**Hemato- Biochemical Profile of Malaria patients in Sub Saharan Africa : A Case of the Urban Health Center of Franceville, Gabon**

**ABSTRACT**

Hemato-biochemical analysis is essential for optimal management, reducing the mortality and sequelae of malaria, particularly in endemic areas such as Gabon. This cross-sectional study examined hematological and biochemical changes associated with malaria in 154 patients at the Franceville Urban Health Center (July-September 2024). A high malaria prevalence of 66.88% (95% CI: 0.6-0.74), a severe reduction in erythrocytes (OR=16.59, 95% CI[6.82-43.94], p<0.001), elevated leukocytes (OR=5.6, 95% CI[2.57-2.7], p<0.001), marked thrombocytopenia (OR=15.59, 95% CI[5.86-49.3], p<0. 001), a significant increase in ALT (OR=6.67, 95% CI [3.85-20.47], p<0.001), an increase in AST in 42.21% of patients (OR=0.37, 95% CI [0.14-0.88], p<0.001), and finally, an increase in CRP levels (OR=0.6, 95% CI [0.28-1.26], p<0.001), were found as results.

This study demonstrates the profound effects of malaria on the hematopoietic and hepatic systems, underlining the need for comprehensive monitoring of these parameters in clinical management.

**Keywords:** Malaria, Hematology, Biochemistry, profile Transaminases, C-reactive protein, Gabon

**I. INTRODUCTION**

Caused by a parasite of the genus *Anopheles* female, malaria is endemic in many regions of the world and constitutes a major public health issue. Although preventable, as it is possible to cure it, this burden is responsible for high mortality and morbidity, particularly among the most vulnerable populations, despite prevention and treatment efforts (WHO, 2024) (Zekar et al., 2024). According to the latest reports from the World Health Organization (WHO), globally in 2022, approximately 249 million people were infected with malaria, and nearly 608,000 deaths were attributed to malaria (WHO, 2024). Sub-Saharan Africa is the region where the majority of cases are concentrated. This region bears a disproportionate share of the global malaria burden, with 94% of cases and 95% of deaths in 2022 (Oladipo et al., 2022).

Furthermore, infection with the parasite *Plasmodium* induces a series of complex physiological changes within the human body. During symptomatic malaria, these alterations, which are the direct consequence of the interaction between the parasite and the host organism, manifest themselves in particular at the blood level, leading to variations in hemato-biochemical parameters such as the destruction of red blood cells, the inflammatory response, and organic complications in infected patients (Sato et al., 2021; Njewa et al., 2024).

**In Gabon, one of the most malaria-affected countries in sub-Saharan Africa, numerous malaria studies have been conducted (**Lendongo-Wombo et al., 2022**). However, Franceville - located in southeastern Gabon with a general population malaria prevalence exceeding 40% (peaking during rainy seasons) - remains classified as a hyperendemic malaria zone, a status persisting for years, including the last three (Sima-Biyang et al., 2024).**

**Notably, there remains a striking paucity of specifically referenced studies on hematobiochemical variations in malaria patients. To better understand malaria's systemic impact and optimize therapeutic management, detailed investigation of patients' hematobiochemical profiles is essential. This study was therefore designed as a complementary tool for disease severity assessment and monitoring, specifically to establish the hematological and biochemical profile of malaria infection in patients attending the Urban Health Center of Franceville.**

**II. MATERIALS AND METHODS**

**II.1. Study Setting and Location**

This study was conducted jointly by the University of Sciences and Techniques of Masuku and the Urban Health Center of Franceville (UHCF). Located in southeastern Gabon, Franceville is the provincial capital of Haut-Ogooué and one of the country’s major cities. Its humid tropical environment, marked by a dry season (May-September) and an intense rainy season (October-April), creates ideal conditions for the proliferation of Anopheles gambiae , the primary malaria vector in Gabon. With a population of approximately 150,000, the city has a youthful demographic typical of developing countries. Its economy is primarily driven by mining (manganese), commercial activities, and public and private services. The urban landscape reveals significant disparities: the city center concentrates health infrastructure, while the peripheral areas suffer from precarious conditions (unsanitary housing, limited access to clean water). These environmental and socio-economic factors, combined with the presence of wetlands and forested areas, make Franceville a region particularly vulnerable to malaria transmission, necessitating targeted public health interventions. **Reference public healthcare facility**, the Franceville Urban Health Center (UHCF). serves as the primary medical resource for treating common illnesses, with particular expertise in malaria management. It provides General and specialized consultations, comprehensive malaria care, monitoring for vulnerable groups (children under 5 and pregnant women, who account for 60% of cases). Staffed by a **multidisciplinary medical team**, the center features a **fully equipped laboratory** capable of Rapid diagnostic testing (malaria RDTs), Hematological analyses (CBC) and Biochemical testing (bilirubin, liver enzymes, blood glucose).

