Risk Factors for *Plasmodium Falciparum* Infection in Pregnant Women in Burkina Faso: A Community-Based Malaria Cross-Sectional Survey

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Research Article

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Abstract

Background: Malaria in pregnancy remains a public health problem in sub-Saharan Africa. Identifying risk factors for malaria in pregnancy could assist in developing interventions to reduce the risk of malaria in Burkina Faso and other countries in the region.

Methodology: Two cross-sectional surveys were carried out to measure *Plasmodium falciparum* infection using microscopy in pregnant women in Saponé Health District, central Burkina Faso. Data were collected on individual, household and environmental variables and their association with *P. falciparum* infection assessed using multivariate analysis.

Results: A total of 356 pregnant women were enrolled in the surveys, 174 during the dry season and 182 during the wet season. The mean number of doses of sulphadoxine pyrimethamine for Intermittent Preventive Treatment in pregnancy (IPTp-SP) was 0.4 doses during the first trimester, 1.1 doses at the second and 2.3 doses at the third. Overall prevalence of *P. falciparum* infection by microscopy was 15.7%; 17.8% in the dry season and 13.7% in the wet season. 88.2% of pregnant women reported sleeping under an insecticide-treated net on the previous night. *P. falciparum* infection risk in pregnancy was reduced in those women who reported using an ITN (Odds ratio, OR=0.31, 95% CI 0.12-0.79, p=0.02) and an increasing number of IPTp-SP doses during pregnancy, with each additional dose reducing the odds by 40% (OR=0.59, 95% CI 0.43–0.81, p<0.001).

Conclusion

The prevalence of *P. falciparum* infection among pregnant women remains high in Burkina Faso although use of IPTp-SP and ITNs were found to reduce the odds of infection. Despite this, compliance with IPTp remains far from that recommended by the National Malaria Control Programme and World Health Organization. Behaviour change communication should be improved to encourage compliance with protective malaria control tools during pregnancy.

Introduction

Malaria in pregnancy remains a major public health problem in sub-Saharan Africa [1], despite the decline in malaria transmission observed throughout the region from 2004–2015 [2]. Burkina Faso is a high burden country and is not experiencing declines in malaria and all-cause mortality in children despite high coverage of insecticide-treated nets (ITNs) and prompt and effective treatment with antimalarials [3].

Pregnant women are at high risk from malaria because of their lowered immunity during pregnancy [4] and because they are more attractive to *Anopheles gambiae*, the most important African malaria vector [5]. Infection with *Plasmodium falciparum* can lead to poor outcomes for the mother, the foetus and child, resulting in maternal anaemia, low birth weight, preterm delivery and perinatal mortality [6–9]. Pregnant women, especially those pregnant for the first time (primigravidae), are at increased risk of more frequent and more severe malaria infections [10–13]. The World Health Organization (WHO) recommends the use of ITNs (distributed free-of-charge at Antenatal Clinic (ANC) visits), intermittent preventive treatment in pregnancy (IPTp) with sulphadoxine pyrimethamine (SP) and prompt access to diagnosis and effective case management, to prevent and manage malaria risk in pregnancy [14]. According to national guidelines in Burkina Faso, pregnant women are advised to receive at least three doses of IPTp-SP starting from the second trimester, with a minimum interval of one month between doses [15].

The incidence of malaria infections in pregnant women in Burkina Faso in 2014 was 39.2 per 1,000 women-months, and was more than twice as great in primigravids at 88.6 per 1,000 women-months than multigravids [13]. In 2014, another study in the country found that malaria infection was five-fold greater in primigravids than in multigravids [12]. There have been many studies of risk factors for malaria in pregnancy in sub-Saharan Africa, where increased risk was reported to be associated with younger age in pregnancy, primigravidae, first trimester of pregnancy infection, non-use of ITNs, lack of education and HIV co-infection [11–13, 16]. Few, however, have evaluated socioeconomic and environmental risk factors for malaria in pregnancy. For example, recently a number of studies have shown that malaria in children is associated with poor housing [17–19], but it is not known whether this is also true for pregnant women. The goal of the present study was to identify risk factors for *P. falciparum* infection in pregnancy in Burkina Faso, including potential socioeconomic and environmental risk factors. Identifying risk factors for malaria in pregnancy could assist in developing interventions to reduce malaria burden in pregnancy in Burkina Faso and other countries in the region.

