and the chi-square test statistics were used to test for association between variables. The Mantel-Haenszel test of trend was used to examine rates across levels of parasitemia. The trend across age ranges was evaluated by the Jonckheere trend test followed by Kendall's tau-b to estimate the effect size. Continuous variables were presented as mean $\pm$ standard error of mean for parametric variables and median (interquartile range) for nonparametric variables. The Kruskal-Wallis test was used to assess the significance of differences for non-parametric variables between controls and different grades of malaria parasitemia, followed by the Bonferroni post hoc multiple comparison test. One-way ANOVA was used to test for the significance of differences for parametric variables between controls and different grades of malaria parasitemia, followed by the Tukey post hoc multiple comparison test. Confidence was set at 95%, and p-value less than 0.05 was considered statistically significant.

Results

One thousand, one hundred and sixty-two (1162) individuals were enrolled for the study, comprising seven hundred and fourteen females (714, 61.4%) and four hundred and forty-eight males (448, 38.6%). The prevalence of malaria among the study enrolment with respect to gender and the LGAs sampled show that Ilorin-West had the highest number of malaria-positives among the three LGAs (266, 34.3%); however, the distribution is comparable ($p > 0.05$). A total of seven hundred and seventy-five individuals (775, 66.7%, $p < 0.001$) from the three LGAs sampled were malaria-positive. A total of 469 (60.5%) females were malaria positive as compared to males 306 (39.5%), but malaria prevalence with respect to gender was not significant ($p > 0.05$) (Table 1).

Malaria-positive individuals were stratified with respect to the following parameters: parasitemia counts across age groups and gender (Table 2). The distribution showed that the association between uncomplicated (UCM) and complicated malaria (CM) across age groups were statistically significant ($p < 0.05$). Children <5 years had the highest number of individuals with CM (103, 45.2%) with a relative risk ratio of 4.005 (2.964–5.413) 95% CI. Parasitemia count with respect to gender indicate that UCM (471, 40.5%) occurred more than CM (304, 26.2%) ($p > 0.05$).

The total number (n), geometric mean, 95% CI, median, and IQR of population with no malaria parasites was 387, 193.46 ± 14.408 , 192.02–194.90, 194.40, and 8.00, while

Table 1 Distribution and prevalence of malaria across the LGAs

Study site	Gender				Total pos. (f+m)	χ^2	<i>p</i> -value
	Female		Male				
	<i>No. Ex.</i>	<i>Pos. (%)</i>	<i>No. Ex.</i>	<i>Pos. (%)</i>			
LGA						0.217	0.897
Ilorin-East	222	149 (67.1)	151	102 (67.5)	251 (32.4)		
Ilorin-South	245	157 (64.1)	147	101 (68.7)	258 (33.3)		
Ilorin-West	247	163 (66.0)	150	103 (68.7)	266 (34.3)		
Total	714(61.4)	469 (65.7)	448 (34.3)	306 (68.3)	775 (66.7)		
* <i>p</i> -value				<0.001			

Key: LGA local government area, No. Ex, number examined, Pos. positive for malaria, (f+m) female and male, χ^2 chi-square value

Asterisk is the point prevalence of malaria across the three LGAs

Table 2 The distribution and relative risk ratio of malaria severity with respect to age and gender

	Non-infected	UCM	CM	Total	RR 95% (CI)	<i>p</i> -value	X^2	* <i>p</i> -value
Age grp.							84.52	<0.001
≤5	76 (33.3)	49 (21.5)	103 (45.2)	228	4.005 (2.964–5.413)	<0.001	89.36	
6–15	98 (32.6)	129 (42.9)	74 (24.6)	301	4.148 (3.166–5.435)	<0.001	115.80	
16–25	53 (35.3)	54 (36.0)	43 (28.7)	150	1.982 (1.460–2.692)	<0.001	19.66	
26–35	68 (33.0)	91 (44.2)	47 (22.8)	206	5.214 (3.714–7.321)	<0.001	104.80	
36–45	44 (31.9)	74 (53.6)	20 (14.5)	138	2.768 (1.980–3.870)	<0.001	37.56	
≥46	48 (34.5)	74 (53.2)	17 (12.2)	139	4.142 (2.832–6.056)	<0.001	60.44	
Total	387 (33.3)	471 (40.5)	304 (26.2)	1162	32.333 (23.572–44.350)	<0.001	735.30	
Gender							120.90	0.546
Female	245 (34.3)	289 (40.5)	180 (25.2)	714	3.834 (3.148–4.668)	<0.001	186.90	
Male	142 (31.7)	182 (40.56)	124 (27.7)	448	2.501 (2.032–3.078)	<0.001	76.68	
Total	387 (33.3)	471 (40.5)	304 (26.2)	1162	32.333 (23.572–44.350)		735.30	

UCM uncomplicated malaria (i.e., 1–9999 μ l asexual parasites), CM complicated malaria (>10,000 μ l asexual parasite; asterisk is the point prevalence with respect to the severity of malaria (i.e., UCM vs CM))

that of uncomplicated malaria was 471, 284.97±143.820, 271.95–287.99, 241.00, and 141.00 and complicated malaria was 304, 221.31±161.293, 203.10–239.51, 169.00, and 156.00 (Fig. 3).

