RESEARCH ARTICLE

Impact of malaria on haematological parameters of urban, peri-urban and rural patients in the Ashanti region of Ghana: a cross-sectional study [version 1; peer review: awaiting peer review]

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Abstract

Background: This study aimed at investigating haematological changes in malaria patients across different demographic settlements. Malaria parasites trigger changes in certain haematological parameters, which may result in a number of clinical manifestations. Differences in demographic settlements, such as rural, peri-urban and urban settlements, may also influence these changes, but this has rarely been studied.

Methods: We conducted a hospital-based, cross-sectional study from January to December 2018 in three different settlements. A total of 598 participants were recruited. Giemsa-stained blood smears were examined to detect and quantify malaria parasitaemia, while haematological parameters were measured using a haematology analyser.

Results: The rural settlement had the highest malaria prevalence compared to the other study communities (p=0.009). The difference in parasite densities across the three communities was also significant (p=0.0149). When the malaria-infected population was compared to the uninfected, there were differences in red blood cell count (p=0.0170), haemoglobin levels (p=0.0165), mean corpuscular volume (p=0.0139) and platelet counts (p<0.0001). The difference in median white blood cell (p-value <0.0001), neutrophil (p-value <0.0001) and lymphocyte (p-value <0.0269) count were significantly higher in infected patients from the peri-urban area compared to malaria patients from the rural and urban areas. There were also significant differences in platelet (p=0.0002), plateletcrit (p=0.0041), mean platelet volume (p=0.0009) and platelet large cell ratio (p=0.0046) levels between patients from the urban, peri-urban and rural areas.

Conclusions: Patients infected with malaria generally had low red blood cell, haemoglobin and platelets in comparison to uninfected patients. There...
were also significant differences in several haematological parameters between malaria-infected patients from the three demographic settlements. Atypical results from routine haematological assays, especially findings of anaemia and thrombocytopenia, may be indicative of malaria and, in cases where the infection is asymptomatic, may improve diagnosis by prompting a more thorough search for the parasite in the peripheral circulation.

**Keywords**
malaria, anaemia, parasitaemia, WBC count, thrombocytopenia,

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Introduction
Malaria remains the most important protozoan infection of humans and continues to have an immense impact on the health and quality of life of people across the world. Despite the decrease in incidence of mortality due to malaria in the last decade, the most recent World Malaria Report revealed that malaria cases increased by about two million in 2018 compared to 2017, resulting in approximately 435,000 deaths, the majority of which were reported in sub-Saharan Africa.1

The introduction of malaria parasites into the host peripheral blood by an infected female *Anopheles* mosquito triggers changes in many host haematological parameters. These changes may subsequently affect the general physiology of the host, resulting in a number of clinical manifestations.23 In fact, the most common complications arising from malaria are associated with changes in host haematological parameters that play a role in malaria pathogenesis, with thrombocytopenia being the most common.2 Haematological parameters that are most often affected include the relative numbers of circulating cell types such as platelets, granulocytes, lymphocytes and erythrocytes, as well as parameters like haemoglobin concentration. A recent study showed a significant reduction in platelet, erythrocyte and leukocyte levels in malaria-infected study participants compared to the control group.7 Moreover, Kotevai et al. (2014) reported that low platelet, white blood cell (WBC) and lymphocyte counts are important predictors of malaria infection and, when used with other clinical methods, could improve malaria diagnosis and treatment.6 Yet another study has reported elevated leukocyte levels in the malaria-infected group compared to uninfected study participants.1

While haematological changes associated with malaria have been well-characterized,8–9, it is possible that factors such as differences in demographic settlements also influence observed changes. However, there is relatively limited data on the differences in haematological indices of malaria patients in rural, peri-urban and urban settlements, especially in forested zones. The aim of this study was to investigate haematological changes that occur in malaria patients across these different settlements.

Methods
This is a hospital-based study. In order to avoid bias and prevent including only ‘sick’ or symptomatic participants, we extended our sampling to include ‘healthy’ participants who accompanied their relatives or friends to the hospital. This increased the chance of having both symptomatic and asymptomatic participants.

Ethical statement
The protocol for data collection was reviewed and approved by the Committee on Human Research Publication and Ethics of the Kwame Nkrumah University of Science and Technology (KNUST) and the Komfo Anokye Teaching Hospital (CHRPE/KATH). All study participants provided written informed consent prior to study enrolment, with parental or guardian consent obtained for children.

