A Cross-Sectional Study of the Prevalence, and Risk Factors Associated With Malaria Transmission among Sickle Cell Anaemia Patients in Urban Communities of Taraba Northeastern Nigeria

ABSTRACT

Introduction: Sickle cell disease (SCD) poses significant health challenges, particularly in regions like sub-Saharan Africa where its prevalence is high. Malaria, a prevalent infectious disease in this region, exacerbates the complications associated with SCD. Understanding the epidemiology and risk factors of malaria among SCD patients is crucial for effective management and control strategies.

Aim: To evaluate the prevalence and risk factors associated with malaria transmission among sickle cell anaemia patients in urban communities of Taraba State, Northeastern Nigeria.

Methods: The study involved the screening of sickle cell anaemia patients in selected health facilities in Taraba State from December 2022 to December 2023. Data on demographic characteristics, risk factors, and malaria status were collected using structured questionnaires and blood samples. Parasitological examination was conducted to determine malaria prevalence, and statistical analysis was performed using SPSS version 25.0.

Results: The study revealed a malaria prevalence of 12.9% among sickle cell anaemia patients, with higher rates observed in Takum compared to other communities. Malaria infection was more common among males, children aged 1-10 years, non-educated individuals, and those engaged in specific occupations like farming and trading. Risk factors such as stagnant water around residences, presence of bushes, lack of insecticidal nets, and use of indigenous herbs were associated with higher malaria transmission rates.

Conclusion: The findings underscore the importance of targeted interventions to mitigate malaria burden among sickle cell anaemia patients, including educational campaigns, access to preventive measures such as insecticidal nets, and improvement in environmental hygiene practices. Implementing these strategies is crucial for reducing malaria-related morbidity and mortality in affected communities.

Keywords: Sickle cell anaemia, Malaria prevalence, Risk factors, Urban communities, Northeastern Nigeria

1. INTRODUCTION

Sickle cell disease is a hereditary blood disorder which distorts the ability of the hemoglobin to bind and transport oxygen to tissues and organs. It is marked by chronic anaemia, pain, crises, jaundice, progressive organ damage, frequent episodes of acute illness and an increased risk of serious bacterial infections among other complications [1]. Individuals who inherit the sickle cell disease often require lifelong interventions including blood transfusions and prophylactic therapy to manage their symptoms and help improve their quality of life.

A 2010 review on the global burden of sickle cell disease estimated that approximately 275,000 children with sickle cell disease are born yearly, with 85% of these births occurring in sub-Saharan Africa [2]. The exact prevalence of sickle cell disease in sub-Saharan Africa is likely to be much higher than reported in the available literature and registers, due to the widespread absence of newborn screening across the region. Moreover, the clinical course of sickle cell disease is often made worse in this population due to limited access to quality healthcare and the high risk of exposure to infectious diseases which may potentially increase disease severity [3]. Among the later, malaria is of great concern due to its tendency to augment hemolytic anaemia and precipitate episodes of painful crises in sickle cell patients [4]. Malaria is a mosquito-borne parasitic infection caused by five species of the genus plasmodium; the most lethal and common being Plasmodium falciparum, which is prevalent in sub-Saharan Africa [5]. In 2017, the World Health Organization reported 219 million cases of malaria in 90 countries and estimated 435,000 resulting deaths. Most deaths occurred among children under the age of 5 living in sub-Saharan Africa [6].

