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Hematological Differences among Malaria Patients in Rural and Urban Ghana

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ABSTRACT

Background: Scarce studies have addressed hematological differences of malaria in urban and rural regions.

Methods: Full or complete blood cell counts from 46 and 75 individuals (age range from < 1 to 92 years) with uncomplicated malaria infection living in urban (Accra) and rural (Dodowa) Ghana, respectively, were assessed. Sickle cell trait and patients were excluded from the study.

Results: Between overall groups, patients from Accra had significantly lower parasite count ($p < 0.0001$) and granulocyte number ($p = 0.026$). Children in Accra had a significantly lower parasitemia ($p = 0.0013$), hemoglobin ($p = 0.0254$), platelet count ($p = 0.0148$) and red blood cell levels ($p = 0.0080$) when compared with the children of Dodowa. In adults, mean cell hemoglobin ($p = 0.0086$) and parasite count ($p < 0.0001$) were significantly higher in Dodowa.

Conclusion: These results indicate that children living in urban setting may experience a greater anemic effect to malaria as compared with those living in a rural setting.

KEYWORDS: anemia, global health, *Plasmodium falciparum* malaria, hematological parameters, Ghana, exposome.

INTRODUCTION

Malaria is the major public health problem in sub-Saharan Africa. It comprises an estimated 90% of the 548,000 malaria deaths world-wide [1]. Its epidemiology varies considerably between countries and regions. Persons at greatest risk for severe illness or death from malaria are low socioeconomic individuals, living in rural areas that lack access to healthcare [2]. Studies reporting relationships between hematological parameters in malaria infection and location of residence in sub-Saharan Africa are scarce. However, there has been interest on the effects of

urbanization on malaria in sub-Sahara [3] as a result of a predictive shift in African populations. By 2050, it is predicted that 56% of African population will be living in urban settings as compared with the current 40% [4].

Previous studies have demonstrated that urbanization can reduce malaria transmission [5–7], mainly owing to a reduction in anopheline biting rates, transmission intensities and parasite rate [8–10]. It has been hypothesized that the reduced transmission is owing to enhanced access to healthcare education and preventative services [11] or the degradation of aquatic sites owing to pollution, impacting anopheline density and longevity [12].

The relationship between malaria severity and location of residence in sub-Saharan Africa has rarely been reported. Two studies did comparative analyses of clinical and laboratory features of young children (mean $<$ 5 years) and found that patients in an urban environment presented with higher proportions of severe anemia [13, 14]. Interestingly, a study with older children found no difference in anemia between urban and rural malaria patients [15]. However, these studies did not account for the possible protective effects of sickle cell trait in their populations [16]. In the current study, we determined the potential differences in hematological features of malarial patients in urban and rural populations of Ghana in the absence of sickle cell trait.

MATERIALS AND METHODS

Study areas

The study was simultaneously conducted in two areas from February to November 2014.

Urban area

The data were collected from six public healthcare facilities in Accra, Ghana. These included Korle-Bu Teaching Hospital, Korle-bu Polyclinic, Princess Marie Louise Children's Hospital, Mamprobi Polyclinic, Ussher Polyclinic and LA General Hospital. The Korle-Bu Teaching Hospital is the premier healthcare facility in Ghana and the leading national referral center for the southern part of Ghana. Accra has a year-round transmission of *Plasmodium falciparum* malaria. During the dry season, December to March, the prevalence of parasitemia in children is between 6.5% and 22.9%, whereas during the rainy season the prevalence is around 16.8% [17].

Rural area

The Shai-Osudoku District Hospital in Dodowa is located in Dodowa in the Dangbe West District, 39 km from Accra. This area is characterized by year-round transmission of *P. falciparum*. According to previous studies in Ghana, during the dry season, the prevalence of parasitemia in children is between 50% and 73% [18–20]. In recent times, however, parasite prevalence and transmission intensity in the Dodowa area have decreased to an average of 20% owing to high (80%) insecticide-treated nets coverage (Dr. Kingsley Badu, unpublished data).