**II.2. Study Type and Period**

This is a prospective and cross-sectional study conducted from July 18 to September 21, 2024.

**II.3. Study Population**

The study population consisted of people, regardless of gender, who came for consultation at the Urban Health Center of Franceville (UHCF).

**II.4. Study Eligibility Criteria**

**II.4.1. Inclusion Criteria**

The study focused on people aged 18 and over, of all genders, living in Franceville and its surroundings, who consulted the Urban Health Center of Franceville for malaria infection and who gave their informed consent.

**II.4.2. Exclusion Criteria**

To avoid any influence on results, pregnant women, people suffering from severe acute illnesses, people involved in other studies, patients with concomitant infections known to alter hematological or biochemical parameters (e.g. HIV, tuberculosis, hepatitis B/C, dengue fever or bacterial sepsis), individuals with chronic diseases affecting metabolic or hematological profiles (e.g. diabetes mellitus, chronic kidney disease, sickle cell disease or liver cirrhosis), in order to avoid confounding effects, patients who had received blood transfusions, iron supplementation or antimalarial treatment in the 14 days prior to sampling, pathologies such as rheumatoid arthritis or neoplasia, newcomers to Franceville, people unable to understand the information provided or who had not given informed consent, were excluded from the study.

**II.4.3. Sample Size Determination**

To determine the number of participants needed for our study on the hematological and biochemical profile of malaria infection in patients seen at the Urban Health Center of Franceville, we used the standard sample size calculation formula for a single proportion. This formula, frequently used in research, is as follows:

n = (Zα / 2)² \* (P \* (1 - P)) / d² (Mba et al, 2024)

Where, n represents the sample size, Zα/2 is the critical value of the standard normal distribution corresponding to the desired confidence level (in our case, 95% confidence), P is the estimated prevalence of the characteristic being studied (here, the prevalence of malaria). In the absence of precise data for Franceville, we used a conservative value of 50%, d is the accepted margin of error. To compensate for potential participant losses, we increased the initial sample size (140 people) by 10%. (Sitotaw et al., 2019; Mba et al. 2024). The final sample size retained for this study was 154 participants.

**II.5. Sample Collection**

A 5 ml venous **blood samples were collected between 7 AM and 12 PM for the majority of patients to standardize collection conditions,** andto perform a complete blood count, creatinine, liver function tests (including transaminases, bilirubin, alkaline phosphatases, and gamma-GT), proteinemia, CRP assay, as well as a rapid diagnostic test for parasites. Participant samples were first screened for malaria infection using the MERISCREEN Malaria Pf/Pv Ag rapid diagnostic test, according to the manufacturer's recommendations.

**II.5.1. Procedure for the Detection of Malaria Infection**

The MERISCREEN Malaria Pf/Pv Ag rapid diagnostic test, manufactured by Meril Diagnostics in India, is an in vitro immunochromatographic test for the qualitative detection of Plasmodium falciparum and P. vivax infections, responsible for malaria, in human whole blood samples. The test has a relative sensitivity greater than 99.9%, a relative specificity of 99.5%, and an accuracy of 99.6%. Each of the tests detects the specific antigen from a concentration of 1 ng/ml of PEI (parasitized erythrocyte) in serum or plasma. The device contains two test lines (Pf line and Pv line) as well as a control line (C line).

**Diagnostic Procedure**

The refrigerated sample and test components were brought to room temperature and homogenized. Then the pouch was opened at the notch and the removed cassette was placed on a clean, flat surface and labeled. The collected blood (5 µL) was blotted onto the sample port marked S by touching the applicator vertically directly onto the sample port. Three drops of buffer were then added to the buffer port and the timer was activated for 20 minutes, at the end of which the reading was taken.

**Result Interpretation**

The results are interpreted as follows:

* The result was positive for *Plasmodium falciparum* when two bands were observed on the C line and the Pf line.
* The result was positive for *P. falciparum* and *P. vivax* when three bands were observed on the C, Pf, and Pv lines.
* The result was positive for *P. vivax* when two bands were observed on the C line and the Pv line.
* The test was negative when only one band was observed on the C line (control).
* The test was invalid: If no bar appears on line C, the test is invalid, regardless of the color development on the test lines (Pf and Pv). The test must be redone with a new cassette.

