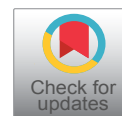




## RESEARCH ARTICLE

## Parasitaemia in Asymptomatic Bantu and Baka Pygmy People Living in the East Region, Cameroon

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### Abstract

**Background:** Asymptomatic malaria constitutes a silent threat to an efficient malaria control strategy. The aim of this study was to assess the level of malaria parasitaemia tolerated by asymptomatic individuals in Baka pygmies and the Bantus of the East Region, Cameroon.

**Methods:** A community-based cross-sectional study was conducted among asymptomatic Bantu and Baka pygmies from 6 months aged to 76-years-old. A questionnaire was used to collect information from 1032 consenting participants about ethnicity, gender, age, level of education, occupation, anti-malarial treatment, seasonality and time spent in the forest. Blood were collected in EDTA tubes and thin and thick blood smear were prepared and parasite densities determined. Data was analyzed using SPSS 22.0. *t*-test and two-ways analyze of variance were performed to compare the log-transformed mean intensities. *P*-values less than 0.05 were taken as statistically significant. The results were expressed as mean  $\pm$  standard deviation (range).

**Results:** The mean malaria parasitaemia of Baka pygmies (7747, 88  $\pm$  7149 (923-56000) trophozoites/ $\mu$ l blood) didn't differ from that of Bantus (8239, 54  $\pm$  8642 (462-72000) trophozoites/ $\mu$ l blood) (*P* = 0.56). Bantu's men carried higher parasitaemia (9429  $\pm$  3256 (667-72000) trophozoites/ $\mu$ l blood) compared to females (7280  $\pm$  3301 (462-43429) trophozoites/ $\mu$ l blood). In Bakas, women had a significant (*P* = 0.02) mean parasitaemia (8274  $\pm$  8306 (923-56000) parasites/ $\mu$ l blood) compared to male (6888  $\pm$  4608 (1212-25333) trophozoites/ $\mu$ l blood). In general, infants of less than 2-years-olds had the least *Plasmodium* parasitaemia (4353  $\pm$  3772 (636-20444) parasites/ $\mu$ l blood). Among Bantus, workers in logging company tolerated the highest mean parasitaemia (9241  $\pm$  3428 (4706-12000) parasites/ $\mu$ l blood respectively) whereas in Bakas, students carried the highest

mean parasitaemia (8855  $\pm$  7834 (1455-40000) parasites/ $\mu$ l blood). In the general population short rainy season (*P* = 0.00) and spending more time in the forest (*P* = 0.04) were factors associated with higher parasitaemia. In the Bakas communities, people who went to secondary school were more resistant (16735  $\pm$  21919 (5200-49600) parasites/ $\mu$ l blood) to malaria parasite whereas in the Bantus, they had the least mean parasitaemia (6760  $\pm$  6177 (462-27200) parasites/ $\mu$ l blood).

**Conclusion:** At the end of this work it was noticed that in Baka as well as in Bantu, asymptomatic people were able to handle up to 55000 trophozoites/ $\mu$ l blood without any sign of the disease. *Plasmodium* parasitaemia depended mainly by the age, levels of education, season, and the time spent in the forest, and not by ethnicity as earlier hypothesized.

### Keywords

Malaria, Asymptomatic, Parasitaemia, Ethnicity, Plasmodium

### Introduction

Despite all the invested control measure, malaria is still an important public health threat in Cameroon, the whole country being at risk [1]. About 41% of the population suffers at least one episode of malaria each year, with pregnant women and under five-years-old children being the most vulnerable [2]. In the country, *Plasmodium falciparum* is responsible for the highest number of cases causing about 50% of medical consultations, 48% of hospital admissions and 30% of total morbidity [3].

Asymptomatic malaria, a previously neglected par-

asite reservoir, is actually recognized as a potential lagging factor, a silent threat to an efficient malaria control strategy [4]. The persistence of asymptomatic parasitaemia inside indigenous communities is a threat since asymptomatic individuals are parasite reservoirs who prevent the achievement of the malaria elimination goal [5]. So this study on asymptomatic people is important to evaluate the threshold parasite density above which a clinical malaria episode can start. In high malaria endemic areas, partial immunity against malaria tends to be high to the extent that majority of malaria infected individuals are normally asymptomatic. Estimating malaria parasite density is necessary for patients' management especially when parasite resistance to available therapy is increasing [6]. Notwithstanding, a good mastery of the parasite control strategies, nature of transmission, epidemiological features, type of habitat as well as the role of ethnicity may be important to control parasitic load among asymptomatic individuals.

In fact, studies have shown that there is a disparity between the malaria risks of different tribes' sharing the same geographical area, with indigenous people often being more at risk [7]. Therefore, some peculiarities linked to ethnic groups may influence the level of tolerance to parasitic load and also fuels the spread of the infection from the reservoirs. The aim of this study was to assess the level of malaria parasitaemia that an asymptomatic individual can tolerate in the malaria en-

demic area of the East-Cameroon. Such information especially concerning indigenous asymptomatic people, is lacking in our country although it may be important in setting up new malaria control programs.

