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Individual and Contextual Factors Associated with Malaria among Children 6-59 Months in Nigeria: A Multilevel Mixed Effect Logistic Model Approach

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Abstract: *Background/Purpose:* Over the last two decades, malaria has remained a major worldwide public health concern, especially in the developing countries leading to high morbidity and mortality among children. Nigeria is the world most burdened malaria endemic nation, contributing more than a quarter of global malaria cases. This study determined the prevalence of malaria among children 6-59 months in Nigeria, and the effects of individual and contextual factors. *Methods:* The study utilized data from 2018 Nigeria Demographic and Health Survey (NDHS) involving a weighted sample size of 10,185 children who were tested for malaria using rapid diagnostic test (RDT). Given the hierarchical structure of the data set, such that children at level-1 are nested in community at level-2, and nested in states and Federal Capital Territory (FCT) at level-3, multilevel mixed effect logistic regression models were used for the analysis. *Results:* The proportion of children 6-59 months of age in Nigeria that had malaria fever positive as assessed by RDTs was 35.5% (3,418/10185), (CI: 33.9-37.1). Kebbi State had the highest proportion of children 6-59 months who were malaria positive, 77.6%, (CI: 70.2-83.5), followed by Katsina State, 55.5%, (CI: 47.7-63.1). The Federal Capital Territory (FCT), Abuja had the proportion of 29.6%, (CI: 21.6-39.0), malaria positive children of 6-59 months of age. Children between the age of 48 and 59 months were 2.68 times more likely to have malaria fever than children 6-11 months of age (AOR=2.68, 95% CI: 2.03-3.54). Also, children from the rural area (AOR= 2.12, 95% CI: 1.75-2.57), were more likely to suffer from malaria infection compare with children from urban area. *Conclusion:* The study identified some individual and contextual predictors of malaria among children in Nigeria. These factors are areas that need to be considered for policy designs and implementations toward control and total elimination of malaria-related morbidity and mortality among children in Nigeria.

Keywords: malaria; fever; *Plasmodium falciparum*; *Falciparum vivax*; under-five; determinants; risk factors doi:10.20944/preprints202108.0168.v1

1. Introduction

Over the last twenty years, malaria has remained a major worldwide public health concern [1], with over 300 million cases reported in 2018 [2] and has remained a leading cause of morbidity and mortality. Low and Medium-Income Countries (LMIC), especially Sub-Sharan Africa (SSA) contributes more than 80% of the global malaria burden [3,4]. Nigeria, with a population of over 200 million people, is the world most burdened malaria endemic nation, contributing more than a quarter of global malaria cases. The risk of malaria infection cut across all age segments with women, (especially the pregnant), and children (especially under-five years), the most vulnerable. Malaria is a deadly disease that kills an estimated 30 children every hour worldwide. There were great commitments by governments and global partners to end malaria induced mortality and morbidity by 2020 [5], and by 2018 there was a further commitment by some commonwealth nations to prevent more than 650,000 deaths arising from malaria infections by 2023 [6].

The transmission of malaria parasites has its root in the socio-cultural and economic statuses of the people[7]. Studies have showed that age of the child [8–11], birth order [8,9], breast feeding status [8], anaemia status [4,9], that the child slept under bed net [10,12], maternal education [4,11,13], body mass index [8], age of household head [4], improved source of drinking water [9], place of residence [8–10,14], household socioeconomic factors [8,11,15], and regional variations [9,10,16] are significant predictors of the risk of malaria infection in under-five years of age in SSA and in Nigeria.

Effective control of malaria in Nigeria will require strategies that identify areas and characteristics of people that are highly vulnerable to malaria infections leading to the development of plans and the implementation of policies to reach them. This study enlarges the findings in previous studies to show proofs of contextual variables at both cluster and state levels [17,18]. Therefore, this study aimed to establish the prevalence of malaria across the states and federal capital territory, and to examine the individual- and contextual-level predictors of malaria fever among children 6-59 months of age in Nigeria.

2. Materials and Methods

2.1 Study Area

Nigeria is a country located in West Africa sharing boundary with Cameroon, Niger, Benin Republic and the Atlantic Ocean with a total area of 923,768 Square Kilometres [19,20]. The Nigeria population grew from over 140 million people as of 2006 population census [21,22] to more than 180 million people in 2016 and is expected to rise to over 260 million people by the year 2030 with an estimated annual national growth rate of 2.38% making her the most populous black nation in the world [22]. The population density for Nigeria was estimated to about 215 people per square kilometre in 2018 from approximately 194 people per square kilometre in 2015 [23]. The country has a variety of rich ethnic groups of over 250 [21] speaking different dialects and customs. The three major ethnic groups with a population of over 68% are the Fulani/Hausa, Yoruba and Igbo, while the Edos, Ijaw, Kanuri, Ibibio, Ebira, Nupe, Tiv and other minority ethnic groups accounted for 32% [21,24]. Nigeria has 37 administrative divisions (36 states and the Federal Capital Territory (FCT) and classified into six geopolitical zones [10]. The 37 political, administrative areas are sub-divided into 774 Local Government Areas (LGAs), and each of the LGAs was divided into wards) with each LGA having between 10 and 15 political ‘wards [25].

2.2 Source of Data

This study is a secondary analysis of two independent nationally representative cross-sectional surveys data sets, such that the 2018 National Human Development Report (known as NHDR 2018) data set is incorporated into the 2018 Nigeria Demographic and Health Survey (otherwise known as 2018 NDHS).

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We extracted Human Development Index (HDI) and Multi-dimensional Poverty Index (MPI) from the NHDR 2018 to serve as the state variables.

2.3 Sampling

In NDHS, the primary data set for this study, samples were selected separately from each stratum using a two-stage stratified cluster design on each stratum derived from the 2006 census identified enumeration demarcation. At the first stage, 1,400 Enumeration Areas (EAs) were selected as sampling units. At the second stage, 30 households were selected randomly from each EA using equal probability sampling, leading to a target total samples of 42,000 (30 x 1400) households used for the survey.

2.4 Outcome Variable

In 2018 NDHS diagnostic tests for malaria parasite were carried out for children age 6 – 59 months in approximately a third of the selected households. Two testing methods were adopted:

(i) Rapid Diagnostic Tests (RDTs) were conducted on blood samples taken from pricking the finger or heal of the child using SD Bioline Ag *Pf* (HRP-II). The RDTs detect the Histidine-rich protein-II (HRT-II) human whole blood (antigen). The results were either classified as positive or negatives for *plasmodium falciparum (Pf).*

(ii) Laboratory microscopy investigation on thick blood smears was done for a three quarter of the households where RDTs was done. Malaria results were also classified as either positive or negative

Most researchers preferred using microscopy thick blood smears result to classify the presence or absence of *Pf*. However, [26] found that RDTs and microscopy laboratory investigation of malaria *Pf* yield similar results with RDTs being more precise [26]. Also, in a recent scoping review (Obasohan et al 2021), RDT was found to be more frequently used by studies compared with microscopic smears. Additionally, in 2018 NDHS, RDTs account for more samples than microscopic blood smear laboratory test. Therefore, in this study, the malaria status of children 6 – 59 months of age in Nigeria using RDT was classified as '1' if the result was positive and '0' when the result was negative.

