Extent of Asymptomatic *Plasmodium* spp. Infections and Associated Risk Factors at Household and Individual Levels in Korhogo Health District, Northern Côte d'Ivoire: implications for Malaria Control

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Research Article

Abstract

Background: *Plasmodium* spp. asymptomatic carriers are potential reservoirs contributing to the persistence of malaria transmission in endemic areas. The study was designed to assess the extent of *Plasmodium* spp. asymptomatic infection at household and individual levels and associated risk factors in Northern Côte d'Ivoire.

Methods: A cross-sectional survey was conducted in July 2016 at household level in the health district of Korhogo. A questionnaire was administered to household's head to capture socio-demographic information and practices including malaria treatment and preventive measures. In each household, adults without malaria symptoms nor history of fever during the week before recruitment were screened. Capillary blood samples were collected and used for the detection of *Plasmodium* spp. infections using both conventional microscopy and a loop-mediated isothermal DNA amplification (LAMP) assay. Logistic regression was used to determine variables that influenced *Plasmodium* spp. asymptomatic infections.

Results: In total, 376 households and 1'011 asymptomatic adults were screened. Asymptomatic *Plasmodium* spp. infections were identified in 12.5% [47/376] and 38.3% [144/376] of the households and in 5.2% [53/1011] and 18.8% [190/1011] of the individuals screened, according to microscopy and LAMP, respectively. At household level, asymptomatic carriers increased about two times when using mosquito repellent coils compared to those where it is not used (OR: 1.8; p=0.005). At individual level, men's risk to be infected was about two times that of women (OR: 1.9; p<0.001). The odd to be infected was also two times higher in population living in periurban areas compared to those leaving in the urban center (OR: 2.3; p<0.001). Additionally, age appear to be risk factor, with younger individuals being at higher risk of infection than elders (OR: 0.5; p=0.001).

Conclusion

Plasmodium spp. asymptomatic carriers is important in Northern Côte d'Ivoire and male, age under 30 and perirban living area appear as significant risk factors. Interventions aiming at eliminating asymptomatic infections in this context, should primarily target among other strategy, the at-risk populations and zones.

Background

Reinforced antimalarial interventions led to a global decline of this disease since 2000 (1). As a result, *Plasmodium* spp. infections tend to become gradually restricted to foci of residual transmission in settings with declining malaria transmission. Capitalizing on this success, the World Health Organisation (WHO) has adopted a Global Technical Strategy for the 2015–2030 period with the ambitious goal to reduce malaria mortality by 90% by 2030 (2). This strategy acknowledges that successful control and elimination strategies need to specifically target transmission reservoirs. Such reservoirs include asymptomatic carries, which typically harbor hard-to-detect low density infections, that can, nevertheless, contribute significantly to malaria transmission in such settings (3).

Asymptomatic infection is defined by the WHO malaria terminology as the presence of asexual parasite in the blood without any fever or malaria-related symptoms (4). Asymptomatic carriage of *P. falciparum* may protect against clinical malaria (5). However, this infection is often undetected and untreated, resulting in a significant source of gametocytes for the transmission of the disease by local mosquito vectors (6). Asymptomatic carriage of *P. falciparum* is not detected by routine heath care system and require active case detection strategies using highly-sensitive diagnostic tools (7).

Molecular diagnostics have shown that this asymptomatic parasitic reservoir is more widespread than expected, even in low-endemic areas (8). Strategies that specifically target this parasite reservoir are therefore needed to accelerate malaria elimination in low- and medium-transmission settings (9). However, in some countries, such as Côte d'Ivoire, national policies have not yet specifically targeted asymptomatic carriers of *Plasmodium* spp. for planning antimalarial elimination interventions (10).

Côte d'Ivoire remains a malaria endemic country (11), where malaria transmission is stable and occurs throughout the year, while morbidity increases during the rainy season (12). A National cross-sectional survey conducted in 2012, in school age children, reported an average prevalence as high as 70% (13). The National antimalarial policies have been improved over the last decade to reinforce control measures. Insecticide-treated nets (ITNs) have been widely distributed free-of-charge to the entire population through regular mass campaigns at the country level. In 2006, 370'000 ITNs were distributed and total of 30'000'000 were distributed between 2010 and 2014 (14). Thus, ITNs household coverage increased from 27% in 2006 to 66 % in 2012 and 95 % in 2015. In parallel, malaria prevalence decreased from 43−33% from 2010 to 2014 (13). Building on this result, the national malaria control program (NMCP) aimed to halve the malaria morbidity by 2020 (14). In order to reach this target, the NMCP strategy is based on three pillars: (i) an appropriate diagnosis and an effective treatment of clinical cases; (ii) the distribution of ITNs free of charge among population, and (iii) the intermittent preventive treatment (IPT) during pregnancy (10).