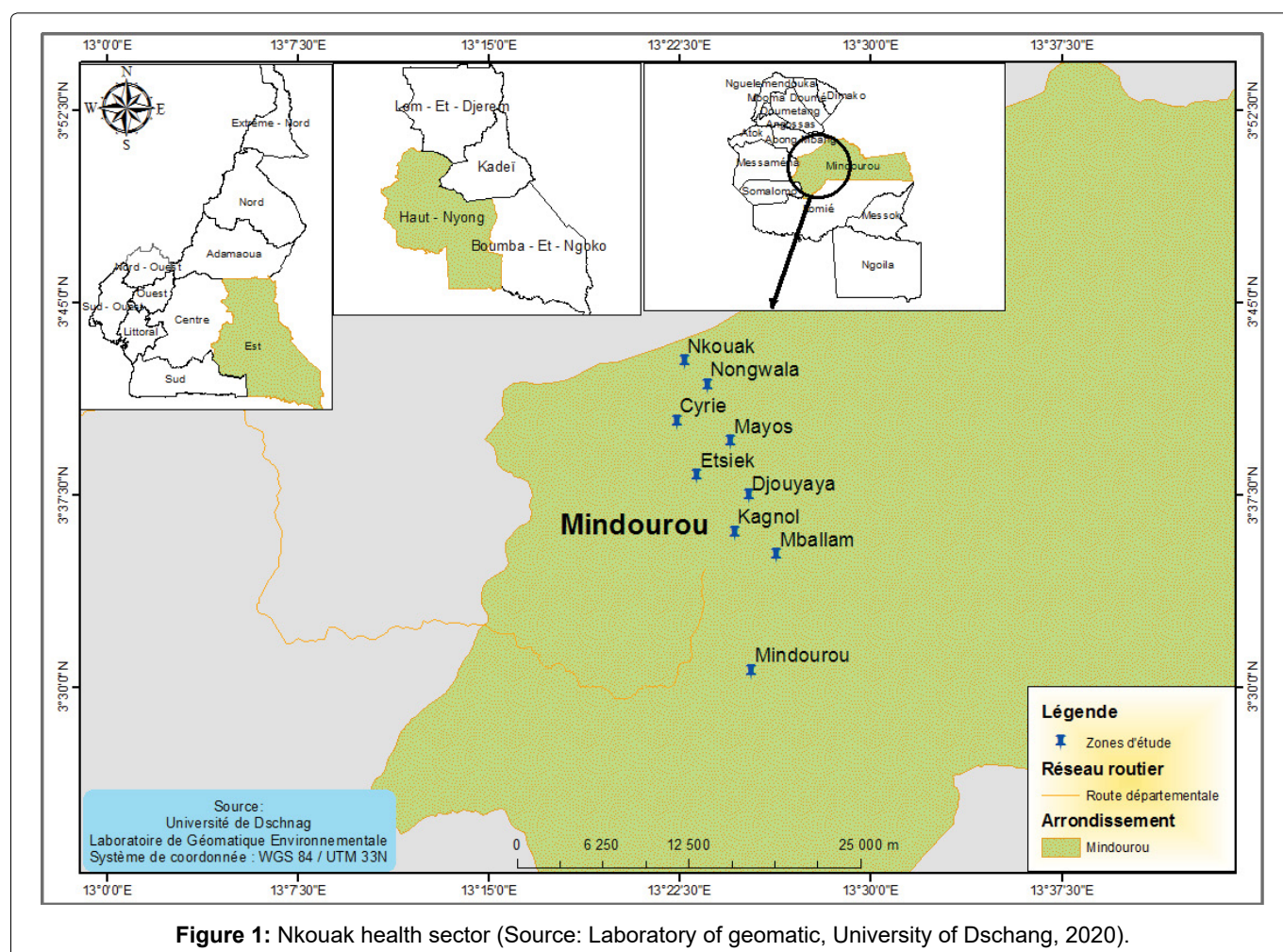
## Methods

### Study period, area and population

This community-based cross-sectional study was conducted from May 2018 to April 2019 in the Nkouak health sector, East Region of Cameroon.

Nkouak is a Congo Basin forest village situated between Abong Mbang (24 km West) and Mindourou (29 km East), in the Upper Nyong division of Cameroon. The study area is situated at latitude 3°N and longitude 13°E and it covers an area of about 20 km of distance [8,9]. Nkouak Integrated Health Sector covers two health facilities including Nkouak integrated health sector where the study was conducted. The sector serves 4315 residents distributed among 8 small villages. Some of these are occupied mainly with Bantus (Nkouak, Nongbwala, Djouyaya, Etsiek, Kagnol) while others are occupied mainly with Baka Pygmies (Mballam II, Cyrie, Mayos) Figure 1.

Nkouak health sector is supplied by several permanent rivers like Dja and Nyong rivers which surround the study area. The climate of the area is a classical equatorial one characterized by two rainy seasons (from



**Figure 1:** Nkouak health sector (Source: Laboratory of geomatic, University of Dschang, 2020).

March to June and from August to November) and two dry seasons (from June to August and from November to March). The annual average temperature varies between 23 °C and 28 °C, with a high atmospheric humidity all year round [9,10]. The average rainfall varied between 1600 mm and 2000 mm/year. The vegetation is characterized with an evergreen transitional forest and a semi-deciduous dense and moist forest [8].

Nkouak is mainly a farming locality. Some of the people are employed by Forest logging Companies like PALISCO, FIPCAM, DINO et Fils. Malaria is the main mosquito-borne disease in that locality and as such a public health problem of primary importance.

