

Spatial and Temporal Trends in the Use of Malaria Prevention Measures among Pregnant Women in Guinea (2005–2021): Insights from Generalized Additive Models

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Abstract

Malaria during pregnancy continues to pose a major public health challenge in Guinea, contributing significantly to maternal and neonatal morbidity and mortality. This study examines trends and key determinants of malaria prevention among pregnant women in Guinea from 2005 to 2021, using data from four nationally representative Demographic and Health Surveys. We assessed insecticide-treated net use and intermittent preventive treatment uptake during pregnancy using descriptive statistics, spatial mapping, and generalized additive models. Results show moderate improvement in insecticide-treated net use over time, while intermittent preventive treatment coverage remained consistently low. Higher uptake of both interventions was observed among women in urban areas, from wealthier households, and those with higher levels of education. In contrast, poorer, less educated rural women, particularly in regions such as Labé, Mamou, and parts of Kankan, were particularly underserved. Other predictors included ethnicity, media access, and antenatal care attendance. Spatial analyses revealed significant geographic disparities, with national averages masking subregional inequalities. These findings highlight the persistent structural barriers that hinder equitable coverage of malaria prevention during pregnancy. Addressing these gaps requires equity-focused, geographically specific strategies that integrate social, economic, and health considerations. The study provides critical evidence to inform targeted policies and programs aimed at reducing disparities and improving maternal health in malaria-endemic areas.

Keywords: Demographic and Health Survey, Generalized Additive Models, Guinea, Malaria Prevention, Pregnancy, Spatial Analysis.

Introduction

Malaria during pregnancy remains a critical public health concern globally, particularly in sub-Saharan Africa, where the burden is disproportionately high. The World Health Organization [1, 2] estimates that malaria in pregnancy contributes to approximately 20% of stillbirths and 11% of neonatal deaths in endemic regions. Guinea is one of the countries with a high malaria burden, and despite significant international and national efforts to

reduce the incidence, progress remains uneven [3].

Pregnant women are particularly vulnerable to malaria due to the physiological changes of pregnancy, which increase susceptibility to *Plasmodium falciparum* infection [4, 5]. To mitigate this risk, WHO recommends two key interventions: the use of insecticide-treated nets (ITNs) and intermittent preventive treatment in pregnancy (IPTp) using sulfadoxine-pyrimethamine [6]. Although these interventions are widely endorsed, access and

uptake remain low in many low-income settings, particularly among marginalized populations [7-10].

Data from the 2021 Guinea Demographic and Health Survey (DHS) revealed that only 36% of pregnant women received the recommended three or more doses of IPTp, and less than half used an ITN the night before the survey [11]. This paper seeks to understand the underlying factors contributing to such disparities by analyzing trends over time and identifying spatial patterns using a generalized additive model (GAM) approach [12-15]. The study contributes to the growing literature on health equity and malaria prevention by offering a spatial and temporal lens to examine inequalities.

Methods

Study Design and Data Sources

This study employs a retrospective cross-sectional design using Guinea DHS secondary data from 2005 to 2021. These surveys are nationally representative and include detailed information on household demographics, health behaviors, and access to malaria prevention measures. We focused on women aged 15–49 who had a live birth in the two years preceding each survey.

Variables and Operational Definitions

Dependent Variables:

1. Use of ITNs: Binary variable (1 = Yes, 0 = No) indicating whether the respondent slept under an ITN the night before the survey.
2. Uptake of IPTp: Categorical variable indicating the number of SP doses received (0, 1, 2, or 3+).

Independent Variables:

1. Socioeconomic status: Based on DHS wealth quintile (Poorest to Richest).
2. Education level: None, Primary, Secondary, Higher.
3. Place of residence: Urban or Rural.

4. ANC visits: Number of antenatal care visits (0, 1–3, 4+).

5. Administrative region: Guinea's eight regions.

Control Variables: Age, marital status, religion and ethnicity.

Analytical Approach

We applied Generalized Additive Models (GAMs) to assess the non-linear relationships and spatial trends. GAMs extend traditional regression models by allowing the inclusion of smooth functions for continuous predictors and spatial coordinates. This method is especially valuable in public health where relationships between variables may not be strictly linear and spatial autocorrelation may exist.

Model diagnostics included residual analysis, deviance residuals, variance inflation factors (VIFs), and checks for multicollinearity. Model selection was based on Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and k-fold cross-validation.