Patient enrolment

Consented patients included in the study were diagnosed with *falciparum* malaria, and who sought treatment at healthcare facilities solely for malaria symptoms. Patient's ages range from $<$1 to 92 years. Adults were classified as individuals $\geq$15 years. For the study controls, enrolled subjects did not have symptoms and carried no parasites in their peripheral blood based on routine laboratory and microscopy examination for malaria and had negative malaria histidine-rich protein II HRP-2 test. All of the hospitals and Polyclinics involved in this study were government-accredited healthcare facilities with similar instruments and methodologies.

Laboratory evaluation

Diagnosis of malaria was performed using the two-band CareStart Malaria HRP-2 rapid diagnostic test (Access Bio). Thick blood smears were prepared for each patient and stained with Giemsa (stained with 20% Giemsa solution at pH 7.2) to aid the detection of malaria parasites. Parasitemia was quantified by counting the number of parasites in 200 white blood cells and then multiplying the count by the total white cell count. Patient's hematological parameters were determined and Complete Blood Counts were determined from capillary or venous blood and conducted by hospital or clinic pathology laboratories. Diagnosis of severe anemia was based on World

Health Organization (WHO) severe anemia definition [21]. Briefly, those considered to have severe anemia based on hemoglobin levels are as follows: children aged 6–59 months, hemoglobin < 7 g/dl; children 5–14 years and adults >15 years, hemoglobin < 8 g/dl; pregnant women were excluded. Genotyping for the sickle cell status was conducted by the Central Laboratory of Korle-bu Hospital using Cellulose Acetate Membrane electrophoresis.

Data management and statistical analysis

The demographic, clinical and laboratory data for each patient were recorded using the same concise medical record forms in all facilities. Descriptive and comparative analysis was carried out using SAS 9.4 (Cary, NC). Proportional comparisons were made by either χ^2 or Fisher's exact test (for groups with an $n < 5$). Comparison of continuous data was performed by nonparametric analyses (Mann–Whitney). Statistical significance was defined as $p < 0.05$. A power analysis was carried out, assuming the hemoglobin levels previously published in an article measuring differences in malaria hemoglobin levels in rural vs. urban populations [13] using OpenEpi application. Assuming a confidence level of 95%, a sample of 24 patients, in each group, would guarantee a power of 0.8 for detecting a difference in hemoglobin means.

Ethical considerations

Ethical approval for this study was granted by the institutional review board committees of The University of Ghana's Korle-bu Teaching Hospital, the Noguchi Memorial Institute for Medical Research and Morehouse School of Medicine. Each study participant $\geq$18 years provided written consent after explaining in lay terms the research subject. Parental or guardian consent was obtained for children $<$18 years.

RESULTS

A total of 500 patients were recruited for this study. After genotyping, 161 (32.2%) individuals were excluded from the study for having the sickle cell trait and 4 (0.8%) were excluded for having missing or unknown Hemoglobin genotype data. Of the 165 patients excluded, 35 (21.2%) were verified malaria cases and 130 (78.8%) did not have malaria. A further 13 patients (nine malaria and four non-malaria cases) were excluded owing to missing or unknown information on age. The study population consisted of 322 patients, 121 (37.6%) verified malaria cases and 201 (62.4%) controls. The malaria patients comprised 46 and 75 individuals in urban Accra and rural Dodowa, respectively. The control population consisted of 94 individuals in Accra and 107 in Dodowa.

Malaria population

The population in Dodowa (median age 17 years) was significantly younger than that of Accra (median age 36 years, $p < 0.0001$). There was also no statistical significance between hematological characteristics between the two cohorts except for significantly higher granulocyte counts for the Dodowa population. Parasitic intensity was significantly higher in the patients in Dodowa as compared with Accra (Table 1).