### Sampling technique

To obtain the sample size, the statistical formula of Yamane (1967) was used:

$$n = \frac{N}{1 + N(e)^2}$$

n: sample size; N: population size; e: sampling error or precision (5%).

According to the last population inventory in the Abong-Mbang health district in 2018, the population of the Nkouak health sector was estimated at 4315 individuals. From this population size, a sample of 366 individuals was obtained. To better represent the population in the study, we collected 1032 samples with 631 Bantus and 401 Bakas.

The survey involved malaria asymptomatic volunteer participants from two ethnic groups: Baka Pygmies and Bantus. In this study, was considered as asymptomatic, anybody who presented no symptom of malaria on the day of data collection (fever, shivering, headache, articular pains etc.). A structured questionnaire was administered to the participants who gave their consent. Community health delegates translated the questionnaire into local language for participants who were unable to read, write or understand French or English. Confidentiality of the information provided was ascertained to the participants. In fact, only the principal investigator had access to questionnaire which contained personal information on the participant. Laboratory manipulation was based on numerical code addressed to identify each participant. The questionnaire contained independent variables such as ethnicity, gender, age, level of education, occupation, anti-malarial treatment, seasonality and time spent in the forest.

The interview with participants and blood collection took place in the community house of each village. Blood was collected using EDTA test tubes either by finger prick or by venous swab according to the participant's desire [11].

### Blood staining procedure

A thick blood smear (about 6 µl of blood) and a thin

smear (2 µl of blood) were prepared from each blood sample. The smears were stained with 10% Giemsa after fixing the thin smear with absolute methanol [12].

The blood smears were then examined using the oil immersion objective. Slides were reported negative for parasites only after observing at least 50 fields. Parasite density was determined by counting the number of malaria parasites against 200 white blood cells and expressing the resultant number of parasites/µl blood assuming a white blood cell count of 8000 per µl of blood [13]. Thin films were examined to confirm the parasite species identified on the thick film. Blood slide was declared positive when a concordant result was produced by two competent microscopists.

### Estimation of parasite density

Parasite densities were recorded as a ratio of parasites to WBC in thick films as follows [12]:

$$\text{Parasite density (in parasite/}\mu\text{l blood)} = \frac{\text{Number of parasites counted} \times 9000}{\text{Number of WBC counted}}$$

### Data analysis

Data was analyzed with the Statistical Package for Social Sciences (SPSS), version 22.0. Those data were firstly log-transformed. t-test for independent sample and two ways analyze of variances were performed to compare the mean parasite densities. Statistical significance was set at  $P \leq 0.05$ .

### Ethical approval

The study was conducted under the ethical clearance number 2018/05/1036/CE/CNERSH/SP delivered by the Cameroon National Ethical Committee for Research on Human Health. All volunteers participating in human landing catches signed a written informed consent form indicating their willingness to take part in the study.

## Results

### Characteristics of the study population

The overall population of this study was 1032 with 401 Baka pygmies and 631 Bantus. Table 1 described the basic characteristics of the population.

From this table, we observed that people of less than 2 years and those above 50-years-old were the less represented in Baka pygmies as well as in Bantus. There was no Baka who attended higher education and only one Bantus reached that education level in the study area. Only one Baka's civil servants and nine Bantus were recorded in the study. In the Bantus, 144 over 631 referred to modern antimalarial treatment whereas only 9 Baka referred to the same treatment went they suffers from malaria.

The prevalence of *Plasmodium* infection was 46.6% and 46.4% in Baka and Bantus. In the general population, infants of less than 2-years-old were the most



**Table 1:** Characteristics of the study population.

Parameters	Variables	Baka	Bantu	Total
Gender	Female	272	409	681
	Male	129	222	351
Age [14,15] (years-old)	< 2	23	49	72
	2-5	97	156	253
	6-15	83	151	234
	16-50	189	253	442
	51-years-old and above	9	22	31
Levels education	No instruction	129	192	321
	Primary education	258	278	536
	Secondary education	14	160	174
	Higher education	0	1	1
Profession	Farmers	201	165	366
	Students	64	182	246
	Civil servants	1	9	10
	House workers	133	243	376
	Forest operators	2	19	21
	Traders	0	13	13
Treatment	NT	2	11	13
	SM	6	198	204
	MT	9	114	123
	TT	188	92	280
	SM + MT	7	42	49
	SM + TT	133	115	248
	SM + MT + TT	7	38	45
Seasons	MRS	111	185	296
	MDS	121	156	277
	SRS	120	172	292
	SDS	49	118	167
Time spent in the forest	Never go through the forest	8	33	41
	Journal	193	467	660
	weeks	113	77	190
	Months	60	37	97
	Years	27	17	44
Total		401	631	1032

**Table 2:** Variation of *Plasmodium* parasitaemia according to ethnicity.

Ethnic groups	Prevalence	Mean parasitaemia ( <i>Plasmodium</i> /μl blood)	Range ( <i>Plasmodium</i> /μl blood)
Baka	46.6%	7748 ± 7149	923-56000
Bantu	46.4%	8240 ± 8642	462-72000

infected (52.8%), in the same ways, Bakas and Bantus who have never attended school education were the most infected (52.6%). The less efficient anti-malarial treatment those people used was the combination of self-medication, traditional and modern treatments (51.1% prevalence). The small rainy season was the season of intense malaria transmission in the general population (57.2%). Globally, comparing to people who spent

years in the forest, those who spent only a day time and who went back in the village in the evening were largely more infected (49.8%).