**II.5.2. Measurement of Hematological and Biochemical Parameters**

**II.5.2.1. Hematological Parameters**

After taking a venous blood sample from each participant into an EDTA tube, it was gently homogenized by successive inversions. The red blood cell, white blood cell, and platelet counts were performed using the URIT 2900 Plus hematology analyzer. After checking the reagent and waste levels, the analyzer probe was inserted into the EDTA tube containing the patient's information. The analyzer automatically aspirates the blood from the EDTA tube. The blood is diluted and mixed with specific reagents. Blood cells are counted and differentiated by flow cytometry. The results are displayed on the touch screen and printed on the analysis report

The results of the red blood cell, white blood cell, and platelet counts were compared to reference values. If an anomaly was found, a microscopic analysis of the blood smear was necessary.

**II.5.2.2. Biochemical Parameters**

The biochemical parameters were analyzed using the ABX Pentra 400 automaton. It is a compact and reliable benchtop analyzer used for in vitro diagnostics, specially designed for routine biochemistry tests. It operates on an open mode principle with random access, thus allowing great flexibility in sample processing. The system also includes a function dedicated to emergency analysis, ensuring priority for urgent tests.

The biochemical parameters measured were:

* **CRP (C-reactive protein)**: This is a protein produced by the liver. It is an important marker of inflammation in the body. CRP testing is a common blood test that can help diagnose infection or inflammation, monitor the progression of inflammatory disease, assess the effectiveness of treatment, and screen for certain diseases. A high CRP level indicates the presence of inflammation in the body. However, it does not specify the cause of the inflammation. Further examinations and analyses are needed to determine the source of the problem.
* **Aminotransferases**: Aminotransferases (ALAT and ASAT) are biochemical markers of hepatocellular and/or muscular cytolysis. The measurement of these enzymes is indicated in the initial assessment of liver disease, to monitor the progression of liver disease, to assess the hepatic toxicity of drug treatment, and to search for an organic cause of asthenia.
* **Total Bilirubin**: This yellow pigment produced during the natural breakdown of red blood cells is transported to the liver, where it is transformed (conjugated) to be eliminated by bile in the intestines. An increase in total bilirubin may indicate various problems such as hemolysis (increased destruction of red blood cells), liver dysfunction which prevents it from conjugating or excreting bilirubin correctly (hepatitis, cirrhosis...), and obstruction of the bile ducts which prevents bile from flowing normally (gallstones...).

**II.6. Quality Assurance**

The questionnaire was pretested with 5% of the study subjects before the actual data collection to assess its validity and comprehensiveness. The laboratory manager closely monitored the data collection process. The questionnaire data obtained from each study donor were reviewed immediately for accuracy and completeness. Samples were processed and tested by an experienced laboratory professional according to the manufacturer's specifications. The performance characteristics of the MERISCREEN Malaria Pf/Pv Ag rapid test indicated relative sensitivities: >99.9%, relative specificities: 99.5%, and accuracies: 99.6%.

**II.7. Data Collection**

To ensure reliable and interpretable results, particular attention was paid to data collection in this study. This required careful planning, rigorous training of the center's healthcare personnel, and strict adherence to the ethical principles governing biomedical research.

**II.9. Data Processing and Statistical Analysis**

The collected data were entered into a Microsoft Excel 2013 spreadsheet, cleaned, and then analyzed using R software version 4.2.1. To assess and measure the strength of the association between malaria infection and changes in the hematological and biochemical parameters of patients, univariate analyses were performed. Odds ratios and their 95% confidence intervals were calculated. P-values were determined and considered significantly associated with malaria infection when they were less than or equal to 0.05.

**III.1. RESULTS**

**III.1.1. Overall Prevalence of Malaria Infection in Study Participants (N=154)**

A total of 154 individuals who consented to participate in this study were screened for malaria infection at the laboratory of the Urban Health Center of Franceville. With a mean age of 45 ± 13.66 years, the number of women (N=83) was greater than men (N=71). Malaria infection was positive among 103 participants, indicating an overall prevalence of 66.88% (95% CI: [0.6 - 0.74]), compared to 33.12% or 51 negative participants.