Comparing hematological characteristics among children between the two populations, there were several statistical differences (Table 2). Children in Accra ($n = 10$) had significantly lower levels of hemoglobin ($p = 0.0254$) and red blood cells ($p = 0.008$) as compared with Dodowa ($n = 30$). Although the sample size may be less than expected, this population represents the actual age group that bears the parasite and malaria-related burden in Dodowa and thus instructive. Accra also had lower parasitemia ($p = 0.0013$) and platelet counts ($p= 0.0321$). For adults (Table 3), there were no significant differences in hematological factors except for mean cell hemoglobin, which was significantly lower in Accra ($p = 0.0086$). Parasite count was also significantly elevated in the Dodowa population ($p < 0.0001$).

Overall, malaria patients in Accra were more likely to report the usage of analgesics as compared with those in Dodowa (82.6 and 45.3%, respectively, $p = 0.0002$). However, among those $<$15 years, there were no significant differences ($p = 0.1671$). Reported anti-malaria drug use was significantly higher among individuals in Dodowa, overall ($p = 0.0009$), but not among individuals $<$15 ($p = 0.0817$).

Table 1. Characteristics of total malaria patient study population

Characteristics	Accra ($n = 46$) median (Q1, Q3) *n* (%)	Dodowa ($n = 75$) median (Q1, Q3) *n* (%)	*p* value
Age (years)[a]	36.0 (17.0, 52.0)	17.0 (7.0, 28.0)	<0.0001
Age dichotomized (<15)[b]	10 (21.7)	30 (40.0)	0.0382
Sex (male)[b]	18 (39.1)	26 (34.7)	0.6203
Parasite count/μl[a]	45.6 (3.2, 68.0)	185.0 (94.0, 255.0)	<0.0001
RBC ($\times 10^6$/μl)[a]	4.2 (3.5, 4.6)	4.1 (3.7, 4.5)	0.9220
Hemoglobin (g/dl)[a]	11.5 (9.2, 12.4)	11.3 (10.1, 12.5)	0.6262
Severe anemia[c,d]	3 (6.5)	2 (2.7)	0.3421
Hematocrit (%)[a]	34.5 (28.0, 39.0)	33.7 (29.0, 36.0)	0.3295
Mean cell hemoglobin (pg)[a]	27.1 (25.5, 28.9)	27.6 (25.7, 29.4)	0.2865
Mean cell hemoglobin volume (fl)[a]	82.5 (79.0, 88.0)	82.1 (76.5, 85.7)	0.2543
Heme (μM)[a]	22.3 (16.8, 31.7)	24.4 (20.5, 31.2)	0.1837
Granulocytes ($\times 10^3$/μl)[a]	3.0 (2.2, 4.3)	4.0 (2.9, 5.3)	0.0260
Lymphocytes ($\times 10^3$/μl)[a]	1.5 (0.8, 2.2)	1.0 (0.8, 1.9)	0.3010
Monocytes ($\times 10^3$/μl)[a]	0.3 (0.1, 0.7)	0.5 (0.2, 0.7)	0.0599
Platelets ($\times 10^3$/μl)[a]	112.0 (69.5, 211.5)	150.0 (102.0, 194.0)	0.1796
Anti-malaria drug use[c]	0	8 (10.7)	0.0009
Analgesic drug use[c]	38 (82.6)	34 (45.3)	0.0002

[a]Mann–Whitney U.
[b]χ^2.
[c]Fisher's Exact Test.
[d]Severe anemia was based on WHO severe anemia definition (WHO, 2015) [21].

Control population

As shown in Table 4, Dodowa had a significantly younger population overall (median age in years: Accra = 31.5 vs. Dodowa = 7.0, $p < 0.0001$). However, there were no significant differences in sex ($p = 0.2351$), RBC count ($p = 0.4173$) or hemoglobin levels ($p = 0.2183$). Similarly, for children <15 years, there were no differences between Accra and Dodowa in age ($p = 0.8416$), sex ($p = 0.9765$), RBC count ($p = 0.2072$) or hemoglobin levels ($p = 0.2341$).