2.5 Independent variables

The predictor variables considered for this study were identified from previous scoping reviews [1,27,28]. These variables were grouped into children/individual-related variables to include, child's sex, age, perceived birth size, order, malaria status, nutritional status, fever, acute respiratory infection status, had diarrhoea, duration of breastfeeding, deworming, iron pills/syrup, and child took vitamin A; parental-related to include, place of delivery; preceding birth interval, maternal religious status, age group, age at first birth, educational status, working status, body mass index, anaemia status, autonomy level, marital status, ante-natal care visit, maternal ethnicity, religious status, maternal iron supplement during pregnancy, and paternal education status and work status; others are household-related to include, household socioeconomic status (wealth index), household size, number rooms for sleeping, number of under-five in the household, age and sex of household head, under-five slept under bed net last; and community-related variables to include, household region of residence, place of residence, community distance to health facility; and area-related variables to include, the state multidimensional poverty index, and the state human development index.

2.6 Statistical Analysis

Descriptive analysis using percentage frequencies was used to establish the prevalence, distribution, and association of the malaria status among children 6-59 months of age in Nigeria with the predictor variables considered in this study. Given the complex/hierarchical nature of the data sets, such that children/individual (at level 1) are nested in communities/clusters (at level 2), and nested in states (at level 3), multiple multilevel logistic regression models were fitted to determine the predictors of malaria status among 6-59 months of age in Nigeria. Likelihood ratio test was carried out to establish that the

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3-level model was more appropriate than the 2-level model (The likelihood-ratio test is LR $\chi^2 = 30.21$, p<0.001 for level-2 nested in level-3).

2.6.1 Multilevel model description for the three-level survey on malaria status

The dependent variable of interest is binary and follows the Bernoulli (π_{ijk}) distribution with a logit link function:

$$\eta_{ijk} = \beta_{0,0}^{*} + \sum_{a=1}^{m} \beta_{a,0}^{*} W_{a,ijk} + \sum_{b=1}^{n} \beta_{b,0}^{*} X_{b,jk} + \sum_{c=1}^{p} \beta_{c,0}^{*} Z_{k} + \varepsilon_{0,jk} + \varepsilon_{0,k} \qquad \text{(i)}$$

Where η_{ijk} is the predicted log odds of individual child *i* (level 1) in community (com) *j* (level-2), and in state (sta) *k* (level-3) having a positive RDT for malaria. $\beta_{0,0}^{*}$ represent the overall intercept (the grand mean of level-3), $\beta_{a,0}^{*}$, $\beta_{b,0}^{*}$, and $\beta_{c,0}^{*}$ are respectively the *m*th, the *n*th, and the *p*th coefficients associated with *W* (level-1), *X* (level-2), and *Z* (level-3) predictors. And $\varepsilon_{0,jk}$ represents the random effect of *j*th community in *k*th state, while $\varepsilon_{0,k}$ denotes the state-level random effect, with the assumption that $\varepsilon_{0,jk} \sim N(0, \sigma_{com}^2)$ and $\varepsilon_{0,jk} \sim N(0, \sigma_{sta}^2)$ are identical and independently distributed [29,30]. The equation (i) has a logistic transformation, where

$$\eta_{ijk} = ln\left(\frac{\pi_{ijk}}{1-\pi_{ijk}}\right) \qquad \text{(ii)}$$

and it denotes the probability that an *i*th child in the *j*th community and the *k*th state will be RDT malaria fever positive.

2.6.2 Model Building

In this study, five multilevel logistic models were considered. Model 1, a null model (or empty model), without any predictors. The essence is to measure the variation across the communities and the states. Model 2 included only child-related variables; Model 3, adjusted for /parental-related variables, while for Model 4 household-related variables were added to model 3; Model 5 (full model) was derived for all the selected variables including the area-related variables. Goodness of fit was determined using Akaike's information criteria (AIC), such that the model with the lowest AIC was chosen as the best fit.

2.6.3 Measure of Association

The measures of association (i.e. fixed effects) were described using adjusted odds ratio (AOR) with their corresponding p-values and 95% confidence intervals (CIs).

2.6.4 Measures of Variations

The measures of variation (i.e. random effects) were captured using intra-cluster correlation (ICC), and variance partition coefficient (VPC).

2.6.5 Intraclass correlation coefficient (ICC)

Intraclass correlation coefficient (ICC) represents the proportion of the total variation in the model that can be accounted for by variations across the different level of clusters. In our model (three-level model), we identified two intraclass correlation coefficients: the one pertaining to children/individuals nested in community-level, and community-level groups nested in the state-level group [30,31]. Therefore:

$$ICC_{com} = \frac{\sigma_{com}^2 + \sigma_{sta}^2}{\sigma_{com}^2 + \sigma_{sta}^2 + \frac{\pi^2}{3}} \qquad \text{(iii)}$$

ICC_{com} is the correlation between two children/individuals (unit of analysis) within the same community and the same state [32,33].

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But equation (iii), in terms of the variance partition coefficient (VPC) differs, as it does not have corresponding interpretation, therefore

$$VPC_{com} = \frac{\sigma^2_{com}}{\sigma^2_{com} + \sigma^2_{sta} + \frac{\pi^2}{3}} \quad \text{(iv)}$$

refers to the proportion of the total variance in the same state, but different communities [32]

$$ICC_{sta} = \frac{\sigma^2_{sta}}{\sigma^2_{com} + \sigma^2_{sta} + \frac{\pi^2}{3}} \quad \text{(v)}$$

ICC_{sta} is the correlation between two children/individuals within the same state, but different in community clusters. In VPC, it refers to the proportion of the total variance that is attributable to between state-level [32].

From (iii), (iv), and (v), σ^2_{com} is across community variance, σ^2_{sta} is the across the state variance, and $\frac{\pi^2}{3} \simeq 3.29$ is the between children/individuals' variance with scale factor 1, and for logistic regression [29]. The values of ICCs help to establish the need for multilevel analysis as against the single-level analysis. The rule of thumb could be that when the ICC is less than 5% at the null model, hierarchical modelling may not be necessary [34].

All computations were done in Stata 16 SE (College Station, TX: StataCorp LP). In recognition of the complexity of the survey design, weight proportion as specified in Stata was used to account for over- and under-estimation. The listwise deletion, the default missing values handling technique in Stata was applied.