Methods

Study design

Putative risk factors for *P. falciparum* infection were measured during two cross-sectional surveys, one in the dry season and one in the wet season.

Study site

The study was conducted in Saponé Health District, situated in the central region of Burkina Faso, 30 Km south-west of Ouagadougou, the capital of Burkina Faso. In the study area, malaria transmission is intense and highly seasonal [20], with the peak of malaria transmission occurring at the end of the rainy season (June to October) and markedly reduced transmission during the dry season (December to May) [21]. The main vectors are *Anopheles gambiae* s.s., *An. arabiensis* and *An. funestus,* and *P. falciparum* accounts for more than 95% of all malaria infections [20-22]. This is a

rural area of open Sudanian savannah, where farming is dominant and the major crops grown are sorghum and millet. Houses in the study area are typically constructed with mud walls and floors, with thatched or metal roofs [23].

Surveys

Two cross-sectional surveys were carried out. One at the beginning of the dry season in December 2018 and the second one at the end of the rainy season from September to October 2019. Pregnant women were enrolled through a Demographic Health Surveillance System (DHSS), with home visits in 21 villages in the study area. All women of child-bearing age in the study area were identified and visited at home for pregnancy screening. This approach was adopted, rather than screening at the ANC because ANC attendance is relatively low in the study area, with only 35% of women attending the ANC at least three times [24]. Women thought to be pregnant were referred to the health facilities for a pregnancy test or, if willing to provide urine for a dipstick pregnancy test, fieldworkers performed the test at the woman's home. Women identify as pregnant, but who had not visited their ANC, were referred to the local health facilities. At the ANC, the study protocol and procedures were explained by trained staff to the potential participants in French or the main local language of Moore. Pregnant women were enrolled if aged between 15-40 years, provided written informed consent and agreed with the study procedures, including taking of blood. Pregnant women with a known history of SP allergy or any other medical condition that in the opinion of a study physician may be a threat to her or the foetus were not recruited into the study.

Clinical data collection

All study participants completed a questionnaire at enrolment, where demographic data, medical and obstetrical history including previous ANC visits, IPTp doses and use of antimalarials or any other medication within 14 days prior to study enrolment were recorded. Each participant donated a finger prick blood sample (100 µL) for malaria infection detection and characterisation. *P. falciparum* quantitative sexual and asexual parasite count and qualitative species identification was performed by microscopy. Two blood smears were prepared and read by two independent experienced microscopists based at the Centre National de Recherche et de Formation sur le Paludisme (CNRFP) according to established standard operating procedures. In case of fever (axillary temperature ≥37.5°C or reported fever in last 24 h) or other symptoms/signs of clinical malaria, a rapid diagnostic test for malaria (SD BIOLINE Malaria Ag P.f/Pan, Abbott Laboratories, Illinois, USA) was performed. Subjects presenting with clinical malaria were referred to the nearest health facility and treated according to national guidelines [15]. Enrolment procedures were performed at home unless there was a need to check more about the health status of the volunteer. If this was the case, the woman was referred to the health facility to complete the clinical examination.

Risk factor data collection

Study participants were visited at home by fieldworkers who recorded information about the household, including whether the woman had slept under an ITN the previous night. If the answer was no, the reason why the woman did not use an ITN was recorded. Women sleeping under an ITN were asked about the bed net source and how many times they left their ITN during the previous night. ITN fabric integrity was also assessed by fieldworker observation and classified as entire/complete, with any hole, or torn. Women were asked to estimate the time they went to bed and the time they get out of bed in the morning. Social and economic risk factors for malaria were recorded, including ethnicity, education level and occupation, ownership of a radio or mobile phone, estimated distance to the nearest health facility, and use of other protective measures, including mosquito coils, insecticide sprays, traditional spatial repellent or commercial topical repellents.

