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Investigating the epidemiological factors responsible for malaria transmission dynamics

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Abstract. Despite concerted efforts by the World Health Organization (WHO) to control malaria, it is still being diagnosed in patients visiting hospitals in Tropical Countries of the World. Hence, this study investigated the risk factors responsible for malaria transmission dynamics through a hospital case study. Data of patients that presented with malaria from June 2019 to December 2020 were acquired from Covenant University Medical Centre in Ota, South West Nigeria. Descriptive statistical analyses were carried out so as to examine the factors associated with malaria incidence rate such as age, gender and travel history using the R programming platform. 14% of the total outpatient visits from June 2019 to December 2020 presented with malaria. Furthermore, the mean of the ages of those that presented with malaria, was 23.10 whereas the median of their ages was 22.0. Out of the total malaria cases, 57.7% were males whereas 42.3% were females. Results also showed that there was a significant positive correlation between malaria and travel. In conclusion, it is recommended that malaria control policy formulators should focus on the most vulnerable group of individuals as identified in this study. Further, more efforts should be geared towards curbing malaria importation as a result of human travel, by the different health authorities across the globe.

Keywords: malaria transmission dynamics, risk factors, hospital, vulnerable group, malaria importation

1 Introduction

Malaria remains a serious public health challenge in Tropical Countries of the World especially in Sub-Saharan Africa [1, 2]. The malaria disease is being transmitted by a *Plasmodium*-infected female *Anopheles* mosquito, when it comes in contact with the uninfected human host [3,4]. However, the uninfected *Anopheles* mosquito can also be infected with *Plasmodium spp*when it comes in contact with a *Plasmodium*-infected human host and it can retransmit the malaria disease.to another uninfected human host [5].

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However, it is not all malaria-suspected cases that are reported in the hospital. Some of the malaria cases are self-diagnosed and self-treated despite the inherent dangers as reported by the health authorities across the globe through case studies [6]. On the other hand, some people still present themselves at public and private clinics for proper diagnosis after showing the known common symptoms of malaria such as high fever, chills and headache [7].

Further, patients presenting for diagnosis based on malaria symptoms are often tested using the microscopy malaria diagnostic method which is the gold standard [8]. In line with this, the microscopy method is advantageous because it can easily be used for more accurate malaria parasite-load detection by any well-trained Medical Laboratory Scientist compared to other malaria testing techniques such as the use of Rapid Diagnostic Testing kits [8, 9].

The microscopy malaria testing method is carried out by staining the collected blood sample of the patient with Giemza for easy identification of the malaria parasite (*Plasmodium spp*) under the microscope [8, 9].On the other hand, the RDT malaria testing technique is used to detect antigens (HRP2 and pLDH proteins) produced by the malaria parasite, from the collected blood sample of the patient by following the specific manufacturer's guide [10].

In tandem with this, patients may be diagnosed using any of the aforementioned malaria testing techniques to have malaria morbidity [11]. Malaria morbidity is a diseased state that occurs when the patient is positive to only malaria but negative to any other disease [11]. Also, patients may be diagnosed to have malaria comorbidity [12]. Malaria comorbidity is the diseased state when a patient is positive to malaria and one or more other disease(s) [13]. Hence, malaria could be presented in patients during hospital visits, in morbid or comorbid form as the case may be.

Specifically, malaria could be presented in patients as mild and severe cases, in morbid or co-morbid form, during hospital visits, based on information about the history of the presenting complaint, the presenting complaint and the laboratory assessment results [14]. However, patients presenting with severe malaria are at high risk of death according to reports from the WHO [2].In 2019, there were 409,000 deaths as a result of severe malaria with Nigeria which is a country in Sub-Saharan Africa, accounting for the highest death rate of 23% based on global statistics [2].

In line with this, several malaria control efforts have focused on dissecting the characteristics of patients presenting with mild and severe malaria cases [15, 16]. The specific characteristics of interest were often age, gender and travel history of the patients [16, 17]. However, several bioinformatics approaches have being used to investigate these factors in other recent studies for different regions but not in the study area of this work[5, 18,19]. Bioinformatics is the application of statistical, mathematical and computational methodologies and tools to analyze clinical data of infectious diseases such as malaria among others [20]. Hence, this study employed the use of descriptive statistical bioinformatics approach to investigate the factors

responsible for malaria transmission dynamicsin Covenant University through a hospital case study.