3. Results

3.1 Prevalence of Malaria Fever

There was a total weighted sample of 10185 children 6-59 months of age in Nigeria considered for the analysis. In fig. 1, the proportion of children 6-59 months of age in Nigeria that had malaria fever positive as assessed by RDTs was 35.5% (3,418/10185), (CI: 33.9-37.1). Kebbi State had the highest proportion of children 6-59 months who were malaria positive, 77.6%, (CI: 70.2-83.5), followed by Katsina State, 55.5%, (CI: 47.7-63.1). The Federal Capital Territory (FCT), Abuja had the proportion of 29.6%, (CI: 21.6-39.0), malaria positive children of 6-59 months of age. Also, Edo state, with a proportion of 14.0%, (CI: 7.5-24.6), and Lagos state with a proportion of 3.4%, (CI: 1.8-6.0), recorded the lowest proportion of malaria positive children of 6-59 months of age in Nigeria. Adamawa and Kaduna states have the same proportion (35%) of malaria positive children, but Adamawa state have a wider confidence interval than Kaduna state.

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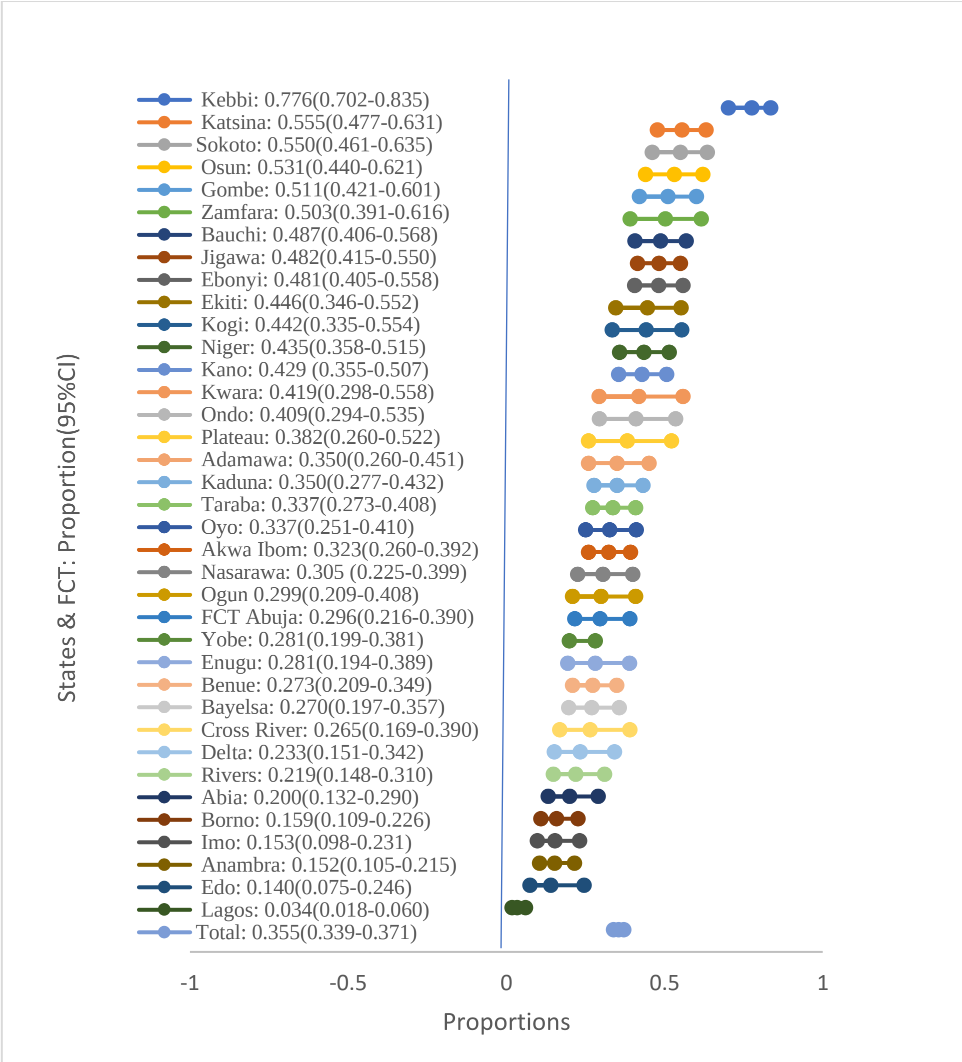

Fig 1. Forest plot of the proportion of malaria positive children 6-59 months of age in Nigeria by state

3.2 Bivariate Analysis of Proportion and Associations between Predictors and Malaria Status

Tables 1a, 1b, 1c, and 1d display the descriptions of the background characteristics, the association with malaria fever status of children 6-59 months in Nigeria and presented under; child-, parental-, household-, and area-related factors, respectively. In Table 1a, there were more children between 12 and 23 months (2421/10185), males (5216/10185), and 1.7% (171/10185), never breastfed in the survey among the age group, sex, and duration of breastfeeding, respectively. The prevalence of malaria fever among children 24 months and above is more than the national prevalence of 35.5%. Furthermore, the result shows that malaria status was strongly associated with child's, age, birth order, ever had the vaccination, malaria status, nutritional status, fever, had diarrhoea, duration of breastfeeding, deworming, and child took vitamin A, iron pills/syrup.

Table 1a: Crosstabulation of malaria status versus child-related predictors

Variables (Categories)	Malaria Status (6-59 months)		
	Total	No	Yes
	(N)	N (%)	N (%)

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Age of the child	10185	χ^2 = 148.15, p-value<0.0001	
06-11 months	1232	925(0.75)	307(0.25)
12-23 months	2421	1686(0.70)	736(0.30)
24-35 months	2159	1379(0.64)	780(0.36)
36-47 months	2229	1332(0.60)	896(0.40)
48-59 months	2143	1245(0.58)	898(0.42)
Sex	10185	χ^2 = 0.551, p-value 0.516	
Male	5216	3346(0.64)	1871(0.36)
Female	4968	3221(0.65)	1747(0.35)
Perceived Birth Size	10060	χ^2 =8.006, p-value 0.073	
Large	923	631 (0.68)	292(0.32)
Average	7915	5094(0.64)	2822(0.36)
Small	1222	764(0.63)	457(0.37)
Ever Had Vaccination Status	3292	χ^2 =18.494, p-value 0.0018	
No	837	475(57)	361(43)
Yes	2455	1601(65)	855(35)
Birth Order	10185	χ^2 = 157.98, p-value<0.0001	
1st order	1945	1373(70)	582(30)
2nd or 3rd order	3483	2388(69)	1095(31)
4th – 6th order	3207	2007(63)	1200(37)
7th+ order	1549	809(52)	740(48)
Duration of breastfeeding	10185	χ^2 = 47.86, p-value<0.0001	
ever, but not currently	7441	4662(63)	2780(37)
never breastfed	171	102(60)	69(40)
still breastfeeding	2572	1803(70)	769(30)
Had Diarrheal in last 2 weeks	10182	χ^2= 41.25, p-value<0.0001	
No	8832	5801(66)	3031(34)
Yes	1350	765(57)	585(43)
Had fever in last 2 weeks	10182	χ^2= 304.96, p-value<0.0001	
No	7487	5201(69)	2285(31)
Yes	2695	1366(51)	1330(49)

