BEYOND MOSQUITO BITES: ANALYZING MALARIA RISK FACTORS IN SOUTHERN NIGERIA

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ABSTRACT

This study investigates how various risk factors affect the prevalence of febrile diseases, with a focus on malaria in the southern states of Nigeria. The study employed Pearson correlation and multilinear regression analyses to examine the relationships between risk factors and disease prevalence. Pearson correlation analysis revealed that genetic conditions, high blood pressure, and direct contact with infected individuals were negatively correlated with malaria, while poor personal hygiene, substandard living conditions, and exposure to endemic areas had weak positive correlations. The strongest association was found with mosquito bites, which also had the highest unstandardized beta coefficient among the factors studied. Nevertheless, the study also highlights secondary risk factors, such as poor living conditions and hygiene, which are often overlooked in malaria intervention programs. These factors, although not as strong as mosquito exposure, can exacerbate the risk of infection, particularly in vulnerable populations living in impoverished areas. These results highlight the critical role of mosquito exposure in malaria and emphasize the need for targeted interventions in such areas. The findings can be beneficial to clinicians, general public, and all stakeholders involved in the fight against malaria.

Key words: Febrile disease; low-and-middle-income countries; malaria, tropical diseases

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1.0 INTRODUCTION

Malaria continues to pose a major public health challenge in low- and middle-income countries (LMICs), particularly in Africa. In 2022, 233 million cases (94%), and 580,000 (95%) malaria deaths were reported in the World Health Organization (WHO) African Region report (WHO, 2023). Tropical and subtropical climates with heavy rainfall create ideal breeding conditions for mosquitoes, contributing to increased incidences of diseases such as malaria and dengue (Awosolu et al., 2021). Beyond their health impacts, febrile diseases such as malaria exert considerable socioeconomic burdens, hindering economic development, exacerbating poverty, and straining healthcare systems (Wilastonegoro et al., 2024). Malaria, transmitted by Anopheles mosquitoes and caused by Plasmodium parasites, is influenced by environmental, social, and individual factors. Southern Nigeria, with its tropical climate, has some of the highest malaria transmission rates globally. Previous research has mainly focused on vector control measures, such as insecticide-treated nets (ITNs) and antimalarial medications. However, there is a growing need for a thorough understanding of other risk factors vital for the effective prevention of febrile diseases such as malaria (Uzoka et al., 2021a).

In Nigeria, malaria transmission occurs year-round, placing over 194 million people at risk of infection. In 2007, Nigeria recorded the highest malaria prevalence globally (FMOH, 2008). Among all other tropical diseases diagnosed in Nigeria, roughly 61.32% of patients were diagnosed with malaria, with almost 49.9% experiencing moderate to very high attack intensity, and only 11.4% presenting with low attack intensity (Uzoka et al., 2021a).

The aim of this paper is to explore the relationship between various risk factors and the prevalence of malaria in southern Nigeria. By identifying key predictors influencing malaria outcomes, the study seeks to inform public health strategies aimed at reducing the disease burden in LMICs. To achieve this, we posed the following research questions :

1. What is the influence of biological factors and genetically detemined conditions, including high blood pressure, elevated cholesterol levels, underlying chronic diseases etc., on the prevalence and confirmed diagnosis of malaria in LMICs?
2. How do socioeconomic factors, including street vendor occupations, overcrowding, travel to endemic areas, and direct contact with infected individuals, contribute to the prevalence and confirmed diagnosis of malaria in LMICs?
3. What is the influence of environmental factors, such as poor environmental conditions, exposure to mosquito bites, indoor pollution, and allergies, on the prevalence and confirmed diagnosis of malaria in LMICs?
4. Do behavioral factors, such as smoking, exposure to second-hand smoke, intravenous drug use, skin punctures, low fluid intake, and poor personal hygiene, affect the prevalence and confirmed diagnosis of malaria in LMICs?

To align with the core objectives of this research, we investigated the relationship between independent variables (i.e., risk factors) and their influence on the confirmed diagnosis of malaria. We hypothesixzed that a direct correlation exists between risk factors and the likelihood of being diagnosed with malaria in LMICs.

2.0 LITERATURE REVIEW

An earlier study by Gallup and Sachs (2001) examined the economic effects of malaria, revealing a strong correlation between malaria endemicity and poverty in African nations. Their findings indicated that countries with high malaria prevalence had income levels up to 33% lower than those with minimal malaria exposure, even after accounting for other factors. This research underscores the substantial economic burden malaria places on African countries and emphasizes the potential economic gains achievable through effective malaria control measures.