There are many factors contributing to persistence of malaria infection in Nigeria such as education, income, housing patterns, social groups, leadership challenge, infrastructure deficiency, water storage, behavioural challenge and lack of knowledge about causes and control [7, 8]. The factors that contribute to the spread and transmission of malaria depend on the interaction between the human host, the anopheles vector, malaria parasite and environmental conditions [9]. However, there is significant risk of infection in urban areas, where indiscriminate waste disposal and the presence of swamps, gutters and thick vegetation encourage the breeding of the mosquito vector that causes malaria [10]. In rural and urban areas, breeding sites of the female Anopheles mosquito is common during the rainy season where there is abundant of bushes, stagnant water around residential homes, while in the dry season, stagnant and smelling streams, irrigation ponds for dry season farming, indiscriminate disposal of domestic, commercial and industrial waste provides suitable environment for the infected mosquito to breed and proliferate. In the northern parts of Nigeria, due to the high shortage of water, many residents in both urban and rural areas harvest and store their water in commercial plastic tanks, clay pot, open buckets and basins. These water storage containers have been identified as good breeding sites of the mosquito vector.

The aim of this study is to assess the malaria status among sickle cell (SS) patients in three urban communities of Taraba State, Nigeria, by determining the overall prevalence of malaria, analyzing its prevalence based on socio-demographic profiles of patients, and identifying associated risk factors.

2. MATERIAL AND METHODS

2.1 Study Area

The study was carried out in Taraba State. Taraba State is located in the north-eastern part of Nigeria. The state lies within the coordinates 8000’N100’E with total area of 54,437km and the total population of 2,294,800 [11]. The river Taraba, Benue, Ibi and Donga which arises from the Cameroun Mountain supplies the state with adequate water supplies for its agricultural activities. The climate of the state is tropical with vegetation characterized by a typical Guinea Savannah. There are two distinct seasons, the wet and dry season. The residents of the state are mostly involved in commercial and subsistence farming and in livestock production. Communities living on the banks of the rivers engage in fishing all year round. Other occupational activities include: pottery, cloth-weaving, dyeing, mat-making, carving, embroidery and blacksmithing. The Mumuye, Fulani, Jenjo, Wurkum and Kona tribes are predominantly located in the northern part of the state. While the Jukun, Chamba, Tiv, Kuteb and Ichen are the tribes that inhabits the southern parts of the state.

2.2Study Design

This is a cross-sectional research study designed to survey the status of malaria in sickle cell anaemia patients in select communities/ health facilities in Taraba state, Nigeria. All sickle cell anaemia (SS) patients who consented were screened for the study.

2.3Study population

The study population comprises of all consenting sickle cell anaemia patients who present themselves in the Out-Patients Department (OPD) in five (5) designated health facilities in Takum L.G.A, Taraba State with various ailments from December 2022 to December 2023. The standard method [13] was used to determine the sample size at 0.05 significant levels.

$$N = \frac{z^2pq}{d^2}$$

Where:

N= Desired sample size

z^2=Standard normal deviate set at 1.9^2

P=Proportion in the target population estimated to have a particular characteristic.

q= 1-p (either the patient has or does not have the characteristics)

d= Degree of accuracy set at 0.05.

$$N=\frac{1.9^2 \text{ X } 820 \text{ X } 0.5}{0.5^2}$$

$$= \frac{3.61 \text{ X } 408 \text{ X } 0.5}{0.0025}$$

$$= \frac{1498.15}{0.0025}$$

=294.576

.

2.4Specimen collection

Structured questionnaire was used to collect information on the respondents' age, gender, occupation status, educational status and risk factors of malaria. After questionnaire administration and some brief minutes of counselling, five (5mls) of whole blood was collected by venipuncture with sterile disposable syringes into labelled EDTA bottles [14]. Two drops of blood was placed on a clean glass slide to form a thick film, Giemsa statin was added to the slide and allowed to fix for 30 minutes. The slide was slanted to allow the stain to run off the slide, tap water was made to run through the slide. The slide is air dried and a drop of oil immersion was added to the slide and viewed under x40 magnification.

The parasite density will be counted according to the WHO standard formula [15].

$$\text{Parasite/µl} = \frac{\text{Number of parasites counted x8000 white cells/µl}}{\text{Number of white cells counted}}$$

Where 8000 = putative means of leucocytes.
The level of parasitemia will be quantified as low (+), moderate (++) and high (+++).