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Had acute respiratory illness in past 2 weeks	10183	χ^2= 0.340, p-value 0.6332	
No	9575	6168	3407
Yes	608	398	209
Took Vitamin A supplements	10141	χ^2= 173.345, p-value<0.0001	
No	5309	3106(58)	2203(42)
Yes	4832	3432(71)	1399(29)
Deworming treatment in the last 6 months	10133	χ^2=235.73, p-value<0.0001	
No	7235	4330(60)	2905(40)
Yes	2898	2203(76)	695(24)
Child took Iron Supplements	10151	χ^2= 42.173, p-value<0.0001	
No	8224	5183(63)	3040(37)
Yes	1927	1367(71)	561(29)
Nutritional Status	10185	χ^2 = p-value<0.0001	
Well-nourished	5688	4060(71)	1627(29)
Poorly nourished	4497	2507(56)	1990(44)
Stunting	10185	p-value<0.0001	
No	6285	4457(71)	1827(29)
Yes	3900	2109(54)	1790(46)
Wasting	10185	p-value 0.1169	
No	9481	6138(65)	3343(35)
Yes	703	429(61)	274(39)
underweight	10185	p-value<0.0001	
No	7915	5355(68)	2560(32)
Yes	2269	1212(53)	1058(47)
Overweight	10185	p-value 0.0337	
No	10019	6445(64)	3573(36)
Yes	166	122(74)	44(26)
Anaemia status	10183	p-value<0.0001	
No	3241	2664(82)	577(18)
Yes	6942	3902(56)	3040(44)

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However, malaria status was not statistically associated with child's sex, perceived birth size, the child had acute respiratory infection two weeks before the survey and wasting.

The results in Table 1b show the relationship between parental characteristics and malaria status of children 6-59 months of age in Nigeria, only marital status and paternal occupational status were not strongly associated with the malaria status at 5% level of significance. Whereas, child's place of delivery; preceding birth interval, maternal religious status, age group, age at first birth, educational status, working status, body mass index, anaemia status, autonomy level, ante-natal care visit, maternal ethnicity, religious status, maternal iron supplement during pregnancy, and paternal education status were all strongly associated with the child's malaria fever status. The proportion of children with malaria fever (38%) was highest among mothers in the youngest age groups (15-24 years) compared to other age groups. More than 50% of children whose mother and father had no education reported RDT positive results.

Table 1b: Crosstabulation of malaria status versus parental-related predictors

Variables (Categories)		Malaria Status	
	Total	No	Yes
Categories	(N)	N (%)	N (%)
Mother's age group	10185	χ^2=14.59, p-value 0.0095	
15-24 years	2048	1265(62)	784(38)
25-34 years	5262	3481(66)	1781(34)
35 years+	2874	1821(63)	1052(37)
Mother's age at first birth	10185	χ^2 = 385.04, p-value<0.0001	
10-19 years	5406	3033(56)	2373(44)
20-29 years	4369	3177(73)	1192(27)
30+ years	409	357(87)	53(13)
Mother working Status	10185	χ^2= 8.83, p-value 0.038	
Not working	2978	1855(62)	1123(38)
Working	7207	4712(65)	2494(35)
Mother's educational status	10185	χ^2= 864.57, p-value<0.0001	
No education	3970	1951(49)	2018(51)
Primary education	1643	985(60)	658(40)
Secondary & above	4571	3631(79)	940(21)
Marital status	10185	χ^2=1.756, p-value 0.5012	
never in union	171	110(64)	61(36)
in union	9733	6265(64)	3468(36)
widow/divorced/separated	281	191(68)	89(32)

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Partner's educational status	9604	χ^2=672.98, p-value<0.0001	
No education	2872	1369(48)	1503(52)
Primary education	1423	817(57)	606(43)
Secondary education	5308	4018(76)	1290(24)
Father's Occupation	10185	χ^2=0.294, p-value 0.7133	
Not working	304	191(63)	112(37)
Working	9881	6376(65)	3505(35)
Mother lives with a partner	9733	χ^2=7.433, p-value 0.0291	
living with partner	8862	5668(64)	3194(36)
living alone	871	598(69)	273(31)
Mother slept under mosquito net	10185	χ^2=91.02, p-value<0.0001	
No	4671	3242(69)	1429(31)
Yes	5514	3325(60)	2188(40)
Mother's body mass index (kg/m2)	8690	χ^2=250.16, p-value<0.0001	
Normal	5310	3219(61)	2092(39)
Underweight	884	513(58)	371(42)
Overweight	2537	1977(78)	559(22)
Preceding Birth Interval	8220	χ^2=15.683, p-value 0.0155	
08-24 months	2190	1356(62)	834(38)
25-35 months	2884	1775(62)	1109(38)
36-59 months	2351	1515(64)	836(36)
60+ months	795	544(68)	251(32)
Succeeding Birth interval	3549	χ^2=9.733, p-value 0.0287	
08-24 months	1224	746(61)	478(39)
25-35 months	1589	875(55)	714(45)
36-59 months	735	424(58)	311(42)
Mother's anaemia status	10053	χ^2=120.013, p-value<0.0001	
Normal	4206	2991(71)	1214(29)
Anaemic	5847	3519(60)	2328(40)
Number of ANC attendance	6375	χ^2=185.99, p-value<0.0001	
None	1342	715(53)	627(47)

Less WHO number	954	624(65)	329(35)
Met WHO number	4079	2987(73)	1092(27)
Maternal Autonomy	10185	χ^2=178.05, p-value<0.0001	
Less autonomy	5071	2947(58)	2124(42)
more autonomy	5114	3620(71)	1494(29)
Maternal ethnicity	10185	χ^2=325.93, p-value<0.0001	
Hausa/Fulani	4067	2226(55)	1841(45)
Ibos	1650	1273(77)	377(23)
Yoruba	1490	1068(72)	421(28)
Others	2978	2000(67)	977(33)
Religion status	10185	χ^2=255.02, p-value<0.0001	
Catholic	1027	754(73)	273(27)
Other Christian	3438	2509(73)	929(27)
Islam	5655	3266(58)	2389(42)
Others (traditional)	64	39(60)	25(40)
Mother's iron tabs during pregnancy	6470	χ^2=55.827, p-value<0.0001	
No	1778	1086(61)	692(39)
Yes	4692	3322(71)	1370(29)
Place of delivery	10184	χ^2=455.18, p-value<0.0001	
Home	5348	2953(55)	2394(45)
Public Health Facility	2977	2137(72)	840(28)
Private Health Facility	1660	1334(80)	326(20)
Somewhere else	200	142(71)	58(29)

Additionally, 38%, 38%, 36%, and 32% of children whose mother has a preceding birth interval of 12-24 months, 25-35 months, 36-59 months, and 60+ months were RDT positive, respectively. Also, the prevalence of malaria fever among children aged 6-59 months was higher for those whose mothers were underweight compared with normal and overweight.