Bhatt et al. (2015) conducted an extensive review of malaria control efforts in Africa from 2000 to 2015, highlighting the limited understanding of the root causes of malaria in sub-Saharan Africa, despite its critical significance. Analyzing 32 highly endemic countries, which account for around 90% of the global malaria burden, the study found that national health records were inadequate for accurately tracking malaria trends. However, the authors reported a 50% reduction in malaria prevalence and a 40% decrease in clinical disease incidence in these countries over the 15-year period, attributing these improvements to targeted interventions such as bed nets among others.

In addressing the effects of climate change on malaria transmission, Caminade et al. (2014) utilized climate models to project future malaria risks in Africa. Their study indicated that while some regions may experience reduced transmission due to increased aridity, others, particularly highland areas, could face heightened risk from rising temperatures.

Nkumama et al. (2017) examined the evolving epidemiology of malaria in Africa amidst ongoing elimination efforts, observing a shift in the age distribution of clinical malaria cases towards older children and adults. This shift was linked to reduced transmission intensity and delayed immunity acquisition, highlighting the need for sustained vigilance and adaptive control strategies.

Monroe et al. (2019) carried out a systematic review of qualitative studies to examine the impact of human behavior on malaria transmission. They identified key behavioral factors affecting malaria risk, such as outdoor nighttime activities, sleeping arrangements, and varying perceptions of malaria risk.

Boyce and O'Meara (2017) reviewed the adoption of rapid diagnostic tests (RDTs) for malaria in Africa, noting a significant rise in their use. However, they identified ongoing challenges related to ensuring the quality of RDTs, their correct usage, and their effective integration into clinical decision-making. The authors stressed the importance of continuous training and robust quality assurance measures to fully realize the potential of RDTs in improving malaria case management.

Uzoka et al. (2021b) explored the use of mobile technology and artificial intelligence for malaria diagnosis, proposing a framework for cell phone-based testing that capitalizes on the widespread availability of mobile devices in LMICs. This approach aims to enhance access to rapid and accurate malaria diagnostics, particularly in remote areas with limited healthcare infrastructure. By incorporating image processing and machine learning algorithms on mobile platforms, these systems hold the potential to improve early detection and treatment, contributing to more effective malaria management and control efforts in endemic regions.

3.0 METHODOLOGY

Purposive sampling was employed to select the states and medical institutions where the study was conducted, based on accessibility and convenience. This method ensured the representation of diverse medical institutions, including large public hospitals, government facilities, private hospitals and clinics. Random sampling was then applied to select participants who expressed interest in the study. Invitations were advertised at the selected medical institutions, and interested patients submitted their names to designated officers. Participants were randomly chosen from this pool for data collection. Table 1 below highlights the study's participants.

The participation rates across the selected states were generally comparable, with the exception of Imo State, where fewer than 1,000 patients participated in the study. Children and adolescents under the age of 19 comprised 40% of the patient population, whereas only 7% were aged 60 years or older. Patients of female gender outnumbered those of the male gender (55% to 45% respectively).

The cross-sectional design of this study facilitated the collection of data from participants at a single point

Table 1. Descriptive Statistics of Study Participants

	Number	**%**
State		
Akwa Ibom	1223	25
Cross River	1531	32
Imo	882	18
Rivers	1232	25
	4868	**100**
Age Group		
<19 yrs	1934	40
19-24 yrs	424	9
25-44 yrs	1557	32
45-60 yrs	600	12
>60 yrs	353	7
	4868	**100**
Gender		
Male	2175	45
Female	2693	55
	4868	**100**

Table 2. Risk factors used in the study

#	Risk Factors	Description
	Biological Factors	
1	**GNCN**	Genetic condition
2	**HIBP**	High blood pressure
3	**HICOL**	High cholesterol
4	**UNCHRIL**	Underlying chronic illness
5	**ALG**	Allergies
	Environmental and Socioeconomic Factors	
6	**STRVEN**	Street vendor
7	**PPHYG**	Poor personal hygiene
8	**PECON**	Poor environmental conditions
9	**OVCRW**	Overcrowding
10	**IVDRUS**	Intravenous drug use
11	**TRVENRG**	Travel to endemic region
12	**SKPUPR**	Skin puncture procedure
13	**DRCOIFPS**	Direct contact with infected person
14	**LWFLIN**	Low fluid intake
15	**EXPMQBT**	Exposure to mosquito bites
16	**SMEXSM**	Smoking or exposure to smoking
17	**EXIDARPOL**	Exposure to indoor air pollution

in time and focused on assessing clinical diagnostic outcomes of malaria based on respondents' exposure to a range of risk factors. Seventeen risk factors—ranging from genetic conditions, high blood pressure, and high cholesterol, to poor personal hygiene, intravenous drug use, travel to endemic areas, and exposure to mosquito bites—were examined for their impact on malaria diagnosis as shown in Table 2 below.