2.5Data Analysis

The data was coded, classified and analyzed by SPSS version 25.0. Descriptive statistic were carried out using Frequency and percentage.The results from these analyzes were presented in the form of tables

3. RESULTS AND DISCUSSION

Table 1 shows the prevalence of malaria in sickle cell patients in different communities of Ardo-kola, Bali and Takum, Nigeria. Out of the 620 blood samples collected, 80 (12.9%) were positive for malaria. Malaria infection was highest in Takum, 44/294 (15%), followed by Ardo-kola, 17/125 (13.6%) while low malaria infection was recorded in Bali, 19/201 (9.4%).

Table 1. Prevalence of malaria transmission among sickle cell anaemia patients in urban communities of Taraba, Northeastern Nigeria

Ardo-kola	**No. infected (%)**	**Bali**	**No. infected (%)**	**Takum**	**No. infected (%)**
KasuwanLadi (25)	2 (8.4)	Gazabu (37)	4 (10.8)	Tati (51)	10 (19.6)
Barkindutse (19)	2 (10.5)	Dania (35)	3 (8.6)	Muji (58)	9 (15.5)
Iware (20)	3 (15.0)	Maihula (40)	4 (10.0)	Simta (62)	6 (9.7)
Divoh (25)	4 (16.0)	Sansani(43)	5 (11.6)	Bette (65)	11 (17.0
Penpetel (36)	6 (16.7)	Mayokan(46)	3 (6.5)	Fette (58)	8 (13.8)
Total (125)	**17 (13.6)**	**Total (201)**	**19 (9.4)**	**Total (294)**	**44 (15.0)**

Table 2 shows the prevalence of malaria based on demographic factors among patients with sickle cell anaemia according to communities in Taraba state, Nigeria. Malaria infection was highest 33/179 (18.4%) among ages 1-10yrs, while a slightly lower prevalence was recorded in ages 11-20yrs 16/129 (12.4%), 21-30yrs 17/138 (12.3%) and 31-40yrs 3 (7.5%). Lowest malaria prevalence was recorded in >40yrs 4/76 (5.3%). Malaria infection was higher among males 51/370 (13.8%) than females 29/250 (11.6%). This was consistent in all communities sampled. Malaria infection was higher among singles 51/299 (17.1%) compared with married 18/150 (12.0%) and divorced/widowed categories 12/153 (7.2%). Similar distribution was observed in all communities sampled. Malaria infection was highest among students 13/82 (15.9%), followed by traders 28/197 (14.2%), artisans 19/145 (13.1%), farmers 17/157 (10.8%), and lowest 2/28 (7.1%) among civil servants. This was consistent in all communities sampled.in two of the communities (Bali 3/24 (12.5%) and Takum 8/38 (21.1%)), while artisans had higher malaria infection prevalence in third community (Ardo-kola 5/30 (16.7%)). Malaria infection was higher among non-educated respondents 53/368 (14.4%) than educated respondents 27/252 (10.7%). This was consistent in all communities sampled.

Table 2. Prevalence of malaria transmission based on demographic factors among sickle cell anaemia patients in urban communities of Taraba, Northeastern Nigeria.

		Ardo-kola L.G.A		Bali L.G.A		Takum L.G.A		Total infected (%)
Indicator	**Respond**	**No.**	**Infected**	**No.**	**Infected**	**No.**	**Infected**	