House construction (metal or thatched roof, presence of open eaves, electricity supply to sleeping room), household size (number of persons) and the presence of clothes hanging in the sleeping room were recorded. The presence or absence of big domestic animals (donkey, horses, sheep, cows, goats, dogs) and rubbish within 5 m of each study participant household was recorded.

Sample size

The sample size was estimated based on the sample size for frequency of the disease in a population (https://www.openepi.com/SampleSize/SSCohort.htm). To determine malaria parasite prevalence, we assumed a population prevalence of 2.5% in the study area based on previous data of the frequency of malaria in pregnant women in the study area recorded in 2017 [25]. We assumed a 2% precision, with 5% level of significance and 95% confidence limits. Considering housing type as major risk factor (improved housing reduces risk of malaria prevalence by~50%, Odds ratio = 2) [26] and 10% non-response, a sample size of 175 pregnant women was considered necessary for each cross-sectional survey.

Data management and statistical analysis

Data were collected on Android personal digital assistants programmed using Open Data Kit (https://getodk.org/) and included drop down boxes and consistency checks to reduce data entry errors. Following cleaning, the dataset was locked and saved in Microsoft Access and analysed with Stata 15 (Statacorp, Texas, USA).

The primary outcome measure was the prevalence of microscopically confirmed *P. falciparum* infection in pregnant women during each cross-sectional survey. Logistic regression was used to investigate the association between predictor variables and the primary outcome, adjusting for clustering by village. The multivariable model was constructed using a forwards stepwise process and models were compared using a Wald test.

Results

A total of 356 pregnant women were enrolled in the surveys, 182 during the wet season and 174 during the dry season (Table 1). The mean age of the study participants was 26.9 years, ranging from 15 to 40 years old, and was similar in both surveys. Of these women, 78 (21.9%) were in their first pregnancy, 74 (20.8%) in their second and 204 (57.3%) in their third pregnancy or more. Most women were enrolled in their second and third trimester of pregnancy (37.1% and 30.3% of women where gestational age was recorded). Fewer were enrolled at their first trimester: only 5/78 (6.4%) of primigravidae, 11/74 (14.9%) of secundigravidae and 20/204 (9.8%) of multigravidae were enrolled in their first trimester of pregnancy. 59.0% of women were illiterate and most were farmers (69.9%) or traders (22.1%). 73.1% of primigravidae were literate compared to only 42.5% of those on their second pregnancy and 27.6% of women with two or more pregnancies. 97.5% of study participants were from the Mossi ethnic group. Most women lived in households with three or fewer people 57.9% (206/356). Only 46.3% of women reported having an electricity supply in the sleeping room. Most houses were constructed with metal roofs (95.5%) with 64.6% of houses having hanging clothes inside. Large domesticated animals were common near the house (78.9%), with 45.8% of participants reporting rubbish within 5m of their households.