3.1 Research Instrument and Data Collection

A questionnaire utilizing a 5-point Likert scale, ranging from Absent, Mild, Moderate, Severe, to Very Severe, was employed to capture the presence of each risk factor for every participant. This data was then used to analyze the impact and correlation of the examined risk factors on the confirmed diagnosis of malaria based on participants' responses. The questionnaire was designed with reference to existing literature and previous studies investigating the relationship between risk factors and disease prevalence (Uzoka et al., 2021a).

Medical doctors at the selected medical institutions were enlisted to administer the questionnaire during routine consultations with patients who had opted in and were randomly selected to participate in the study. The data collection process spanned eight months, from May to December 2021, and covered four states in Southern Nigeria (Akwa Ibom, Cross River, Imo, and Rivers). A total of 4,870 patient consultation forms were distributed, yielding 4,868 usable responses, resulting in a remarkable response rate. The focus of this study was on non-clinical factors that may affect the patients. These were categorized as biological, environmental and socioeconomic factors as shown in Table 2 above.

The reliability of the study instrument was assessed using Cronbach's alpha, which yielded a value of 0.740. Since this value exceeds the 0.7 rule of thumb threshold (Nunally, 1978), it indicates that the instrument was reliable. The validity of the research tool was ensured through a pilot study, while content validity was confirmed via an independent review conducted by experienced colleagues who were not involved in the study.

3.2 Ethical Considerations

Table 3. Risk Factors for Malaria with R^2 = 0.37

	Correlation Analysis		Regression Analysis		Beta coefficients
Risk Factors	R-value	P-value	T	P-value	β
GNCN	**-0.06**	**0.000**	-3.69	0.00	-.131
HIBP	**-0.03**	**0.032**	-1.86	0.06	-.063
HICOL	0.010	0.478	0.26	0.80	.014
STRVEN	**0.087**	**0.000**	0.59	0.56	.025
PPHYG	**0.054**	**0.000**	-5.51	0.00	-.185
PECON	**0.126**	**0.000**	-2.11	0.04	-.065
OVCRW	0.009	0.513	-3.09	0.00	-.104
IVDRUS	0.012	0.405	2.21	0.03	.156
TRVENRG	**0.300**	**0.000**	11.72	0.00	.275
SKPUPR	0.021	0.135	-6.60	0.51	-.045
DRCOIFPS	**-0.054**	**0.000**	-5.95	0.00	-.162
LWFLIN	**0.111**	**0.000**	5.13	0.00	.173
EXPMQBT	**0.570**	**0.000**	41.68	0.00	.807
SMEXSM	-0.026	0.072	-1.65	0.10	-.062
UNCHRIL	-0.025	0.086	-0.69	0.49	-.019
EXIDARPOL	0.015	0.303	-1.78	0.08	-.077
ALG	-0.027	0.062	-2.79	0.01	-.116

Informed consent was obtained from participants who chose to participate in the study. They were thoroughly informed about the study's purpose and procedures prior to providing their consent. Participant confidentiality was maintained through data anonymization to protect their identities, and the data was stored securely. The Mount Royal University Ethics Committee a (Human Research Ethics Board # 102232) and the University of Uyo Teaching Hospital health research ethical committee (Ref # UUTH/AD/S/96/VOL.XX1/450) approved this research.

4.0 RESULTS AND DISCUSSIONS

SPSS version 20 was used to carry out the data analysis. The regional demographics, alongside with participants' gender and age were examines, utilizing frequency distributions. Additionally, multilinear regression analysis was carried out to investigate the influence of selected risk factors. With a sample size of 4,868, the analysis had adequate data to identify significant predictors. Table 3 below shows the correlations between malaria and the associated risk factors .