Comparison of malaria and non-malaria

RBC count and hemoglobin were found to be significantly lower in malaria patients for total study population ($p = 0.254$ and hemoglobin, $p = 0.0163$). These results were similar when the total population was dichotomized by age and by location, except RBC in individuals ≥15 years was not significantly different between malaria and non-malaria patients (Table 5).

DISCUSSION

This study compared differences in hematologic factors of uncomplicated malaria patients in urban and rural populations in Southern Ghana with matching control populations. The study found that parasitemia is significantly elevated in the rural setting. Also there appears to be age-specific differences in malaria infection and hematologic response to malaria, particularly in factors related to anemia based on location.

In highly malaria endemic settings, children and pregnant women are the at-risk population, constituting the target population of new malaria control strategies [22]. Although southern Ghana is malaria endemic area, the differences in the proportion of malaria-infected children is higher in rural setting compared with the urban setting in this study. These

Table 2. Characteristics of malaria patient study population <15 years

Characteristics	Accra ($n = 10$) median (Q1, Q3) *n* (%)	Dodowa ($n = 30$) median (Q1, Q3) *n* (%)	*p* value
Age (years)[a]	9.5 (6.0, 12.0)	6.0 (2.5, 9.0)	0.0556
Sex (male)[b]	7 (70.0)	15 (50.0)	0.4645
Parasite count/μl[a]	55.0 (0.0, 171.0)	253.5 (192.0, 392.0)	0.0013
RBC ($\times 10^6$/μl)[a]	3.5 (3.2, 3.8)	4.1 (3.7, 4.6)	0.0080
Hemoglobin (g/dl)[a]	9.1 (8.1, 9.7)	10.6 (9.6, 11.9)	0.0254
Severe anemia[b,c]	1 (10.0)	1 (3.3)	0.4130
Mean cell hemoglobin (pg)[a]	25.8 (24.4, 26.6)	25.7 (24.3, 27.0)	0.8545
Mean cell hemoglobin volume (fl)[a]	78.0 (75.9, 82.0)	76.8 (74.0, 80.8)	0.4045
Hematocrit (%)[a]	28.0 (24.0, 29.0)	32.0 (28.4, 35.0)	0.0688
Heme (μM)[a]	24.4 (19.1, 35.9)	27.0 (21.3, 31.3)	0.6769
Granulocytes ($\times 10^3$/μl)[a]	3.1 (1.6, 8.1)	4.5 (3.3, 5.7)	0.3420
Lymphocytes ($\times 10^3$/μl)[a]	2.5 (1.3, 3.5)	1.6 (0.9, 2.6)	0.1818
Monocytes ($\times 10^3$μl)[a]	0.5 (0.1, 1.0)	0.7 (0.4, 1.0)	0.5585
Platelets ($\times 10^3$/μl)[a]	77.0 (51.0, 131.0)	157.0 (126.0, 196.0)	0.0148
Anti-malaria drug use[b]	0	4 (13.3)	0.0817
Analgesic drug use[b]	8 (80.0)	15 (50.0)	0.1671

[a]Mann–Whitney U.
[b]Fisher's Exact Test.
[c]Severe anemia was based on WHO severe anemia definition (WHO, 2015) [21].

age group differences by setting may be related to differences on malaria-related behaviors and socio-demographic determinants [23, 24]. The average age for the total urban patients vs. rural patients was significant; however, when we dichotomize the data, it is not significant. It is also not significant when we compare the <15 years old children. The age group of <15 years fall within those with low partial immunity in endemic area [25]. In addition, malaria risk increases in school-aged children in the rural area because they usually spend more time outside [26]. In a typical rural area with intense malaria transmission, the greatest burden tends to be borne on children <5 years. However, in a low transmission area such as the highlands in Kenya, the risk of malaria tends to be evenly distributed among the population [27]. Dodowa is a semi-rural area with moderate transmission, and what we see typically is that the malaria burden impacts all the younger population <15 years. It is only the adult population that is seen to be better able to control their parasitemia. This may explain why the adults in Dodowa have similar malaria and hematological characteristics like those in urban Accra.

