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Original Research Article

Multilevel modelling of the predictors of malaria among under-five children in Nigeria: how do housing types and source of drinking water count?

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ABSTRACT

Background: Malaria remains a major public health issue, especially in sub-Saharan Africa (SSA), which still bears the brunt of the disease, with under-5 children disproportionately affected and Nigeria being one of the countries severely impacted. The study investigated predictors of malaria among under-5 children in Nigeria, with special focus on the impacts of housing types and source of drinking water.
Methods: Data analysis covered a weighted sample of 9,946 under-5 children from the 2021 Nigeria Malaria Indicator Survey. Descriptive and analytical analyses were conducted, including frequency distributions and logistic regression models at the multivariate level, using Stata software (version 15).
Results: The results showed that over half of the children lived in improved houses (53.67%) and nearly three-quarters (74.75%) had access to improved drinking water. However, more than half (54.41%) were still exposed to malaria risk. Children living in houses built with improved materials had a 32% (aOR: 0.68, CI: 0.53-0.87) lower risk of malaria compared to those in unimproved houses. Additionally, those with access to improved drinking water sources had a 15% (aOR: 0.85, CI: 0.67-1.06) reduced risk of malaria infection.
Conclusions: The study established a high malaria prevalence among under-5 children, even among those living in improved houses. Also, improved housing quality and access to clean drinking water significantly reduce the risk, highlighting the importance of environmental factors in preventing malaria. Policymakers should focus on enhancing housing and environmental conditions to prevent malaria, prioritising better homes, clean water access, and comprehensive prevention strategies, especially for high-risk areas and under-5 children.

Keywords: Drinking water, Housing types, Malaria infection, Nigeria, Under-five children

INTRODUCTION

Malaria remains a major global public health concern, with sub-Saharan Africa (SSA) bearing the brunt of its devastating impact.[1,2] In 2023, the worldwide malaria burden was estimated to be approximately 263 million cases, translating to a significant incidence rate of 60.4 cases per 1,000 people at risk.[2] Malaria is a fatal disease typically caused by five Plasmodium species, which are transmitted to humans through the bite of an infected mosquito that has previously fed on an infected person's blood and then injects the parasites into a new host during its next meal.[3] Among the Plasmodium species that infect humans, Plasmodium falciparum and Plasmodium vivax pose the greatest threat, with Plasmodium falciparum being the most virulent and deadly.[4]

In spite of a robust recovery in many regions of the world, malaria persists as a significant public health challenge, particularly in SSA, due to the rapidly growing population at risk, and it continues to be the leading cause of illness and death among children under five in the region.[2,5] The region is one of the top five countries which bore the heaviest burden of malaria infections in 2023.[2] Children are more vulnerable to malaria than adults due to their weakened immune systems, making them susceptible to severe malaria infections.[6,7] This vulnerability stems from their developing immune systems and inability to produce sufficient antibodies to combat Plasmodium parasites.[8] In 2023, children under five accounted for approximately 76% of malaria-related deaths in the WHO African region, including Nigeria.[2]

Nigeria has the unfortunate distinction of shouldering the largest malaria burden globally, accounting for 26% of the world's malaria cases.[2] The impact of malaria on child health and survival in Nigeria is profound, leading to stunted growth, diminished cognitive function, and detrimental educational attainment.[9] Nigeria faces numerous challenges, including a conducive climate for malaria transmission, socioeconomic determinants, and ineffective control strategies.[10] The prevalence of malaria transmission among U-5 children is unclear due to the complex interplay of risk factors and prevention measures, as well as poverty and low socioeconomic status.[11] Over the past six years, poverty has skyrocketed in Nigeria, affecting more than half of the population, according to the World Bank.[2] It was reported that Nigerians living below the national poverty line has seen a drastic increase from 40.1% in 2018 to 56.0%. This alarming rise means that approximately 129 million people are now living in poverty.[2] Poverty has a profound impact on housing types and sources of drinking water, leading to inadequate and unsafe living conditions.