Table 1
Characteristics of the study participants and households

Variables		Dry season n (%) N = 174	Wet season n (%) N = 182	Total n (%) N = 356
Age	< 20	11 (6.3)	23 (12.6)	34 (9.6)
	20–30	101 (58.1)	90 (49.5)	191 (53.7)
	30–45	62 (35.6)	69 (37.9)	131 (36.8)
Education	Illiterate	107 (61.5)	103 (56.6)	210 (59.0)
	Literate	65 (37.4)	79 (43.4)	144 (40.4)
Occupation	Farmers	115 (66.1)	134 (73.6)	249 (69.9)
	Traders	46 (26.4)	33 (18.1)	79 (22.1)
	Other	11 (6.3)	12 (6.6)	23 (6.5)
Gravidity	Primigravida	31 (17.8)	47 (25.8)	78 (21.9)
	secundigravida	42 (24.1)	32 (17.6)	74 (20.8)
	multigravida	101 (58.1)	103 (56.6)	204 (57.3)
Gestation	1st trimester	19 (10.9)	17 (9.3)	36 (10.1)
	2nd trimester	75 (43.1)	57 (31.3)	132 (37.1)
	3rd trimester	61 (35.1)	47 (25.8)	108 (30.3)
Ethnic group	Mossi	169 (97.1)	178 (97.8)	347 (97.5)
	Fulani	4 (2.3)	2 (1.1)	6 (1.7)
	Other	1 (0.6)	2 (1.1)	3 (0.8)
Roof material of sleeping room	Metal	165 (94.8)	175 (96.2)	340 (95.5)
	Non-metal (Thatch/mud)	7 (4.0)	6 (3.3)	13 (3.7)
Eave status of sleeping room	Closed	*	30 (16.5)	-
	Open	*	149 (81.9)	-
Electricity supply in the sleeping room	No	91 (52.3)	87 (47.8)	178 (50.0)
	Yes	72 (41.4)	93 (51.1)	165 (46.3)
Presence of large domestic animals within 5 m of the household	No	31 (17.8)	37 (20.3)	68 (19.1)
	Yes	138 (79.3)	143 (78.6)	281 (78.9)
Presence of solid waste within 5 m of the household	No	90 (51.7)	98 (53.8)	188 (52.8)
	Yes	79 (45.4)	84 (46.2)	163 (45.8)
Household size	< 1–3	92 (52.9)	114 (62.6)	206 (57.9)
	4–5	68 (39.1)	55 (30.2)	123 (34.6)
	≥ 6	8 (4.6)	13 (7.1)	21 (5.9)
Distance to health facility	< 3Km	100 (57.5)	98 (53.9)	198 (55.6)
	3-5Km	42 (24.1)	65 (35.7)	107 (30.1)
	> 5Km	28 (16.1%)	19 (10.4)	47 (13.2)
Hanging clothes in the sleeping room	No	28 (16.1)	92 (50.5)	120 (33.7)
	Yes	140 (80.5)	90 (49.5)	230 (64.6)

* missing data

The overall prevalence of *P. falciparum* infection (asexual stage) by microscopy was 15.7% (56/356), with 17.8% (31/174) during the dry seasonal survey and 13.7% (25/182) in the wet season survey (p = 0.3). The overall geometric mean of asexual stage parasites density (GMPD) of infected pregnant women was 777.3/μl (95% CI = 496.0-1218.2) (Table 2). GMPD was higher in the wet season (876.2/μl (95% CI = 367.0– 2092.0)) than in the dry season (705.7/μl (95% CI = 444.8–1119.5)). GMPD was higher in women in their first pregnancy (1375.5/μl (95% CI = 720.5–2626.1)) compare to those in their second pregnancy or more ((474.0/μl (95% CI = 260.1– 863.8)). GMPD was higher in women aged under 20 years old than older women, with a GMPD of 3374.7/μl (95% CI = 946.1- 12036.9) among women aged under 20 years, 633.5/μl (95% CI = 368.0-1090.7) among women aged 20–30 and 552.0/μl (95% CI = 204.8-1487.5) among women aged 30 years or more. *P. falciparum* gametocyte carriage was rare, 6/356 (1.7%) in the survey.

At the time of the survey, women had on average received 1.7 doses of IPTp-SP (95% CI = 1.5–1.8) with increasing number of doses according to the trimester of pregnancy (0.4, 1.1 and 2.3 doses at first, second and third trimester of pregnancy, respectively). Secundigravidae were more likely to report taking no IPTp (25.7%) than primigravidae (7.7%) or multigravidae women (11.3%) (p = 0.003). Women aged 20–30 years were more likely to report taking no IPTp-SP (17.8%) than women aged under 20 (8.8%) or women aged over 30 years (8.4%) (p = 0.003). There was no difference in the proportion of literate and illiterate pregnant women reporting not taking IPTp-SP in this study (p = 0.8).