Features of anemia, such as reduced hemoglobin or RBC levels were observed in urban children. Similar to these results, previous studies in West Africa (Gabon and Burkina Faso) found a significant decrease in hemoglobin levels among young children in the urban setting [13, 14]. However, unlike in these previous studies, the current study did not find a difference in severe anemia between groups. This could be the result of differences in participant age, as this study was composed of older participants or owing to the smaller sample size of this population. Interestingly, there was no difference between rural and urban groups in other anemia markers such as mean cell hemoglobin, mean cell hemoglobin volume, hematocrit or heme, suggesting that the urban anemia maybe normocytic. Also, the adult populations had similar anemia characteristics between locations.

The relationship between malaria parasite and hemoglobin levels has been well characterized [28].

Table 3. Characteristics of malaria patient study population ≥15 years

Characteristics	Accra ($n = 36$) median (Q1, Q3) *n* (%)	Dodowa ($n = 45$) median (Q1, Q3) *n* (%)	*p* value
Age (years)[a]	42.0 (28.5, 56.5)	27.0 (19.0, 31.0)	0.0003
Sex (male)[b]	11 (30.6)	11 (24.4)	0.6186
Parasite count/μl[a]	45.0 (6.3, 64.0)	143.5 (67.0, 203.0)	<0.0001
RBC ($\times 10^6$/μl)[a]	4.4 (3.8, 4.6)	4.1 (3.7, 4.4)	0.1376
Hemoglobin (g/dl)[a]	11.6 (10.5, 13.0)	11.9 (10.6, 12.9)	0.8379
Severe anemia[c,d]	2 (5.6)	1 (2.2)	0.5657
Mean cell hemoglobin (pg)[a]	27.3 (25.9, 29.4)	29.1 (27.7, 30.1)	0.0086
Mean cell hemoglobin volume (fl)[a]	84.1 (80.0, 89.6)	84.8 (82.2, 87.2)	0.7673
Hematocrit (%)[a]	37.0 (32.0, 40.0)	34.0 (29.5, 38.0)	0.1369
Heme (μM)[a]	21.2 (16.1, 31.7)	23.6 (19.9, 29.5)	0.3178
Granulocytes ($\times 10^3$/μl)[a]	3.0 (2.3, 4.2)	3.8 (2.4, 5.0)	0.1839
Lymphocytes ($\times 10^3$/μl)[a]	1.4 (0.7, 2.0)	0.9 (0.7, 1.6)	0.2861
Monocytes ($\times 10^3$/μl)[a]	0.3 (0.1, 0.7)	0.4 (0.2, 0.7)	0.1825
Platelets ($\times 10^3$/μl)[a]	115.0 (75.0, 228.0)	130.0 (90.5, 185.0)	0.9186
Anti-malaria drug use[c]	0	4 (8.9)	0.0265
Analgesic drug use[c]	30 (83.3)	19 (42.2)	0.0007

[a]Mann–Whitney U.
[b]χ^2.
[c]Fisher's Exact Test.
[d]Severe anemia was based on WHO severe anemia definition (WHO, 2015) [21].