This strategic plan is mainly focused on symptomatic cases, identified through a passive detection system within the health system. Intervention targets are youngest children and pregnant women in priority because they are at higher risk of clinical malaria (15). Asymptomatic infections are not specifically targeted in this strategic plan because of limited available resources which are currently targeted to better control until elimination-specific measures can be considered.

It has been shown that asymptomatic *Plasmodium* spp. infections are frequent in the country (16). In Korhogo, city of Northern Côte d'Ivoire, twenty years ago, a 70% prevalence of asymptomatic *Plasmodium* spp. infections has been reported (12); however, another study carry out in 2015, in the same city showed a prevalence below 20% and 7.7% during the rainy and dry season, respectively (10). Both studies have used routine malaria diagnostic tools for the detection of *Plasmodium* infections and are likely to have missed a significant number of low-density infections. Sensitive molecular techniques, based on nucleic acid amplification and providing much lower limit of detection (LOD) than routine diagnostic methods, in the order of magnitude of 0.02 parasite per microliter of blood (p/µL) at best, are available to detect

Plasmodium infections (17). Simplified molecular assays, using loop-mediated isothermal amplification (LAMP), have also been developed and enable the sensitive detection of malaria infections, in the range of 1 to 5 p/µL, in remote laboratories with limited equipment and capacity (18). Commercially available LAMP kits have shown a similar performance than PCR, especially when used in remote settings, making it a useful tool to investigate the prevalence of malaria infections, including asymptomatic low-density infections, in endemic areas (18).

Plasmodium spp. asymptomatic carrier are potential malaria reservoir that not considered in our national malaria policy because of limited resources. Theirs weights should underrate based on routine diagnosis test and LAMP test should be more suitable to detect asymptomatic. This study assesses the extent of asymptomatic *Plasmodium* spp. infections in Northern Côte d'Ivoire, based on result of a cross-sectional survey using both microscopy and LAMP diagnostic kits. We also investigated the risk factors associated with asymptomatic infections and discuss their relevance for malarial control interventions.

Method

Study area

The study was carried out from 17 to 28 July 2016 in the health district of Korhogo, North Côte d'Ivoire. The district population was estimated at 536 851 inhabitants in 2014 (19). The climate is characterized by two seasons: a rainy season that occurs from May to October and a dry season from November to April. The yearly rainfall is 1200 mm and the average temperature is 26.6°C (20). A dam has been built in 1972 to provide water for irrigation of fields and market gardening. *Anopheles gambiae* is the most prevalent vector species in this district (20). Among malaria parasites, *Plasmodium falciparum* is the quasi-exclusive species, with rare cases of *P. malariae* and *P. ovale* also being reported (10).

Study design and procedures

The study is a cross-sectional household survey. As described in a recent study carried out in Korhogo (10), 390 households were randomly selected from 30 demographic zones. Three teams (each including a medical doctor or a nurse, a laboratory technician, and questionnaire administrator) have enrolled participants using a households-based approach for 10 days. The study area was divided into three parts: urban center, intermediate zone and periurban. Households located in town square were considered belong to urban center. Those were situated in a peripheral of this city were considered belong to periurban. Households between center and periurban areas were assigned to the intermediate zone (Fig. 1). Participant inclusion criteria were: (i) absence of fever (axillary temperature >37.5°C) or self-reporting history of fever during the last seven days; (ii) self-reporting less than two malaria-suggesting symptoms, such as headache, shiver, sweat, nausea, vomiting, dizziness, tiredness, abdominal pain; (iii) no self-reported use of antimalarial treatments over the four previous weeks; (iv) written informed consent of the participant.

A questionnaire was addressed to the household's head or his/her representative. A finger-prick blood sample was collected for *Plasmodium* spp. infection detection by microscopy and LAMP. Participants without malaria symptom, positive for malaria diagnosis test were considered as asymptomatic *Plasmodium* spp. carriers.

Ethical consideration

The study was approved in 2016 by the National Ethic and Research Committee of Côte d'Ivoire (NCER) (N/Réf : 120/MSHP/CNER-dk), NMCP and the local health district authorities. In agreement with recommendations of NMCP pertaining to the national policy on the management of malaria cases, asymptomatic participants positive to *Plasmodium* spp. were not treated. All of them received ITNs. They were also advised, if any malaria symptom would appear, to rapidly present to a health centre for malaria diagnosis and, if needed, treatment.

Data collection

Questionnaire

A questionnaire relative to promiscuity (household size, household crowd), use of preventive measures (ITNs, mosquito's repellents coils and insecticide sprayed) and treatment seeking behaviour was addressed to the household's head or his/her representative. Socio-demographic data (sex and age) were recorded for all members of the selected household.

Microscopy

Microscopy is gold standard. It was used as routine malaria diagnosis test. A thick and thin blood film was made on a slide and air dried on site. This diagnostic was performed as described elsewhere (10) A slide was classified as negative if no *Plasmodium* asexual forms or gametocytes were found after counting 500 white blood cells.