**III.1.2. Hematological Parameters Obtained with the "URIT 2900 Plus" Automaton Compared to Normal Values in Study Participants (N=154).**

Table 1 shows that after a complete blood count examination, taking into account the standard normal laboratory values for hematological parameters, the red blood cell count was lower than normal among 83 patients (53.9%). 73 (47.40%) of patients had a white blood cell (WBC) count above normal. Finally, a platelet count lower than normal was noted among 70 patients (92.11%).

**Table 1**: Values lower than, within, and higher than the reference values for hematological parameters obtained in the study participants.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Values** | **Below reference values** | **Within reference values** | **Above reference values** | **Reference values** |
| **Hematological parameters of patients** | **Number of patients (%)** | **Number of patients (%)** | **Number of patients (%)** |
| **White blood cells** | 17 (11.04) | 64 (41.56) | 73 (47.40) | 4.0 – 9.0 K/µl |
| **Red blood cells** | 83(53,9) | 71 (46,1) | 0 (0) | 3,9 à 5,5 millions/mm3 of blood |
| **Platelets/ µl** | 70 (45,45) | 76 (49,35) | 8 (5,2) | 150 – 450 K/µl |

**III.1.3. Overall Prevalence of Malaria Infection, According to Changes in Hematological Parameters Observed in Study Participants, Compared to Normal Values (N=154)**

A Fisher's exact test used to analyze the association between the prevalence of malaria infection and changes in hematological parameters observed in study participants indicated that a decrease in red blood cell count (Odds Ratio = 16.59; 95% CI [6.82; 43.94], p≤0.001\*), an increase in white blood cells (Odds Ratio = 5.6; 95% CI [2.57; 2.7], p≤0.001\*), and a decrease in platelet count (Odds Ratio = 15.59; 95% CI [5.86; 49.3], p≤0.001\*) were significantly associated with the overall prevalence of malaria infection in this study (table 2).

**Table 2: Fisher's Exact Test of the Prevalence of Malaria Infection, According to Changes in Hematological Parameters Observed in Study Participants, Compared to Normal Values (n=154)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Altered haematological parameters** | **Total number of patients *N* (%)** | **Prevalence of malaria infection** | | **Univariate analysis** | |
| **Positive N (%)** | **Negative N (%)** | **Crude OR 95%CI** | **p-value** |
| **Red blood cells** | | | | | |
| Yes | 93 (60,38) | 83(89,25) | 10 (10,75) | 16,59 [6,82 ; 43,94] | **≤0,001\*** |
| No | 61(39,62) | 20 (32,79) | 41(67,21) | Reference | - |
| **White blood cells** | | | | | |
| Oui | 87 (56,49) | 73 (83,91) | 14 (16,09) | 5,6 [2,57 ; 2,7] | **≤0,001\*** |
| Non | 67 (43,51) | 30 (44,78) | 37 (55,22) | Reference | - |
| **Platelets** | | | | | |
| Yes | 76 (49,35) | 70 (92,11) | 6(7,89) | 15,59 [5,86 ; 49,3] | **≤0,001\*** |
| No | 78(50,65) | 33(42,31) | 45 (57,69) | Référence | **-** |

OR = Odds Ratio; CI = Confidence Interval; \* = Significant Test

**III.1.4. Biochemical Parameters Measured Using the "ABX Pentra 400" Automaton Compared to Normal Values in Study Participants (N=154)**

Table 3 shows in the biochemical assessment of the study participants that, taking into account the standard normal laboratory values, the levels of liver transaminases (ALAT and ASAT) were higher than the reference values among 84 patients (53.5%), and among 65 patients, (42.21%), respectively. It was also noted that 64 (41.56%) of patients had a total bilirubin level. C-reactive protein was elevated among 79 (51.3%) of patients.

**Table 3: Values lower than, within, and higher than the reference values for biochemical parameters obtained in the study participants.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Values | Below reference values | Below reference values | Above reference | Reference values |
| Patient biochemical parameters | Number of patients ( %) | Number of patients ( %) | Number of patients ( %) |
| **ALAT** | 13(9,49) | 57 (37,01) | 84 (53,50) | 1,7 – 8,3 mmol/L |
| **ASAT** | 9 (5,84) | 80 (51,95) | 65 (42,21) | 1 – 42 UI/L |
| Total bilirubin | 17 (11,04) | 73 (47,4) | 64 (41,56) | < 17,1 µmol/L |
| **CRP** (c-reactive protein) | 7 (4,54) | 68 (44,16) | 79 (51,3) | 15 – 115 µmol// |

**III.1.5. Overall Prevalence of Malaria Infection, According to Changes in Biochemical Parameters Observed in Study Participants, Compared to Normal Values (N=154)**

A Fisher's exact test of the overall prevalence of malaria infection, according to changes in biochemical parameters observed in study participants, indicated that an increase in liver transaminases such as ALAT (Odds Ratio = 6.67; 95% CI [3.85; 20.47], p≤0.001\*) and ASAT (Odds Ratio = 0.37; 95% CI [0.14; 0.88] p≤0.001\*), and a high level of C-reactive protein (Odds Ratio = 0.6; 95% CI [0.28; 1.26] p≤0.001\*) were significantly associated with the overall prevalence of malaria infection in this study.