On the household-related categories of predictors, Table 1c indicates that household socioeconomic status (wealth index), household size, number of rooms for sleeping, number of under-five in the household, age and sex of household head, under-five slept under bed net last, the various household characteristics were statistically associated with RDT positive status among children 6-59 months of age in Nigeria at 5% level of significance, while disposal of youngest child's stool methods and household sharing toilet facilities were not statistically associated with malaria status. The proportion of malaria fever among children 6-59 months in Nigeria varied inversely with the level of household

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wealth index. The highest was recorded among the poor household (53%) followed by middle (38%) and rich (18%) household.

Table 1c: Crosstabulation of malaria status versus household-related predictors

Variables (Categories)	Malaria Status (6-59 months)		
	Total	No	Yes
	N (%)	N (%)	N (%)
Household Wealth status	10185	χ^2=1102.49, p-value<0.0001	
Poor	3882	1813(47)	2069(53)
Middle	2139	1335(62)	804(38)
Rich	4163	3419(82)	744(18)
Household had mosquito bed net	10185	χ^2=65.709, p-value<0.0001	
No	3111	2187(70)	924(30)
Yes	7074	4389(62)	2693(39)
Household member size	10185	χ^2=159.22, p-value<0.0001	
0-3 persons	980	678(71)	282(29)
4 - 6 persons	4835	3322(69)	1513(31)
7-9 persons	2461	1521(62)	940(38)
10+ persons	1908	1026(54)	881(46)
Number of rooms for sleeping	10185	χ^2=47.584, p-value<0.0001	
One room	2807	1952(70)	854(30)
two rooms	3489	2221(64)	1268(36)
three rooms	2030	1239(61)	791(39)
four rooms	981	604(62)	377(38)
five+ rooms	877	550(63)	326(37)
Number of children U5 in household	10185	χ^2=130.40, p-value<0.0001	
No or 1 child	2700	1880(70)	819(30)
Two children	4315	2848(66)	1468(34)
Three children	2054	1270(62)	783(38)
Four children+	1115	568(51)	547(49)
Source of drinking water	10185	χ^2=298.76, p-value<0.0001	
Unimproved	3078	1601(52)	1477(48)

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Improved	7106	4966(70)	2140(30)
Type of toilet facilities	10185	χ^2=650.37, p-value<0.0001	
Unimproved	4607	2357(51)	2250(49)
Improved	5577	4210(75)	1367(25)
Youngest child's stool disposal	6408	χ^2=0.102, p-value 0.8208	
Proper	3606	2348(65)	1257(35)
improper	2803	1836(66)	967(34)
Type of Floor material type	10185	χ^2=329.83, p-value<0.0001	
Unimproved	2877	1460(51)	1418(49)
Improved	7307	5107(70)	2200(30)
Type of roofing materials	10185	χ^2=87.795, p-value<0.0001	
Unimproved	1125	583 (52)	542(48)
Improved	9060	5984(66)	3076(34)
Type of wall materials	10184	χ^2=638.88, p-value<0.0001	
Unimproved	3265	1535(47)	1730(53)
Improved	6919	5032(73)	1887(27)
Sex of Household Head	10185	χ^2=7.815, p-value 0.0283	
Male	9008	5824(64)	3273(36)
Female	1087	743(68)	344(32)
Household head age group	10185	χ^2=27.139, p-value 0.0026	
less 34 years	2828	1825(65)	1003(35)
35-44 years	3946	2648(67)	1298(33)
45-55 years	2091	1300(62)	792(38)
56 year+	1318	794(60)	524(40)
Shared Toilet with Others household	7727	χ^2=8.364, p-value 0.0691	
No	4761	3157(66)	1693(34)
Yes	2966	2064(70)	902(30)
Household had electricity	10066	χ^2=590.89, p-value<0.0001	
No	4296	2186(51)	2109(49)
Yes	5771	4296(74)	1475(26)
Type of cooking fuel	10182	χ^2=384.85, p-value<0.0001	

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Electricity & Gas	1211	1088(90)	123(19)
Biofuel/mass	8971	5477(61)	3494(39)
Under-5 slept under bed net	10112	χ^2=104.81, p-value<0.0001	
No child	1317	863(66)	454(34)
All children	4715	2965(63)	1750(37)
Some children	996	530(53)	466(47)
No net in the house	3083	2165(70)	918(30)

Accordingly, the household where only some under-five years slept under a bed net the night before the survey witnessed the highest prevalence of malaria fever among children 6-59 months of age in Nigeria when compared with the household where 'no net in the house' (30%), 'no child' (34%), 'all children' (37%), slept under a bed net the night before the survey.

Table 1d displays the results of the univariate analysis and the association between the area-related factors and the malaria fever status of children 6-59 months of age in Nigeria. All the area variables (human development index, multidimensional poverty index, regions of residence, and place of residence) were strongly associated with malaria fever status of children 6-59 months in Nigeria.

Table 1d: Crosstabulation of malaria status versus area-related predictors

Variables (Categories)	Malaria Status (6-59 months)		
	Total	No	Yes
	N (%)	N (%)	N (%)
State Human Development Index (SHDI)	10185	χ^2=344.14, p-value<0.0001	
Lowest HDI	4566	2516(55)	2050(45)
Average HDI	2223	1511(68)	712(32)
Highest HDI	3395	2539(75)	856(25)
Region of residence	10185	χ^2=428.79, p-value<0.0001	
North-central	1436	906(63)	530(37)
North-east	1573	1034(66)	538(34)
north-west	2967	1502(51)	1465(49)
South-east	1328	826(76)	336(25)
South-south	1086	826(76)	260(24)
South west	1794	1307(73)	487(27)
State Multidimensional Poverty Index (SMPI)	10185	χ^2=350.43, p-value<0.0001	
Highly Deprived	3939	2140(54)	1799(46)

Averagely Deprived	2318	1499(56)	819(35)
Lowest deprived	3926	2927(75)	999(25)
Type of Place of Residence	10185	χ^2=724.32, p-value<0.0001	
Urban	4485	3538(79)	946(21)
Rural	5700	3029(53)	2671(47)