LAMP

LAMP is a novel malaria diagnosis. According its similar performance as PCR (21), it was used in this study. A finger-prick blood sample was collected for *Plasmodium* spp. infection detection by LAMP (Loopamp[TM] MALARIA Pan/Pf Detection Kit, Eiken Chemical Company). Sixty µL of capillary blood were collected from finger prick, immediately mixed with an equal volume of extraction buffer, stored at ambient temperature, until processed the same day for LAMP as described elsewhere and using a "boil and spin" sample preparation (22). The LAMP reactions were conducted according to the manufacturer's recommendations using a standard heat block and results were read under a UV lamp. Extracted DNA samples were first tested using a Pan LAMP assay detecting all human-infecting *Plasmodium* spp. All pan-positive positive samples were further tested using a *P. falciparum* specific LAMP assay (Pf LAMP). Samples were classified as negative (Pan LAMP negative), *P. falciparum* positive (Pan and Pf LAMP positive) or non-*falciparum* positive (Pan LAMP positive and Pf LAMP negative).

Data analysis

Double data entry was done using the Epidata 3.1 software. Labelling, and data transcription was carried out from software SPSS 18.0.0. Statistical analysis was conducted using STATA 12.1. Data were analysed both at household and at individual levels. For both levels, the dwelling setting was also considered. A household with at least one member diagnosed as positive for *Plasmodium* infection was considered as positive.

Prevalence of asymptomatic carrier was determined with 95 % confidence interval. Pearson chi-square or Fisher's exact tests was used to determine association between asymptomatic *Plasmodium* spp. infection prevalence and promiscuity, prevention, treatment seeking behaviour, sex, ages groups and dwelling setting. The age group defined were ≤30 years, 31-40 years and >40 years (23). Bivariate logistic regression was used to identify crude odds ratios (cOR) of variables associated with *Plasmodium* spp. asymptomatic infection and multiple logistic regression model to identify adjusted odds ratios (aOR). Variables were considered significant when the p value was < 0.05.

Results

Study population characteristics

Out of 390 households visited, 376 were included in this study. Fourteen households without any eligible participant were excluded. A total of 1'149 individuals were screened for eligibility and 1'011 eligible participants were enrolled in the study. The 138 non-eligible participants were spread across the 14 excluded households and 61 included ones. All enrolled participants underwent malaria testing as described above (fig. 2).

Household characteristics

The mean number of people per households was 7.7 persons. The majority of households (228/376, 60.8%) had less than 8 residents. On average, there were about 2 persons per room. The average number of reported of malaria episode per year per household was 2.8. ITNs were owned by 62% (233/376) of households and almost all of them (231/376, 61.4%) declared to use them. Mosquito repellent coil and insecticide spray were used respectively by 56.9% (214/376) and 47.9% (180/376) of the households. A large majority of household (229/376, 60.9%) declared to attend health centre in first intention, when needing medical care (Table 1).

Individual characteristics

Table 2 summarizes the demographic data and *Plasmodium* spp. prevalence of the study population screened by microscopy and LAMP. The mean age of the study population was 35.1 (range, 18 to 87 years old) and the median age was 31 years. Women representing 69% (697/1'011) of the included population. Approximately half of the included participants (501/1'011, 49.6 %) are from in the intermediate zone.

Household prevalence and risk factors

Plasmodium spp. infections were detected in 12.5% (47/376) and 38.3% (144/376) of the households by microscopy and Pan LAMP, respectively. Prevalence of *Plasmodium* spp. was higher in household reporting using mosquito repellents than those not using any (14% versus [vs] 10.5%, p=0.306 by microscopy and 44.4% vs 30.2%, p<0.005 by LAMP) (Table 1). Among, households, which do not use mosquito repellents coils (162/376, 43.1%), few (8/162, 4.9%) used any malaria prevention measures; but ITNs and insecticide spray were used alone or both by almost all households (154/162, 95.1%) (Table 3).

Household *Plasmodium* spp. infection risk is summarized in table 4. The risk to be infected in household using mosquito repellent coil compared to those not doing so increased slightly according to microscopy (OR 1.4, p=0.308) and about two-fold (OR 1.8, p=0.005) according to LAMP. Household risk to be infected were not associated to promiscuity, malaria morbidity and treatment seeking behaviour.

Individual prevalence and risk factors

Plasmodium spp. infections were detected in 5.2% (53/1'011) of study participants by microscopy and in 18.8% (190/1'011) by LAMP. Pf LAMP revealed that 82.1% (156/190) of infection were due to *Plasmodium falciparum* and 17.9% (34/190) were non-*Plasmodium falciparum* (Table 2). Among *Plasmodium* spp. carriers detected by LAMP, 22.6% (43/190) were detected by microscopy and a large fraction (147/190, 77.4%) were missed. (Table 5).