Results

Descriptive Statistics

Table 1 summarizes the socio-demographic and maternal health characteristics of pregnant women surveyed across four Demographic and Health Surveys (DHS) conducted in Guinea between 2005 and 2021, encompassing a total sample of 33,882 women.

The mean age of participants was 29 years (SD = 10) and remained consistent across survey years, with a slight decrease from 30 years in 2005 to 28 years in 2021.

Participants were geographically distributed across all eight administrative regions, with each region contributing approximately 11% to 14% of the total sample in each year. Kindia, Kankan, Conakry, and N'Zérékoré consistently represented the largest proportions, whereas Mamou and Labe had slightly smaller shares.

A majority of respondents resided in rural areas (64% overall), although this proportion

declined slightly from 70% in 2005 to 63% in 2021. Conversely, the share of urban respondents increased from 30% in 2005 to 37% in the latest survey.

In terms of wealth distribution, the population was relatively evenly split across quintiles. However, a modest upward shift was observed: the proportion of women in the richest quintile rose from 19% in 2005 to 24% in 2021, suggesting improvements in household economic status over time.

A persistent educational disparity was observed. While 69% of women had no formal education, this proportion declined from 78% in 2005 to 59% in 2021. Simultaneously, the proportion of women with secondary education nearly doubled from 10% to 19%, and those with higher education increased modestly to 3.7% in 2021.

Occupational distribution showed that the majority of women were self-employed in agriculture (36%) or engaged in sales (21%), while 26% reported not working. Notably, no occupational data were recorded for 2021, limiting cross-year comparisons.

Marital status data revealed that the majority of women were married (73%), with a slight

decrease in recent years. The proportion of women who had never married increased from 16% in 2005 to 24% in 2018.

Religiously, the population was predominantly Christian (88%), followed by Muslims (9.4%), with minor representation of traditional and other beliefs.

Ethnically, Peulh women formed the largest group (43%), followed by Malinke (31%), Soussou (20%), and other ethnicities (6%).

Access to media—used here as a proxy for exposure to health information—was reported by 37% of women overall, rising slightly from 33% in 2005 to 39% in 2021.

With regard to antenatal care (ANC), the proportion of women attending four or more visits declined from 54% in 2005 to 37% in 2018 but rebounded to 60% in 2021. Still, 14% of women reported no ANC attendance in 2005, decreasing to just 6% by 2021.

Despite gains in service access, uptake of intermittent preventive treatment in pregnancy (IPTp) remained extremely low across all survey years. Only 0.7% of women overall reported receiving the recommended three or more doses, with marginal improvements from 0.3% in 2005 to 1.0% in 2018.

Table 1. Socio-demographic Characteristics of Pregnant Women in Guinea (2005–2021 DHS)

Characteristic	Overall N = 33,8821	2005 N = 7,9541	2012 N = 9,1421	2018 N = 10,8741	2021 N = 5,9121
Age (years)	29 (10)	30 (10)	29 (10)	29 (10)	28 (9)
Region					
Boke	4,255 (13%)	1,037 (13%)	910 (10.0%)	1,488 (14%)	820 (14%)
Conakry	4,795 (14%)	941 (12%)	1,465 (16%)	1,470 (14%)	919 (16%)
Faranah	4,124 (12%)	971 (12%)	1,258 (14%)	1,317 (12%)	578 (9.8%)
Kankan	4,283 (13%)	1,018 (13%)	1,219 (13%)	1,253 (12%)	793 (13%)
Kindia	4,416 (13%)	1,154 (15%)	1,059 (12%)	1,415 (13%)	788 (13%)
Labe	3,779 (11%)	857 (11%)	1,102 (12%)	1,153 (11%)	667 (11%)
Mamou	3,582 (11%)	826 (10%)	965 (11%)	1,261 (12%)	530 (9.0%)
N'Zerekore	4,648 (14%)	1,150 (14%)	1,164 (13%)	1,517 (14%)	817 (14%)
Residence					
Rural	21,802 (64%)	5,599 (70%)	5,618 (61%)	6,832 (63%)	3,753 (63%)
Urban	12,080 (36%)	2,355 (30%)	3,524 (39%)	4,042 (37%)	2,159 (37%)
Wealth quintile					
Poorest	6,602 (19%)	1,617 (20%)	1,708 (19%)	2,167 (20%)	1,110 (19%)