Three hundred and eighty-seven (387, 42.9%) individuals among the study enrolment had normal platelet count with no *P. falciparum* parasitemia at the time of presentation in the various study sites. Among the confirmed population with uncomplicated malaria, 385 (81.7%) had normal platelet counts, while 48 (10.2%) presented with thrombocytosis and 38 (8.1%) had thrombocytopenia. Distribution of platelet counts among the patients who had complicated malaria showed the following outcomes: normal platelets were 131 (43.1%), thrombocytosis 30 (9.9%), and thrombocytopenia 143 (47.0%). In all, the association was statistically significant ($p<0.05$) (Table 3).

The severity of malaria among the study enrolment was quantified with respect to platelet count. It was observed that the population with uncomplicated malaria had the highest

geometric mean of platelets (284.97 ± 143.82) when compared with the complicated malaria group (284.97 ± 143.82). This might be due to differences in population sampled for both malaria severity (Table 4).

Out of the total with UCM (49), children ≤5 years who had thrombocytosis was 12.2%, and thrombocytopenia was 8.2%. For adults between 36 and 45 years (52), 10.8% had thrombocytosis, and 18.9% had thrombocytopenia ($p<0.05$). The population of individuals with thrombocytopenia among the CM was higher when compared to the group with UCM, for instance, children ≤5 years (61.2%), adults 36–45 years (55.0%), and >46 years (70.6%) ($p<0.05$) (Table 5).

Discussion

In Nigeria, *Plasmodium falciparum* parasite remains the most common cause of malaria morbidity (Sabina 2017; Yakubu et al. 2019; Quan et al. 2020). We observed a high

Fig. 3 Comparison of graded platelet counts and its geometric mean values among the population with respect to malaria infection status. Boxes represent 25th–75th percentiles, solid bars within boxes represent median values, and values within the bars represent non-outlier maximum and minimum, mild (●), moderate (○), and extreme (*) outliers (alpha levels of both geometric mean of platelets and no malaria, uncomplicated and complicated malaria categories were significantly different at $p < 0.05$)

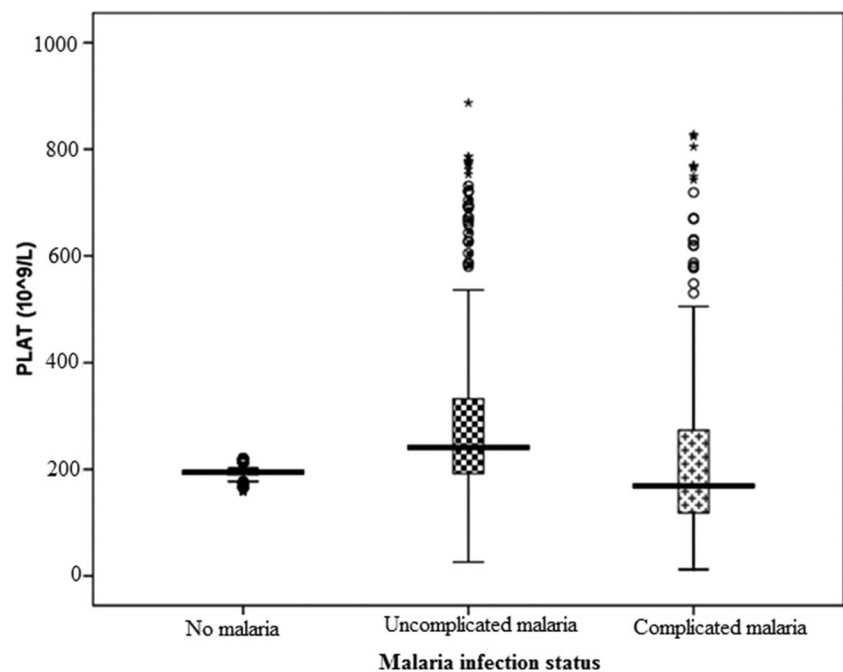


Table 3 Distribution of platelet counts with respect to the severity of malaria

Grade	Malaria-negative (%)	Uncomplicated malaria (%)	Complicated malaria (%)	Total ($n = X$)	* p -value
Normal	387 (100)	385 (81.7)	131 (43.1)	903	<0.001
Thrombocytosis	0	48 (10.2)	30 (9.9)	78	
Thrombocytopenia	0	38 (8.1)	143 (47.0)	181	
Total per group	387	471	304	1162	