A total of 95.1% of women reported using an ITN in the rainy season survey, compared to 81.5% in the dry season survey (p < 0.001). 95.2% of women reported that the National Malaria Control Program provided their ITNs. The mean age of the ITN was 7.9 months (standard deviation = 8.2) and 89.9% of them were reported to be un-holed. On average women self-reported an estimated time to bed of 20.21 h during the dry season and 20.13 h during the rainy season, and leave the bed at 05.29 h during the dry season and 5:39 h during the wet season. Only 4.5% of pregnant women reporting that they did not leave their ITN until the morning. However, 47.2% of them exited their ITN once or twice a night, and 42.7% exited their ITN three or more times a night. Mosquito coils were used by 19.4% of participants, 5.9% other types of spatial repellent (traditional repellents such as herbs or insecticide sprays) and 9.6% topical commercial repellents.

Multivariable analysis showed that *P. falciparum* infection risk in pregnancy was reduced among pregnant women who used ITNs (Odds ratio, OR = 0.31, 95% CI 0.12–0.79, p = 0.02) and with use of IPTp-SP, with each additional dose reducing the odds by 40% (OR = 0.59, 95% CI 0.43–0.81, p = 0.001) (Table 3).

Table 2
Malariometric characteristics and use of personal protection according to season

Variables	Dry season N = 174				Wet season N = 182			
	Primigravidity	Secundigravidity	Multigravidity	Total	Primigravidity	Secundigravidity	Multigravidity	Total
	n = 31	n = 42	n = 101		n = 47	n = 32	n = 103	
P. falciparum **infection**								
Parasitaemia (any level)	7 (22.6%)	10 (23.8%)	14 (13.9%)	31 (17.8%)	7 (14.9%)	2 (6.3%)	16 (15.5%)	25 (13.7%)
Parasitaemia ≥ 1000/µl	4 (12.9%)	2 (4.8%)	4 (4.0%)	10 (5.7%)	5 (10.6%)	1 (3.1%)	6 (5.8%)	12 (6.6%)
**GMPD/µl (95% CI)	1435.7 (412.7–4995.2)	738.7 (276.0–1976.8)	478.9 (263.7–869.7)	705.7 (444.8–1119.5)	2925.3 (421.0–20325.6)	Low number of observations	469.7 (160.3–1376.3)	876.2 (367.0–2092.2)
Use of personal protective measures								
Access to ITN	23 (74.2%)	37 (88.1%)	93 (93.0%)	153 (88.4%)	41 (87.2%)	32 (100%)	99 (96.1%)	172 (94.5%)
Used an ITN the previous night	21 (67.7%)	35 (83.3%)	85 (85.0%)	141 (81.5%)	42 (89.4%)	31 (96.9%)	100 (97.1%)	173 (95.1%)
Mosquito coils	8 (25.8%)	9 (21.4%)	24 (24.0%)	41 (23.7%)	10 (21.3%)	3 (9.4%)	15 (14.6%)	28 (15.4%)
Other spatial repellent	1 (3.2%)	0	5 (5.0%)	6 (3.5%)	4 (8.5%)	1 (3.1%)	10 (9.7%)	15 (8.2%)
Commercial repellent (topical)	3 (9.7%)	5 (11.9%)	9 (9.0%)	17 (9.8%)	8 (17.0%)	1 (3.1%)	8 (7.8%)	17 (9.4%)
0 dose of IPTp-SP	6 (19.4%)	15 (35.7%)	16 (15.8%)	37 (21.3%)	0	4 (12.5%)	7 (6.8%)	11 (6.0%)
1 doses of IPTp-SP	9 (29.0%)	8 (19.0%)	35 (34.7%)	52 (29.9%)	11 (23.4%)	8 (25.0%)	28 (27.2%)	47 (25.8%)
2 doses of IPTp-SP	7 (22.6%)	4 (9.5%)	23 (22.8%)	34 (19.5%)	12 (25.5%)	9 (28.1%)	35 (34.0%)	56 (30.8%)
3 or more doses of IPTp-SP	5 (16.1%)	8 (19.0%)	12 (11.9%)	25 (14.4%)	20 (42.6%)	6 (18.8%)	21 (20.4%)	47 (25.8%)
Mean IPTp-SP dose (95% CI)	1.4 (1.0-1.8)	1.3 (0.8–1.7)	1.4 (1.2–1.6)	1.4 (1.2–1.6)	2.2 (1.9–2.5)	1.8 (1.3–2.3)	1.8 (1.6–2.1)	1.9 (1.8–2.1)
Use of antimalarial drug two weeks before the survey	3 (10.7%)	6 (15.0%)	18 (18.4%)	27 (16.3%)	7 (14.9%)	2 (6.3%)	10 (9.7%)	19 (10.4%)