3.3 Multilevel multivariable models of predictors of malaria fever status

In the first instance, a multicollinearity test was conducted to check for highly correlated predictors. Out of the 38 included variables, two factors: 'under-five slept under a bed net the night before the survey' and 'household had bed net' were perfectly correlated with variance inflation factors (VIF) of 7.08 and 11.18, respectively such that the mean VIF was 2.23. The variable 'household had bed net' was dropped resulting in a mean VIF of 1.79. We used a forward stepwise variable selection procedure by entering all variables that are statistically associated with the malaria status of children 6-59 months of age in Nigeria at a 5% level of significance, and removal was by p>0.20. Because of this, 24 variables (child's age, duration of breastfeeding, anaemia status, nutritional status fever status, deworming, maternal age in group, age at first birth, maternal education status, paternal education status, maternal anaemia status, ethnic group, religious status, household wealth number of under-five in household, household head age group, under-five slept under a bed net, number of rooms for sleeping, state multidimensional poverty index, state human development index, region of residence, and place of residence), were finally retained for the multilevel model building.

3.3.1 Multilevel model results

A measure of variation (Random effects)

Model 1 in Table 2 displays the result of the null model (no predictors) with the fixed effect showing that the average estimated log-odds of malaria status is significantly 0.4445 and resulting into a probability of 0.3077. Therefore, the overall proportion of prevalence of malaria among children 6-59 months of age in Nigeria without adjusting for any source of variation is 30.8%. The variations due to differences in the communities and the states were respectively, 1.266 and 0.614, while the variance due to individual level is 3.29 ($\pi^2/3$), which is fixed for logit. Therefore, the variations in the prevalence of malaria status due to the three-level factors were assessed through intrastate correlation coefficient = 0.1188 (95% CI: 0.75-0.183) and intracommunity correlation coefficient = 0.3636 (95% CI: 0.318-0.412), indicating that 11.9% and 36.4% of the total variation in the odds of malaria positive are respectively due to state and community levels, while 51.7% is due to individual-level. The variance partition coefficient (VPC) at the state level corresponds with the ICC at the state level. However, the VPC at community level is 0.249, meaning that 24.9% of the total variance is collectively attributed to both the state and community levels. The Performance of models was established using AIC and likelihood ratio. Improvements in model fit was achieved at model 4 (full model), with AIC = 9646, and loglikelihood= -14763.47. The ICC at the community-level = 21.0% (95% CI:0.17-0.25) and state-level=4.8% (95% CI: 0.03-0.08) remained significant.

Measures of Association (Fixed effects)

Model 2 in Table 2 represents the fitting with child/individual-level variables. Age of the child, the child still breast feeding, had fever two weeks before the survey, dewormed in the last six months before the survey, a child is anaemic, maternal age at first birth, maternal and paternal have secondary education and above, mother's anaemia and ethnicity statuses, household wealth, number of under-five

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in the house is more than 4 children, and the household head is between 35 and 44 years of age were statistically significant predictors of malaria status among children 6-59 months of age in Nigeria. The child's nutritional status, maternal age and religious status, under-five slept under a bed net and the number of rooms used for sleeping in the household were not statistically significant predictors. However, after including all the predictor variables (model 4), the significant status of the child-specific factors remains.

The odds of a child having malaria increased as the child's age increased. Children between the age of 48 and 59 months were 2.68 times more likely to have malaria fever than children 6-11 months of age (AOR=2.68, 95% CI: 2.03-3.54). Children who were still breastfeeding (AOR=0.61, 95% CI: 0.51-0.76), and dewormed (AOR=0.75, 95% CI: 0.65-0.87), were 39% and 25% less likely to suffer from malaria infection. Similarly, children whose mother had their first birth after the age of 20 years were

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Table 2: Multilevel multivariate models of predictors of malaria with adjusted odds ratios (AOR) among children 6-59 months in Nigeria

	Model 1 (No Covariates)	**Model 2 (Added level-1 factors)**			**Model 3 (Added level-2 factors)**			**Model 4 (Added level-3 factors)**		
Individual-level		**AOR**	**95% CI**	**p-value**	**AOR**	**95% CI**	**p-value**	**AOR**	**95% CI**	**p-value**
Child's age										
6-11 months		1.00			1.00			1.00		
12-23 months		1.26	1.02-1.56	0.031	1.26	1.02-1.56	0.029	1.28	1.04-1.58	0.021
24-35 months		1.65	1.26-2.16	<0.001	1.65	1.26-2.15	<0.001	1.65	1.26-2.16	<0.001
36-47 months		2.20	1.67-2.88	<0.001	2.20	1.67-2.89	<0.001	2.20	1.68-2.89	<0.001
48-59 months		2.69	2.04-3.55	<0.001	2.68	2.03-3.54	<0.001	2.66	2.02-3.51	<0.001
Duration of breastfeeding			-			-			-	
Ever breastfed		1.00	-		1.00	-		1.00	-	
Never breastfed		1.28	0.84-1.94	0.251	1.26	0.83-1.92	0.276	1.28	0.84-1.96	0.243
Still breastfeeding		0.63	0.51-0.76	<0.001	0.62	0.51-0.76	<0.001	0.61	0.50-0.75	<0.001
Anaemia status			-			-			-	
Not anaemic		1.00	-		1.00	-		1.00	-	
Anaemic		3.84	3.36-4.39	<0.001	3.82	3.34-4.37	<0.001	3.82	3.34-4.37	<0.001
Nutrition status			-			-			-	
Well-nourished		1.00	-		1.00	-		1.00	-	
Poorly nourished		1.07	0.95-1.2	0.284	1.06	0.94-1.19	0.378	1.05	0.94-1.19	0.386
Fever in last 2 weeks			-			-			-	
No		1.00	-		1.00	-		1.00	-	
Yes		1.95	1.72-2.2	<0.001	1.94	1.71-2.2	<0.001	1.96	1.73-2.22	<0.001
Dewormed in last 2 weeks			-			-			-	
No		1.00	-		1.00	-		1.00	-	
Yes		0.75	0.65-0.87	<0.001	0.75	0.65-0.87	<0.001	0.75	0.65-0.87	<0.001
Maternal age group				-			-			-
15-24 years		1.00	-		1.00	-		1.00	-	