Study sites
We carried out a hospital-based, cross-sectional study that was conducted concurrently at the Kumasi South Hospital (KSH), the Kutanase Government Hospital (KGH) and the Agona Government Hospital (AGH) in the Ashanti region of Ghana. KSH is located in Atumsu, a suburb of Kumasi, the regional capital and second largest city in Ghana, and served as the urban site. KGH is situated in Kutanase, the capital of the Bosomtwe district. The Bosomtwe district is one of the 27 districts in the Ashanti region and is located approximately 28 kilometers from Kumasi. AGH is in the Sekyere East district and is located approximately 37 kilometres away from Kumasi. KGH and AGH served as the peri-urban and rural study sites, respectively.

Study participants
The sample size was determined using the binomial model. Confidence intervals of 95% and a precision level of 5% was used. In the equation below, \( n \) is the sample size, \( z \) is the critical value of the standard normal distribution at 5% level (1.96), \( p \) is the estimated malaria prevalence, \( q = 1 - p \) and \( d \) is the precision level. The prevalence of malaria had previously been determined by Paintsil et al. (2019) to be about 26%.10

\[
    n = \frac{z^2 \cdot pq}{d^2}
\]

The minimum sample size required was calculated to be 295; however, we sampled 601 participants to make up for the different transmission seasons (January to December 2018) across which samples were collected. The study targeted patients accessing healthcare at the various hospitals. They included patients referred to the laboratory for malaria test and accompanying caregivers who were not sick. The purpose of the study was explained to potential participants using a participant information leaflet to seek their informed consent, a copy of which is provided as Extended data.11 An interpreter was employed to translate the written document into their local dialect (Akan) for those who could not read. In addition, thumbprints were obtained for those who could not sign/write. Patients who were critically ill and those refusing consent were excluded from the study. All age groups were considered for the study except infants under six months. Demographic data such as malaria drug use and insecticide-treated net (ITN) use were obtained from participants using a semi-structured questionnaire, a copy of which is provided as Extended data.11

Haematological analysis
From each participant, 2 ml of venous blood was drawn by a trained phlebotomist in the hospital laboratory as part of their routine medical care. This was transferred into an EDTA tube with a unique patient identifier. The blood sample was used to prepare thin and thick films for microscopic examination and automated complete blood counts (CBCs). Blood parameters were estimated using the Sysmex XP-300 Automated Haematology Analyzer. The cell counter provided data on red blood cell (RBC) count, haemoglobin (Hb) level, mean corpuscular volume

Extended data

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.96</td>
<td>Critical value of the standard normal distribution at 5% level</td>
</tr>
<tr>
<td>0.26</td>
<td>Estimated malaria prevalence</td>
</tr>
<tr>
<td>1.00</td>
<td>Precision level</td>
</tr>
<tr>
<td>295</td>
<td>Minimum sample size required</td>
</tr>
</tbody>
</table>

[1] Paintsil et al. (2019)
Parasitological analysis
From the EDTA-treated blood, 6 µL and 3 µL were used to prepare thick and thin blood films, respectively. After air-drying, the thin blood smears were fixed with methanol and both smears subsequently stained with 10% Giemsa for 15 minutes. Two experienced microscopists independently examined the slides under x100 oil immersion to determine the presence or absence of malaria parasites. Parasites were quantified after counting 200 or 500 WBCs. Parasite densities were calculated as parasite per microliter of blood (parasite counted / WBCs counted × total WBC in 1µL of blood). A slide was only declared negative when no malaria parasite was seen after scanning 100 high power fields (HPFs).

Statistical analysis
The data collected were coded and entered into Microsoft Excel 2016. The data were checked for completeness. Samples with missing data were excluded from the analysis. Thus, three samples with missing microscopy were excluded completely from all analysis. Data analysis was performed using GraphPad Prism v6 (GraphPad Software, Inc., San Diego, CA, USA). Data normality was checked using the Shapiro-Wilk normality test. For normally distributed data, comparisons were carried out using one-way ANOVA, whilst data not conforming to the normal distribution were compared using the Kruskall-Wallis or Mann-Whitney Tests. Pairwise multiple comparison tests across communities was done using Dunn’s multiple comparison test. Categorical data on community and age groups were compared using Pearson’s chi-squared test. Results were considered statistically significant if p ≤ 0.05.