#### Variation of *Plasmodium* parasitaemia according to ethnic group

Table 2 shows the variation of *Plasmodium* parasitaemia according to ethnicity. The mean of *Plasmodium*

parasitaemia in Baka pygmies ( $7748 \pm 7149$  *Plasmodium*/μl blood) didn't differ ( $P = 0.56$ ) from that of Bantus ( $8240 \pm 8642$  *Plasmodium*/μl blood).

### ***Plasmodium* parasitaemia according to ethnic group and gender**

In the general population (Baka and Bantu take together), gender had no influence on the ability of people to support high *Plasmodium* parasitaemia ( $P = 0.25$ ). Asymptomatic Bantu males carried higher parasitaemia compared to females ( $P = 0.07$ ). In Bakas, men and women had approximately the same mean parasitaemia ( $6888 \pm 4608$  (1212-25333) and  $8274 \pm 8306$  (923-56000) parasites/μl blood respectively). Ethnicity did not influence the gender distribution of parasitaemia ( $P = 0.23$ ).

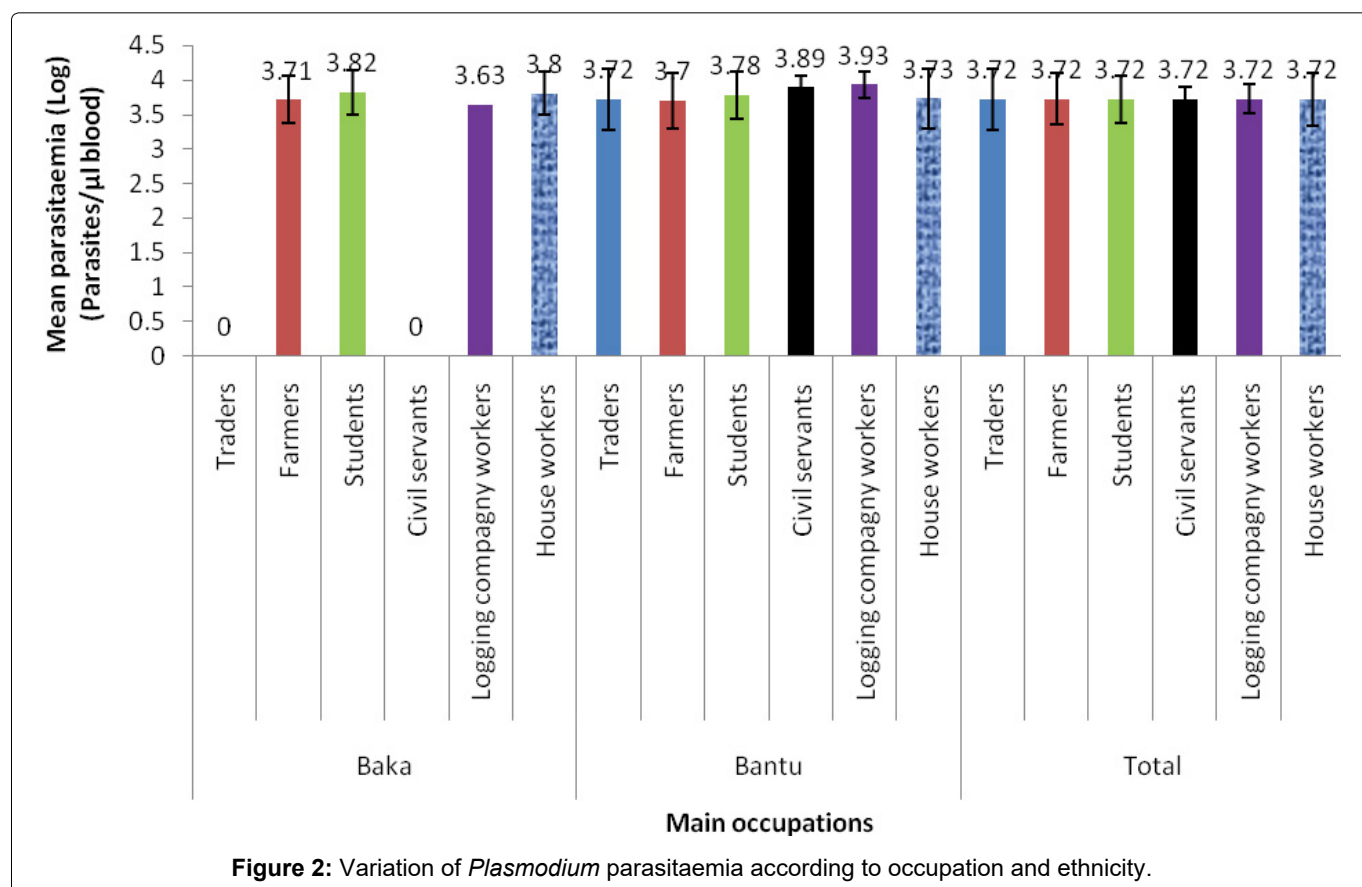
### **Distribution of *Plasmodium* parasitaemia according to ethnic groups and age**

Table 3 presents the distribution of *Plasmodium* parasitaemia in asymptomatic individuals according to age and ethnic groups.