There have several efforts to control and eliminate malaria through various programs, including the High Burden High Impact approach under the 2021-2025 National Malaria Strategic Plan in Nigeria, but the country continues to grapple with a high prevalence of malaria, particularly among children.[12-14] In 2021, approximately 22% of children aged 6-59 months tested positive for malaria through microscopy, while 37% of under-five children experienced fever.[15] This alarming situation significantly hinders progress toward achieving several Sustainable Development Goals (SDGs) by increasing healthcare costs, reducing household productivity and causing high mortality and morbidity rates.[16]

Research has shown that malaria-related deaths could be prevented with housing improvement and source of drinking water.[17] Studies in Nigeria have focused on the influence of housing sanitation facilities, social conditions and household head on malaria risk in U-5 children.[6,18-19] Although, a study has shown the effect of housing type on malaria risk among U-5 children in Nigeria,[20] but there is limited evidence on the interaction effects of housing type and source of drinking water on malaria risk using the latest Nigeria Malaria Indicator Survey (NMIS) data. This study, therefore, examined the predictors of malaria among U-5 children in Nigeria, with emphasis on housing types and source of drinking water, using the 2021 NMIS. The outcome of this study is expected to highlight the need for a multifaceted approach to reduce malaria burden among U-5 children, including housing improvements and access to clean drinking water in Nigeria.

METHODS

Data source and study design

This study utilised secondary data from the 2021 Nigeria Malaria Indicator Survey (NMIS), specifically the children's recode. The survey was conducted after the National Malaria Strategic Plan (2014-2020) and aimed to reduce malaria infections and deaths by 2020.[14] The 2021 NMIS collected data on household characteristics, respondents' backgrounds, and malaria prevention behaviours. Detailed reports of the survey methods and procedures are published elsewhere.[15] This study focused on a nationally representative weighted sample of 9,946 under-5 children.

Variable measurements

Outcome variables

The outcome variable was a history of malaria in under-five children, derived from mothers' reports of the children's healthcare provider-diagnosed malaria. In line with a previous study, the responses were categorised as a binary outcome, and coded '1' if a mother responded affirmatively and '0' if otherwise.[7]

Explanatory variables

The main explanatory variables were housing type and source of drinking water. The housing type was derived as a composite score of three different questions on the materials used for floors, roofs and walls, and grouped into 'improved' and 'unimproved' categories, consistent with prior research.[20] For instance, improved materials included cement, ceramic tiles, vinyl asphalt strips, parquet, and polished wood, while unimproved materials included earth, sand, dung, rudimentary materials, wood planks, palm, and bamboo. Building walls were categorised based on materials like cement, stone with lime or cement, cement blocks, and bricks as improved, while unimproved materials included no walls, cane, palm or trunks, dirt, rudimentary materials, bamboo with mud, and plywood. Roofing materials like cement and roofing shingles were considered improved, while unimproved materials included thatch, palm leaf, sod, rustic mat, palm or bamboo, wood planks, cardboard, and wood.[18,21] Therefore, housing types were considered

'improved' if all the materials used for the roofs, walls, and floors were improved and 'unimproved' if none of the materials were improved. Also, the source of drinking water was classified into 'improved' and 'unimproved' in line with the WHO/UNICEF Joint Monitoring Programme (JMP) for Water Supply, Sanitation, and Hygiene.[22] Improved water sources designed to be protected from contamination include piped water into homes or yards, public fountains, boreholes with pumps, protected wells and springs, and rainwater collection systems. Otherwise, unimproved water sources including unprotected wells and springs, surface water from lakes, ponds, rivers, and irrigation channels, as well as water delivered by tanker trucks or carts with small tanks are more prone to contamination.