			(%)		(%)		(%)	
Age (yrs)	1-10	43	9 (20.0)	53	7 (13.2)	83	17 (20.5)	33 (18.4)
	11-20	28	3 (10.7)	35	3 (8.6)	66	10 (15.2)	16 (12.4)
	21-30	35	4 (11.4)	48	5 (10.4)	55	8 (14.5)	17 (12.3)
	31-40	13	2 (7.7)	37	3 (8.1)	50	6 (12.0)	11 (11.0)
	>40	8	0 (0.0)	28	1 (3.5)	40	3 (7.5)	4 (5.3)
Gender	Male	70	10 (14.3)	113	12(10.6)	187	29(15.5)	51 (13.8)
	Female	55	7 (12.7)	88	7 (7.9)	107	15(14.0)	29 (11.6)
Marital status	Single	48	11 (23.0)	68	10 (11.6)	183	30 (16.4)	51 (17.1)
	Married	25	3 (12.0)	51	5 (9.8)	74	10 (13.5)	18 (12.0)
	Divorced	52	3 (5.8)	64	4 (6.3)	37	4 (10.8)	11 (7.2)
Occupational status	Artisan	30	5 (16.7)	55	5 (9.1)	60	9(15.0)	19 (13.1)
	Trader	37	6 (16.2)	61	6 (10.0)	99	16(16.2)	28 (14.2)
	Farmer	26	3 (11.5)	50	4 (8.0)	81	10(12.3)	17 (10.8)
	Students	20	2 (10.0)	24	3 (12.5)	38	8(21.1)	13 (15.9)
	Civil servants	12	1 (8.3)	0	0 (0.0)	16	1(6.3)	2 (7.1)
Educational status	Non-educated	81	12 (14.8)	119	14 (11.8)	168	27(16.1)	53 (14.4)
	Educated	44	5 (11.4)	82	7 (6.1)	126	17(13.5)	27 (10.7)
	Total	**125**	**17 (13.6)**	**201**	**19 (9.4)**	294	44(14.0)	80 (12.9)

Table 3 shows the risk factors associated with malaria transmission among sickle cell anaemia patients in urban communities of Taraba, Northeastern Nigeria. Stagnant water around residences, presence of bushes around residences, lack of LLITNs (Long-lasting insecticidal nets), lack of mosquito repellants, absence of malaria prophylaxis, and use of indigenous herbs are associated with higher malaria transmission rates.

Table 3. Risk factors associated with malaria transmission among sickle cell anaemia patients in urban communities of Taraba, Northeastern Nigeria

		Ardo-kola L.G.A		Bali L.G.A		Takum L.G.A		**Total**	
Risk factors	**Respond**	**No Ex.**	**Infected (%)**	**No Ex**	**Infected (%)**	**No Ex**	**Infected (%)**	**No Ex**	**Infected (%)**
Stagnant water around home	Yes	93	14 (15.1)	89	11 (12.4)	169	41(24.3)	351	66(18.8)
	No	32	3 (9.4)	112	8 (8.9)	125	3(2.4)	269	14(5.2)
Bushes around residence	Yes	89	14 (15.7)	156	15 (9.6)	200	37(18.5)	445	66(14.8)
	No	36	3 (8.3)	45	4 (8.9)	94	7 (7.4)	175	14(8.0)
Use of LLITNs	Yes	34	3 (8.8)	75	4 (5.3)	62	11(17.7)	171	18(10.5)
	No	91	14 (15.4)	126	15 (11.9)	232	33(14.2)	449	62(13.8)
Use of mosquito repellants	Yes	51	5 (9.8)	77	2 (2.6)	79	5(6.3)	207	12(5.8)
	No	74	12(16.2)	124	17 (13.7)	215	39(18.1)	413	68(16.5)
Use of malaria	Yes	74	13(17.6)	81	5 (6.2)	104	13(12.5)	259	31(12.0)