Increased parasite levels are associated with a reduction in hemoglobin levels [29]. However, in the current study, we observed decreased parasitemia and hemoglobin levels in the urban setting and increased parasitemia and hemoglobin levels in the rural setting. This observation may be owing to the differences in treatment practices between Accra and surrounding rural populations. In many African countries, inadequacy of resources and trained personnel in healthcare necessitate the purchase of antimalarials over the counter [30]. On fever onset, the majority of individuals in Accra self-medicated with anti-malarial drugs before seeking care at the hospital [31]. Improper pre-hospital anti-malarial treatment may result in low parasitemia and protracted infections, with malaria parasite causing clinically significant RBC destruction [32]. Because individuals in Accra are more likely to practice pre-hospital antimalaria treatment, this may be one of the reasons for the observed low parasitemia and low hemoglobin level in the urban setting in this study. In addition, as a result of the pre-hospital treatment, the urban participants may have only sought professional medical assistance as a result of further complications from the malaria infection. This may explain why urban individuals in this study are more likely to use analgesics as compared with rural individuals. Interestingly, although studies have shown that individuals in Accra practice self-medication with antimalarials, urban individuals in our study were less likely to report self-treat with anti-malarial medications. The self-reports of medication need to be taken with caution, as patients may not reveal all of the treatments they used on the hospital intake questionnaires.

Furthermore, rural areas typically first treated with herbal medications (herbal preparation from Neem tree, guava and lime leaves, three times daily in total), which may not have impact on parasitemia [31]. In addition, it is inevitable to associate malaria infection with low hemoglobin levels, although prevalence of low levels of hemoglobin exists in the

Table 4. Characteristics of total control study population

Characteristics	Accra median (Q1, Q3) *n* (%)	Dodowa median (Q1, Q3) *n* (%)	*p* value
Total population	$n = 94$	$n = 107$	
Age (years)[a]	31.5 (4.0, 42.0)	7.0 (1.0, 26.0)	<0.0001
Age dichotomized (<15)[b]	27 (28.7)	66 (61.7)	<0.0001
Sex (male)[b]	42 (44.6)	39 (36.4)	0.2351
RBC ($\times 10^6/\mu l$)[a]	4.4 (4.0, 4.8)	4.4 (4.1, 4.8)	0.4173
Hemoglobin (g/dl)[a]	12.0 (10.7, 13.3)	11.7 (10.8, 12.6)	0.2183
Severe anemia[c]	0 (0.0)	0 (0.0)	–
Children <15 years	$n = 27$	$n = 66$	
Age (years)[a]	3.0 (1.0, 4.0)	2.0 (1.0, 5.0)	0.8416
Sex (male)[b]	13 (48.1)	32 (48.5)	0.9765
RBC ($\times 10^6/\mu l$)[a]	4.4 (4.1, 4.7)	4.6 (4.3, 4.9)	0.2072
Hemoglobin (g/dl)[a]	11.0 (10.5, 11.9)	11.5 (10.6, 12.3)	0.2341
Severe anemia[c]	0 (0.0)	0 (0.0)	–
Adult ≥15 years	$n = 67$	$n = 41$	
Age (years)[a]	36.0 (29.0, 50.0)	29.0 (24.0, 33.0)	<0.0001
Sex (male)[b]	29 (43.3)	7 (17.1)	0.0050
RBC ($\times 10^6/\mu l$)[a]	4.4 (3.9, 4.8)	4.2 (3.9, 4.7)	0.2617
Hemoglobin (g/dl)[a]	12.7 (10.9, 13.8)	11.8 (11.1, 12.9)	0.2686
Severe anemia[c]	0 (0.0)	0 (0.0)	–

[a]Mann–Whitney U.
[b]χ^2.
[c]Severe anemia was based on WHO severe anemia definition (WHO, 2015) [21].

developing world where its causes are multi-factorial [33]. Family sizes, duration of illness, palpable spleen, history of fever, general body weakness, diarrhea, hookworm and recrudescent infections have been associated with hemoglobin levels [32, 34–36]. Malaria anemia may also be influenced by nutritional differences, and previous studies have linked folate deficiencies with increased anemia levels [37, 38]. However, in malaria, there is still controversy over whether it may cause malnutrition [39] or malnutrition modulates susceptibility to the disease [40], factors that were not assessed in this study. As a result, future studies comparing hematological characteristics, particularly anemia, should take in consideration the nutritional intake values and other causes of anemia between groups. Lastly, differences in particulate matter could influence RBC and hemoglobin levels of individuals in urban populations. Increased levels of particulate matter have been correlated with reduced hemoglobin [41]. Furthermore, children are more susceptible to incur negative health consequences of particulate matter as compared with adults [42, 43]. In Accra, average particulate matter ($\leq$10 μm) was found to be between 49 and 96 $\mu g/m^3$ in high and low socioeconomic neighborhoods, respectively [44]. No published measurements for particulate matter in Dodowa are available, but given it is a rural community, pollution levels may be less compared with Accra. This could possibly explain why this study found increased anemia only in children and not adults in Accra compared with Dodowa. Measuring hematologic characteristics in malaria patients alongside ambient air pollution may help to determine if particulate matter has an effect on malaria severity.