Elderly Baka people (51-years-old and above) were not included in the statistical analysis since only one was positive to malaria test. In general, age had a significant effect on the ability of people to tolerate high *Plasmodium* parasitaemia ( $P = 0.00$ ). Infants of less than 2 years of age had the lowest *Plasmodium* parasitaemia ( $4353 \pm 3772$  (636-20444) parasites/μl blood). A higher parasitaemia occurred in older individuals (2-5 and 6-15 years-old). Parasitaemia dropped again in the last age groups (16-50 and > 50-years-old). This same general trend was observed in each ethnic group except that Baka infants (less than 2-years-old) were slightly more resistant than Bantu infants ( $5736 \pm 4949$  (1212-20444) and  $3547 \pm 2684$  (636-11636) parasites/μl blood respectively in Baka and Bantu). The effect of age on parasitaemia

**Table 3:** Variation of *Plasmodium* parasitaemia according to age and ethnic groups.

Age [14,15] (years)	Log. mean parasitaemia $\pm$ Standard Deviation (Parasites/μl blood)			P-value (Baka and Bantu)
	Baka	Bantu	Total	
> 2	$3.64 \pm 0.32$	$3.44 \pm 0.33$	$3.51 \pm 0.34$	0.75
(2-5)	$3.8 \pm 0.31$	$3.8 \pm 0.40$	$3.8 \pm 0.36$	0.95
(6-15)	$3.86 \pm 0.31$	$3.8 \pm 0.37$	$3.82 \pm 0.34$	0.36
(16-50)	$3.7 \pm 0.34$	$3.74 \pm 0.4$	$3.72 \pm 0.37$	0.4
50 <	4	$3.7 \pm 0.27$	$3.73 \pm 0.27$	0.3
P-value	0.04	0.00	0.00	<b>0.02</b>



mia was influenced by ethnicity ( $P = 0.02$ ).

### ***Plasmodium* parasitaemia according to the occupation and ethnic group of participants**

Figure 2 described the variation of *Plasmodium* parasitaemia in malaria asymptomatic individuals with respect to different occupations and ethnicity.

Figure 2 shows that in the Baka, neither trader nor civil servant were infected with *Plasmodium* parasites. Logging company workers parasitaemia was lower (4286 (4286-4286) parasites/ $\mu$ l blood) but higher in students than in people of others occupations (8855  $\pm$  7834 (1455-40000) parasites/ $\mu$ l blood). In the Bantus, forest logging company workers carried the highest *Plasmodium* parasitaemia (9242  $\pm$  3428 (4706-12000) parasites/ $\mu$ l blood). Globally, farmers tolerated approximately the same *Plasmodium* parasitaemia, irrespective to ethnic group.

### ***Plasmodium* parasitaemia in relation to type of anti-malarial treatment and ethnicity**

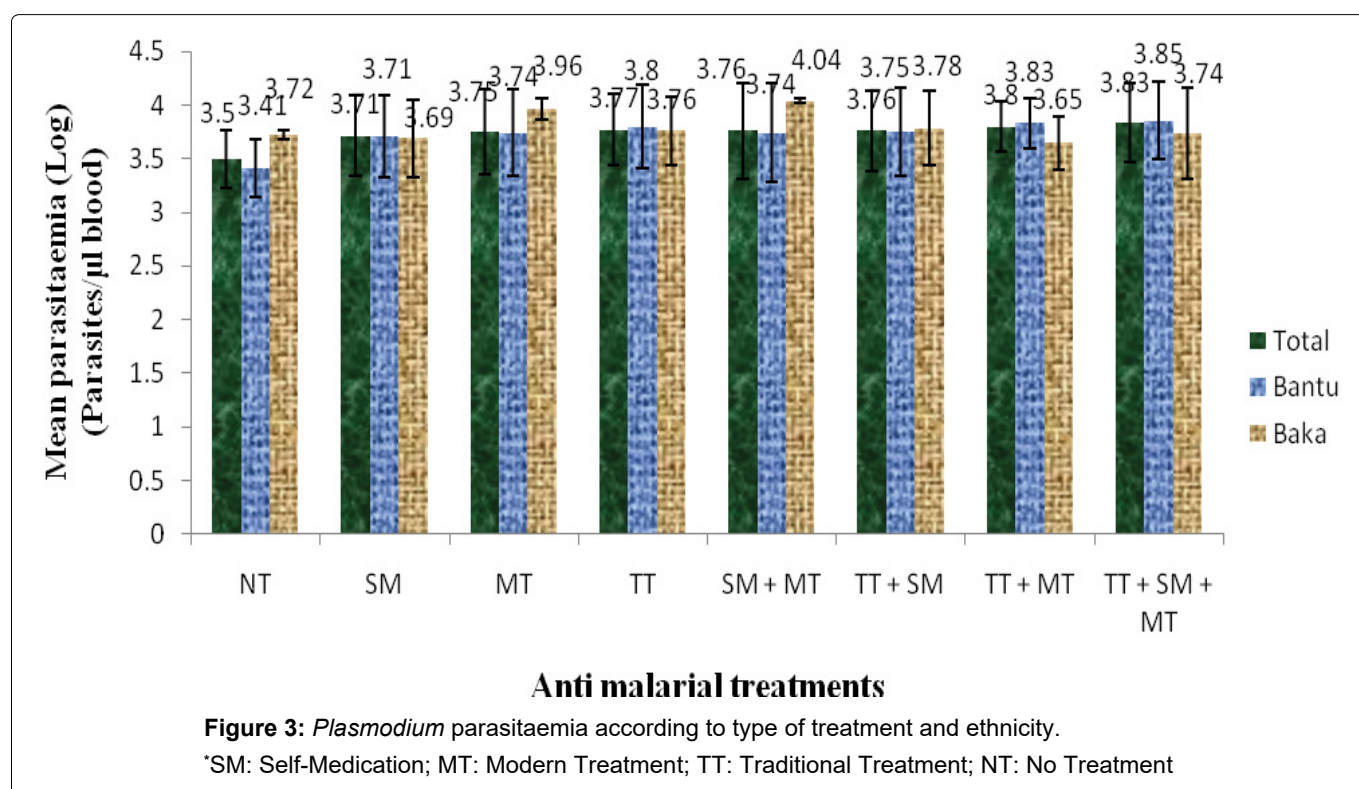
Figure 3 shows the variation of *Plasmodium* parasitaemia in asymptomatic carriers according to type of