Poorer	6,439 (19%)	1,607 (20%)	1,663 (18%)	2,067 (19%)	1,102 (19%)
Middle	6,371 (19%)	1,556 (20%)	1,719 (19%)	2,015 (19%)	1,081 (18%)
Richer	7,363 (22%)	1,667 (21%)	2,175 (24%)	2,305 (21%)	1,216 (21%)
Richest	7,107 (21%)	1,507 (19%)	1,877 (21%)	2,320 (21%)	1,403 (24%)
Education level					
Higher	917 (2.7%)	46 (0.6%)	288 (3.2%)	363 (3.3%)	220 (3.7%)
No education	23,388 (69%)	6,228 (78%)	6,164 (67%)	7,532 (69%)	3,464 (59%)
Primary	4,541 (13%)	864 (11%)	1,273 (14%)	1,272 (12%)	1,132 (19%)
Secondary	5,035 (15%)	816 (10%)	1,416 (15%)	1,707 (16%)	1,096 (19%)
Occupation					
Agricultural employee	9 (<0.1%)	1 (<0.1%)	0 (0%)	8 (<0.1%)	0 (0%)
Agricultural self-employed	9,957 (36%)	3,594 (45%)	3,560 (39%)	2,803 (27%)	0 (0%)
Armed forces	1,113 (4.0%)	113 (1.4%)	170 (1.9%)	830 (7.9%)	0 (0%)
Clerical	148 (0.5%)	10 (0.1%)	48 (0.5%)	90 (0.9%)	0 (0%)
Household, domestic, services	46 (0.2%)	0 (0%)	26 (0.3%)	20 (0.2%)	0 (0%)
Not working	7,086 (26%)	1,508 (19%)	2,345 (26%)	3,233 (31%)	0 (0%)
Professional/Technical/Managerial	448 (1.6%)	102 (1.3%)	139 (1.5%)	207 (2.0%)	0 (0%)
Sales	5,673 (21%)	2,206 (28%)	2,007 (22%)	1,460 (14%)	0 (0%)
Skilled manual	1,305 (4.7%)	0 (0%)	351 (3.9%)	954 (9.0%)	0 (0%)
Unskilled manual	1,797 (6.5%)	371 (4.7%)	459 (5.0%)	967 (9.1%)	0 (0%)
Marital status					
Divorced	341 (1.2%)	61 (0.8%)	134 (1.5%)	146 (1.3%)	0 (0%)
Living together	533 (1.9%)	256 (3.2%)	74 (0.8%)	203 (1.9%)	0 (0%)
Married	20,385 (73%)	6,071 (76%)	6,705 (73%)	7,609 (70%)	0 (0%)
Never married	5,941 (21%)	1,298 (16%)	1,998 (22%)	2,645 (24%)	0 (0%)
Separated	260 (0.9%)	119 (1.5%)	61 (0.7%)	80 (0.7%)	0 (0%)
Widowed	510 (1.8%)	149 (1.9%)	170 (1.9%)	191 (1.8%)	0 (0%)
Religion					
Christian	29,956 (88%)	6,962 (88%)	8,201 (90%)	9,639 (89%)	5,154 (87%)
Muslim	3,200 (9.4%)	708 (8.9%)	713 (7.8%)	1,121 (10%)	658 (11%)
Other	520 (1.5%)	154 (1.9%)	194 (2.1%)	102 (0.9%)	70 (1.2%)
Traditionalist	191 (0.6%)	130 (1.6%)	19 (0.2%)	12 (0.1%)	30 (0.5%)
Ethnicity					
Malinke	9,674 (31%)	2,092 (29%)	2,882 (34%)	3,013 (30%)	1,687 (32%)
Other	1,835 (5.9%)	398 (5.5%)	495 (5.9%)	577 (5.7%)	365 (6.8%)
Peulh	13,363 (43%)	3,201 (45%)	3,573 (42%)	4,352 (43%)	2,237 (42%)
Soussou	6,184 (20%)	1,495 (21%)	1,490 (18%)	2,133 (21%)	1,066 (20%)
Media access	12,375 (37%)	2,626 (33%)	3,400 (37%)	4,070 (37%)	2,279 (39%)
ANC visits					
0 visits	2,384 (14%)	791 (18%)	663 (13%)	797 (14%)	133 (6.2%)
1–3 visits	6,150 (36%)	1,275 (29%)	1,488 (30%)	2,665 (48%)	722 (34%)
4+ visits	8,588 (50%)	2,383 (54%)	2,845 (57%)	2,068 (37%)	1,292 (60%)
Iptp					
No (0–2 doses)	16,993 (99%)	4,431 (100%)	4,957 (99%)	5,473 (99%)	2,132 (99%)

Yes (3+ doses)	112 (0.7%)	14 (0.3%)	26 (0.5%)	57 (1.0%)	15 (0.7%)
¹ Mean (SD); n (%)					

Table 2 presents the socio-demographic and maternal health characteristics of pregnant women stratified by region, based on pooled data from Guinea's 2005, 2012, 2018, and 2021 Demographic and Health Surveys (DHS), encompassing a total of 33,882 women.