GNCN=Genetic condition, HIBP=High blood pressure, HICOL =High cholesterol, STRVEN=Street vendor, PPHYG=Poor personal hygiene, PECON=Poor environmental conditions, OVCRW=Overcrowding, IVDRUS=Intravenous drug use, TRVENRG=Travel to endemic region, SKPUPR=Skin puncture procedure, DRCOIFPS=Direct contact with infected person, LWFLIN=Low fluid intake, EXPMQBT=Exposure to mosquito bites, SMEXSM=Smoking or exposure to smoking, UNCHRIL=Underlying chronic illness, EXIDARPOL=Exposure to indoor air pollution, ALG=Allergies

Correlation coefficients highlighted in bold text indicate a significant association with malaria. Our analysis reveals that certain genetic conditions, high blood pressure, and direct contact with infected individuals were negatively correlated with malaria prevalence. Research on the association between genetic disorders and malaria susceptibility or resistance is growing (Tiwari et al., 2023; Gallego-Delgado et al., 2016).

Conversely, factors such as being a street vendor, poor personal hygiene, living in substandard environmental conditions, traveling to endemic areas, and low fluid intake exhibited positive correlation with malaria prevalence, though the correlations are relatively weak. The most pronounced correlation was observed in patients exposed to mosquito bites (r = 0.570, *p-value* of < 0.001). This finding aligns with the results of Bhatt et al. (2013), who noted that rapid urbanization, inadequate infrastructure, and population growth created environments conducive to the spread of mosquito-borne diseases. This result also aligns with the findings of de-Souza and Weaver (2024), who linked vector-borne diseases to poor environmental conditions and stagnant water. Also, low fluid intake or dehydration increases the prevalence of malaria-associated diarrhea and children with dehydration are more likely to manifest malaria parasitaemia (Ibadin et al, 2000).

The various risk factors were plugged in as independent variables against the dependent variable (Malaria) to evaluate the impact and significance of those risk factors on the confirmed diagnosis of malaria in LMICs. The multilinear regression results on Malaria exhibited a high F-value of 166.91, $p < 0.01$ and an R^2 value of 0.37, indicating that 37% of the variance in malaria diagnoses can be explained by the risk factors included in this study.

The variance inflation factors (VIF) for all predictor variables (risk factors) were below 5, and all tolerance values were above 0.25, indicating minimal multicollinearity and a moderate, acceptable level of correlation among the predictors. Table 3 displays the statistical significance of each risk factor for the disease. The most significant factor was the impact of mosquito bites on the confirmed diagnosis of malaria, with a *t-value* of 41.68 and *p-value* < 0.01.

Furthermore, the unstandardized beta coefficients indicate the impact of a one-unit increase in each independent variable on the dependent variable (malaria). The results show that the highest coefficient is associated with the impact of mosquito bites on the confirmed diagnosis of malaria (β = 0.807, $p < 0.001$).

5.0 CONCLUSIONS

In summary, this research examined the hypothesis of a direct correlation between risk factors and the likelihood of being diagnosed with malaria in LMICs, specifically in Nigeria. With nearly 5,000 participants across four Nigerian states, our findings highlight a complex interplay of factors that influence malaria risk.

Firstly, a Pearson correlation analysis identified several risk factors: certain genetic conditions, high blood pressure, and direct contact with infected individuals negatively correlated with malaria prevalence. In contrast, risk factors such as poor personal hygiene, inadequate living conditions, exposure to endemic areas, and low fluid intake exhibited weak positive correlations with malaria. Among the various risk factors, mosquito bites were identified as the most significant predictor, both in terms of correlation and impact. The unstandardized beta coefficient for mosquito bites was notably high ($\beta = 0.807$, $p < 0.001$).

Secondly, the explained variance of 37% in malaria diagnoses underscores the role of environmental factors, particularly mosquito exposure, in malaria transmission. The strong association with mosquito bites supports vector control as the primary intervention, as outlined by Bhatt et al. (2013).

Lastly, our findings support the hypothesis and highlight that mosquito exposure is a predominant factor in malaria prevalence, emphasizing the need for targeted interventions to address this critical risk factor in the fight against malaria. Addressing mosquito exposure through preventive measures and improving living conditions in LMICs could significantly reduce malaria and especially in tropical African countries such as Nigeria. Understanding the risk factors associated with malaria within LMICs is crucial for developing targeted public health interventions and policies.

Conflict of Interest

The authors declare they have no conflict of interest to disclose.