Results
Three samples had haematology data only and thus were excluded completely. In total, 598 participants samples were examined for parasite prevalence and density of infections. A further 16 were excluded from the haematological analysis because the sample obtained was either too small or the haematological indices were not determined.

Out of the 598 analysed in the study, 75.4% (n=451) were female. While the overall median age was 27 years (IQR=19–40), there was a statistically significant difference in the age profiles of patients from the three study sites (p<0.0001). Patients in the rural area were comparatively younger, with a median age of 24.5 years (IQR=14–35), followed by those in the peri-urban area, with a median age of 27 years (IQR=19.5–41.5). Patients in the urban area were the oldest, with a median age of 29 years (IQR=22.5–43.0). This observation is conceivable because, typically, the youth tend to leave their rural communities in search of jobs as they get older. 16% (n=93) of study participants had Plasmodium falciparum infection, confirmed by microscopy, while the remaining uninfected patients were used as controls.

Malaria causes significant changes in several haematological parameters
The median haematological parameters of the infected and non-malaria groups were compared using the Mann-Whitney test due to the non-parametric distribution of the data. There was no significant difference in the median counts of neutrophils, lymphocytes or WBCs between the infected and non-infected groups; however, malaria-infected patients in our study population (n=93) had significantly lower median values of RBCs (p=0.017), Hb (p=0.0165), haematocrit (p=0.0015), MCV (p=0.00139), platelets (p<0.0001) and plateletcrit (p<0.0001) compared to control patients (Table 1).

ITN usage and malaria prevalence vary significantly with age and settlement
There was a significant relationship between ITN usage and malaria prevalence (χ²=48.41; p<0.0001). When we tested the relationship between these two variables and age or settlement, we found a statistically-significant association between age and ITN usage (p<0.0001), with children less than five years constituting the majority of those who slept under insecticide-treated mosquito nets, while children between the ages of six and 14 (inclusive) recorded the lowest ITN usage. Malaria prevalence was also significantly related to age (p<0.0001), with the highest prevalence seen in children from six to 14 years of age (Table 2). Furthermore, there was a significant difference in the parasite densities of infected patients across the different age groups (H=8.64; p=0.0133). Children under five years harboured the highest number of parasites, with a median parasite density of 665 (IQR=327–1038), followed by patients 6–14 years, with a median density of 504 (IQR=160–4139), and patients ≥15 years, with a median density of 24.5 (IQR=13–40).

As shown in Table 2, ITN usage was also significantly related to settlement type (p=0.0017). Patients from the urban area reported the highest ITN usage (32.3%; n=66/204), with patients from the peri-urban (29.2%; n=57/195) and rural areas (30.3%; n=61/202) reporting significantly lower percentages of usage. Malaria prevalence was similarly significantly related to settlement type (p=0.0144). In this case, however, the highest malaria prevalence was recorded in rural patients (21.3%; n=43/202), followed by the peri-urban area (13.3%; n=26/195), with the urban centre recording the lowest prevalence (11.8%, n=24/204).

There was a significant difference in the parasite densities of infected patients across the three communities (H=8.41; p=0.0149). Patients in the peri-urban area recorded the highest median parasite density (568; IQR=190–1312), followed by the rural area (224; IQR=126–1198), with the urban area recording the lowest median parasite density (167; IQR=20.5–311.5) (Figure 1).

Haematological indices differ significantly in patients from different areas
The median haematological parameter values of malaria-infected patients from the three study areas were compared...
using the Kruskal-Wallis test. The difference in median WBC (p<0.0001), neutrophil (p<0.0001) and lymphocyte (p<0.0269) counts were significantly different across the three communities and higher in infected patients from the peri-urban area compared to malaria patients from the rural and urban areas. Red blood cell indices such as MCV (p=0.0006), RDW-SD (p=0.0005) and RDW-CV (p=0.0218) were significantly different across the three communities, with the lowest values recorded from malaria patients from the peri-urban area compared to those from the rural and urban areas. There were also significant differences in platelet (p=0.0002), plateletcrit (p=0.0041), mean platelet volume (p=0.0009) and platelet large cell ratio (p=0.0046) levels between patients from the urban, peri-urban and rural areas (Table 3).