The analysis controlled for various potential confounders, including the child's age, whether the child slept under an insecticide-treated net (ITN), the child's sex, whether the mother took sulfadoxine-pyrimethamine (SP) or Fansidar during pregnancy to prevent malaria, the mother's educational attainment, the household's wealth quintile, ownership of household insecticide nets, the sex of the household head, media exposure, knowledge of ways to avoid getting malaria, whether the mother has heard or seen malaria messages in the last 6 months, place of residence, and region. Some variables were re-categorised for easier interpretation. For example, the mother's education was grouped into categories such as no education, primary, secondary, or tertiary education. The wealth quintile was categorized into lowest, middle, and highest. Media exposure was determined based on whether mothers reported regularly listening to the radio, watching television, or reading newspapers and magazines. The source of drinking water and housing type were classified as either improved or unimproved. The selection of these covariates was based on existing literature showing their significant impact on malaria infection rates.[20,23]

Data processing and statistical analysis

The dataset was checked for missing values, which were excluded from the analysis. The data was then weighted using the appropriate sampling weights from the Demographic and Health Survey (DHS) to ensure proper representation and accurate statistical estimates.

The analysis used Stata software (version 15) for univariate and multivariate analysis. Univariate analysis involved descriptive statistics of background characteristics, presented in Tables 1 and 2, as well as Figure 1. At the multivariate analysis, binary logistic regression was used to examine the likelihood of malaria risk of the outcome variable at $p<0.05$. Four models were fitted: Model 1 presented the unadjusted regression results for each explanatory variable and covariates, Model 2 adjusted for the main explanatory variables, while Model 3 adjusted for main explanatory variables and significant covariates. The results were presented as odds ratios (OR) with 95% Confidence Intervals (CIs). An OR higher than 1.00 indicated an increased likelihood of malaria risk, while an OR below 1.00 indicated a decreased likelihood.

RESULTS

Descriptive analysis of the sample

The study included 9,946 under-five children. Most children were aged 24-59 months (63.39%) and males (51.19%). About 57.8% didn't sleep under an insecticide-treated net (ITN) the night before the survey. Many mothers had received SP/Fansidar during pregnancy. Approximately 43% of mothers had secondary or tertiary education, and 40% belonged to the lowest wealth quintile households. Most children (65.46%) lived in households without an insecticide mosquito net, and 92.54% lived in male-headed households. Over half of the mothers had no media exposure. The majority of the mothers (84.81%) had knowledge of ways to avoid getting malaria, while 45.25% did not hear or see malaria messages in the last 6 months. Most children resided in rural areas (69.87%) and North-west region had the largest proportion of children (30.67%). Most children lived in improved houses (53.67%), while 74.75% had access to improved drinking water. More than half (54.41%) of the children experienced malaria risk.

Table 1: Descriptive statistics of the sampled population in Nigeria (Nigeria MIS: 2021).

Variable	Frequency (n=9,946)	Percentage (%)
Child's age (months)		
0-6	1,013	10.73
7-23	2,445	25.89
24-59	5,987	63.39
Child slept under ITN last night		
No	5,487	57.81
Yes	4,005	42.19
Sex of child		
Male	5,091	51.19
Female	4,855	48.81

Continued.

Variable	Frequency (n=9,946)	Percentage (%)
Mother took SP/Fansider during pregnancy		
No	1,777	36.52
Yes	3,089	63.48
Mother's education		
No education	4,191	42.14
Primary	1,471	14.79
Secondary/tertiary	4,284	43.07
Wealth quintile		
Lowest	3,906	39.27
Middle	2,049	20.60
Highest	3,991	40.13
Ownership of household insecticide net		
No	3,435	34.54
Yes	6,511	65.46
Sex of household head		
Male	9,204	92.54
Female	742	7.46
Media exposure		
Not exposed	5,730	57.61
Exposed	4,216	42.39
Knowledge of ways to avoid getting malaria		
No	1,511	15.19
Yes	8,435	84.81
Heard/seen malaria messages in the last 6 months		
No	5,445	54.75
Yes	4,501	45.25
Place of residence		
Urban	2,997	30.13
Rural	6,949	69.87
Region		
North-central	1,797	18.07
North-east	1,840	18.50
North-west	3,050	30.67
South-east	1,067	10.73
South-south	1,212	12.19
South-west	980	9.85
Housing type		
Unimproved	4,111	41.33
Improved	5,835	53.67
Source of drinking water		
Unimproved	2,511	25.25
Improved	7,435	74.75
History of malaria in child		
No	1,831	54.41
Yes	1,553	45.59