prophylaxis	No	51	4(7.8)	120	14 (11.7)	190	31(16.3)	361	49(13.6)
Use of indigenous herbs	Yes	82	5 6.1)	95	12 (12.6)	159	42(26.4)	336	59(17.6)
	No	43	12 (27.9)	106	7 (6.6)	135	2(1.5)	284	21(7.4)
Farming close to residence	Yes	-		156	16 (10.3)	201	40(19.9)	357	56(15.7)
	No	-	-	45	3 (6.7)	93	4(4.3)	138	7(5.1)
Open drainage	Yes	-	-	-	-	194	40(20.6)	194	40(20.6)
	No	-	-	-	-	100	4(4.0)	100	4 (4.0)
Blood transfusion	Yes	69	13 (18.8)	-	-	-	-	69	13(18.8)
	No	56	4 (7.1)	-	-	-	-	56	4(7.1)
Hospital admission	Yes	74	15 (20.3)	-	-	-	-	74	15(20.3)
	No	51	2 (3.9)	-	-	-	-	51	2(3.9)
	Total	125	**17** (**13.6**)	-	-	-	-	125	**17 13.6**)

Farming close to residence and open drainage systems also contribute to increased malaria transmission. Blood transfusions and hospital admissions seem to be associated with higher malaria prevalence among sickle cell patients.

Discussion

The prevalence of Plasmodium falciparum infection in this study was 12.9%. This figure aligns with findings in Ekiti [16] but is lower than reports from Ebonyi and Ibadan [17, 18]. Geographical differences and environmental conditions may influence mosquito breeding habitats and malaria transmission dynamics. Takum, with its higher malaria prevalence, might have more conducive environmental factors, such as standing water bodies.

Malaria infection was higher among males (13.8%) than females (11.6%), consistent across all sampled communities. This trend mirrors findings in Colombia [19] and Ibadan [20], where a higher prevalence among males was reported compared to females. Gender disparities in malaria prevalence could be influenced by differences in outdoor activities, exposure to mosquito breeding sites, and stress [21,22].

Malaria infection was highest (18.4%) among ages 1-10 years and lowest in those over 40 years (5.3%). This pattern is consistent with findings in Ebonyi, where children under 10 years had the highest prevalence of Plasmodium falciparum infection ([18]. The higher prevalence among younger age groups, particularly 1-10 years, may reflect increased vulnerability due to immature immune systems and higher exposure to mosquito bites.

Malaria infection was higher among non-educated respondents (14.4%) than educated respondents (10.7%), consistent across all sampled communities. This finding is similar to results in Ekiti [16] and Ibadan [17], where those without formal education had the highest prevalence of Plasmodium falciparum infection. Education improves the effectiveness of malaria campaigns as it aids in understanding the epidemiology and predisposing factors associated with disease transmission [23].

In this study, stagnant water around residences, presence of bushes, lack of LLITNs (Long-lasting insecticidal nets), mosquito repellants, absence of malaria prophylaxis, and use of indigenous herbs are associated with higher malaria transmission rates. This finding is consistent with results from Ekiti [16], Ibadan [20], and Cameroon [24], where Plasmodium falciparum infections were associated with stagnant water around homes and failure to use Long Lasting Insecticide Nets.The potential of hydroxyurea treatment in reducing malaria infection in sickle cell patients was also found in a study [31]

The presence of bushes and stagnant water enhances mosquito breeding in the environment, leading to increased transmission of infections [25].
Due to the nocturnal feeding habits of most Anopheles mosquitoes, malaria transmission primarily occurs at night. Protection against mosquito bites includes using mosquito bed nets (preferably insecticide-treated nets), wearing clothes that cover most of the body, and using insect repellent on exposed skin. The use of ITNs has been reported in several other countries, especially Western Kenya [26], Africa [27], Myanmar [28], and Eastern Afghanistan [29]. LLITNs not only create a barrier between the mosquito and the intended meal but also kill the mosquito if it lands on the net [30]. Reduction of human-vector contact through insecticide-treated bed nets is well-suited for malaria control in Africa, as it enjoys greater community acceptance and is as efficacious as indoor residual spraying. However, despite being inexpensive and effective, fewer than 2% of Africans sleep under them [31, 32]. Massive campaigns to increase their use are urgently needed, especially in rural Nigeria.