2 Materials and Methods

Malaria data from June, 2019 to December, 2020 whose summary was shown in Table 2.1 was acquired from Covenant University Medical Centre (CUMC). CUMC is a hospital located inside Covenant University (Latitude 6.671823^0N, Longitude 3.158125^0E) which is a private University in Ota, Ogun State of Southwestern Nigeria. It provides outpatient and inpatient clinical services to people within the academic community and its environs which extend to some parts of Lagos Statealso in Southwestern Nigeria. The CUMC laboratory currently employs the use of the microscopy method to test for the presence of malaria parasites in symptomatic and asymptomatic patients.

Table 1: Summary data of the clinical presentation of malaria at CUMC

Malaria Data Occurrences	Severe Malaria	Mild Malaria
Malaria Morbidity	✓	✓
Malaria Comorbidity	✓	✓

Descriptive statistical analyses were carried out on the patients that presented with malaria during the study period at CUMC. Specifically, frequency distribution, percentage distribution, mean and correlation were the descriptive statistical methods employed in this study. The aforementioned statistical methods were applied on the malaria data on the R programming platform using the statistical libraries in R. Further, this study programmatically classified malaria into severe and mild cases, based on factors shown in Table 2, using the acquired malaria data from CUMC. The statistical analyses were useful to investigate the factors responsible for malaria transmission dynamics. Moreover, the factors of interest in this study were age, gender and travel history.Age was investigated statistically using mean and median whereas gender was investigated using frequency and percentage distributions. Further, travel was investigated graphically using the correlation method. This was explicitly achieved by examining the association between malaria incidences and the academic activities on campus.

Table 2: Factors for Classifying Malaria into Mild and Severe Cases [21, 22, 23, 24, 25**]**

Factors	Severe Malaria	Mild Malaria
Severe anaemia	✓	X
Cerebral Malaria	✓	X
Renal dysfunction	✓	X
Hepatic dysfunction	✓	X
Respiratory distress (Sepsis)	✓	X
Circulatory collapse	✓	X
Hyperemesis	✓	X
Hyperpyrexia	✓	X
Hyperlactatemia	✓	X
Hypoglycemia	✓	X
Hyperglycemia	✓	X
Hyperparasitemia	✓	X

3 Results and Discussion

Table 3 shows the statistical presentation of patient records at CUMC during the study period. Results showed that 14% out of all the total outpatient visits presented with malaria during the study period. This suggests that malaria is still very much endemic in Nigeria in line with recent reports from WHO in 2020.Although, the study area in Nigeria is a low malaria transmission zone based on the result. Table 4 shows the total malaria prevalence rate across different age groups. The total malaria prevalence rate was the highest among the Undergraduate Students whose age range are within fifteen to twenty-two (15 – 22). However, this is because the Undergraduate Students have the highest population in Covenant University. Table 5 shows the descriptive statistical presentation of severe and mild malaria. 10.72% out of those that presented with malaria had the severe variant whereas 89.28% out of those that presented with malaria had the mild variant. This suggests that 10.72% out of those that presented with malaria are at a higher risk of death due to the severity of the malaria illness. This statistic further corroborates

the report about the high risk of death due to severe malaria in Nigeria by the WHO in 2020. Table 6 shows the severe malaria prevalence across different age groups. The prevalence of severe malaria was highest among children under the age of five which is in line with reports from the WHO in 2020. Table 7 shows the mild malaria prevalence across different age groups.

Table 3: Statistical Presentation of Patient Records at CUMC during the study period

Patient Records	Frequency Distribution	Percentage Distribution (%)
Outpatient Visits	49241	100
Malaria Cases	6779	14

Table 4: Total malaria prevalence across different age groups

Age Groups	Malaria Prevalence	Prevalence Percentage (%)
< 5	1099	16.2
5-14	753	11.1
15-22	3376	49.8
>22	1551	22.9

Table 5: Statistical Presentation of Severe and Mild Malaria at CUMC

Malaria Types	Number of cases	Prevalence Percentage (%)
Severe	727	10.72
Mild	6052	89.28

Table 6: Severe malaria prevalence across different age groups

Age Groups	Malaria Prevalence	Prevalence Percentage (%)
< 5	284	39.0
5-14	136	18.7
15-22	177	24.3
>22	130	18.0

Table 7: Mild malaria prevalence across different age groups

Age Groups	Malaria Prevalence	Prevalence Percentage (%)
< 5	815	13.5
5-14	617	10.2
15-22	3199	52.8
> 22	1421	23.5

Table 8 showed the total malaria cases to gender statistics. Table 9 showed the severe malaria cases to gender statistics while Table 10 showed the mild malaria cases to gender statistics.From the results, the male gender presented with the malaria disease than the female in both mild and severe cases. Hence, this study identified the male gender to be at a higher risk to be infected with malaria unlike the female gender. Findings from this study were similar to what was reported in earlier works [26, 27, 28].