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25-34 years	1.04	0.89-1.22	0.611	1.05	0.9-1.23	0.532	1.06	0.91-1.24	0.464
35 years+	1.16	0.95-1.4	0.143	1.17	0.96-1.42	0.111	1.19	0.98-1.44	0.085
Age at first birth		-			-			-	
10-19 years	1.00	-		1.00	-		1.00	-	
20-29 years	0.82	0.72-0.93	0.003	0.82	0.72-0.94	0.003	0.81	0.71-0.93	0.002
30 years+	0.52	0.35-0.77	0.001	0.52	0.36-0.77	0.001	0.51	0.35-0.75	0.001
Maternal education status		-			-			-	
No education	1.00	-		1.00	-		1.00	-	
Primary	0.82	0.68-0.99	0.038	0.85	0.7-1.03	0.093	0.86	0.71-1.04	0.128
Secondary+	0.61	0.5-0.75	<0.001	0.65	0.53-0.79	<0.001	0.67	0.55-0.82	<0.001
Paternal education status		-			-			-	
No education	1.00	-		1.00	-		1.00	-	
Primary	0.87	0.71-1.06	0.157	0.89	0.73-1.08	0.244	0.90	0.74-1.10	0.304
Secondary+	0.74	0.62-0.88	0.001	0.77	0.64-0.92	0.004	0.80	0.66-0.95	0.013
Maternal anaemia status		-			-			-	
Not anaemic	1.00	-		1.00	-		1.00	-	
Anaemic	1.24	1.11-1.39	<0.001	1.24	1.1-1.39	<0.001	1.23	1.1-1.38	<0.001
Maternal ethnic group		-			-			-	
Hausa/Fulani/Kanuri	1.00	-		1.00	-		1.00	-	
Ibo	0.83	0.54-1.28	0.401	0.86	0.56-1.32	0.489	0.81	0.49-1.31	0.387
Yoruba	1.57	1.08-2.26	0.017	1.61	1.11-2.34	0.012	1.45	0.98-2.15	0.064
Others	1.36	1.08-1.71	0.010	1.33	1.05-1.68	0.016	1.29	1.02-1.63	0.037
Maternal religion status		-			-			-	
Catholics	1.00	-		1.00	-		1.00	-	
Other Christian	0.89	0.7-1.14	0.359	0.91	0.72-1.16	0.460	0.92	0.72-1.17	0.491
Islam	0.82	0.6-1.11	0.199	0.85	0.62-1.15	0.288	0.90	0.66-1.23	0.499
Traditionalists	0.78	0.39-1.54	0.467	0.78	0.39-1.54	0.470	0.80	0.41-1.58	0.526
Household wealth		-			-			-	

Low	1.00	-		1.00	-		1.00	-	
Middle	0.71	0.6-0.84	<0.001	0.84	0.7-1.01	0.070	0.86	0.71-1.03	0.102
Rich	0.43	0.36-0.52	<0.001	0.55	0.44-0.69	<0.001	0.61	0.49-0.76	<0.001
Number of under-5 in household		-			-			-	
None or One child	1.00	-		1.00	-		1.00	-	
Two children	1.03	0.9-1.19	0.667	1.04	0.90-1.20	0.584	1.04	0.91-1.20	0.556
Three children	1.12	0.94-1.33	0.222	1.12	0.94-1.34	0.201	1.11	0.93-1.32	0.249
Four children+	1.48	1.18-1.85	0.001	1.47	1.17-1.84	0.001	1.46	1.16-1.83	0.001
Household head age group		-			-			-	
Less 35 years	1.00	-		1.00	-		1.00	-	
35-44 years	0.85	0.73-0.98	0.031	0.85	0.73-0.99	0.041	0.86	0.74-1.00	0.050
45-55 years	0.87	0.72-1.05	0.135	0.89	0.73-1.07	0.204	0.90	0.75-1.09	0.270
56 years+	1.07	0.86-1.32	0.549	1.10	0.89-1.36	0.386	1.12	0.90-1.38	0.304
Under-5 slept under a bed net		-			-			-	
No child	1.00	-		1.00	-		1.00	-	
All children	0.89	0.74-1.07	0.217	0.89	0.74-1.07	0.202	0.88	0.73-1.06	0.176
Some children	1.15	0.91-1.46	0.244	1.16	0.91-1.47	0.234	1.15	0.91-1.46	0.239
No net in household	0.96	0.8-1.17	0.701	0.99	0.81-1.2	0.887	0.98	0.8-1.19	0.802
Number of rooms for sleep		-			-			-	
One room	1.00	-		1.00	-		1.00	-	
Two rooms	1.03	0.88-1.20	0.705	1.01	0.87-1.18	0.894	1.00	0.86-1.17	0.989
Three rooms	1.07	0.89-1.28	0.477	1.04	0.86-1.25	0.692	1.02	0.84-1.22	0.869
Four rooms	0.91	0.72-1.14	0.392	0.87	0.69-1.1	0.240	0.84	0.67-1.06	0.148
Five+ rooms	0.82	0.64-1.05	0.122	0.78	0.61-1.01	0.062	0.76	0.59-0.98	0.037
Cluster level		-			-			-	
Proportion of Cluster's household with no bed net		-			-			-	

Low	-	1.00	-		1.00	-	
High	-	0.92	0.76-1.12	0.410	0.97	0.80-1.17	0.718
Distance to a health facility is no big problem	-		-			-	
Low	-	1.00	-		1.00	-	
High	-	0.72	0.6-0.86	<0.001	0.76	0.64-0.90	0.002
The Proportion of low cluster wealth status	-		-			-	
Low	-	1.00	-		1.00	-	
high	-	1.41	1.13-1.75	0.002	1.15	0.92-1.43	0.226
State-level	-		-			-	
Region of residence							
North central	-		-		1.00	-	
North east	-		-		0.48	0.22-1.05	0.065
North west	-		-		1.46	0.62-3.45	0.387
South east	-		-		1.07	0.51-2.25	0.854
South-south	-		-		0.50	0.25-0.98	0.045
South west	-		-		1.44	0.64-3.25	0.378
Place of residence	-		-			-	
Urban	-		-		1.00	-	
Rural	-		-		2.12	1.75-2.57	<0.001
State human development index (HDI)	-		-			-	
Lowest HDI	-		-		1.00	-	
Low HDI	-		-		1.32	0.71-2.45	0.374
Average HDI	-		-		1.50	0.68-3.33	0.314
High HDI	-		-		1.87	0.73-4.80	0.192
Highest HDI	-		-		1.03	0.35-2.98	0.961
Multi-dimensional poverty		-		-			-