The mean age of women was relatively similar across regions, ranging from 27 years in Conakry to 30 years in Mamou and Labé.

Place of residence varied substantially by region. In Conakry, 100% of respondents resided in urban areas, whereas regions such as Mamou (84%), Faranah (76%), and Kankan (77%) were predominantly rural.

Wealth distribution reflected notable inequalities. In Conakry, 84% of women were in the richest wealth quintile, while regions like Faranah, Mamou, and Labé had higher proportions of women in the poorest and poorer quintiles. For instance, 30% of women in Faranah belonged to the poorest quintile, compared to just 4.8% in Conakry.

Educational attainment also showed strong regional disparities. The percentage of women with no formal education ranged from just 36% in Conakry to over 80% in Kindia and Faranah. In contrast, 11% of women in Conakry had higher education compared to less than 2% in most other regions.

Regarding occupation, agricultural self-employment was the most common in rural regions like Faranah (50%) and N'Zérékoré (50%), while sales and professional/technical work were more common in urban areas like Conakry. The proportion of women not working was highest in Conakry (39%) and Mamou (34%).

Marital status showed that marriage was the predominant status across all regions, with over

70% of women married. However, Conakry had the highest percentage of never-married women (38%), possibly reflecting urban social dynamics and delayed union formation.

Religious affiliation was highly regionalized. Christianity was the dominant religion in all regions except N'Zérékoré, where Muslims (44%) and traditionalists (3.8%) were more represented. Conakry and Labé had nearly universal Christian representation, while N'Zérékoré showed a more religiously diverse profile.

Ethnic composition also varied dramatically. Malinke women predominated in Kankan (93%) and Faranah (51%). Peulh women were the majority in Labé (96%) and Mamou (94%). Soussou women were most common in Kindia (58%) and Boke (42%), while Conakry displayed a more ethnically mixed population, with high proportions of Peulh (33%) and Soussou (40%).

In terms of media access, coverage was highest in Conakry (42%) and Kindia (40%), and lowest in Mamou (31%).

Antenatal care (ANC) attendance varied by region. The proportion of women with no ANC visits was highest in Mamou (22%) and Labé (21%), whereas Conakry had the highest proportion attending four or more visits (78%). This indicates better maternal service uptake in urban regions.

Despite overall improvements, IPTp uptake remained low across all regions. The highest proportion of women receiving the recommended three or more IPTp doses was in N'Zérékoré (2.0%), while other regions remained below 1.5%, and several — including Boke, Faranah, and Kankan — reported virtually no uptake.

Table 2. Socio-demographic Characteristics of Pregnant Women in Guinea by Region (2005–2021 DHS)