Anaemia and thrombocytopenia comprise two of the most common complications associated with malaria. Anaemia and acute anaemia are defined as having Hb levels <11g/dl or <5g/dl, respectively, while thrombocytopenia is defined as platelet count<150×10^3/µL. It was found that 48.4% (n=45/93) of all malaria-infected patients in this study were anaemic compared to 33.3% (n=164/492) of the control group (p=0.0054), with two malaria-infected patients matching the criteria for acute anaemia. In addition, 58.1% (n=54/93) of patients from the infected

Table 1. Levels of haematological parameters in infected vs uninfected study participants.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Malaria-infected</th>
<th>Uninfected</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red blood cells (RBC) (×10^6 /µL)</td>
<td>Median (IQR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Haemoglobin (g/dL)</td>
<td>4.16 (3.78 – 4.67)</td>
<td>4.42 (3.93 – 4.85)</td>
<td>0.0170</td>
</tr>
<tr>
<td>Haematocrit (%)</td>
<td>11.10 (9.5 – 12.4)</td>
<td>11.60 (10.40 – 12.80)</td>
<td>0.0165</td>
</tr>
<tr>
<td>Mean corpuscular volume (MCV) (fL)</td>
<td>94.20 (89.3 – 100.5)</td>
<td>97.80 (91.70 – 102.70)</td>
<td>0.00139</td>
</tr>
<tr>
<td>Mean corpuscular haemoglobin (MCH) (pg)</td>
<td>26.60 (25.2 – 28.0)</td>
<td>26.80 (24.80 – 28.50)</td>
<td>0.5413</td>
</tr>
<tr>
<td>Red cell distribution width (RDW-SD) (fL)</td>
<td>50.90 (47.40 – 57.10)</td>
<td>51.00 (47.70 – 57.40)</td>
<td>0.7782</td>
</tr>
<tr>
<td>Red cell distribution width (RDW-CV) (%)</td>
<td>14.30 (14.30 – 15.90)</td>
<td>13.80 (12.60 – 15.80)</td>
<td>0.1482</td>
</tr>
<tr>
<td>Platelet (×10^3 /µL)</td>
<td>128.00 (72.0 – 186.0)</td>
<td>172 (119.0 – 229.0)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Plateletcrit (%)</td>
<td>0.15 (0.08 – 0.22)</td>
<td>0.20 (0.13 – 0.26)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Platelet distribution width (PDW) (fL)</td>
<td>16.30 (14.30 – 19.60)</td>
<td>16.20 (13.60 – 19.05)</td>
<td>0.1544</td>
</tr>
<tr>
<td>Mean platelet volume (MPV) (fL)</td>
<td>11.20 (10.20 – 12.30)</td>
<td>11.20 (10.10 – 12.20)</td>
<td>0.9878</td>
</tr>
<tr>
<td>Platelet large cell ratio (P-LCR) (%)</td>
<td>35.70 (29.40 – 43.0)</td>
<td>35.50 (28.30 – 43.90)</td>
<td>0.7465</td>
</tr>
<tr>
<td>White blood cells (WBC) (×10^3 /µL)</td>
<td>3.50 (2.20 – 5.35)</td>
<td>3.50 (2.40 – 4.80)</td>
<td>0.5078</td>
</tr>
<tr>
<td>Neutrophil (×10^3 /µL)</td>
<td>1.00 (0.50 – 2.10)</td>
<td>1.00 (0.70 – 1.70)</td>
<td>0.9702</td>
</tr>
<tr>
<td>Lymphocyte (×10^3 /µL)</td>
<td>1.80 (1.20 – 3.0)</td>
<td>2.20 (1.50 – 3.10)</td>
<td>0.8222</td>
</tr>
</tbody>
</table>

* T.test; * Man-Whitney U; IQR=Interquartile range

Table 2. Relationship between age & settlement type and insecticide-treated net (ITN) usage & malaria prevalence.