anti-malarial treatment taken and ethnicity.

People who have never taken any anti-malarial treatment presented the lowest *Plasmodium* parasitaemia (3646  $\pm$  1874 (1311-5622) parasites/ $\mu$ l blood). The highest parasitaemia occurred in people treating themselves with a combination of traditional, modern treatment and self-medication (9337  $\pm$  7403 (1517-26667) parasites/ $\mu$ l blood). *Plasmodium* parasitaemia of Bantus people combining traditional treatment with modern treatment and self-medication was not significantly higher compare to the parasitaemia of people using others treatment ( $P = 0.7$ ). The highest *Plasmodium* parasitaemia (11000  $\pm$  471 (10667-11000) parasites/ $\mu$ l blood) was observed in Baka pygmies who treated themselves with a combination of self-medication and modern treatment. But in general, the effect of treatment on parasitaemia was not influenced by ethnicity ( $P = 0.8$ ).

### ***Plasmodium* parasitaemia according to the level of education and ethnicity**

Table 4 describes the relationship between parasitaemia, levels of education and ethnic group.



**Table 4:** Variation of parasitaemia according to the levels of education and ethnicity.

Levels of education	Log. mean parasitaemia $\pm$ Standard Deviation (Parasites/ $\mu$ l blood)			P-value (Baka and Bantu)
	Baka	Bantu	Total	
No modern education	3.8 $\pm$ 0.33	3.73 $\pm$ 0.42	3.76 $\pm$ 0.38	0.2
Primary education	3.73 $\pm$ 0.32	3.80 $\pm$ 0.34	3.77 $\pm$ 0.33	0.1
Secondary education	3.99 $\pm$ 0.47	3.4 $\pm$ 0.43	3.66 $\pm$ 0.44	0.1
P-value	0.13	0.02	0.09	0.02

Globally, Table 4 shows that people who attended up to the secondary education had the lowest *Plasmodium* parasitaemia ( $7330 \pm 7891$  (462-49600) parasites/ $\mu$ l blood). In the opposite, Bakas who attended that secondary education had the highest *Plasmodium* parasitaemia ( $16735 \pm 3514$  (5200-49600) parasites/ $\mu$ l blood) whereas in Bantus, it was the contrary ( $P = 0.02$ ). In the Bantus, participants who attended only primary education were significantly more infected than others ( $P = 0.02$ ). The effect of levels of education on parasitaemia was influenced by ethnic group ( $P = 0.02$ ).

### ***Plasmodium* parasitaemia according to seasonality and ethnicity**

Table 5 describes how *Plasmodium* parasitaemia varies in asymptomatic people by season and by ethnic group.

Table 5 shows that the highest *Plasmodium* par-

asitaemia occurred during the small rainy season ( $P = 0.00$ ) ( $9053 \pm 8614$  (1833-56000) and  $11288 \pm 11825$  (1250-72000) parasites/ $\mu$ l blood in Bakas and Bantus respectively). Bakas as well as Bantus carried the lowest parasitaemia during the main rainy season ( $5910 \pm 5862$  (923-26667) parasites/ $\mu$ l blood and  $5226 \pm 5489$  (462-25778) parasites/ $\mu$ l blood respectively). Ethnic group influenced the seasonal distribution of parasitaemia ( $P = 0.00$ ).