Platelet counts of 150,000 to 450,000/dL are defined as normal grade; >450,000 dL is graded as thrombocytosis; and <150,000 dL is graded as thrombocytopenia. Asterisk is the point prevalence with respect to the severity of malaria (i.e., UCM vs CM) with grades of platelet outcome

Table 4 Geometric mean of platelet counts with respect to the severity of malaria among the study enrolment

Parameters	Non-Infected ($N = 387$)		UCM ($N = 471$)		CM ($N = 304$)		* p -value	F
	Mean $\pm$ St. dev	95% CI	Mean $\pm$ St. dev	95% CI	Mean $\pm$ St. dev	95% CI		
Platelet ($10^9/L$)	193.46 $\pm$ 14.40	192.02–194.90	284.97 $\pm$ 143.82	271.95–297.99	221.31 $\pm$ 161.293	203.10–239.51	<0.001	61.98

Asterisk is the point prevalence with respect to the severity of malaria (i.e., UCM vs CM) in relationship with platelet counts

prevalence (66.7%) of *P. falciparum* malaria in the present study which is similar to a recent report in the Republic of Djibouti, also a malaria-endemic country (Moussa et al. 2023). Malaria infection was high in children ≤ 5 years (i.e., 19.6%), and this age group forms the majority of hospital visits, a similar trend in many malarious zones (Margono et al. 2016; Mohamedahmed et al. 2020). The present study found that depression of platelet count occurred in patients who had complicated malaria infection with symptoms as well as in persons with uncomplicated malaria without obvious symptoms. The aforementioned is in tandem with several other studies in other environs (Maina et al. 2010; Jojera

et al. 2013; Gupta et al. 2019; Mahittikorn et al. 2021). In general, several reports have enunciated disseminated intravascular coagulopathy (DIC) as the most probable initiator of thrombocytopenia in acute malaria infections (Gérardin et al. 2002; Arif et al. 2016). In the present study, thrombocytopenia was high among patients with complicated malaria. Although thrombocytopenia is often benign and transient, its relevance cannot be shoved aside as an early diagnostic tool during the onset of malaria in both children and adults (Srikanth et al. 2012; Gill et al. 2013). Till date, thrombocytopenia is yet to be fully understood for its correlation to the malaria morbidity (Srivastava et al. 2017). In

Table 5 Distribution of platelet counts with respect to age group stratified with the severity of malaria among the study enrolments

Age grp.	Platelet counts with respect to WHO*									
	Uncomplicated malaria					Complicated malaria				
	No. infect	^a Normal n (%)	^b Th-cytosis n (%)	^c Th-cytopenia n (%)	p-value	No. infect	^a Normal n (%)	^b Th-cytosis n (%)	^c Th-cytopenia E (%)	* p-value
≤5 yrs.	49	39 (79.6)	6 (12.2)	4 (8.2)	<0.05	103	36 (35.0)	4 (3.9)	63 (61.2)	<0.001
6–15 yrs.	129	115 (89.1)	6 (4.7)	8 (6.2)		74	43 (58.1)	9 (12.2)	22 (29.7)	
16–25 yrs.	54	45 (83.3)	9 (16.7)	0		43	19 (44.2)	9 (20.9)	15 (34.9)	
26–35 yrs.	91	74 (81.3)	10 (11.0)	7 (7.7)		47	19 (40.4)	8 (17.0)	20 (42.6)	
36–45 yrs.	74	52 (70.3)	8 (10.8)	14 (18.9)		20	9 (45.0)	0	11 (55.0)	
>46 yrs.	74	60 (81.1)	9 (12.2)	5 (6.8)		17	5 (29.4)	0	12 (70.6)	
Total (%)	471	385 (81.7)	48 (10.2)	38 (8.1)		304	131 (43.1)	30 (9.9)	143 (47.0)	

Key: Platelet counts with respect to WHO normal levels

^aNormal (150,000–450,000)^bThrombocytosis (>450,000)^cThrombocytopenia (<150,000)