Plasmodium spp. infection prevalence was associated to younger age, men and periurban zone. It was more limited in older (>40 years) than in younger (<30 years) study participants (5.2% vs 5.9%, p=0.62 by microscopy and 14.3% vs 24%, p=0.001 by LAMP). Men were significantly more infected than women (7.3% vs 4.3% by microscopy, p=0.046 and 25.8% vs 15.6% by LAMP, p<0.001). *Plasmodium* spp. infection prevalence increased significantly from urban center to intermediate and periurban zone (3%, 5.2% and 9.9%, p=0.004 by microscopy and 14.8%, 18.2% and 28.5%, p=0.001 by LAMP) (Table 2).

Individual's risk to be infected by *Plasmodium* spp. is summarized in table 6. Risk to be infected was practically similar for older (>40 years) and younger (<30 years) according to microscopy (OR 0.9, p=0.682) and reduced by half according to the LAMP (OR 0.5, p=0.001). Compared to women, men are significantly more at risk of *Plasmodium* infection, by about two-fold (OR 1.7, p=0.049 by microscopy and OR 1.9, p<0.001 by LAMP). Compared to urban center, living in the periurban area increases from two- to three-fold the likelihood to be infected by *Plasmodium* spp. according to the microscopy and LAMP (OR=3.6, p=0.002 vs OR=2.3, p<0.001).

Discussion

Asymptomatic carriers of *Plasmodium* spp. can act as parasite reservoirs that contribute to malaria transmission in some endemic areas. These infections are characterized by low parasitemia which frequently was missed by RDTs and microscopy. In this study, conducted in the city of Korhogo, Northern

Côte d'Ivoire, we used microscopy and LAMP to assess the extent of asymptomatic *Plasmodium* spp. infections. We also investigated the risk factors associated with asymptomatic infections at household and individual level. This study included 1'011 individuals of 376 households.

In this population, the prevalence of asymptomatic *Plasmodium* spp. infection was found to be high, with slightly more than one third (38.3%) of all included household having at least one infected individual and approximately one out of five individual (18.8%) being infected overall when using LAMP for asymptomatic infection detection. Apparent prevalence by microscopy are only about a third of those by LAMP (12.5% versus 38.3% at the household level, and 5.2% versus 18.8% at the individual level). This clearly indicates that any active case detection intervention would miss most of all infections if based on microscopy or other methods with similar LOD, such as rapid diagnostic tests. It is likely that a more sensitive method, such as LAMP, which could be successfully implemented for the screening activities described here, would allow to capture a vast majority of all these infections (24). Importantly, LAMP allowed here to screen a relatively high number of individuals, more than a thousand, over a short period of time, with more than 100 samples tested per day in average over 10 days, showing that this method is compatible with large-scale screening campaigns. It cannot be excluded that additional asymptomatic infections, below the LOD of LAMP, remained undetected, yet the transmissibility of such very low-density infections is unlikely to be significant and, by extension, detecting such infections is likely to be of limited relevance from a programmatic point-of-view. Whether the use of more sensitive methods than microscopy or RDT but also more ones, such as LAMP, is ultimately cost-effective for active case detection screening campaign remains to be determined. Although some studies show high sensibility of LAMP (21, 25), its performance should be demonstrated in our context.

Our results show that both at household and individual level, asymptomatic carriers risk increased when moving from the urban center to the intermediate and periurban zones. It is well reported that malaria infections are more prevalent in the periurban setting compared to urban (26). The high risk of asymptomatic *Plasmodium* spp. infection in periurban setting was highlighted by another study (27). In our case, the high risk observed in periurban setting can be related to the presence of shallows suitable for agricultural activities including market gardening and irrigation rice field. These typically lead to several malaria vectors breeding sites (28). Previous studies have reported that, the low socioeconomic status observed in periurban areas (26), and living close to a permanent stagnant water (at a distance < 1 km from the house) were more likely to increase the risk to be infected with malaria parasite (29).

Malaria prevention measures, particularly mosquito repellent coil, were used in more than half of household. Yet, household reporting the use mosquito repellent coil were found to be at greater risk of asymptomatic *Plasmodium* spp. infection, an apparently counter-intuitive observation. It can be hypothesized that coil use is prompted by the actual presence of mosquitos within or near the households in question but that these coils might be only partially effective at preventing bites. Indeed, mosquito mortality due to application of various mosquito coils averagely ranged between 24 and 64% (30). On the other hand, coil might simply not be used in households free of mosquitos, where the risk of infections would be lower to null.