### **Variation of parasitaemia according to the time spent in the forest and ethnicity**

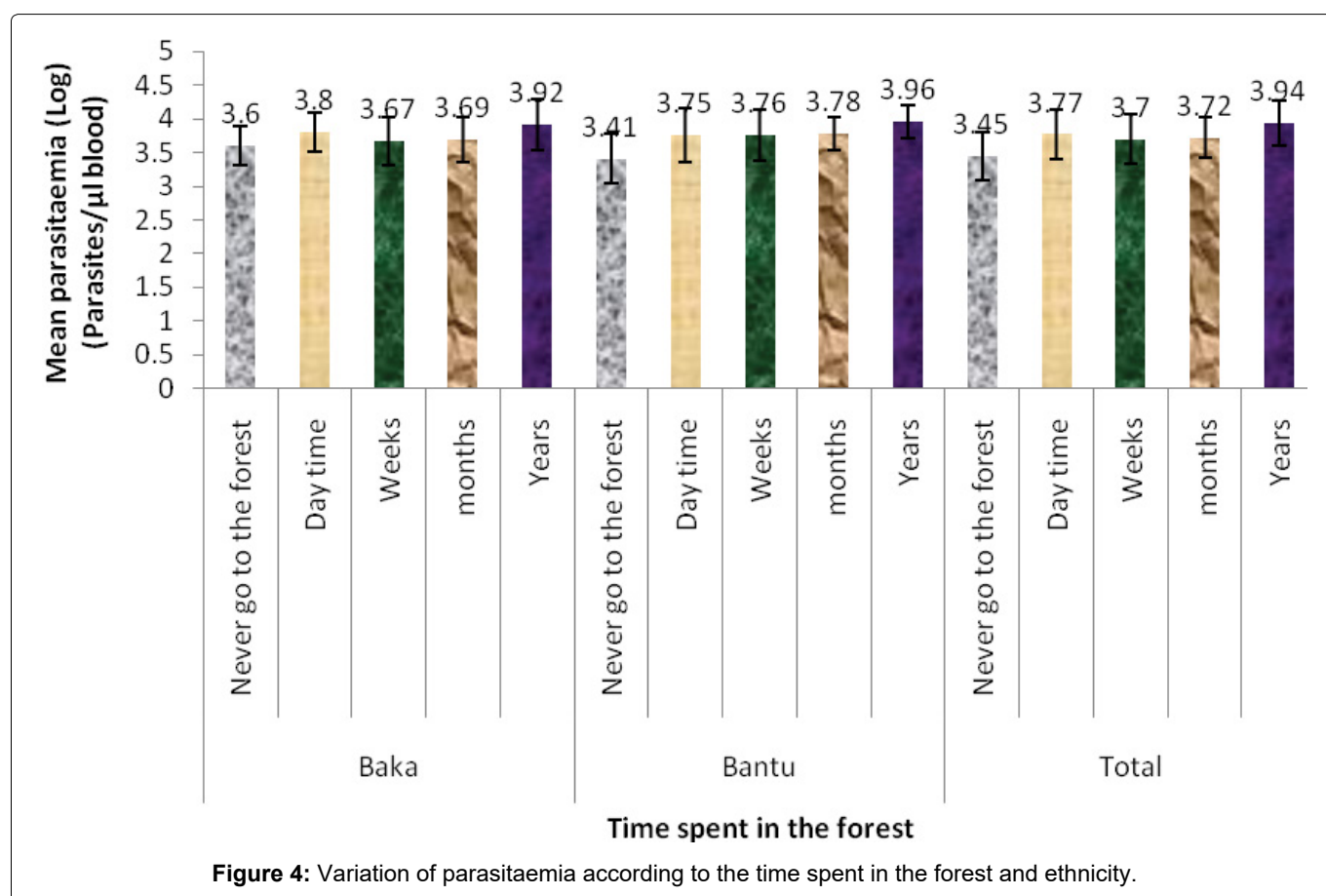
Figure 4 describes the variation of *Plasmodium* parasitaemia in asymptomatic people according to the time spent in the forest and ethnicity.

The level of parasitaemia was significantly influenced by the amount of time people spent in the forest ( $P = 0.00$ ). In fact, the longer in stays in the forest,

**Table 5:** Variation of *Plasmodium* parasitaemia according to the season and ethnicity.

Seasons	Log. mean parasitaemia $\pm$ Standard Deviation (Parasites/ $\mu$ l blood)			P-value (Baka and Bantu)
	Baka	Bantu	Total	
MRS	$3.60 \pm 0.38$	$3.52 \pm 0.42$	$3.54 \pm 0.41$	0.3
MDS	$3.79 \pm 0.3$	$3.84 \pm 0.31$	$3.82 \pm 0.3$	0.3
SRS	$3.83 \pm 0.32$	$3.89 \pm 0.36$	$3.87 \pm 0.34$	0.2
SDS	$3.72 \pm 0.25$	$3.63 \pm 0.33$	$3.66 \pm 0.30$	0.2
P value	0.007	0.00	0.00	<b>0.00</b>

\*MRS: Main Rainy Season; MDS: Main Dry Season; SRS: Small Rainy Season; SDS: Small Dry Season





the highest the parasitaemia one carries ( $11380 \pm 8086$  (2400-25333) and  $10502 \pm 5966$  (4000-21714) parasites/ $\mu$ l blood respectively in Bakas and Bantus). In the Baka Pygmies as well as in Bantus, people who never go to the forest were less parasitized ( $4760 \pm 3558$  (1951-9959) parasites/ $\mu$ l blood and  $3702 \pm 3976$  (711-16000) parasites/ $\mu$ l blood respectively) than people of all others groups ( $P = 0.02$ ). Ethnic group doesn't influenced the distribution of parasitaemia according to time spent in the forest ( $P = 0.18$ ).

## Discussion

This study revealed that asymptomatic Baka pygmies as well as Bantus were able to tolerate approximately the same *Plasmodium* parasitaemia (462-72000 parasites/ $\mu$ l blood) without any sign of the disease. A similar range of parasitaemia was found by Nkuo-Akendjo, et al. [13] in Bolifamba, an atypical Cameroonian rainforest zone (38 - 50252 Trophozoites/ $\mu$ l blood). It would therefore seem that the activities of both the vector and the final host are similar within the two ethnic communities. In fact both Bakas and Bantus live in the same environments (village and forest).

Asymptomatic Bantus men tolerated high parasitaemia compared to females while in Bakas, the reverse result was observed. It may appear that Bantu male tend to spend more time outside at night in various outdoor activities (visits, meetings, drinking and other distractive activities).