**Table 4: Fisher's Exact Test of the Prevalence of Malaria Infection, According to Changes in Biochemical Parameters Observed in Study Participants, Compared to Normal Values (n=154)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Biochemical parameters**  **modified** | **Patients total Number *N* (%)** | **Prevalence of Malaria Infection** | | **Univariate analysis** | |
| **Positive**  **N (%)** | **Négative**  **N (%)** | **Crude OR Brut**  **95% CI** | **p-value** |
| **ALAT** | | | | | |
| Yes | 101 (65,58) | 84(83,17) | 17 (16,83) | 6,67 [3,85 ; 20,47] | **≤0,001\*** |
| No | 53 (34,42) | 19 (35,85) | 34(64,15) | Reference | - |
| **ASAT** | | | | | |
| Yes | 107 (69,48) | 65 (60,75) | 42 (39,25) | 0,37 [0,14 ; 0,88] | **0,016\*** |
| No | 47 (30,52) | 38 (80,85) | 9 (19,15) | Reference | - |
| **Total Bilirubine** | | | | | |
| Yes | 90 (58,44) | 56 (62,22) | 34(37,78) | 0,6 [0,28 ; 1,26] | 0,17 |
| No | 64(41,56) | 47(73,44) | 17 (26,56) | Reference | **-** |
| **CRP** (c-reactive protein) | | | | | |
| Yes | 94 (61,04) | 79 (84,04) | 15(15,96) | 0,6 [0,28 ; 1,26] | **≤0,001\*** |
| No | 60 (38,96) | 24(40) | 36 (60) | Reference | **-** |

OR = Odds Ratio; CI = Confidence Interval; \* = Significant Test

**IV. DISCUSSION**

Malaria remains a serious health problem, especially in sub-Saharan Africa and Gabon, where it mainly affects rural and peri-urban populations. To better understand how this disease affects the body, this study examined the changes it causes in the blood and in the body's chemistry. While a study conducted in Cameroon revealed a prevalence of malaria infection of 34.7% (Ngum et al., 2023), the present study indicated an overall prevalence of 66.88%. This result, which is practically similar to that found in Equatorial Guinea (69%) (Guerra et al., 2018), is higher than the 41.0% found in a study in Ethiopia (Lakew et al., 2023), and lower than the 73% obtained in the Ashanti region of Ghana (Hinemann et al., 2020). The differences in malaria prevalence between studies are explained by several factors. First, the difference between the Plasmodium species studied, with varying levels of virulence and drug resistance. Then the stage of development of the parasite at the time of the test can affect its detection. Finally, the emergence of drug resistance can influence transmission and prevalence (Su et al., 2019). Host-related factors can be noted, such that the level of immunity in the population, acquired naturally or through vaccination, can influence susceptibility to infection and disease severity. Some genetic variations may confer partial protection against malaria. The presence of comorbidities (HIV, malnutrition, etc.) can alter the immune response and increase vulnerability to infection (Netea et al., 2021). Furthermore, temperature, humidity, and rainfall influence mosquito survival and parasite development. Altitude, vegetation, and the presence of water points can alter transmission conditions. Global warming can change the geographical distribution of vectors and promote the emergence of new endemic areas (Agyekum et al., 2021). Finally, the diagnostic criteria used (microscopy, rapid tests, PCR) can vary and influence the results. Small sample sizes can lead to less accurate prevalence estimates. Prevalence can vary seasonally, depending on the transmission cycle. Selection bias can influence results if participants are not representative of the general population (Madkhali et al., 2022). The study showed a strong association between decreased red blood cell count and malaria prevalence. This result confirms other research suggesting that certain genetic variations affecting red blood cells may offer protection against malaria (Goheen et al., 2017). Decreased red blood cell count is a common symptom in patients with malaria. This link is explained by the complex mechanisms of the disease. It is therefore crucial to take anemia into account when treating malaria to improve diagnosis, prognosis, and patient management (Engeda et al., 2024). Corroborating previous studies that showed fluctuation in interindividual variability of white blood cells during an acute malaria episode (Naser et al., 2024), the present study revealed that the increase in white blood cells was 5.6 times associated with malaria infection. This can be explained because malaria infection induces a systemic inflammatory response, with the release of pro-inflammatory cytokines that stimulate the production of white blood cells in the bone marrow (Khermach et al., 2017). Similarly, it has been shown elsewhere that the decrease in platelet count, coupled with an increase in their average volume and their heterogeneity, constitutes a characteristic hematological profile of patients at risk of developing severe malaria (Bayleyegn et al., 2021). The present study revealed a significant link between a decrease in platelet count and the prevalence of malaria. This result can be justified because thrombocytopenia (low platelet count) is a common and important clinical sign of malaria, caused by various mechanisms affecting the production and lifespan of platelets. It is therefore essential to monitor platelet counts in patients with malaria for better diagnosis, prognosis, and treatment (Gebreweld et al., 2021). Statistical analysis (Fisher's exact test) showed that the increase in liver enzymes (ALAT/ASAT) was significantly associated with the prevalence of malaria. This result, consistent with other studies that have shown that malaria damages liver cells, thus releasing enzymes into the blood (Haftu et al., 2023), could be justified by the fact that liver cytolysis during malaria is the direct consequence of parasitic infection and the host's immune response. It is an important part of the clinical picture of severe malaria and can lead to serious complications (White et al., 2022). The study found no link between total bilirubin levels and malaria prevalence. This lack of a significant link with the prevalence of malaria infection in the patients of the present study may be explained by individual variations, other possible causes of hyperbilirubinemia, and varying degrees of liver damage (Cheaveau et al., 2019).