Distribution of housing quality measures

Figure 1 presents the percentage distribution of the housing quality measures. The results showed that most of the children lived in houses built with improved floor materials (84.39%), improved wall materials (58.67%) and improved floor materials (56.74%). The policy implications of these results on malaria risk among children are significant. Given that improved housing materials are associated with reduced malaria risk, government should invest in housing improvement programmes that provide subsidies or incentives for families to upgrade their homes with mosquito-proof

materials, such as screened windows and doors, and improved flooring.

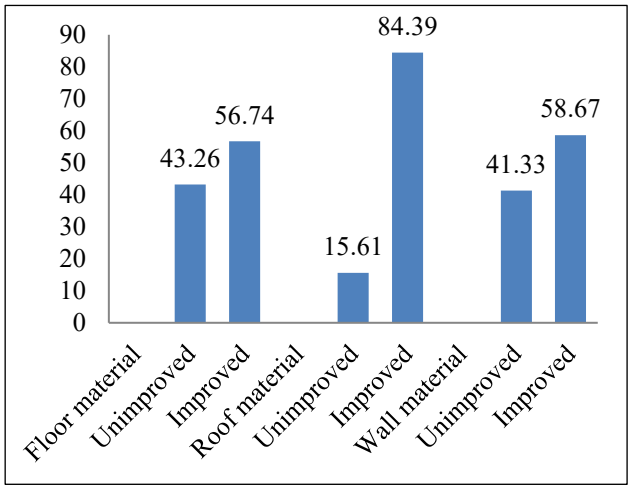

Figure 1: Measures of housing quality (%).

Bivariate association of the main explanatory variables and malaria risk among sampled children

The bivariate results of the relationship between the main explanatory variables and risk of malaria as presented in Table 2 showed that wall materials, housing materials and source of drinking water were significantly associated with malaria risk among U-5 children at $p<0.05$. For instance, a larger proportion of U-5 children who lived in houses built with unimproved wall materials and who lived in houses built with unimproved materials (48.6%) had malaria risk. This similar pattern was observed for children who had access to unimproved housing materials (48.4%). These results have policy implications towards improving housing conditions, particularly for walls and roofs, using materials that prevent mosquito entry, as well as consider integrating housing upgrades with existing malaria control measures to reduce malaria risk in U-5 children.

Table 2: Bivariate analysis of the relationship between malaria risk and main explanatory variables (Nigeria MIS: 2021).

Variable/category	No	Yes	
	Number (%)	**Number (%)**	***x2***
	1,831 (54.4)	1,534 (45.6)	
Floor materials			1.348
Unimproved	899 (53.4)	784 (46.6)	
Improved	932 (55.4)	750 (44.6)	
Roof materials			0.377
Unimproved	276 (53.2)	243 (46.8)	
Improved	1,555 (54.6)	1,291 (45.4)	
Wall materials			11.582**
Unimproved	828 (51.4)	784 (48.6)	
Improved	1,003 (57.2)	750 (42.8)	
Housing materials			11.592**
Unimproved	828 (51.4)	784 (48.6)	
Improved	1,003 (57.2)	750 (42.8)	
Source of drinking water			4.107*
Unimproved	482 (51.6)	452 (48.4)	
Improved	1,349 (55.5)	1,082 (44.5)	

Note:*p<0.05; **p<0.01

Multivariate results of malaria risk in U-5 children

The relationship between explanatory variables and malaria risk in under-five children is revealed in Table 3, showing unadjusted and adjusted odds ratios. The unadjusted results in Model 1 showed that the risk of malaria significantly reduced among U-5 children who lived in houses built with improved materials (OR: 0.79, CI: 0.69-0.90) and had access to improved drinking water (OR: 0.86, CI: 0.74-0.99). The results further showed that the risk of malaria among U-5 children was significantly influenced by child's age in months, child sleeping under ITN, mother receiving SP/Fansidar during pregnancy, household ownership of insecticide net, mother hearing or seeing malaria messages in the last 6 months and region of residence.