Table 8: Total Malaria Cases to Gender Statistics

Prevalence of malaria cases	Gender	Gender Percentage (%)
3914	Male	57.7
2865	Female	42.3

Table 9: Severe Malaria Cases to Gender Statistics

Prevalence of severe malaria cases	Gender	Gender Percentage (%)
389	Male	53.51
338	Female	46.49

Table 10: Mild Malaria Cases to Gender Statistics

Frequency of mild malaria cases	Gender	Gender Percentage (%)
3525	Male	58.25
2527	Female	41.75

Table 11 showed the mean and median of the ages of the patients within the study period. Results showed that the mean of the ages of those that presented with mild malaria was 29.48 whereas that of those that presented with severe malaria was 16.72. Results showed that the median of the ages of those that presented with mild malaria was 32.32 whereas that of those that presented with severe malaria was 1.68. The result of the median showed that most patients that presented with malaria, were children which is in line with the WHO report of 2020. Also, the mean and median of the ages of those that presented with severe and mild malaria were 23.10 and 22.0, respectively. The results about the mean and median of the ages of those that presented with mild and severe malaria correspond with the ages of most students in the University which are Undergraduates.

Table 11: Malaria Cases to Age Statistics

Malaria Cases	Median of their Ages	Mean of their Ages
Mild MalariaCases	32.32	29.48
Severe Malaria Cases	1.68	16.72
All Malaria Cases	22.0	23.10

Figure 1 showed the malaria peak periods during the study period. The resumption of academic activities on campus is an important factor responsible for high rate of travel into campus. From

the results, there was evidence of malaria importation into campus during resumption which was during the month of September in 2019. Those that imported malaria retransmitted the infection which made the number of cases in the following months (October and November 2019) to be higher. Similar scenario played out in the following year in the monthsof September, October and November.Results from this study corroborated the findings which showed that there was a positive correlation between malaria and travel [29].