The patient population recruited may not be representative of the malaria patients in the Accra and Dodowa regions. The overall sample size on age stratification was not large, leading to a low statistical power of the study. Further studies with larger

Table 5. Characteristics of patient study population for malaria compared with non-malaria

Characteristics	Malaria median (Q1, Q3) *n* (%)	Non-malaria median (Q1, Q3) *n* (%)	*p* value
Total study population	$n = 121$	$n = 201$	
Age (years)[a]	23.0 (10.0, 38.0)	19.0 (3.0, 33.0)	0.0055
Age dichtomized (<15)[b]	40 (33.1)	93 (46.3)	0.0197
Sex (male)[b]	44 (36.4)	81 (40.3)	0.4829
RBC ($\times 10^6$/μl)[a]	4.1 (3.7, 4.6)	4.4 (4.1, 4.8)	< 0.0001
Hemoglobin (g/dl)[a]	11.4 (9.8, 12.4)	11.8 (10.7, 12.9)	0.0026
Children (<15 years)	$n = 40$	$n = 93$	
Age (years)[a]	6.5 (3.0, 10.0)	2.0 (1.0, 4.0)	<0.0001
Sex (male)[b]	22 (55.0)	45 (48.4)	0.4842
RBC ($\times 10^6$/μl)[a]	4.0 (3.6, 4.6)	4.5 (4.3, 4.9)	<0.0001
Hemoglobin (g/dl)[a]	10.3 (9.3, 11.9)	11.3 (10.6, 12.2)	0.0006
Adult (>15 years)	$n = 81$	$n = 108$	
Age (years)[a]	29.0 (23.0, 45.0)	33.0 (27.0, 40.5)	0.4016
Sex (male)[b]	22 (27.2)	36 (33.3)	0.3625
RBC ($\times 10^6$/μl)[a]	4.1 (3.7, 4.6)	4.3 (3.9, 4.8)	0.0661
Hemoglobin (g/dl)[a]	11.8 (10.6, 12.9)	12.2 (11.0, 13.5)	0.0185

[a]Mann–Whitney U.
[b]χ^2.

sub-sample sizes are needed. However, the younger age groups (<15 years) represent either way the actual population that bears the scourge of malaria burden and thus reveals useful information for targeting control. It is also unknown if patients sought treatment before reporting to the hospital. Furthermore, the participants could have been suffering from more than one illness. This might explain why the platelet levels in children and the granulocytes for the Accra study population were lower than in Dodowa. It would be expected that differences in other aspects of health in these populations, such as nutrition or other parasitic infections, could also affect the results. In addition, malaria-related behaviors such as bed-net use were not assessed in the study.

This study indicates that children with malaria, living in the urban environment, may have greater risk for anemia as measured through laboratory diagnostics. Potential speculative factors that may contribute to these variations based on location include differences in pre-hospital treatment, host-genetic and parasite interaction and the effects of pollution or nutrition on anemia. Even though the data generated here should be heeded with caution, as sample size was too small to generalize the results to the whole urban vs. rural population, these results provide insight into the difference in hematological factors of malaria patients in urban and rural areas. Further studies should also be made with clear pollution and nutrition estimates on malaria anemia. This could help save lives of children and serve as a pilot for public health policy suggestions.

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