In Model 2, the adjusted results for the main explanatory variables were similar as observed in Model 1. The risk of malaria was significantly reduced among U-5 children who lived in houses built with improved materials (aOR: 0.81, CI: 0.70-0.93). There was a reduced likelihood of malaria infection among children who had access to improved drinking water (aOR: 0.91, CI: 0.78-1.07), although not significant.

After adjusting for main explanatory variables and significant covariates, the results showed that U-5 children found in houses built with improved materials

maintained significantly lower risk of malaria (aOR: 0.68, CI: 0.53-0.87) relative to those who lived in houses built with unimproved materials. Also, children who had access to improved source of drinking water maintained a reduced likelihood of malaria infection (aOR: 0.85, CI: 0.67-1.06). The results further showed that the risk of malaria decreased as a child grew older. Surprisingly, the malaria risk increased among children who slept under ITN (aOR: 1.29, CI: 1.01-1.64); children whose mothers received SP/Fansidar during pregnancy (aOR: 1.46, CI: 1.18-1.81) and children of mothers who had heard or seen malaria messages in the last 6 months (aOR: 1.77, CI: 1.45-2.17).

Table 3: Unadjusted and adjusted odds ratio of predictors of malaria infection in U-5 children in Nigeria (Nigeria MIS: 2021).

Variable/category	Model 1	Model 2	Model 3
	OR (95% CI)	aOR (95% CI)	aOR (95% CI)
Housing type			
Unimproved	1.00	1.00	1.00
Improved	0.79 (0.69-0.90)**	0.81 (0.70-0.93)**	0.68 (0.53-0.87)**
Source of drinking water			
Unimproved	1.00	1.00	1.00
Improved	0.86 (0.74-0.99)*	0.91 (0.78-1.07)	0.85 (0.67-1.06)
Child's age (months)			
0-6	1.00		1.00
7-23	1.56 (1.16-2.10)**		1.64 (1.20-2.23)**
24-59	1.88 (1.42-2.50)***		1.98 (1.43-2.76)***
Child slept under ITN last night			
No	1.00		1.00
Yes	1.35 (1.18-1.55)***		1.29 (1.01-1.64)*
Sex of child			
Male	1.00		-
Female	0.96 (0.84-1.10)		-
Mother took SP/Fansider during pregnancy			
No	1.00		1.00
Yes	1.45 (1.19-1.76)***		1.46 (1.18-1.81)**
Mother's education			
No education	1.00		1.00
Primary	1.22 (1.00-1.49)		0.99 (0.73-1.35)
Secondary/tertiary	0.94 (0.81-1.09)		0.94 (0.70-1.27)
Wealth quintile			
Lowest	1.00		-
Middle	1.14 (0.95-1.36)		-
Highest	0.94 (0.81-1.10)		-
Ownership of household insecticide net			
No	1.00		1.00
Yes	1.18 (1.02-1.37)*		0.93 (0.71-1.23)
Sex of household head			
Male	1.00		-
Female	0.78 (0.59-1.02)		-
Media exposure			
Not exposed	1.00		-
Exposed	1.08 (0.94-1.24)		-
Knowledge of ways to avoid getting malaria			
No	1.00		-
Yes	1.17 (0.98-1.40)		-
Heard/seen malaria messages in the last 6 months			
No	1.00		1.00
Yes	1.60 (1.40-1.84)***		1.77 (1.45-2.17)***
Place of residence			
Urban	1.00		-

Continued.