<table>
<thead>
<tr>
<th></th>
<th>ITN usage (%)</th>
<th>χ²</th>
<th>P-value</th>
<th>Malaria prevalence</th>
<th>χ²</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–5</td>
<td>58.9</td>
<td></td>
<td>26.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6–14</td>
<td>28.9</td>
<td></td>
<td>34.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15+</td>
<td>30.2</td>
<td>34.34</td>
<td>&lt;0.0001</td>
<td>12.7</td>
<td>21.29</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Settlement</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>32.3</td>
<td></td>
<td>11.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peri-urban</td>
<td>29.2</td>
<td></td>
<td>13.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rural</td>
<td>30.3</td>
<td>10.73</td>
<td>0.0017</td>
<td>21.3</td>
<td>8.05</td>
<td>0.0179</td>
</tr>
</tbody>
</table>

χ² is the chi-squared value. The results were considered significant if p ≤ 0.05.
group were thrombocytopenic. We therefore tested the relationship between these two conditions and settlement type to determine if the occurrence of either anaemia or thrombocytopenia in malaria-infected patients was influenced by the type of settlement. The prevalence of thrombocytopenia was significantly influenced by the type of settlement (p=0.0006), with malaria-infected patients in the urban area recording the highest prevalence. There was a strong relationship between anaemia and settlement type, although it was not statistically significant (p=0.072). Similar to thrombocytopenia, the highest prevalence of anaemia was observed in patients from the urban area (Table 4).

**Table 3. Haematological parameter levels in infected patients from the three communities.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Urban Median (IQR)</th>
<th>Peri-urban Median (IQR)</th>
<th>Rural Median (IQR)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red blood cells (RBC) (×10⁶/µL)a</td>
<td>4.16 (3.50–4.39)</td>
<td>4.12 (3.81–4.89)</td>
<td>4.23 (3.72–4.67)</td>
<td>0.3758</td>
</tr>
<tr>
<td>Haemoglobin (g/dL)a</td>
<td>10.60 (8.85–11.45)</td>
<td>11.70 (10.30–12.90)</td>
<td>11.10 (9.30–12.45)</td>
<td>0.1455</td>
</tr>
<tr>
<td>Hematocrit (%)</td>
<td>40.80 (33.20–44.30)</td>
<td>38.05 (34.40–41.60)</td>
<td>41.40 (36.10–44.85)</td>
<td>0.2797</td>
</tr>
<tr>
<td>Mean corpuscular volume (MCV) (fL)a</td>
<td>97.45 (90.20–103.5)</td>
<td>90.35 (86.4–92.0)</td>
<td>97.2 (90.25–103.0)</td>
<td>0.0006</td>
</tr>
<tr>
<td>Mean corpuscular haemoglobin (MCH) (pg)a</td>
<td>97.45 (90.20–103.15)</td>
<td>90.35 (86.40–92.20)</td>
<td>97.20 (92.25–103.0)</td>
<td>0.3488</td>
</tr>
<tr>
<td>Red cell distribution width (RDW-SD) (fL)b</td>
<td>55.95(50.20–66.00)</td>
<td>47.40 (44.80–51.30)</td>
<td>50.90 (48.70–57.30)</td>
<td>0.0005</td>
</tr>
<tr>
<td>Red cell distribution width (RDW-CV) (%)b</td>
<td>15.00(13.70–16.50)</td>
<td>14.45(13.40–16.30)</td>
<td>13.60(12.30–15.05)</td>
<td>0.0218</td>
</tr>
<tr>
<td>Platelet (×10³/µL)b</td>
<td>121.50 (87.0–87.0)</td>
<td>195.50 (138.0–233.0)</td>
<td>103 (55.0–170)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Plateletcrit (PCT) (%)a</td>
<td>0.12 (0.08–0.17)</td>
<td>0.24 (0.16–0.28)</td>
<td>0.12 (0.06–0.18)</td>
<td>0.0041</td>
</tr>
<tr>
<td>Platelet distribution width (PDW) (fL)a</td>
<td>16.00(13.70–19.80)</td>
<td>15.95(14.60–19.40)</td>
<td>17.60 (15.0–19.65)</td>
<td>0.497</td>
</tr>
<tr>
<td>Mean platelet volume (MPV) (fL)b</td>
<td>10.30 (9.45–11.15)</td>
<td>12.00 (10.90–12.50)</td>
<td>11.30 (9.80–12.15)</td>
<td>0.0009</td>
</tr>
<tr>
<td>Platelet large cell ratio (P-LCR) (%)a</td>
<td>29.90 (24.15–38.75)</td>
<td>41.55 (34.60–46.50)</td>
<td>34.70 (29.90–41.95)</td>
<td>0.0046</td>
</tr>
<tr>
<td>White blood cells (WBC) (10⁶/µL)b</td>
<td>1.85 (1.35–3.60)</td>
<td>4.70 (3.40–6.70)</td>
<td>3.50 (2.35–5.20)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Neutrophil (10³/µL)b</td>
<td>0.50 (0.30–1.30)</td>
<td>2.20 (1.60–3.30)</td>
<td>0.90 (0.50–1.55)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Lymphocyte (10³/µL)a</td>
<td>0.90 (0.30–2.40)</td>
<td>2.10 (1.40–2.80)</td>
<td>2.00 (1.40–3.50)</td>
<td>0.0269</td>
</tr>
</tbody>
</table>