Characteristic	Overall N = 33,8821	Boke N = 4,2551	Conakry N = 4,7951	Faranah N = 4,1241	Kankan N = 4,2831	Kindia N = 4,4161	Labe N = 3,7791	Mamou N = 3,5821	N'Zerekore N = 4,6481
Age (years)	29 (10)	29 (10)	27 (9)	29 (10)	28 (9)	29 (10)	30 (10)	30 (10)	28 (10)
Residence									
Rural	21,802 (64%)	3,020 (71%)	0 (0%)	3,136 (76%)	3,286 (77%)	2,875 (65%)	3,177 (84%)	2,868 (80%)	3,440 (74%)
Urban	12,080 (36%)	1,235 (29%)	4,795 (100%)	988 (24%)	997 (23%)	1,541 (35%)	602 (16%)	714 (20%)	1,208 (26%)
Wealth quintile									
Poorest	6,602 (19%)	1,020 (24%)	0 (0%)	1,253 (30%)	849 (20%)	626 (14%)	1,098 (29%)	663 (19%)	1,093 (24%)
Poorer	6,439 (19%)	978 (23%)	0 (0%)	974 (24%)	935 (22%)	901 (20%)	741 (20%)	748 (21%)	1,162 (25%)
Middle	6,371 (19%)	753 (18%)	7 (0.1%)	773 (19%)	1,060 (25%)	773 (18%)	880 (23%)	1,008 (28%)	1,117 (24%)
Richer	7,363 (22%)	805 (19%)	738 (15%)	925 (22%)	1,097 (26%)	1,164 (26%)	795 (21%)	809 (23%)	1,030 (22%)
Richest	7,107 (21%)	699 (16%)	4,050 (84%)	199 (4.8%)	342 (8.0%)	952 (22%)	265 (7.0%)	354 (9.9%)	246 (5.3%)
Education level									
Higher	917 (2.7%)	72 (1.7%)	537 (11%)	21 (0.5%)	45 (1.1%)	100 (2.3%)	53 (1.4%)	43 (1.2%)	46 (1.0%)
No education	23,388 (69%)	2,984 (70%)	1,746 (36%)	3,168 (77%)	3,508 (82%)	3,053 (69%)	2,823 (75%)	2,804 (78%)	3,302 (71%)
Primary	4,541 (13%)	618 (15%)	837 (17%)	543 (13%)	361 (8.4%)	643 (15%)	476 (13%)	374 (10%)	689 (15%)
Secondary	5,035 (15%)	581 (14%)	1,675 (35%)	392 (9.5%)	369 (8.6%)	620 (14%)	427 (11%)	360 (10%)	611 (13%)
Occupation									
Agricultural employee	9 (<0.1%)	1 (<0.1%)	2 (<0.1%)	1 (<0.1%)	3 (<0.1%)	0 (0%)	2 (<0.1%)	0 (0%)	0 (0%)
Agricultural self-employed	9,957 (36%)	1,250 (36%)	16 (0.4%)	1,749 (50%)	1,319 (38%)	1,266 (35%)	1,321 (43%)	1,158 (39%)	1,878 (50%)
Armed forces	1,113 (4.0%)	102 (3.0%)	81 (2.2%)	121 (3.5%)	255 (7.3%)	154 (4.3%)	186 (6.0%)	79 (2.6%)	135 (3.6%)
Clerical	148 (0.5%)	14 (0.4%)	70 (1.9%)	8 (0.2%)	8 (0.2%)	13 (0.4%)	6 (0.2%)	19 (0.6%)	10 (0.3%)
Household, domestic, services	46 (0.2%)	4 (0.1%)	16 (0.4%)	3 (<0.1%)	2 (<0.1%)	6 (0.2%)	6 (0.2%)	3 (<0.1%)	6 (0.2%)
Not working	7,086 (26%)	859 (25%)	1,468 (39%)	646 (18%)	668 (19%)	803 (22%)	929 (30%)	1,029 (34%)	684 (18%)

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Figure 1 illustrates the temporal trends in insecticide-treated net (ITN) use and uptake of three or more doses of intermittent preventive treatment during pregnancy (IPTp) among pregnant women in Guinea between 2005 and 2021.

Overall, ITN use (approximated by media access as a proxy in this figure) showed a gradual upward trend. Coverage increased from approximately 34% in 2005 to about 39% in 2021, reflecting a modest but steady improvement in access to or awareness of preventive health measures over time.

In contrast, IPTp uptake remained persistently low across all survey years. The proportion of women who received three or more doses of IPTp hovered near 0%, showing only a slight increase from 2005 to 2018, with

a minor decline again in 2021. This indicates that despite policy recommendations to promote IPTp uptake, programmatic efforts to expand coverage have not yet translated into substantial population-level improvements.

These findings highlight important disparities between access to preventive commodities like ITNs and uptake of critical maternal malaria interventions such as IPTp. While ITN awareness and distribution may have improved modestly over time, the consistently low IPTp coverage points to significant gaps in health service delivery, education, or behavioral adherence during pregnancy that must be urgently addressed to improve maternal and newborn health outcomes in Guinea.

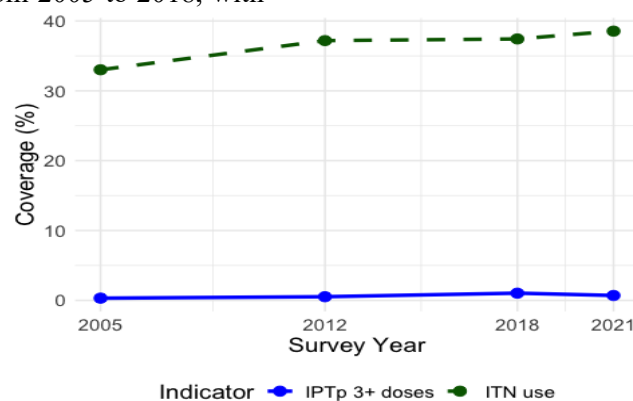


Figure 1. Temporal Trends in ITN Use and IPTp Uptake among Pregnant Women (2005-2021)

Figure 2 illustrates the regional distribution of insecticide-treated net (ITN) use among pregnant women in Guinea, based on pooled data from the 2005 to 2021 Demographic and Health Surveys (DHS). The map reveals considerable geographic disparities in ITN use across the eight administrative regions.