4. CONCLUSION

This study emphasizes malaria prevalence among sickle cell anaemia patients, highlighting demographic disparities and environmental influences on transmission. Targeted interventions, particularly education campaigns and access to preventive measures such as insecticide treated nets, environmental hygiene practices and access to preventive and curative healthcare services, is crucial for reducing malaria burden among sickle cell anaemia patients in these communities.

Consent and Ethical Approval

Ethical permission for the study was sought and obtained from the Health and Research Committee, Taraba State Ministry of Health, Jalingo and presented to the Management of the health facilities where the blood samples were collected in compliance with the Declaration on the Right of the Patient [12]. Informed consent was sought and obtained from the patients in accordance with standards for human experimentation and the Helsinki Declaration.

Disclaimer

This paper is an extended version of a preprint document of the same author.

The preprint document is available in this link https://www.researchsquare.com/article/rs-4516627/v1

[As per journal policy, preprint article can be published as a journal article, provided it is not published in any other journal]

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

REFERENCES

1. Aju-Ameh, C.O. (2020). Mosquitoes are not the major culprits for the high burden of malaria in Nigeria: a commentary. Pan African Medical Journal, 35(11): 1 – 5.

2. Anumudu, C. I., Adepoju, A., Adediran, M., Adeoye, O., Kassim, A., Oyewole, I., &Nwuba, R. I. (2006). Malaria prevalence and treatment seeking behaviour of young Nigerian adults. *Annals of African Medicine*, *5*(2), 82-88.

3. Arora DR and Arora B (2009). Medical Parasitology 2nd edition.Pp.67-81

4. Awosolu, O. B., Yahaya, Z. S., Farah Haziqah, M. T., Simon-Oke, I. A., &Fakunle, C. (2021b). A cross-sectional study of the prevalence, density, and risk factors associated with malaria transmission in urban communities of Ibadan, Southwestern Nigeria. Heliyon, 7(1), e05975. https://doi.org/10.1016/j.heliyon.2021.e05975

5. Awosolu, O., Adesina, F., Afolabi, O. and Ogunsanya, D. (2020) Malaria parasite distribution and knowledge among students of Federal University of Technology, Akure, Nigeria. Animal Research International (2020) 17(3): 3903 – 3910

6. Aygun B, Odame I (2012). A global perspective on sickle cell disease. *Journal of Pediatric Blood and Cancer.* 2012, 59: 386-390.

7. Chaparro Narváez, P. E., Jimenez-Serna, M. M., GunturizAlbarracin, M. L., & Carrasquilla Gutierrez, G. (2023). Malaria prevalence in Commune 5 in Tumaco (Nariño, Colombia). F1000Research, 11, 448. https://doi.org/10.12688/f1000research.110361.3

8. Cheesebrough, M. (2006). District Laboratory Practice in Tropical Countries Part 2. New York: Cambridge University Press.

9. Eisele, T.P., Lindblade, K.A., Wannemuehler, K.A., Gimnig, J.E., Odhiambo, F., Hawley, W.A., Kuile, F.O.T., Phillips-Howard, P., Rosen, D.H., Nahlen, B.L., Vulule, J.M., Slutsker, L. (2005). Effect of sustained insecticide-treated bed net use on all-cause child mortality in an area of intense perennial malaria transmission in western Kenya. *Am J Trop Med Hyg* 73:149–156

10. Grover KE, Kawano M, Klaver R, Blumental B, Connor S (2006). An online operational rainfall monitoring resource for epidemic malaria early warning systems in Africa. Journal of Infectious Disease. 185(8):1143-1146.

11. Howard, N., Shafi, A., Jones, C., Rowland, M. (2010). Malaria control under the Taliban regime: insecticide-treated net purchasing, coverage, and usage among men and women in eastern Afghanistan. Malar J 9:7. doi:10.1186/1475-2875-9-7

12. Kasiulevicius V, Sapoka V, Filipaviciute R. (2006) Sample size calculation in epidemiological studies. Gerontology.;7:225-231.