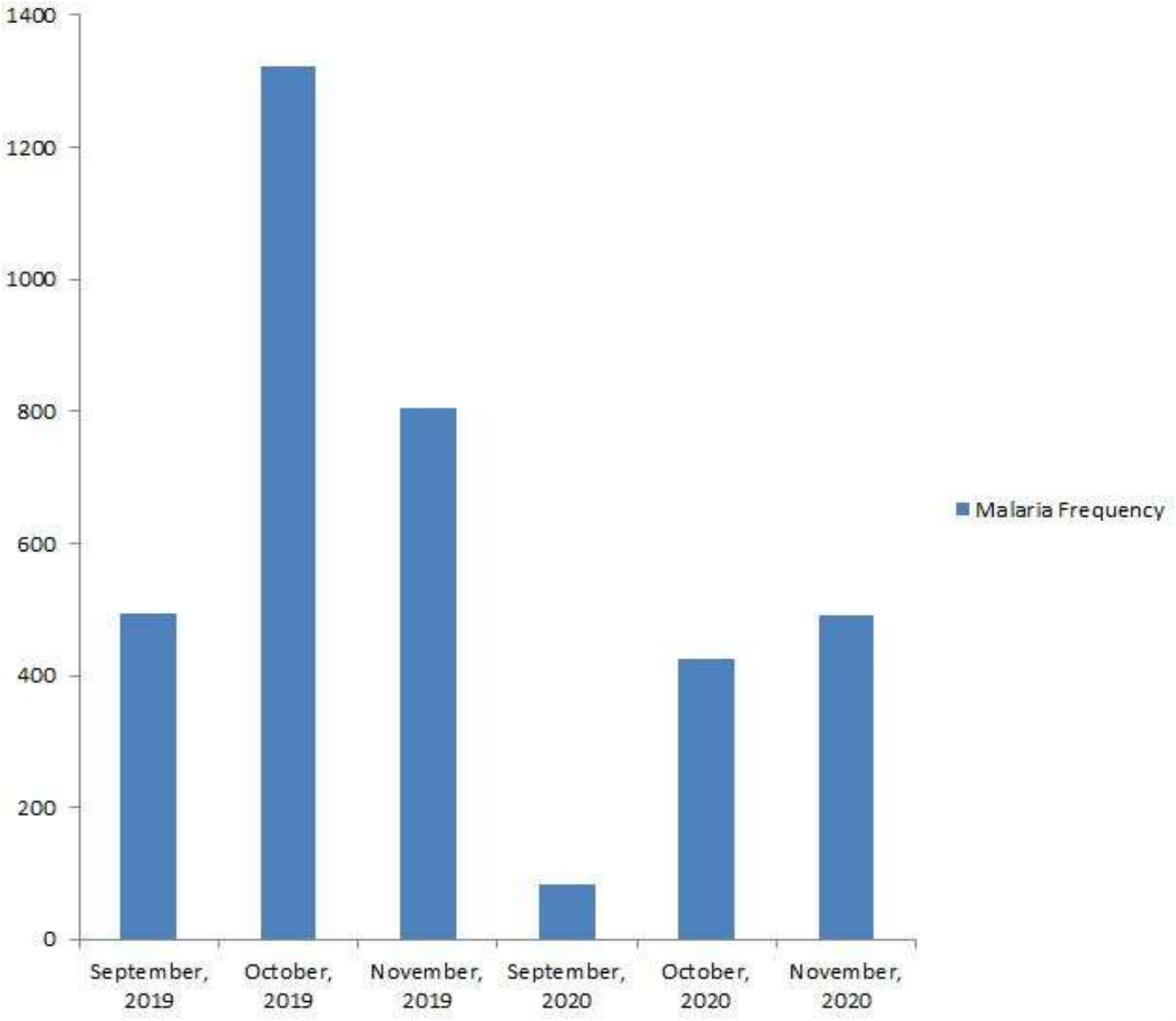

Figure 1: Malaria Peak Incidences at CUMC and the evidence of malaria importation as a result of travel using the academic calendar data

4 Conclusion

This work investigated the factors responsible for malaria transmission dynamics through a private hospital case-study in Nigeria. It identified the male gender to be more vulnerable to malaria than the female gender similar to some other studies. Severe malaria was more prevalent in children under the age of five similar to reports from the WHO. Also, there was significant evidence of malaria importation as a result of travel. This is evident as the malaria incidence peaks occurred during periods where there were high rate of travel into the study area which was similar to some other studies.

Hence, this study recommended that malaria control policy formulators should focus on the most vulnerable group of individuals as identified in this study. Further, more efforts should be geared towards curbing malaria importation as a result of human travel, by the different health authorities across the globe such as the Nigeria Centre for Disease Control, Nigerian Institute of Medical Research, Centre for Disease Control and Prevention, and the WHO..

This study is limited because it is a case study and there was no control study to validate its outputs. Specifically, the significance of age as a factor can be investigated through a control study where the hospital where the data will be acquired, will be located outside an academic environment. This study did not investigate the effect of environmental conditions such as rainfall, temperature, relative humidity and wind on malaria transmission dynamics in the study area which is an open research question in further studies. The comorbidity rate of other infectious diseases with malaria was not investigated in the study area which is also an open research problem.

In line with this, this study only used descriptive statistical approach to investigate the factors responsible for malaria transmission dynamics. Further studies could employ other bioinformatics approaches such as inferential statistics, mathematical modelling and machine learning approaches to further investigate the epidemiological factors responsible for malaria transmission dynamics in the study area as enunciated in this work.

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References

[1] Abioye, A.I.; Ibrahim, M.O.; Peter, O.J.;Ogunseye H.A. Optimal Control on a Mathematical Model of Malaria. *U.P.B. Sci. Bull*.,**2020**, *82*, 1-14.

[2]. World Health Organization. 20 years of global progress and challenges. *World malaria report*.,**2020**, *1*, 1-5.

[3]. Vantaux, A.; Riehle, M.M.;Piv E.; Farley E.J.; Chy S.;Kim S.; Corbett, A.G.; Fehrman, R.L.; Pepey, A.; Eiglmeier, K.;. Lek, D.*Anopheles* ecology, genetics and malaria transmission in northern Cambodia. *Scientific reports*.,**2021,** *11*, 1-17.

[4]. Teboh-Ewungkem, M.I.; Ngwa, G.A.; Fomboh-Nforba, M.Y. A Multistage Mosquito-Centred Mathematical Model for Malaria Dynamics that Captures Mosquito Gonotrophic Cycle Contributions to Its Population Abundance and Malaria Transmission. *Infectious Diseases and Our Planet. Mathematics of Planet Earth*., **2021**, *7*, 97-148.