Asterisk is the point prevalence with respect to the severity of malaria (i.e., UCM vs CM) in relationship with age groups

otherwords, alterations in the volume of circulating platelets as observed here may be used singly or in association with other key hemtological parameters as an adjuvant tool in strengthening the suspicion of malaria severity due to *Plasmodium falciparum* (Chimalizeni et al. 2010; George and Ewelike-Ezeani 2011; Bayleyegn et al. 2021). In the tropics, thrombocytopenia is common among the inhabitants owing to persistently high levels of malaria disease occurrence all year round irrespective of the season, and the progression to severe or ultimately fatal disease is largely confined to *P. falciparum* infections, although only a small percentage, approximately 1% to 2% of infections, lead to severe malaria (Gérardin et al. 2002; 2014; Wassmer et al. 2015; WHO 2014). We observed different clinical symptoms among patients presenting with CM confirming that in Africa, malaria immune status differs and it is premised on the transmission intensity, different parasite binding types, human polymorphism, and age-dependent changes in the microvascular system (Wassmer et al. 2015; Milner Jr. 2018). Uncomplicated malaria is succinctly defined by WHO as the presence of symptoms without clinical or laboratory signs to indicate severity or vital organ dysfunction; this may however explain the reason why some of the samples in our finding came up with thrombocytopenia (Ashley et al. 2018; Milner Jr. 2018). Thrombocytosis or thrombocythemia refers to having too many platelets in the blood which may occur as a result of a certain inherited genetic condition (primary, essential thrombocythemia) or secondary (reactive) thrombocytosis. Secondary thrombocytosis often emanates in patients with anemia due to iron deficiency and or inflammation (Thakur and Kattel 2018). Our finding revealed that certain population in the present enrolment showed thrombocytosis, although in fewer samples, of course, this may be due to malaria-related anemia. More importantly, the few occurrences of thrombocytosis in our study were observed among children ≤5–15 years and adults above ≥45 years of age, which is a further reflection of what obtains in other climes (Siagian et al. 2018; White 2018; Papaioannou et al. 2019). At the onset of any malaria infection, the macrophages stimulate the release of tumour necrotic factor alpha (TNF-α), thereby initiating inflammation and also stimulates the display of adherence molecules in the brain endothelium-like intracellular adhesion molecule1 (ICAM-1) (Epelboin et al. 2013; Milner Jr. 2018). Furthermore, the general habit of self-medication before hospital presentation in which febrile patients takes blood thinners such as aspirin, acetomorphin, and other non steroidal antiinflammatory drugs (NSAID) may exercebate thrombocytosis. It is not unlikely that the population in our study that were positive for thrombocytosis may have engaged in taking antipyretic drugs (Lell et al. 2001; Meremikwu et al. 2012). We observed a remarkable upsurge in parasitaemia among individuals that presented with complicated malaria.

Earlier reports had potentiated that high parasitaemia is a subjective risk factor for determining the severity of malaria infections and may subsequently drive systematic inflammation, endothelial activation, and metabolic acidosis (Erdman 2011; Patel et al. 2020). The aforementioned is usually initiated by microvascular obstruction, and essentially, high parasite burden can be multifactorial (Lim et al. 2013; Wasmer et al. 2015).

Conclusion

The study observed the relevance of platelet count in the pathophysiology and the diagnosis of complicated malaria, although it did not ascertain its' innate etiology as the only biomarker of disease severity. High parasitemia count is reflective of platelet clump and the manifestation of several pathogenesis associated with malaria disease progression. Obviously, many of the patients with high *P. falciparum* parasitemia recorded low platelet count, indicating that such patients may otherwise suffer other malaria pathogenesis not covered in the present study. Thrombocytopenia is a silent pathophysiological attribute that can trigger other cofactors during severe malaria disease. Although further studies are pertinent in order to specifically clarify its relevance to clinical disease spectrum.

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Author contribution Olalere Shittu: conceptualization, carried out the laboratory exercise and the statistical data analysis respectively, and wrote the first draft.

Mobolanle Oladipo Oniya: conceptualization, supervision, statistical data analysis, edited the first draft, and contributed to the literature review.

Titus Adeniyi Olusi: collated the literature review and contributed to the final draft.

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Data availability All relevant data are within the paper and its supporting files.

Declarations

Ethical approval Approval for this study was sought and approved by the Ethical Review Committee of the Kwara State Ministry of Health, Ilorin, followed by that of the Ethics Committee of the University of Ilorin, Nigeria, before undergoing the research. Parents and caregivers of the minors gave consent prior to blood collection.

Consent to participate Not applicable

Consent for publication Not applicable

Conflict of interest The authors declare no competing interests.

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