REFERENCES

1. Awosolu, O. B., Yahaya, Z. S., Haziqah, F., Simon-Oke, I. A., & Fakunle, C. A cross-sectional study of the prevalence, density, and risk factors associated with malaria transmission in urban communities of Ibadan, Southwestern Nigeria. Heliyon, 2021; 7(1): 1-7. https://doi.org/10.1016/j.heliyon.2021.e05975
2. Bhatt, S., Gething, P. W., Brady, O. J., Messina, J. P., Farlow, A. W., Moyes, C. L., ... & Hay, S. I. The global distribution and burden of dengue. Nature, 2013; 496(7446): 504-507. https://doi.org/10.1038/nature12060
3. Bhatt, S., Weiss, D. J., Cameron, E., Bisanzio, D., Mappin, B., ... & Gething, P. W. The effect of malaria control on Plasmodium falciparum in Africa between 2000 and 2015. Nature, 2015; 526(7572): 207-211. https://doi.org/10.1038/nature15535
4. Boyce, M. R., & O'Meara, W. P. Use of malaria RDTs in various health contexts across sub-Saharan Africa: A systematic review. BMC Public Health, 2017; 17(1): 470. https://doi.org/10.1186/s12889-017-4398-1
5. Caminade, C., Kovats, S., Rocklov, J., Tompkins, A. M., Morse, A. P., Colón-González, F. J., Stenlund, H., Martens, P., & Lloyd, S. J. Impact of climate change on global malaria distribution. Proceedings of the National Academy of Sciences, 2014; 111(9): 3286-3291. https://doi.org/10.1073/pnas.1302089111
6. de-Souza, W. M., & Weaver, S. C. Effects of climate change and human activities on vector-borne diseases. Nature Reviews Microbiology, 2024; 1-16.
7. Federal Ministry of Health (FMOH). National Malaria Control Programme, Nigeria, Abuja, Strategic Plan 2009-2013: A Road Map for Malaria Control in Nigeria. Draft 16. 2008. Retrieved from http://www.nationalplanningcycles.org/sites/default/files/country_docs/Nigeria/nigeria_draft_malaria_strategic_plan_2009-2013
8. Gallego-Delgado, J., Walther, T., & Rodriguez, A. The high blood pressure-malaria protection hypothesis. Circulation Research, 2016; 119: 1071-1075. https://doi.org/10.1161/CIRCRESAHA.116.309602
9. Gallup, J. L., & Sachs, J. D. The economic burden of malaria. The American Journal of Tropical Medicine and Hygiene, 2001; 64(1_suppl): 85-96. https://doi.org/10.4269/ajtmh.2001.64.85
10. Ibadin, O. M., Airauhi, L., Omoigberale, A. I., & Abiodun, P. O. Association of malarial parasitaemia with dehydrating diarrhoea in Nigerian children. Journal of Health, Population and Nutrition, 2000; 115.
11. Monroe, A., Moore, S., Koenker, H., Lynch, M., & Ricotta, E. Measuring and characterizing night time human behaviour as it relates to residual malaria transmission in sub-Saharan Africa: A review of the published literature. Malaria Journal, 2019; 18(1): 6. https://doi.org/10.1186/s12936-019-2638-9
12. Nkumama, I. N., O'Meara, W. P., & Osier, F. H. A. Changes in malaria epidemiology in Africa and new challenges for elimination. Trends in Parasitology, 2017; 33(2): 128-140. https://doi.org/10.1016/j.pt.2016.11.006
13. Nunnally, J. C. Psychometric theory (2nd ed.). New York, NY: McGraw-Hill; 1978.
14. Tiwari, A., Dea, A., & Sinha, A. Increasing blood pressure: Could malaria have a role? The Lancet Global Health, 2023; 11(11): e1697. https://doi.org/10.1016/S2214-109X(23)00419-9
15. Uzoka, F. M. E., Akwaowo, C., & Nwafor-Okoli, C. Risk factors for some tropical diseases in an African country. BMC Public Health, 2021a; 21: 2261. https://doi.org/10.1186/s12889-021-12286-3 https://doi.org/10.1186/s12889-021-12286-3
16. Uzoka, F. M. E., Osuji, J., & Obot, O. A framework for cell phone-based malaria diagnosis. Journal of Medical Systems, 2021b; 45(1): 3.
17. Wilastonegoro, N., Andriani, S., Sebong, P. H., Shepard, D. S., & Agarwal-Harding, P. Estimating dengue disease and economic burden to inform municipal-level policymakers: Method for a pragmatic city-level observational cohort study. Gates Open Research, 2024; 8(3): 1-27. https://doi.org/10.12688/gatesopenres.15015.3
18. World Health Organization. Report of the Regional Director: The work of the World Health Organization in the African Region, July 2023 - June 2024. World Health Organization, 2023. https://www.afro.who.int/publications/annual-report-regional-director-work-who-african-region-july-2022-june-2023. Accessed March 24, 2025.