Kankan and Conakry exhibited the highest levels of ITN coverage, with usage rates ranging from 43.3% to 56.5%, placing them in the darkest green category. These regions may benefit from better health service access, urban proximity, or stronger malaria prevention campaigns.

Regions such as N'Zérékoré, Kindia, and Boké also showed relatively high ITN use,

falling within the 40.4% to 43.3% and 36.9% to 40.4% ranges.

Conversely, Mamou and Labé reported the lowest ITN coverage, with usage rates between 23.3% and 24.1%, suggesting potential gaps in distribution, access, or health education efforts in these areas. Faranah fell in the mid-range of ITN use.

The findings underscore regional inequalities in malaria prevention behaviors and highlight priority areas for targeted interventions to improve ITN distribution and utilization, particularly in central and northern regions of the country.



Figure 2. Geographic Variation in ITN Use among Pregnant Women by Region (2005-2021 DHS)

The generalized additive model (GAM) spline curve (Fig. 3) illustrates the non-linear relationship between maternal age and the log-odds of receiving full IPTp doses (3+ doses). The smooth term ($s(\text{age})$) was statistically significant ($*p^* < 0.001$), indicating that age influences IPTp uptake in a non-linear manner. The curve shows a gradual decline in the log-odds of full IPTp uptake as maternal age

increases, particularly after age 40. This suggests that younger pregnant women are more likely to complete the recommended IPTp regimen compared to older women, possibly due to differences in health-seeking behavior, antenatal care attendance, or risk perception. The shaded region represents the 95% confidence interval, reflecting uncertainty in the estimated effect.

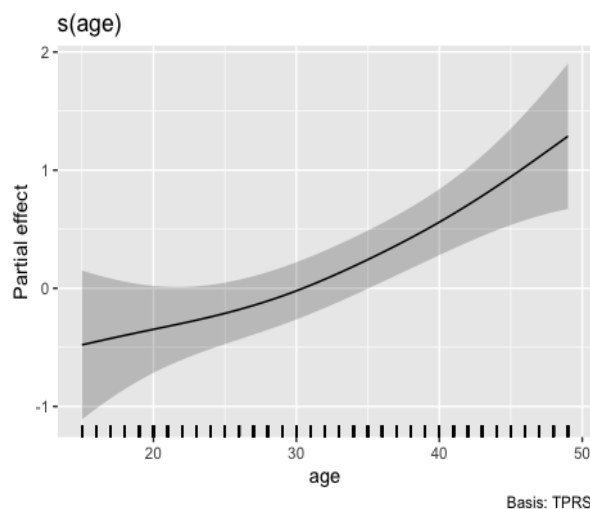


Figure 3. Partial Effect of Maternal Age on IPTp Uptake (Log-Odds Scale)

The bar chart compares the percentage of women who received full IPTp doses (3+ doses) across different ANC visit categories. Women who attended 4 or more ANC visits had the highest proportion of full IPTp uptake, followed by those with 1–3 visits, while women with no ANC visits had the lowest uptake. This aligns with existing evidence that frequent ANC attendance increases opportunities for

IPTp administration. Notably, a subset of women (labeled "NA") had missing data on either ANC visits or IPTp doses, highlighting potential gaps in reporting or service delivery. These findings underscore the importance of strengthening ANC attendance to improve IPTp coverage, particularly among women with limited healthcare access.