where CI = confidence interval, GMPD = geometric mean parasite density, IPTp-SP = intermittent preventive treatment in pregnancy with sulphadoxine pyrimethamine, ITN = insecticide treated net, SD = standard deviation

Table 3

Risk factors for P. falciparum **infection in pregnant women in Saponé Health District**

Factors		*P. falciparum* infection positivity	Univariate analysis			Multivariable analysis		
		n/N (%) N = 356	Odds Ratio	95% CI	p-value	Odds Ratio	95% CI	p-value
Pregnancy characteristics								
Gestation	1st trimester	10/48 (20.8)	1					
	2nd trimester	34/132 (25.8)	1.32	0.90–1.94	0.16			
	3rd trimester	7/108 (6.5)	0.26	0.12–0.58	0.001			
Gravidity	Primigravidae	14/78 (17.9)	1					
	Secundigravidae	12/74 (16.2)	0.88	0.48–1.64	0.70			
	Multigravidae	30/204 (14.7)	0.79	0.41–1.50	0.47			
Socio-demographic characteristics								
Mean age (years)		-	0.98	0.94–1.02				
Education	No formal education	24/210 (11.4)	1					
	Literate	31/144 (21.5)	2.13	1.29–3.52	0.003			
Occupation	Farmers	34/249 (13.7)	1					
	Traders	15/79 (19.0)	1.48	0.75–2.93	0.26			
	Other	6/23 (26.1)	2.23	0.72–6.90	0.16			
Use of personal protective measures								
ITN use the previous night	No	12/41 (29.3)	1			1		
	Yes	43/314 (13.7)	0.38	0.18–0.81	0.01	0.31	0.12–0.79	0.02
Number of exits from the ITN the previous night	2 or more times	18/152 (11.8)	1					
	Less than 2 times	31/184 (16.8)	1.51	0.84–2.71	0.17			
Number of IPTp-SP doses		-	0.57	0.41–0.80	0.001	0.59	0.43–0.81	0.001
Number of IPTp-SP doses	0	13/48 (27.1)	1					
	1 or more	43/307 (14.0)	0.44	0.17–1.15	0.09			
Mosquito coils	No	46/286 (16.1)	1					
	Yes	9 /69 (13.0)	0.78	0.48–1.29	0.33			
Other spatial repellent	No	54/335 (16.1)	1					
	Yes	2/21 (9.5)	0.55	0.09–3.53	0.53			
Commercial repellent (topical)	No	51/320 (15.9)	1					
	Yes	4/34 (11.8)	0.70	0.24–2.04	0.52			
Distance to nearest health centre	< 3km	26/198 (13.1)	1					