**V. CONCLUSION**

This cross-sectional study conducted at the Centre de Santé Urbain de Franceville (July-September 2024) sheds essential light on the haematological and biochemical disturbances associated with malaria infection in Gabon. With a high prevalence rate of 66.88%, malaria remains a major public health problem in the region. Key findings from this study confirm that malaria significantly disrupts hematological and biochemical homeostasis, underlining the need for integrated malaria management protocols in Gabon. Future work should explore personalized therapeutic approaches based on these biomarkers.

**Study highlights :**

The study focuses on a specific aspect of malaria infection, namely its impact on haematological and biochemical parameters. This enables an in-depth analysis of the physiological changes induced by the disease. Secondly, it provides quantified data with confidence intervals and p-values, reinforcing the reliability of the results and quantifying the association between infection and the observed changes. The study also revealed statistically significant associations between malaria infection and several blood (red blood cells, white blood cells, platelets) and liver (ALT, ASAT, C-reactive protein) parameters. These results confirm and reinforce existing knowledge of the impact of malaria on the body, particularly with regard to anemia, inflammation and liver damage, while also highlighting the importance of monitoring blood and liver parameters for the diagnosis, prognosis and management of malaria patients. In summary, this study contributes to a better understanding of the physiological consequences of malaria and has potential implications for clinical practice.

**Study limitations :**

Although this study provides valuable information on the hematological and biochemical profile of malaria in Franceville, it has some limitations. First, in its design as a cross-sectional study, the results obtained in this study do not allow establishing a cause-and-effect relationship, nor following the evolution of biological parameters over time. The sample size, although sufficient to identify significant associations, limits the analysis of specific subgroups or finer associations. Due to the context of the study (Urban Health Center), the results obtained here may not be generalizable to other populations (rural, hospitalized). Diagnosis by Rapid Diagnostic Test (RDT) can be subject to variations in interpretation because RDTs are less sensitive than microscopy for detecting low parasite densities. They can therefore give false negatives, especially at the beginning of infection or in the case of low parasitemia. Confounding factors such as malnutrition, co-infections, and the use of medications were not taken into account. In statistics, multivariate analyses could have been used to refine the results by taking into account confounding factors. These limitations highlight the importance of conducting further research to deepen understanding of malaria and optimize diagnostic and treatment strategies.

**Ethical approval and Consent :**

Ethical authorization for the study was obtained from the ethics committee of the Regional Health Directorate of South East Franceville, by letter no. 0345/PHO/SG/DRSSE/SGP/D. The sampling was designed on the basis of the voluntary participation of blood donors in the study. The objectives and procedures of the study were explained to all participants and to the team at the Urban Health Center of Franceville. Participation in this study was finalized by the written informed consent of each participant. To maintain the anonymity of the participants, code numbers were used instead of nominal identifiers.