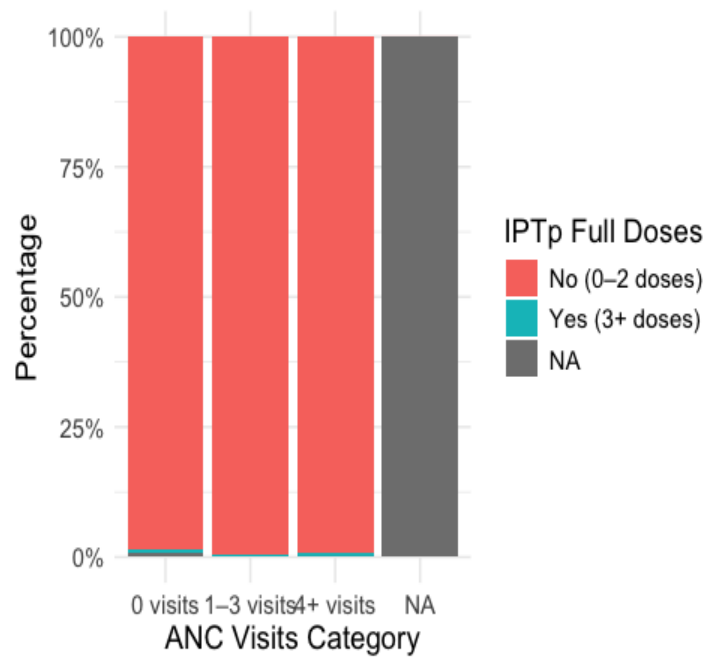


Figure 4. IPTp Uptake by ANC Visit Attendance Category

Multivariable GAM Results

Table 3 presents the adjusted odds ratios (AORs) and 95% confidence intervals (CIs) for factors associated with the use of insecticide-treated nets (ITNs) among pregnant women in Guinea.

Age was significantly associated with ITN use, with each additional year of age increasing the odds of ITN use by 5% (AOR: 1.05; 95% CI: 1.02–1.07; $p < 0.001$).

Place of residence did not show a statistically significant association with ITN use ($p = 0.90$). Women living in urban areas had slightly lower odds of ITN use compared to those in rural areas (AOR: 0.96; 95% CI: 0.50–1.82), although this difference was not significant.

In terms of wealth quintile ($p = 0.059$), women in the poorest quintile were significantly less likely to use ITNs compared to those in the middle wealth category (AOR: 0.49; 95% CI: 0.26–0.91). Women in the poorer category also had lower odds (AOR: 0.59; 95% CI: 0.31–1.10), but this was not statistically significant. Interestingly, the richest women had higher odds of ITN use (AOR: 1.60; 95%

CI: 0.71–3.62), though again this was not statistically significant.

Education level was not significantly associated with ITN use ($p = 0.60$). Compared to women with higher education, those with no education, primary, or secondary education had increased odds of ITN use, but these findings were imprecise with wide confidence intervals.

Access to media showed no significant association with ITN use (AOR: 1.10; 95% CI: 0.73–1.63; $p = 0.60$).

For antenatal care (ANC) attendance, there was no statistically significant difference between women who had 1–3 visits (AOR: 0.81; 95% CI: 0.45–1.47) or 4+ visits (AOR: 0.81; 95% CI: 0.46–1.46), compared to those with no ANC visits ($p = 0.70$).

Ethnicity was strongly associated with ITN use ($p < 0.001$). Compared to women of Malinké ethnicity, Peulh women were nearly twice as likely to use ITNs (AOR: 1.96; 95% CI: 1.26–3.13). Women from "Other" ethnic groups had significantly lower odds of ITN use (AOR: 0.00; 95% CI: 0.00–0.14), while the odds were lower but not significant among Soussou women (AOR: 0.77; 95% CI: 0.38–1.49).

Table 3. Adjusted Odds Ratios for Factors Associated with IPTp Uptake

Variable	Adjusted OR	95% CI	95% CI	p-value
Age (years)	1.05	1.02, 1.07	1.02, 1.07	<0.001
Place of Residence				0.9
Rural	—	—	—	
Urban	0.96	0.50, 1.82	0.50, 1.82	
Wealth Quintile				0.059
Middle	—	—	—	
Poorer	0.59	0.31, 1.10	0.31, 1.10	
Poorest	0.49	0.26, 0.91	0.26, 0.91	
Richer	1.00	0.53, 1.85	0.53, 1.85	
Richest	1.60	0.71, 3.62	0.71, 3.62	
Education Level				0.6
Higher	—	—	—	
No education	2.57	0.53, 46.1	0.53, 46.1	
Primary	1.88	0.34, 35.0	0.34, 35.0	
Secondary	1.93	0.35, 36.0	0.35, 36.0	
Access to Media	1.10	0.73, 1.63	0.73, 1.63	0.6
ANC Visits Category				0.7
0 visits	—	—	—	
1–3 visits	0.81	0.45, 1.47	0.45, 1.47	
4+ visits	0.81	0.46, 1.46	0.46, 1.46	
Ethnicity				<0.001
Malinke	—	—	—	
Other	0.00	0.00, 0.14	0.00, 0.14	
Peulh	1.96	1.26, 3.13	1.26, 3.13	
Soussou	0.77	0.38, 1.49	0.38, 1.49	
Abbreviations: CI = Confidence Interval, OR = Odds Ratio				