Factors		*P. falciparum* infection positivity	Univariate analysis			Multivariable analysis		
		n/N (%) N = 356	Odds Ratio	95% CI	p-value	Odds Ratio	95% CI	p-value
	3-5km	19/107 (17.8)	1.43	0.73–2.78	0.30			
	> 5km	10/47 (21.3)	1.79	0.66–4.83	0.25			
Use of antimalarial drug during the last two week before the survey	No	48/302 (15.9)	1					
	Yes	5/46 (10.9)	0.65	0.32–1.31	0.23			
House characteristics and construction								
Household size	< 4	31/206 (15.0)	1					
	4 ≤ no.<6	20/123 (16.3)	1.10	0.58–2.07	0.78			
	≥ 6	4/21 (19.0)	1.33	0.36–4.91	0.67			
Roof material of sleeping room	Metal	52/340 (15.3)	1					
	Thatch or mud	3/13 (23.1)	1.66	0.62–4.42	0.31			
Electricity supply in sleeping room	No	33/178 (18.5)	1					
	Yes	21/165 (12.7)	0.64	0.37–1.11	0.11			
Clothes hanging in sleeping room	No	16/120 (13.3)	1					
	Yes	38/230 (16.5)	1.29	0.58–2.84	0.53			
Asset ownership								
Own a radio	No	24/127 (18.9)	1					
	Yes	31/224 (13.8)	0.74	0.42–1.30	0.29			
Own a mobile phone	No	8/56 (14.3)	1					
	Yes	47/295 (15.9)	1.14	0.62–2.09	0.68			
Environmental factors								
Season enrolled	Dry season	31/174 (17.8)	1					
	Rainy season	25/182 (13.7)	0.73	0.41–1.31	0.30			
Presence of large domestic animals within 5 m of the household	No	10/68 (14.7)	1					
	Yes	45/281 (16.0)	1.11	0.48–2.55	0.81			
Presence of solid waste within 5 m of the household	No	30/188 (16.0)	1					
	Yes	24/163 (14.7)	0.91	0.50–1.64	0.75			

where CI = confidence interval, IPTp-SP = intermittent preventive treatment in pregnancy with with sulphadoxine pyrimethamine, ITN = insecticide-treated net

Discussion

This study aimed to identify risk factors for malaria infection in pregnant women living in an area of intense and stable seasonal malaria transmission in Burkina with increased pyrethroid resistance in malaria vectors. The overall prevalence of *P. falciparum* infection during both surveys was 15.7%. The parasite rates in this study are similar to those recorded in other studies in Burkina Faso (e.g. 18.1% [12]) and other high burden

countries in sub-Saharan Africa e.g. 20.1% in Kenya [27] and 21.6% in Ghana [28]. These results suggest that *P. falciparum* malaria infection is common in pregnant women in the community and the burden of *P. falciparum* infection in pregnancy remains high despite the use of standard malaria control interventions. The overall geometric mean of parasites density in the study area was 777.3/µl (95% CI 496.0–1218.2). Fana and co-workers from Nigeria, another high burden country, recorded a similar mean parasite density of 800/µl [16]. The high parasite densities found in pregnant women results from their decreased immune competence [4, 29]. As expected, the parasite density was higher in primigravidae and secundigravidae compared to those women multigravide and in younger women compared to older women, since younger women are more likely to be primigravid. There was no significant difference in *P. falciparum* prevalence between the wet season (13.7%) and dry season (17.8%). This may be because we conducted the dry season survey in the early stages of the dry season when infections from the end of the rains may still be present. Parasite density was, however, higher in the wet season compared to dry season, showing that even in this high burden area, malaria is seasonal in pregnancy [20]. *P. falciparum* gametocyte carriage was low in this study (1.7%). Low parasites density may result in lower gametocyte identification by microscopy.

Overall, 91.3% of pregnant women owned an ITN, with 88.2% reporting using an ITN the night before the survey. This is similar to other surveys from Burkina Faso; in the Banfora Region, 80.6 % of surveyed children reported sleeping under an ITN the previous night [18]. The high reported ITN use is encouraging, although accurately determining net use is challenging and reporting can be susceptible to response bias [30].

The study found that IPTp-SP and ITNs are highly effective interventions for preventing malaria infection during pregnancy. For each additional dose of IPTp reported as being received by women, the odds of malaria infection fell by 40%. At the time of the survey, relatively few women, had however taken three or more doses of IPTp-SP (20.2%) which is recommended by the NMCP and WHO [1, 15]. We also found lower use of IPTp-SP among women aged 20–30 compared to other age groups and among secundigravidae compared to other women. This suggests that women in their second pregnancy may be more compliant with ANC attendance and malaria prevention than women in their first pregnancy or later pregnancies. This finding contrasts with another study in Burkina Faso that found compliance with IPTp-SP in adolescent women to be more problematic due to structural constraints (e.g. social position and household labour requirements) and needs (e.g. anonymity in the health encounter) [31]. Numbers of secundigravidae women were relatively small and so this finding requires further exploration.