**Disclaimer (Artificial intelligence)**

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**VI. REFERENCES:**

World Health Organization. (2024). *Malaria highlights* [Consulted in September 2024].

Zekar, L., & Sharman, T. (2023, August 8). Plasmodium falciparum malaria. In *StatPearls* [Online]. Treasure Island (Florida): StatPearls Publishing. Available from <https://www.ncbi.nlm.nih.gov/books/NBK555962/>

Oladipo, H. J., Tajudeen, Y. A., Oladunjoye, I. O., Yusuff, S. I., Yusuf, R. O., Oluwaseyi, E. M., et al. (2022, August 18). Growing challenges to malaria control in sub-Saharan Africa: Priorities for public health research and policy makers. *Annals of Medicine and Surgery, 81*, 104366. https://doi.org/10.1016/j.amsu.2022.104366. PMID: 36046715; PMCID : PMC9421173

Sato, S. (2021). Plasmodium – A brief introduction to the parasites that cause human malaria and their basic biology. *Journal of Physiological Anthropology, 40*, 1. <https://doi.org/10.1186/s40101-020-00251-9>

Njewa, B., Eyong, E. E. J., & Ebai, C. B. (2024, March 1). Malaria parasitemia and its impact on biological parameters in children < 16 years attending Nkwen District Hospital, Cameroon. *MalariaWorld Journal, 15*, 3. https://doi.org/10.5281/zenodo.10731943. PMID: 38476708 ; PMCID : PMC10929319

Lendongo-Wombo, J. B., Oyegue-Liabagui, S. L., Biteghe-Bi-Essone, J. C., Ngoungou, E. B., & Lekana-Douki, J. B. (2022, December 10). Epidemiology of malaria from 2019 to 2021 in the southeastern city of Franceville, Gabon. *BMC Public Health, 22*(1), 2313. https://doi.org/10.1186/s12889-022-14765-7 PMID: 36496354; PMCID: PMC9739344.

Sima-Biyang, Y. V., Ontoua, S. S., Longo-Pendy, N. M., Mbou-Boutambe, C., Makouloutou-Nzassi, P., Moussadji, C. K., et al. (2024, July). Epidemiology of malaria in Gabon: A systematic review and meta-analysis from 1980 to 2023. *Journal of Infection and Public Health, 17*(7), 102459. https://doi.org/10.1016/j.jiph.2024.05.047 Epub 2024 Jun 3. PMID: 38870682

Mba, T. N., Missang, E. A. E. E., Obiang, C. S., Mihindou, M. C. P., Ntoutoume, A. J. E., Sah, U. L. O., ... & Engonga, L. C. O. (2024). Type 2 diabetes mellitus: Prevalence and risk factors associated with patients at Franceville Amissa Bongo Regional Hospital, Gabon. *Open Access Research Journal of Biology and Pharmacy, 11*(1), 001-012.

Ngum, N. H., Fakeh, N. B., Lem, A. E., & Mahamat, O. (2023, January 19). Prevalence of malaria and associated clinical manifestations and myeloperoxidase among populations living in different altitudes of Mezam Division, North West Region, Cameroon. *Malaria Journal, 22*(1), 20. https://doi.org/10.1186/s12936-022-04438-6. PMID: 36658587; PMCID: PMC9850770

Guerra, M., Sousa, B. D., Ndong-Mabale, N., Berzosa, P., & Arez, A. P. (2018). Determinants of malaria risk factors at the household level in two rural villages of continental Equatorial Guinea. *Malaria Journal, 17*, 203. https://doi.org/10.1186/s12936-018-2354-x

Lakew, Y. Y., Fikrie, A., Godana, S. B., Wariyo, F., & Seyoum, W. (2023, September 6). Magnitude of malaria and associated factors among febrile adults in Siraro District Public Health facilities, West Arsi Zone, Oromia, Ethiopia 2022: A facility-based cross-sectional study. *Malaria Journal, 22*(1), 259. https://doi.org/10.1186/s12936-023-04697-x PMID: 37674201; PMCID: PMC10483761.).