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Index (MDPI)										
Highly deprived			-			-		1.00	-	
Above averagely deprived			-			-		1.75	0.90-3.43	0.101
Averagely Deprived			-			-		1.51	0.62-3.68	0.362
Mildly Deprived			-			-		1.20	0.44-3.26	0.721
Lowest Deprived			-			-		1.29	0.41-4.03	0.665
Intercept	0.444	0.24	0.14-0.40	<0.001	0.20	0.11-0.35	<0.001	0.07	0.02-0.21	<0.001
Random effect			-			-			-	
Community-level variance	1.266	0.73	0.58-0.90		0.74	0.59-0.91		0.67	0.54-0.84	
State-level variance	0.614	0.38	0.22-0.65		0.39	0.23-0.68		0.20	0.11-0.36	
VPC: Child-level	0.636	0.749	-		0.74	-		0.79	-	
VPC: Community-level	0.245	0.165	-		0.167	-		0.161	-	
VPC: State-level	0.119	0.09	-		0.089	-		0.048	-	
ICC%: Child-level	51.76	66.17	-		65.53	-		74.18	-	
ICC%: Community-level	36.36	25.18	0.21-0.30		25.57	0.21-0.30		21.00	0.17-0.25	
ICC%: State-level	11.88	8.65	0.05-0.14		8.90	0.05-0.14		4.82	0.03-0.08	
Model fit statistics						-			-	
Log-likelihood	-5966.75	-4818.16	-		-4804.56	-		-4763.47	-	
AIC	11939.50	9722.32	-		9701.12	-		9646.94	-	

AOR: Adjusted Odds Ratios, ICC: Intraclass Correlation Coefficient, VPC: Variance Partition Coefficient, AIC: Akaike Information Criterion (Given a set of candidate models for the data, the preferred model is the one with the minimum AIC value)

less likely to suffer from malaria infection than those who had their first birth earlier than 20 years. Also, children whose mother (AOR=0.67, 95% CI: 0.55-0.82), or father (AOR=0.79, 95% CI: 0.66-0.95) had secondary education and above were significantly less likely to be malaria fever positive. The wealthier the household (AOR=0.61, 95% CI: 0.49-0.76), the less likely the child can be malaria positive. Children from a community with high proportion of mothers who said distance to the nearest health centre is 'no big problem' has a lower odds of malaria fever infested. The result from among the area-specific variables shows that children from South-South geopolitical zones (AOR=0.50, 95% CI: 0.25-0.98), were 50% less likely to contract malaria fever than children from the North central zone. On the contrary, children from the rural area (AOR= 2.12, 95% CI: 1.75-2.57), were more likely to suffer from malaria infection compare with children from urban area.
Finally, the result shows that the state-level multidimensional poverty index and state human development index were not statistically significant predictors of malaria status among children 6-59 months of age in Nigeria.

4. Discussion

This study assessed the prevalence of malaria across the states and the federal capital territory and examined its predictors among children 6-59 months of age in Nigeria. The study enlarges the findings in previous studies [4,10,35], to show proofs of contextual variables at both cluster and state levels. About one-third of children were found to be malaria positive. The study also established that malaria status among children 6-59 months of age in Nigeria is determined by both child- parental/household-, community-, and state-related variables. The results showed that children in the higher age group are more prone to malaria infection than their younger counterparts. This agrees with other studies [4,10,11,16]. The reason for this may be that the younger the child, the more attention he/she gets from caregivers. This means priority is often given to the younger ones in the use of bed net when available. The study also revealed that currently breastfeeding children had reduced odds of malaria. This agrees with another study [8]. The possible reason for this is that a breastfeeding child often sleeps alongside the mother who normally would ensure that the child is unexposed to mosquito bites and the maternal antibodies could provide additional protection [4]. Furthermore, evidence of malaria positive with comorbidity in anaemia and non-malaria fever increased the chance of malaria infection [4], but had decreased influence with anaemia [8].

As the maternal age at first birth increases, the odd of child's RDT outcome decreases. The study also found that maternal and paternal education statuses are significantly associated with child's malaria status. The odds reduced with an increased in educational level [4,8,16]. This finding further demonstrates the important role parental education plays in a child's health [4]. Also, the result shows that the anaemia status of the mother is significantly associated with the child's malaria prevalence.

Household wealth plays a significant role in child's health. The study found that children from rich household are less likely to be infected with the malaria parasite. Similar conclusions were reached in recent studies [4,8,10,36]. Furthermore, the study revealed that the higher the number of rooms available in the household for sleep, the less likely the child will be malaria RDT positive. This agrees with the result found in a similar study [14]. This may relate to the fact that when fewer people sleep in a room, the tendency for increased cross-infection may reduce. Children from the rural area were found to be more vulnerable to malaria infection compared with their urban counterparts. This finding is consistent with similar studies [8–12]. The study also shows that the higher the proportion of respondents whose distance getting to health centre 'is no big problem', the less likely is the children contract malaria infections. In other words, when getting to health facility for prompt medical attention becomes a big problem in a community, the children are highly exposed to the risk of malaria fever and other childhood diseases. This is consistent with the findings in

4.1 Strengths and limitations of the study

A recent scoping review conducted has revealed that there are very few studies that analysed the influence of contextual factors on the risk of contracting malaria infection among children under-five years in SSA countries (Obasohan et al 2021-Malaria paper). This study has contributed to bridging this knowledge gap. Moreover, the few studies available adopted a two-level multilevel analysis procedure, but in this study, we found that a three-level multilevel analysis was more appropriate, as such the study is the first to carry out such analysis in Nigeria. The study involved large data sets, which might make it possible to draw inference over the country.

However, there are some limitations: (i) The data sets are cross-sectional and as such we could not ascertain the remote causes of RDT malaria positive among children 6-59 months of age in Nigeria. Information regarding the causes are better obtained from a longitudinal study which requires periodic follow up of participants [37]. (ii) The accuracy of the information provided at the survey time may not be ascertained to be correct because of high maternal illiteracy in Nigeria which might result in recall errors while responding to some questions.

5. Conclusion

Despite the huge resources committed to eliminating malaria induced morbidities and mortalities, Nigeria has remained the most burdened malaria-endemic nation in the world. This study has identified some important individual and contextual predictors of malaria among children 6-59 months of age in Nigeria. These predictors are areas that need to be considered for policy designs and implementations toward control and total elimination of malaria-related morbidity and mortality among children in Nigeria.

Ethical Approval

The ethical approval to carry out this research study had been granted by the School of Health and Related Research (ScHARR) Ethics Committee of the University of Sheffield (Reference Number: 031534). This study is a secondary analysis of two nationally representative samples. Permission to use the data sets (2018 Nigeria Demographic and Health Survey and 2018 National Human Development Report) had been obtained from two organizations: Inner City Fund (ICF)-International, and United Nations Development Programme (UNDP-Nigeria).

Author Contributions: The conceptualization of this study was done by P.E.O. and K.K.; the formal drafting of manuscript was carried out by P.E.O.; while S.J.W., R.J. and K.K. supervised, revised, and edited the manuscript. All authors read and agreed to the published version of the paper.

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Data Availability Statement: The data set used in this study is available in MeasueDHS https://dhsprogram.com › data › available-datasets, and UNDP-Nigeria http://hdr.undp.org/sites/default/files/hdr_2018_nigeria_finalfinalx3.pdf

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