[5]. Porter, T.R.; Finn, T.P.; Silumbe, K.; Chalwe, V.;Hamainza, B.; Kooma,E.; Moonga, H.; Bennett, A.; Yukich, J.; Steketee, R.; Keating, J.; Miller, J.M.;. Eisele, T.P. Recent Travel History and *Plasmodium falciparum M*alaria Infection in a Region of Heterogenous Transmission in Southern Province, Zambia. *American Journal of Tropical Medicine and Hygiene*., **2020**, *103*, 74-81.

[6]. Adeboye, N.O.; Abimbola, O.V.; Folorunso, S.O. Malaria patients in Nigeria: Data exploration approach. *Data in Brief*.,**2020**, *28*, 104997.

[7]. Okoro, C.I.; Ihenetu, F.C.; Dunga, K.E.; Achigbu, K..; Obasi, C.C.; Odinaka, K..K.; Anikwo, E.S. Fever Cases Associated with *Plasmodium falciparum* Malaria Infection among Children Attending a Tertiary Health Facility in Imo State, Nigeria. *International Journal of Tropical Disease & Health*.,**2020**, *1*, 7-14.

[8]. Berzosa, P.; de Lucio, A.; Romay-Barja, M.;Herrador, Z.; González, V.; García, L.; Fernández-Martínez, A.; Santana-Morales, M.; Ncogo, P.; Valladares, B.; Riloha, M. Comparison of three diagnostic methods (microscopy, RDT, and PCR) for the detection of malaria parasites in representative samples from Equatorial Guinea. *Malaria journal*.,**2018**, *17*, 1-12.

[9]. Muhammad, Z.S.; Iliyasu, M.Y.; Musa, H S.; Mustapha, I.; Lawan, G.M. Comparative study on the performance of microscopic and rapid diagnostic test (RDT) for malaria

among some patients in Maiduguri metropolis. *World Journal of Biology Pharmacy and Health Sciences*.,**2020**, *3*, 023-029.

[10] Oladosu, O.O.; Adedokun, V.A.; Adeniyi, A.V.; Oyibo, W.A. Performance Evaluation of Malaria HRP-2 Rapid Diagnostic Test among Febrile Patients with Malaria in Iwo, Osun State, Nigeria. *Int J Trop Dis*.,**2021**, *4*, 46.

[11]. Kalil, F.S.; Mohammed, H.B.; Shukri K.W. Trends of Malaria Morbidity and Mortality from 2010 to 2017 in Bale Zone, Ethiopia: Analysis of Surveillance Data.*Infection and Drug Resistance*.,**2020**, *13*, 4379.

[12]. Graham, H.; Ayobami, A.; Bakare, A.I.; Ayede, O.B.;. Oyewole, A.G.; Eleanor N.; Shamim A.; Trevor D.; Adegoke G.F. Diagnosis of pneumonia and malaria in Nigerian hospitals: A prospective cohort study.*Pediatric pulmonology*.,**2020**, *55*, S37-S50.

[13]. Lompo, P.; Marc C.T.; Hermann S.; William K.; Adama K.; Ashmed C.; Bachirou, N.; Hamtandi, M.N.; Isidore,J.; Ouindgueta, B.;Nicolas, B.; Halidou, T. "Pathogens associated with acute diarrhea, and comorbidity with malaria among children under five years old in rural Burkina Faso. *The Pan African Medical Journal*., **2021**, *38*, 1.

[14]. Atukunda, A.; Deogratius, M.A.; Arinaitwe, E.; Orishaba, P.; Kamya, M.R.; Nankabirwa, J.I. Do clinicians in areas of declining malaria transmission adhere to malaria diagnosis guidelines? A cross-sectional study from Kampala, Uganda. *Malaria Journal*., **2021**, *20*, 1-8.

[15]. Mousa, A., Al-Taiar, A., Anstey, N.M., Badaut, C., Barber, B.E., Bassat, Q., Challenger, J.D., Cunnington, A.J., Datta, D., Drakeley, C..; Ghani, A.C. The impact of delayed treatment of uncomplicated P. falciparum malaria on progression to severe malaria: A systematic review and a pooled multicentre individual-patient meta-analysis. *PLoS medicine*.,**2020**,*17*, e1003359.