Hinemann, M., Phillips, R. O., Vinnemeier, C. D., Rolling, C. C., Tannich, E., & Rolling, T. (2020). High prevalence of asymptomatic malaria infection in adults, Ashanti region, Ghana, 2018. *Malaria Journal, 19*, 366. https://doi.org/10.1186/s12936-020-03441-z

Su, X. Z., Lane, K. D., Xia, L., Sá, J. M., & Wellems, T. E. (2019, July 31). Plasmodium genomics and genetics: New insights into malaria pathogenesis, drug resistance, epidemiology, and evolution. *Clinical Microbiology Reviews, 32*(4), e00019-19. https://doi.org/10.1128/CMR.00019-19 PMID: 31366610; PMCID: PMC6750138

Netea, M. G., Domínguez-Andrés, J., van de Veerdonk, F. L., van Crevel, R., Pulendran, B., & van der Meer, J. W. M. (2022, February). Natural resistance against infections: Focus on COVID-19. *Trends in Immunology, 43*(2), 106-116. https://doi.org/10.1016/j.it.2021.12.001 Epub 2021 Dec 7. PMID: 34924297; PMCID: PMC8648669.

Agyekum, T. P., Botwe, P. K., Arko-Mensah, J., Issah, I., Acquah, A. A., Hogarh, J. N., Dwomoh, D., Robins, T. G., & Fobil, J. N. (2021). A systematic review of the effects of temperature on Anopheles mosquito development and survival: Implications for malaria control in a future warmer climate. *International Journal of Environmental Research and Public Health, 18*(14), 7255. https://doi.org/10.3390/ijerph18147255

Madkhali, A. M., Ghzwani, A. H., & Al-Mekhlafi, H. M. (2022, June 17). Comparison of rapid diagnostic test, microscopy, and polymerase chain reaction for the detection of *Plasmodium falciparum* malaria in a low-transmission area, Jazan region, southwestern Saudi Arabia. *Diagnostics (Basel), 12*(6), 1485. https://doi.org/10.3390/diagnostics12061485 PMID: 35741295; PMCID: PMC9222139

Goheen, M. M., Campino, S., & Cerami, C. (2017). The role of red blood cells in host defense against *P. falciparum* malaria: A growing repertoire of evolutionary alterations. *British Journal of Haematology, 179*, 543–556. https://doi.org/10.1111/bjh.14886

Engeda, E. H., Aldersey, H. M., Davison, C. M., Gelaye, K. A., Abebe, A. B., Chala, M. B., & Fayed, N. (2024). Severe malaria-related disability in African children: A scoping review. *Disability and Rehabilitation, 46*(1), 31-39.

Naser, R. H., Rajaii, T., Farash, B. R. H., Seyyedtabaei, S. J., Hajali, V., Sadabadi, F., & Saburi, E. (2024). Hematological changes due to malaria: An update. *Molecular and Biochemical Parasitology, 111635*.

Khermach, A., Khalki, H., Louzi, L., Zinebi, A., Moudden, K., & Elbaaj, M. (2017, March 27). Biological disturbances affecting people with malaria: About thirty cases. *Pan African Medical Journal, 26*, 174. https://doi.org/10.11604/pamj.2017.26.174.9008 PMID: 28674567; PMCID: PMC5483358

Bayleyegn, B., Asrie, F., Yalew, A., & Woldu, B. (2021, March 16). Role of platelet indices as a potential marker for malaria severity. *Journal of Parasitology Research, 2021*, 5531091. https://doi.org/10.1155/2021/5531091 PMID: 37601293; PMCID: PMC10435314

Gebreweld, A., Erkihun, Y., Feleke, D. G., Hailu, G., & Fiseha, T. (2021, April 10). Thrombocytopenia as a diagnostic marker for malaria in patients with acute febrile illness. *Journal of Tropical Medicine, 2021*, 5585272. https://doi.org/10.1155/2021/5585272 PMID: 33936215; PMCID: PMC8055386

Asmerom, H., Gemechu, K., Sileshi, B., & Arkew, M. (2023). Hematological abnormalities in adult malaria-infected patients in association with ABO blood groups at Jinella Health Center, Harar, Eastern Ethiopia. *Journal of Blood Medicine, 14*, 463–476. https://doi.org/10.2147/JBM.S419815

White, N. J. (2022). Severe malaria. *Malaria Journal, 21*, 284. <https://doi.org/10.1186/s12936-022-04301-8>

Cheaveau, J., Marasinghe, D., Akakpo, S., Deardon, R., Naugler, C., Chin, A., & Pillai, D. R. (2019, May 16). The impact of malaria on liver enzymes: A retrospective cohort study (2010-2017). *Open Forum Infectious Diseases, 6*(6), ofz234. https://doi.org/10.1093/ofid/ofz234