Age and gender are characteristics often significantly associated with specific risk of asymptomatic *Plasmodium* spp. infections (23, 31). Our study also found that, older age was associated with a reduction of asymptomatic *Plasmodium* spp. infection. Asymptomatic prevalence in age < 30 years (24%) declined significantly in age > 40 years (14.3%, by LAMP). In stable malaria transmission areas, repeated contact with parasites, contribute to increase immunity with age (32).

Men were most likely to be infected than women (25.8 % vs 15.6% (p < 0.001). It is possible that men may spend longer time outdoor during evening and thus are more exposed to risk of infection (33). A study performed in Eastern Myanmar associated men infection to professional activities. Individuals who worked as farmers or wood and bamboo cutters were found to be at increased risk of asymptomatic *Plasmodium* infection (23). In our case, it is possible that national control measures mainly focused women, as ITNs and IPT have been distributed free-of-charge during pregnancy, could partially explain this observation.

Conclusion

Plasmodium spp. asymptomatic infection is highly prevalent in Korhogo. Infection risks appear linked to dwelling setting, gender and age. Better controlling and ultimately eliminating malaria in Korhogo will require to take into consideration these asymptomatic infections. We report here that LAMP molecular assay could represent a valuable and potential cost-effective approach to tackle these infections. Our results also provide guidance as to which populations should be prioritized when investigating such infections and could serve to define specific elimination policies and more effective programmatic interventions in the future.

Abbreviations

WHO: World Health Organisation; ITNs: insecticide-treated mosquito net; NMCP: national malaria control program; IPT: intermittent preventive treatment; LOD: lower limit of detection; LAMP: Loop-mediated isothermal DNA amplification; cOR: crude odds ratios; aOR: adjusted odds ratios; CI: confidence interval; VS: versus.

Declarations

Ethics approval and consent to participate

The study was approved by the National Ethic and Research Committee in Côte d'Ivoire (NCER) (N/Réf : 120/MSHP/CNER-dk), National Malaria Control Program (NMCP) and the local Health District authorities. Written informed consent was obtained by all participants. In agreement with recommendations of NMCP, asymptomatic participants positive to *Plasmodium* spp. were not treated, according to national policy for malaria case management. All of them received ITNs. They were also advised, if any malaria symptom would appear, to go to a health centre for confirmation.

Consent for publication

Not applicable.

Availability of data and materials

The datasets supporting the conclusions of this article are included within the article. Raw data used for analysis of the study are available from the corresponding author on reasonable request.

Authors'contributions

XCD wrote the protocol and trained the local team in Côte d'Ivoire; KDS, LJCEE, BB and EKN coordinated the process of ethical approval of the protocol, designed and supervised field data collection. SBA Coordinated internal information at NMCP, MoH and local district; KDS, LJCEE EMAB KIK and KT coordinated the data entry and storage study document. LJCEE, CGNG, AK and EMAB were involved in statistically analysis and interpretation. YEK register global position system. EMAB wrote the initial version of the manuscript; KDS, LJCEE, JTC, EKN and XCD revised the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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Tables

Table 1 Characteristic and Plasmodium spp. prevalence of included household

		Microscopy			LAMP		
	N (%)	n (%)	95%CI	p value	n (%)	95%CI	p value
Household	376 (100)	47 (12.5)	9.1-15.9		144 (38.3)	33.4-43.2	
Localisation							
Urban center	121 (32.2)	9 (7.4)	2.7-12.1		41 (33.9)	25.4-42.4	
Intermediate zone	181 (48.1)	23 (12.7)	7.8-17.6		70 (38.7)	31.5-45.8	
Periurban	74 (19.7)	15 (20.3)	10.9-29.6	0.031	33 (44.6)	33.2-56	0.325
Means							
Person per household	7.7 (95% CI: 7.3-8.2)	-	-	-	-	-	-
Person per room	1.97 (95% CI: 1.89.-2)	-	-	-	-	-	-
Malaria crisis during the last 12 months	2.8 (95% CI: 2.4-3.3)	-	-	-	-	-	-
Promiscuity							
Size							
≤ 7 residents per household	228 (60.8)	29 (12.7)	8.4-17.1		85 (37.3)	31-44.6	
>7 residents per household	147 (39.2)	18 (12.2)	6.9-17.6	0.892	58 (39.5)	31.5-47.4	0.672
Crowd							
< 2 residents per room	192 (51.3)	26 (13.5)	8.7-18.4		71 (37)	30.1-43.8	
≥ 2 residents per room	182 (48.7)	21 (11.5)	6.9-16.2	0.559	72 (39.6)	32.4-46.7	0.608
Malaria crisis during the last 12 months							
≤2	186 (49.9)	26	9-19		76	33.7-	