Variable/category	Model 1	Model 2	Model 3
	OR (95% CI)	aOR (95% CI)	aOR (95% CI)
Rural	1.09 (0.93-1.28)		-
Region			
North-central	1.00		1.00
North-east	0.85 (0.66-1.09)		0.84 (0.57-1.23)
North-west	1.07 (0.86-1.33)		1.13 (0.81-1.58)
South-east	1.16 (0.87-1.55)		1.46 (0.95-2.26)
South-south	0.74 (0.56-0.98)*		1.08 (0.71-1.64)
South-west	0.62 (0.44-0.87)*		0.80 (0.49-1.29)

Note: Ref. = reference category; * p<0.05; ** p<0.01; ***p<0.001

DISCUSSION

Given the significant burden of malaria on under-five morbidity and mortality in Nigeria, this study provides valuable insights into the influence of housing types and source of drinking water on the risk of malaria among U-5 children. The study further highlights a potential avenue for targeted interventions to control malaria infections in this vulnerable population.

The study revealed that with a significant proportion of U-5 children living in houses built with improved materials, one might expect a corresponding reduction in malaria risk. However, the finding that more than half of the children in the study experienced malaria risk is concerning. This high prevalence highlights the ongoing burden of malaria among children in the country, which corroborates a study of malaria among children under five in SSA.[24] This suggests that the improved housing materials might not be uniformly mosquito-proof with socioeconomic and environmental factors like poor maintenance, gaps in construction, or proximity to breeding sites at play. The finding showed that housing quality, specifically the use of improved housing materials, has a significant impact on reducing the risk of malaria among children under 5. This supports the observations of previous studies on the association between housing type and malaria infection among U-5 children.[20,25] Plausibly, improved housing quality reduces humidity and moisture, making the environment less conducive to mosquito survival. Also, this could help to reduce mosquito entry points, preventing them from entering homes and biting children. In line with previous studies in Nigeria, this study indicated that access to improved drinking water have a positive impact, with a reduced likelihood of malaria infection among children, although the association is not statistically significant.[26-27] This suggests that access to safe water promotes hygiene and reduces the overall burden of disease on children, making them healthier and better able to fight against malaria infections.

The study found that younger children were more likely to get malaria, compared to their older counterparts. This corroborates earlier research in Nigeria and Ghana.[20,28] This might be attributed to the fact that as children grow older, they are exposed to different illnesses and get vaccinated, which help their immune system learn how to fight against malaria parasites. Interestingly, the study showed that U-5 children who slept under ITN had higher risk of malaria compared to those who did not sleep under ITN. This finding is in contrast with the observation of an earlier study that sleeping under insecticide-treated bed nets could lower your risk of mosquitoes' bites which cause malaria in SSA.[29] Despite sleeping under insecticide-treated nets, children can still contract malaria due to issues such as net damage, inconsistent or incorrect use, and mosquitoes biting outdoors or during early evening hours, insecticide resistance, and the nets losing their potency over time. Similarly, the study found that U-5 children whose mothers took SP/Fansidar during pregnancy actually had a higher risk of malaria, contradicting a previous African study.[30] One possible explanation is that high parasite levels in the mother might have limited the transfer of protective antibodies to the child, making them more vulnerable to infection, especially in areas where malaria is common.

CONCLUSION

The study concludes that the high prevalence of malaria among under-5 children in the study is concerning, despite many living in houses built with improved materials. This implies that improving housing conditions alone may not be enough to fully protect this population from malaria risk. Additionally, it highlights that improved housing quality significantly reduces malaria risk among under-5 children, while access to improved drinking water also shows a positive impact, suggesting that environmental factors play a crucial role in malaria prevention. Policymakers should prioritise improved housing and environmental modifications to prevent malaria. Efforts should concentrate on improving housing quality, ensuring access to clean water, and implementing integrated malaria prevention strategies, targeting high-risk areas and populations, particularly under-5 children. Also, there is the need to strengthen healthcare systems for effective distribution of preventive measures to achieve the SDGs targets, especially ending malaria by 2030 in Nigeria.

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