The lower parasitaemia observed in infants of less than 2 years may be due to the fact that this age group still benefits from immunity acquired and transferred from mothers to the baby [16]. As from 2 to 5 years until 15 years, the number of people tolerating high parasitaemia increased. In general, children of endemic areas are able to develop the ability to tolerate high parasitaemia without any sign of morbidity [6,17]. Similarly, Richard, et al. [15] showed that in children from forest areas, the pyrogenic threshold was high (20 000 parasites/ $\mu$ l blood). It is suggested that as people grow up, they are frequently exposed to vectors bites and this will make them resist to the toxic effects of parasites [15]. As individuals reach adult age, their malaria parasitaemia decreases, which is also supported by Jean, et al. [6] who found that 95% of asymptomatic adults had a parasite density of less than 500 trophozoites/ $\mu$ l blood. In fact, in malaria endemic areas, the immune system of non-treated adults, due to frequent re-infection, may prevent the multiplication and survival of malaria parasites [15].

In Baka pygmies, the most important parasitic load was observed in people who reached secondary education while in Bantus, it was the reverse. In fact, the study area has only one secondary school, so that most Bantus will move to the nearest towns (Abong-Mbang and Mindourou) for their secondary education. There,

they acquire information on malaria (use of ITNs, modern treatment, environmental sanitation, etc...). Once back in the village, they are more likely to apply protective measures against malaria, hence their low *Plasmodium* parasitaemia. However among the Bakas on the other hand, secondary education is always local and it is permanently disrupted by the frequent migrations of the family towards the forest. Knowledge related to the prevention and treatment of malaria will not differ much from that acquired in primary school. This explains why parasitaemia in Bakas was not influenced by the level of education.

The intensity of *Plasmodium* infection is also characterized by seasonal fluctuations linked to larval breeding sites, human activities and rainfall [18]. The highest parasitaemia occurred during the small rainy season because mosquito activity is at its peak, water accumulates in gutters, pits, containers, abandoned tires, leaves, water reservoirs around homes, offices, market places and schools [19]. This creates a diversity of breeding sites for malaria vectors, increasing exposure to mosquito bites hence to infection and finally promoting high immunity against *Plasmodium* parasite [18]. This means, when the frequency and amount of rainfall decrease, the people's vulnerability to malaria increases [20]. On the other hand, during the main rainy season, when mains activities (hunting, fishing and agriculture) slowed down *Plasmodium* parasitaemia was low. Indeed, with animals hidden in their burrows, hunting becomes less attractive. At the same time, the high water level of rivers does not facilitate the effective practice of fishing. Agricultural activities are disturbed by heavy rains which often cause the leaching of crops. For these reasons, the inhabitants of the study area tend to spend more time indoors during the main rainy season, reducing contact with mosquito vectors and hence, reducing parasitaemia.

The most used modes of treatment in the study area were traditional medicine and self-medication probably because access to health centers is generally difficult in rural areas. Bantu people who combined three modes of treatment (traditional medicine, modern treatment and self-medication) tolerated the highest parasitic load. On the other hand, Baka pygmies who treated their malaria with a combination of self-medication and modern treatment were those harboring the highest parasite load. The frequent consumption of anti-malarial treatment as well as the frequent exposition to mosquito bites may have enhanced the immune system of participants and tackle the toxic effects of the parasites.

Certain occupations expose more to malaria than others [21,22]. The highest *Plasmodium* parasitaemia observed in Bantus logging company workers may be due to the frequent exposition to vector bite during the discharge of their duties in the forest. In fact, Ricci [23] have demonstrated in his studies that there is a



significant link between regular work in the forest and increased risk of malaria.

Forests seem to be areas of high malaria endemicity [24,25]. That is why people who spend more of their time in the forest harbored high *Plasmodium* parasitaemia. Indeed, tree canopy provides shade even during the hottest hours of the day and humidity protects mosquitoes from estivation and death. Moreover, in the forest, there are protected breeding pools, rich in nutrients, which favor the development of vectors. Most of all, people living or working in forest don't have protected infrastructure or any vector-control measures [17].

## Conclusion

At the end of this work which aimed to determine the threshold *Plasmodium* parasitaemia among malaria asymptomatic indigenous communities, it turned out that in Bakas as well as in Bantus, asymptomatic individuals were able to carry more than 55,000 (56000 in Baka and 72,000 in Bantus) trophozoites/ $\mu$ l blood without any sign of the disease. *Plasmodium* parasitaemia was mainly influenced by the age and level of education of hosts, season, and by time spent in the forest, not significantly by ethnicity as initially hypothesized.

## Recommendation

A KAP (knowledge, attitude and practice) study in this population is necessary to help design a malaria control strategy ratified by the Ministry of Public Health in the perspective of malaria eradication in forest area.

## Limitation

*Plasmodium falciparum* was the only malaria parasite discovered in this study. The study was supposed to stay about 2 years but the difficulty in getting the assistance of the head of the health center for a longer period has shortened the study period. The sample study was heterogeneous; some factors collected were not statically analyses. It would have been interesting to follow those asymptomatic carriers over the time, in order to determine the threshold *Plasmodium* parasitaemia needed to initiate malaria symptoms.

## Acknowledgements

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## Conflict of Interest

The authors declared that there is no conflict of interest.

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