		(14)			(40.9)	48	
>2	187 (50.1)	20 (10.7)	6.2-15.1	0.335	67 (35.8)	28.9-42.7	0.318
Prevention							
ITNs ownership							
No	143 (38)	-	-	-	-	-	-
Yes	233 (62)	-	-	-	-	-	-
ITNs used							
No	145 (38.6)	23 (15.9)	9.9-21.8		62 (42.8)	34.6-50.9	
Yes	231 (61.4)	24 (10.4)	6.4-14.3	0.118	82 (35.5)	29.3-41.7	0.159
Mosquito repellents coils used							
No	162 (43.1)	17 (10.5)	5.7-15.2		49 (30.2)	23.1-37.4	
Yes	214 (56.9)	30 (14)	9.3-18.7	0.306	95 (44.4)	37.7-51.1	0.005
Insecticide spray used							
No	196 (52.1)	26 (13.3)	8.5-18		79 (40.3)	33.4-47.2	
Yes	180 (47.9)	21 (11.7)	6.9-16.4	0.64	65 (36.1)	29-43.2	0.403
Treatment seeking behaviour							
Health centre	229 (60.9)	24 (10.5)	6.5-14.5		77 (33.6)	27.5-39.8	
Self-medication	104 (27.7)	16 (15.4)	8.4-22.4		46 (44.2)	34.6-53.8	
Traditional health cure	43 (11.4)	7 (16.3)	5-27.5	0.332	21 (48.8)	33.7-64	0.058

-: Not applicable, *ITNs* Insecticide-treated mosquito net, *CI* Confidence interval

Table 2 Characteristic of individual tested and harbouring Pasmodium spp

	microscopy				LAMP		
	N (%)	n (%)	95%CI	p value	n (%)	95%CI	p value
Participants	1011 (100)	53[a] (5.2)	3.9-6.6		190[b] (18.8)	16.4-21.2	
Age							
Mean age (Year)	35.1 (SD :13.9, min:18 max:87)			-	-	-	-
<30	441 (43.6)	26 (5.9)	3.7-8		106 (24.0)	20.0-28.0	
30-40	262 (25.9)	11 (4.2)	1.8-6.6		40 (15.3)	10.9-19.6	
>40	308 (30.5)	16 (5.2)	2.7-7.7	0.62	44 (14.3)	10.4-18.2	0.001
Sex							
Female	697 (69.0)	30 (4.3)	2.8-5.8		109 (15.6)	12.9-18.3	
Male	314 (31.0)	23 (7.3)	4.4-10.2	0.046	81 (25.8)	20.9-30.6	<0.001
Site							
Urban center	338 (33.4)	10 (3)	1.1-4.8		50 (14.8)	11.0-18.6	
Intermediate zone	501 (49.6)	26 (5.2)	3.2-7.1		91 (18.2)	14.8-21.5	
Periurban	172 (17)	17 (9.9)	5.4-14.3	0.004	49 (28.5)	21.7-35.3	0.001

-: Not applicable, SD Standard deviation, CI Confidence interval, [a] All of them were *Plasmodium falciparum* detected by microscopy, [b]Pf LAMP revealed that 82.1% (156/190) were *Plasmodium falciparum* and 17.9% (34/190) were non-*Plasmodium falciparum*

Table 3 Additional malaria prevention measures to households use and not mosquito repellents coils

Malaria prevention measures	Households, n (%)
Households use mosquito repellents coils, N=214	
Mosquito repellents coils only	44 (20.6)
Mosquito repellents coils + ITNs, n (%)	63 (29.4)
Mosquito repellents coils +Insecticide spray, n (%)	61 (28.5)
Mosquito repellents + ITNs + Insecticide spray, n (%)	46 (21.5)
Households do not use mosquito repellents coils, N=162	
None, n (%)	8 (4.9)
ITNs, n (%)	81 (50)
Insecticide spray, n (%)	32 (19.8)
ITNs + insecticide spray, n (%)	41 (25.3)

ITNs Insecticide-treated mosquito net

Table 4 Asymptomatic risk factor associated to household

	Microscopy		LAMP	
Characteristics	cOR (95%CI)	*P value*	cOR (95%CI)	*P value*
Localisation				
Urban center	1		1	
Intermediate zone	1.8 (0.8-4)	0.149	1.2 (0.7-2)	0.398
Periurban	3.2 (1.3-7.7)	0.011	1.6 (0.9-2.8)	0.136
Promiscuity				
Size				
≤ 7 residents	1		1	
>7 residents	0.1 (0.1-0.2)	0.892	1 (0.7-1.7)	0.672
Crowd				
< 2 residents per room	1		1	
≥ 2 residents per room	0.8 (0.4-1.5)	0.559	1.1 (0.7-1.7)	0.608
Malaria crisis during the last 12 months				
≤2	1		1	
>2	0.7 (0.4-1.4)	0.336	0.8 (0.5-1.2)	0.318
Prevention				
ITNs used				
No	1		1	
Yes	0.6 (0.3-1.1)	0.121	0.7 (0.5-1.1)	0.159
Mosquito repellents coils used				
No	1		1	
Yes	1.4 (0.7-2.6)	0.308	1.8 (1.2-2.8)	0.005
Insecticide spray used				
No	1		1	
Yes	0.9 (0.5-1.6)	0.64	0.8 (0.5-1.2)	0.403
Treatment seeking behaviour				
Health centre	1		1	
Self-medication	1.5 (0.8-3)	0.205	1.6 (0.9-2.5)	0.065