ITNs were associated with 69% reduction in the odds of *P. falciparum* infection, which is higher than other studies have found [32]. This indicates that ITNs are protective against malaria in pregnancy despite high levels of insecticide resistance present in Burkina Faso [33, 34]. This contrasts with findings from a cohort study in children aged 5–15 years in south-west Burkina Faso which showed no difference in malaria risk between ITN users and non-users [18], and in all age in a community-wide survey in Banfora region (Yaro *et al*, unpublished). Women reported going to bed at 20.21 h during the dry season and 20.13 h during the rainy season. This finding contrasts with a study by Guglielmo and co-workers who reported that 100% of females in south-west Burkina Faso (sample of 211 and 695 females observed in two villages) were outdoors until 22.00 h, after which point women started to move indoors to bed [35]. It may be that pregnant women tend to go to bed earlier and so those using ITNs are more likely to be protected from vectors biting during the early evening which has been observed in Burkina Faso [35]. Increased malaria risk in human including pregnant women who go to bed later has been observed in other studies in sub-Saharan Africa [36–38].

Our study has a number of limitations. Firstly, the sample size was probably not large enough to identify minor risk factors in this study. Secondly, ITN ownership and use was self-reported and subject to social desirability bias and we lack objective tools for measuring bednet use in this study.

What are the implications of this research for control of malaria in pregnancy in Burkina Faso? Behaviour change communication is necessary to ensure high ANC attendance and compliance with IPTp-SP and ITN use. Messages need to be tailored to the different vulnerable groups of women. For example, we found lower IPTp-SP compliance among women aged 20–30 than the other age groups. As it this common in sub-Saharan Africa, pregnant women are often unaware that they are pregnant and so do not attend or are unwilling to attend an ANC in the early stages of pregnancy. An association between early ANC attendance and a higher average number of IPTp-SP doses has been demonstrated in several studies [39–41]. One option to increase IPTp-SP coverage is community delivery by community health workers, rather than ANC. This delivery route has been shown in a clinical trial in Burkina Faso to increase IPTp-SP compliance from 2.1 to 2.8 doses in the community delivery study arm with no apparent decrease in ANC attendance [42].

Conclusion

The prevalence of *P. falciparum* infection among pregnant women remained high despite wide deployment of ITNs and access to IPTp-SP. Nonetheless, women who took IPTp-SP and use ITNs during their pregnancy were at much reduced risk of being infected by malaria. These findings suggest that IPTp-SP and ITNs use are effective at reducing malaria infection in pregnant women living in malaria high burden countries, but that research is needed to increase uptake of IPTp-SP.

Declarations

Ethics approval and consent to participate

Study participants provided informed consent before they were enrolled in the study. The caregivers of study participants aged <20 years provided informed consent (while participants provided assent). Study documents were approved by the Burkina Faso Ministry of Health Research Ethics Committee, CNRFP Institutional Bioethics Committee, the London School of Hygiene and Tropical Medicine ethical Committee and Durham University Department of Biosciences Ethics Committee. The study was conducted in compliance with principles set out by the International Conference on Harmonization Good Clinical Practice, the Declaration of Helsinki and the regulatory requirements of Burkina Faso.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests. All authors declare that they had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Authors' contributions

Conceived and designed the study: JBY, ABT, SWL, ALW. Conducted field and laboratory work: JBY, ABT, AO, SS, AD. Conducted data analysis: JBY, SWL, ALW, ABT, ZAO, AO. Contributed to and approved the final manuscript: JBY, AO, AD, SS, ZAO, INO, TB, CD, SBS, ABT, SWL, ALW. All authors read and approved the final manuscript.

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