*aANOVA; bKruskall-Wallis test; IQR=Interquartile range*
By 2050, it is predicted that 58% of people in sub-Saharan Africa will be living in urban areas, compared with approximately 40% currently\textsuperscript{20}. This is expected to have a significant impact on the prevalence and clinical outcomes of infectious diseases like malaria as the increasing urban population further widens urban-rural economic and resource divides. In this study, patients from the rural area recorded the highest prevalence of malaria compared to patients from the urban and peri-urban areas, a finding that is consistent with results from other studies conducted in Ghana\textsuperscript{14,27}. Rural areas are often described as intense and perennial transmission areas as there are often several suitable *Anopheles* breeding sites available, coupled with poor access and/or adherence to vector control measures by rural inhabitants\textsuperscript{24,29}. The relatively younger age observed in the rural area may also be a contributing factor to the high prevalence observed in this study area, as children represent a high risk group for malaria infection\textsuperscript{31}. In line with this, the majority of infected individuals in the rural area were children less than five years. Children under five years may not have a fully developed immune system and are, therefore, more susceptible to infections. Adults, on the other hand, have relatively stronger immune systems and often have partial immunity to malaria from previous exposure\textsuperscript{31}. This might explain why the older generation recorded the lowest parasite densities. A comparison of haematological parameters of malaria-infected patients across the three areas revealed significant differences in the levels of key platelet and WBC indices, including platelet and plateletcrit, platelet, WBC, lymphocyte and neutrophil counts. Interestingly, higher levels of all the above blood indices were recorded in patients from the peri-urban area compared to those from the rural and urban areas, though the significance of this observation is unclear at present.

Observation of abnormal values of haematological parameters that are associated with malaria infection may prompt a more vigilant search for the parasite in routine microscopic diagnosis and could help avoid missing cases of malaria. Furthermore,
differences in the haematological parameters of malaria patients can also serve as an auxiliary criterion for malaria diagnosis, especially in cases of low parasite density. With the increasing rates of urbanisation in Africa, it is more important than ever to better understand the impact of such socio-geographic and demographic changes on infectious diseases.

Data availability

Underlying data
Harvard Dataverse: Replication Data for: Impact of malaria on haematological parameters of urban, peri-urban and rural patients in the Ashanti region of Ghana. https://doi.org/10.7910/DVN/NGBMZ

This project contains the following underlying data:

- Combined data.xlsx (raw demographic, haematological and parasitological data for all participants)
- Combined Data_Age.tab (raw demographic, haematological and parasitological data for all participants, including ages)
- Malaria Infected population.xlsx (raw demographic, haematological and parasitological data for malaria infected participants)
- Malaria Uninfected.xlsx (raw demographic, haematological and parasitological data for uninfected participants)
- Peri-Urban population.xlsx (raw demographic, haematological and parasitological data for participants in the peri-urban area)
- Rural population.xlsx (raw demographic, haematological and parasitological data for participants in the rural area)
- Urban population.xlsx (raw demographic, haematological and parasitological data for participants in the urban area)
- Data Dictionary.xlsx

Extended data

Harvard Dataverse: Replication Data for: Impact of malaria on haematological parameters of urban, peri-urban and rural patients in the Ashanti region of Ghana. https://doi.org/10.7910/DVN/NGBMZ

This project contains the following extended data:

- CHRPE Participant Information Leaflet_Malaria.pdf
- Questionnaire-Malaria.pdf

Data are available under the terms of the Creative Commons Zero “No rights reserved” data waiver (CC0 1.0 Public domain dedication).

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References