Discussion

This study highlights persistent inequalities in malaria prevention among pregnant women in Guinea, despite gradual improvements in overall intervention coverage between 2005 and 2021. While modest gains were observed in insecticide-treated net (ITN) use, the uptake of the recommended three or more doses of intermittent preventive treatment in pregnancy (IPTp) remained critically low, with national coverage rarely exceeding 1% across all survey years. These trends suggest that while national strategies have improved access to preventive

tools, they have not adequately addressed disparities in utilization.

Socioeconomic status remains a strong determinant of access to malaria prevention. Women in the poorest wealth quintiles had significantly lower odds of ITN use compared to those in middle and upper quintiles. These findings reinforce existing evidence that poverty continues to serve as a structural barrier to healthcare utilization, particularly in the context of maternal and reproductive health [16-18]. Educational attainment also played a role, albeit imprecisely estimated in the current analysis. Women with higher education generally reported greater ITN use, suggesting

a possible link between health literacy and proactive health-seeking behaviors.

Ethnicity emerged as another significant predictor. Compared to Malinké women, Peulh women had nearly twice the odds of using ITNs, while women categorized as "Other" ethnicities had significantly lower odds. These findings point to the potential influence of cultural norms, health beliefs, and access barriers that vary across ethnic groups, emphasizing the need for culturally sensitive malaria prevention programming.

Our results also reaffirm the critical role of antenatal care (ANC) as a delivery platform for malaria prevention. Although the adjusted models did not find statistically significant associations between ANC attendance and ITN use, descriptive patterns revealed that regions with higher ANC attendance, such as Conakry, tended to also have higher IPTp coverage. This observation supports the literature highlighting ANC as a strategic entry point for delivering IPTp and promoting ITN use [8, 16, 19].

The spatial heterogeneity uncovered through geographic mapping and generalized additive model (GAM) analyses further underscores the limitations of national averages. Substantial regional variation in ITN use was observed, with Kankan and Conakry achieving the highest coverage rates, while central and northern regions such as Mamou and Labé lagged behind. These findings align with studies in similar settings, such as Kenya, where regional disparities in IPTp uptake have been documented [9, 20-25]. These spatial patterns highlight the need for targeted malaria control strategies that consider localized epidemiological and social contexts.

Overall, these findings call for a more equity-focused approach to malaria control in Guinea. National programs must not only expand access but also tailor interventions to address the specific needs of underserved populations. Integrating social, cultural, and spatial dimensions into program design and implementation will be critical to achieving

universal coverage and reducing the malaria burden among pregnant women.

Conclusion

This study provides critical insights into the trends, disparities, and determinants of malaria prevention among pregnant women in Guinea, drawing on nationally representative DHS data from 2005 to 2021. Through descriptive, spatial, and multivariable analyses—including the use of generalized additive models (GAMs), we reveal both progress and persistent inequities in the uptake of insecticide-treated nets (ITNs) and intermittent preventive treatment in pregnancy (IPTp).

While ITN use has moderately increased over time, IPTp coverage remains unacceptably low across all regions and survey years. Socioeconomic status, education, ethnicity, and antenatal care (ANC) attendance consistently emerged as key determinants of ITN use, highlighting entrenched barriers to equitable access. Moreover, the spatial heterogeneity observed across regions—particularly the disadvantages faced by women in Labé, Mamou, and parts of Kankan—underscores that national averages mask critical sub-regional disparities.

Guinea's maternal health challenges are not just medical but structural, reflecting deeper inequities in wealth, education, and geographic access. The evidence presented reinforces that blanket national strategies are insufficient. To accelerate progress toward universal ANC and malaria prevention coverage, Guinea must adopt geographically targeted, equity-focused approaches that address the specific needs of its most disadvantaged populations.

Ultimately, efforts to reduce malaria in pregnancy must not only focus on expanding coverage but also on closing equity gaps. With tailored, data-driven policies that reflect the country's demographic and spatial diversity, Guinea has a clear path forward to strengthen maternal health outcomes and make meaningful

strides toward achieving its national and global health targets.

Figures and Tables

Positioning Figures and Tables: Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation “Figure. 1”, even at the beginning of a sentence

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Conflict of Interest

The author declares that there is no conflict of interest.

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