13. Lin, K., Aung, S., Lwin, S., Min, H., Aye, N.N., Webber, R. (2000). Promotion of insecticide-treated mosquito nets in Myanmar. *Southeast Asian J Trop Med Publ Health* 31:444–447

14. Luzzatto, L. (2012). Sickle cell anaemia and malaria. *Mediterranean journal of hematology and infectious diseases*, *4*(1).

15. McAuley C.F., Odame I., Atrash H.K., Amendah D. D., Piel F.B., Williams T.N (2011) The sickle cell disease in Africa: a neglected cause of early childhood mortality. *American Journal of Preventive Medicine*.2011;41(6suppl 4): S398-405.

16. National Population Commission, (2017) National Population Estimates.

17. Ndamukong-Nyanga, J. L., Kimbi, H. K., Sumbele, I. U. N., Emmaculate, L., Nweboh, M. N., Nana, Y. and Ndamukong, J. K. (2014). Socio-demographic and environmental factors influencing asymptomatic malaria and anaemia incidence among school children in Fako division, Southwest Cameroon. Journal of Advances in Medicine and Medical Research, 4(20): 3814 – 3827.

18. Noor, A.M., Kirui, V.C., Brooker, S.J. and Snow, R.W. (2009) The use of insecticide treated nets by age: implications for universal coverage in Africa. *BMC Public Health* 9:369. doi:10.1186/1471-2458-9-369

19. Nwele, D. E., Onyali, I. O., Iwueze, M. O., Elom, M. O., &Uguru, O. E. S. (2022). Malaria Endemicity in the Rural Communities of Ebonyi State, Nigeria. The Korean journal of parasitology, 60(3), 173–179. https://doi.org/10.3347/kjp.2022.60.3.173

20. Olowe O.A., Makanjuola O.B., Awa A.O., and Olowe R.A (2015) Malaria in Africa and the Historical Perspective: The Journey so Far. Journal of Biology and Medical Sciences, 3, 33-41

21. Onah, I. E., Adesina F. P., Uweh, P. O. And Anumba, J. U. (2017). Challenges of malaria elimination in Nigeria: a review. International Journal of Infectious Diseases and Therapy, 2(4): 79 – 85.

22. Oyeyi T.I, Muhammad *R.H. and Muhammad A.D. (2009) Slide positivity rate of malaria among patients attending two hospitals in Kano metropolis. Bayero Journal of Pure and Applied Sciences, 2(2): 194 - 196

23. Piel F.B., Patil A.P., Nyangiri O.A., Gething P.W., Williams T.N., Weatherall D.J., Hay S.I (2010) Global distribution of sickle cell gene and geographical confirmation of malaria hypothesis. *American Journal of Nature Communication*. 2010;1:104.

24. Rees, D. C., Williams, T. N., & Gladwin, M. T. (2010). Sickle-cell disease. *The Lancet*, *376*(9757), 2018-2031.

25. SPJELDNÆS, A. O., KITUA, A. Y. and BLOMBERG, B. (2014).Education and knowledge helps combating malaria, but not degedege: a cross-sectional study in Rufiji, Tanzania. Malaria Journal, 13(1): 200. https://doi.org/10.1186/14752875-13

26. WHO (2015). QA manual for malaria microscopy. 2nd Edition. Geneva. 2015.

27. World Health Organisation (2000). Fighting disease fostering development. World Health Report10:45-47.

28. World Malaria Report. (2017). World Health Organization, 2017.

29. World Medical Association (2013). World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA, 310(20), 2191–2194. https://doi.org/10.1001/jama.2013.281053

30. Hilly M, Adams ML, Nelson SC. A study of digit fusion in the mouse embryo. Clin Exp Allergy. 2002;32(4):489-98.

31. **https://doi.org/10.1182/blood.2022017051, https://doi.org/10.1182/blood.V128**