Traditional health cure	1.7 (0.7-4)	0.276	1.9 (0.9-3.6)	0.059

ITNs Insecticide-treated mosquito net, *cOR* crude odds ratios, *aOR* adjusted odds ratios, *CI* Confidence interval

**Table 5 LAMP and microscopy data crossing**

Diagnosis	Proportion, n (%)
Pan LAMP positive, N=190	
Microscopy negative, n (%)	147 (77.4)
Microscopy positive, n (%)	43 (22.6)
Pan LAMP negative, N=821	
Microscopy negative, n (%)	811 (98.8)
Microscopy positive, n (%)	10 (1.2)

Table 6 Asymptomatic risk factor associated to participant tested

Characteristics	Microscopy				LAMP			
	cOR (95%CI)	*P value*	aOR (95%CI)	*P value*	cOR (95%CI)	*P value*	aOR (95%CI)	*P value*
Age								
<30	1				1		1	
30-40	0.7 (0.3-1.4)	0.332	-	-	0.6 (0.4-0.8)	0.006	0.6 (0.4-0.9)	0.017
>40	0.9 (0.5-1.6)	0.682	-	-	0.5 (0.4-0.8)	0.001	0.5 (0.4-0.8)	0.002
Sex								
Female	1		1		1		1	
Male	1.75 (1-3.1)	0.049	1.7 (1-3.1)	0.052	1.9 (1.3-2.6)	<0.001	1.9 (1.3-2.6)	<0.001
Site								
Urban center	1		1		1		1	
Intermediate zone	1.8 (0.8-3.8)	0.123	1.8 (0.8-3.8)	0.125	1.3 (0.9-1.9)	0.201	1.2 (0.8-1.8)	0.303
Periurban	3.6 (1.6-8)	0.002	3.6 (1.6-8)	0.002	2.3 (1.5-3.6)	<0.001	2.2 (1.4-3.5)	<0.001