[16]. Boushab, B.M.; Ould Ahmedou Salem, M.S.;Ould Mohamed Salem Boukhary, A.; Parola, P.; Basco, L. Clinical features and mortality associated with severe malaria in adults in southern Mauritania. *Tropical Medicine and Infectious Disease*., **2021**, *6*, 1.

[17]. Pousibet-Puerto, J.; Lozano-Serrano, A.B.; Soriano-Pérez, M.J.; Vázquez-Villegas, J.; Giménez-López, M.J.; Cabeza-Barrera, M.I.; Cuenca-Gómez, J.Á.; Palanca-Giménez, M.; Luzón-García, M.P.; Castillo-Fernández, N.; Cabezas-Fernández, M.T. Migration-associated malaria from Africa in southern Spain. *Parasites & Vectors*., **2021**, *14*, 1-10.

[18] Matsee, W.; Chatapat, L.; Chotivanich, K.; Piyaphanee, W.. Case report: a cluster of plasmodium falciparum malaria cases among Thai Workers in Gembu, Nigeria. *The American journal of tropical medicine and hygiene*., **2018**, *99*, 623.

[19]. Guerra,C.A.; Kang, S.Y.; Citron, D.T.; Hergott, D.E.; Perry, M.; Smith, J.; Phiri, W.P.; Nfumu, J.O.; Eyono J.N.; Battle K.E.; Gibson H.S. Human mobility patterns and malaria importation on Bioko Island. *Nature communications*.,**2019**, *10*, 1-10.

[20]. Tapprich, W.E.; Reichart, L.; Simon, D.M.; Duncan, G.; McClung, W.; Grandgenett, N.; Pauley, M.A. An instructional definition and assessment rubric for bioinformatics instruction. *Biochemistry and Molecular Biology Education*.,**2021**, *49*, 38-45.

[21]. Chaparro-Narváez, P.E.; Mary L.; Lina M.R.; Julio P.; Sócrates H.; Myriam A. Clinical and epidemiological aspects of complicated malaria in Colombia, 2007–2013.*Malaria journal*.,**2016,***15*, 1-11.

[22]. Atere, M.; Muzangwa, L.,; Munoh, Kenne, F.,; Hanna, C.,; Saverimuttu, J.; Kopetz, V. Severe Malaria: A Case of a Significant Rapid Rise in the Parasite Level. *Case reports in infectious diseases*.,**2020**, *1*, 1.

[23] Mohamedahmed, K.A.; Nour, B.Y..; Abakar, A.D.; Babker, A.M. Diagnostic and prognostic value of thrombocytopenia severity in Sudanese children with *falciparum* malaria. *World Journal of Advanced Research and Reviews*.,**2020**, *6*, 197-204.

[24] Mohapatra, M.K.; Bariha, P.K.; Padhee, B.; Mohanty, B.;Nayak, S. K. Hypovitaminosis-D, Altered Mineral Status and Electrolytes in Severe *Falciparum* Malaria. *The Indian Journal of Nutrition and Dietetics*.,**2020,***57*, 498-505.

[25] Possemiers, H.,; Vandermosten, L..; Van den Steen, P.E.. Etiology of lactic acidosis in malaria. *PLoS pathogens*.,**2021**, *17*, e1009122.

[26]. Ipa, M.; Mutiara W.; Agung D.;, Ina Kusrini.; Pandji W. Variation of preventive practices and its association with malaria infection in eastern Indonesia: Findings from community-based survey.*PLoS One*.,**2021**, *15*, e0232909.

[27] Marasinghe, M M.; Vissundara, M.K.; Arundika S.S.; Hema D.B.; Herath, D.F.; Rajitha W.; Kamini, N. M.;, Dewanee R. Mass radical treatment of a group of foreign workers to mitigate the risk of re-establishment of malaria in Sri Lanka.*Malaria Journal*., **2020**, *19*, 1-6.

[28] Lema, S.Y.; Kabiru A.; Yahaya, M.A.; Fana A.S.. Age Groups and Haemoglobin Genotypes Influence Malaria Occurrence among Patients in Sokoto Specialist Hospital, Sokoto State, Nigeria.*South Asian Journal of Parasitology*.,**2021**, *1*,8-16.

[29]. Marasinghe, D.H.; James, C.; Bonnie, M.; Susan, K.; Stephen, V.; Rudolf, Z.; Dylan, R. P. Risk of malaria associated with travel to malaria-endemic areas to visit friends and relatives: a population-based case–control study.*CMAJ open*.,**2020**, *8*, E60.