-: Not applicable*, cOR* crude odds ratios*, aOR* adjusted

Figures
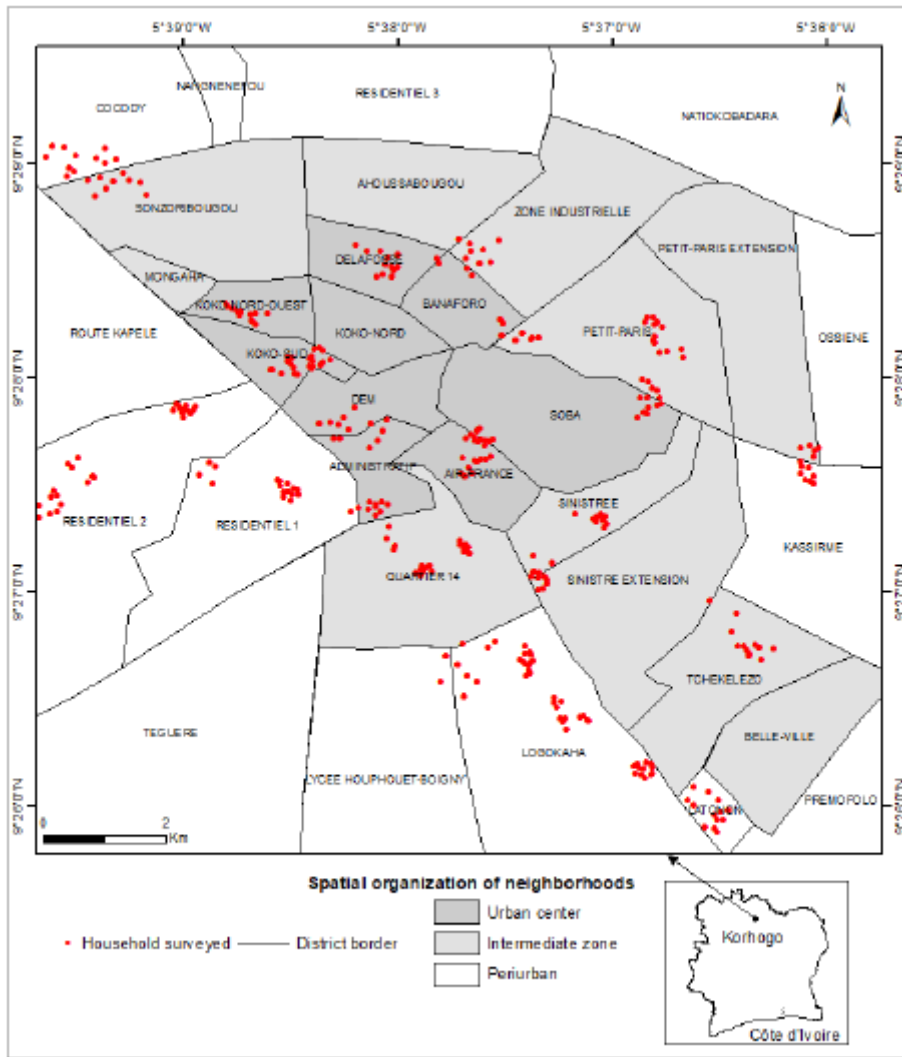
Figure 1

Spatial distribution of household visited in the health district of Korhogo Northern Côte d'Ivoire Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
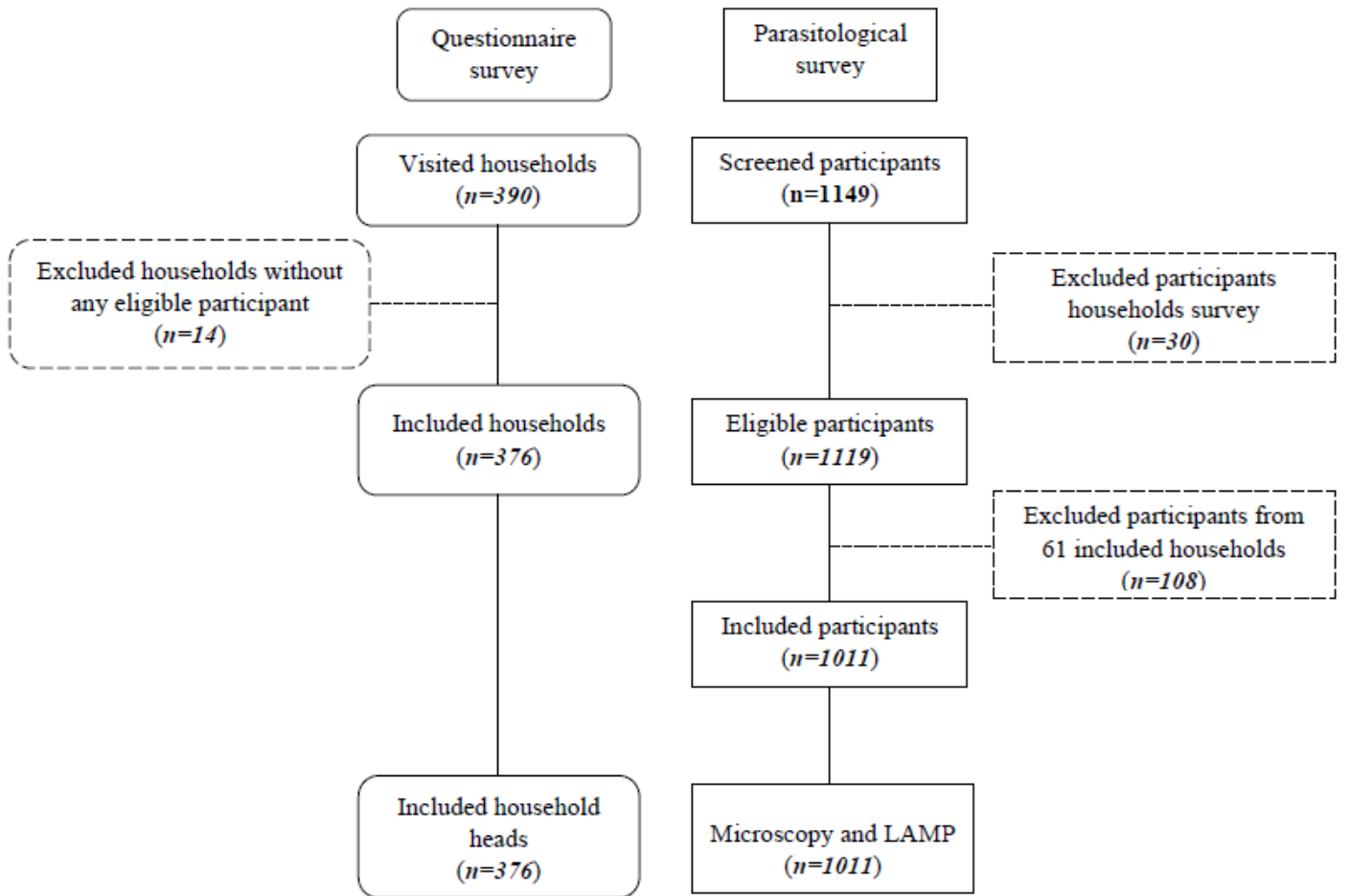
Figure 2

Flow chart of study