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Spatio-Temporal Distribution of Malaria Parasites in Vihiga County, Western Kenya

Muzame Aleyo Beatrice, Omukunda Elizabeth and Mulama David
Department of Biological Sciences, School of Natural Sciences, Masinde Muliro University of Science and Technology, Kakamega, Kenya
E-mail : beatricealeyo@yahoo.com

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ABSTRACT

Malaria is the leading cause of mortality and morbidity in Sub-Saharan Africa. The study was carried out at Mbale Provincial Rural Training Health Center in Vihiga County, Western Kenya. The study determined the spatial and temporal distribution of malaria parasites for one year. 768 malaria patients were purposively recruited and stratified according to age and location. Data was collected using interviews and microscopic examination and analyzed using SPSS software version 17. P-value ≤ 0.05 was considered statistically significant. 98.7% malaria patients had *Plasmodium falciparum*, *P. malariae* 0.8%, *P. vivax* 0.4% and *P. ovale* 0.1%. Edzava ward recorded all *Plasmodium* species. Lugaga/Wamuluma ward had 45.1% malaria patients, Edzava 36.2% and Central Maragoli 18.3%. Male malaria patients were 49.3% who recorded all *Plasmodium* species while 51.7% were females without *Plasmodium ovale*. All age groups were diagnosed with *P. falciparum* while *P. malariae* and *P. ovale* were missing among 14-18 years old children and no *P. ovale* in children below 5 years old. Linear regression results showed effect of age, ward, gender on malaria infection as ($R^2 = 0.7$, [$F(3,764) = 1.854$] , $p < 0\ 136$) but wards were statistically significant ($p = 0.034$). Linear regression result for effect of time trend on malaria infection was ($R^2 = 0.527$, [$F(3,8) = 2.976$], $p < 0.097$). Climate, altitude and land use activities favored the breeding of mosquitoes which increased malaria transmission. Study results obtained will assist malaria case management bodies in frequently monitoring the effect of geographical location and time trends on malaria infection.

INTRODUCTION

Malaria is a life-threatening disease that affects most under-developed countries in sub-Saharan Africa and India (Ayele *et al*., 2013 and Ubydel *et al*., 2011). Despite numerous global intervention strategies, malaria still remains the leading cause of morbidity and mortality in sub-Sahara Africa (Rowe *et al*., 2006; WHO, 2015 and AMREF, 2013). A female anopheles' mosquito (*Anopheles gambiae, A. arabiensis* or *A. funestus*) takes in human blood meal and when infected with *Plasmodium* parasites, causes uncomplicated or severe malaria that kills a child every minute around the globe (Presidents' Malaria Initiative (PMI), 2014 and CDC, 2019). Parasites that cause human malaria are; *Plasmodium falciparum*, *P. vivax*, *P. ovale*, and *P. malariae* which differ in geographical distribution (CDC, 2019 and Zhou *et al*., 2011), microscopic appearance, periodicity of infection, the potential for severe disease (CDC, 2015(b), ability to cause relapses (*P. vivax*, *P. ovale*,) and potential to develop resistance to antimalarial drugs (Bloland, 2001, CDC, 2019 AND Arora, 2005). About 99% of malaria in Kenya is *falciparum* malaria (PMI, 2016). Other *Plasmodium* species that constitute 1% of human malaria infection are; *P. vivax*, *P. ovale* and *P. malariae* (PMI, 2016 and WHO, 2020).

Malaria targeted risk populations include; pregnant women, children below five years old, immunosuppressed patients such as those with HIV/AIDS, the aged and travelers to malaria-endemic regions due to their low body immunity (Arora, 2005; Chemtai, 2007 and PMI, 2016). Malaria parasites and mosquitoes have become resistant to drugs that are supposed to eliminate them (WHO, 2015 and PMI, 2014).

The geographical distribution of malaria parasites varies from region to region due to differences in climate, land use, drug resistance and topography (Minoo, M. and Khodadad, S., 2016). A Spatio-temporal distribution study was conducted in various parts of the world including China (Yongze *et al*., 2016), Nepal, Malaysia, Bangladesh, Northern Ethiopia, Zambia, Sudan and South Africa (Dhimal *et al*., 2014, Lin *et al*., 2009) which assessed whether malaria prevalence was increasing, decreasing or remained the same in different regions and at different times to provide strategies for malaria intervention programs (Alemu *et al*., 2013 and Ubydel *et al*., 2011). Results from India showed a decrease in malaria prevalence because the study was able to identify and locate geographical distribution and time trends which was also seen in a study done in China (Lin *et al*., 2009). There was an increase or decrease in malaria prevalence at different times and appropriate malaria intervention strategies were applied in India (Ubydel *et al*., 2011). In Kenya, malaria-endemic areas are the Coastal and Lake Victoria regions (Ageep *et al*, 2009 and PMI, 2016). There are various malaria zones in Kenya which vary in geographical location, altitude, topography (Tawanda *et al.,* 2016) land use and climate (Republic of Kenya, Malaria Indicator Survey, 2010) that influence mosquito breeding and in turn affect malaria prevalence (Minakawa *et al*, 2002 and PMI, 2016). Adult mosquito population dynamics is an indicator of malaria transmission risk (Ndenga *et al*., 2006 and Omukunda *et al.*, 2013). A study carried out on the impact of climate change on the spread of malaria in Vihiga County revealed that temperature and rainfall had an impact on malaria prevalence (Wafula, & Mulinya, 2018).

In Western Kenya, a study on the spatial and temporal distribution of malaria was carried out in; Rarieda, Bondo, Yala, Siaya and Karemo all situated in Luo Nyanza (Nyaguara *et al.,* 2012). There are two rainy seasons in Kenya with long rains from April to June and short rains from October to December while the highest temperatures are from February to March and the lowest from July to August (PMI, 2016). Drug exposure patterns differ in different geographical regions and malaria parasites' gametocytes increase after antimalarial treatment, especially for individuals harboring drug-resistance malaria parasites (WHO, 2015a). Bodies in Kenya that monitor malaria case management include; President's Malaria Initiative, Kenya National Malaria Strategy 2009-2017 and World health organisation (WHO). Challenges facing malaria case management in Kenya include; the lack of adequate and modern laboratory facilities to accurately diagnose different types of malaria parasite species (Amexo *et al.*, 2004 and Maryceline *et al.*, 2013). Rapid diagnostic malaria diagnosis is the most commonly used method but it does not show different malaria parasite species (Adesanmi *et al*, 2014). Most public facilities in rural regions of Kenya have very few microscopes and lack other modern diagnostic techniques that can be used to confirm malaria parasite species (Republic of Kenya, Vihiga County. First County Integrated Development Plan 2013-2017, Kenya Vision 2030). Vihiga County lacks documentary evidence on the Spatio-temporal distribution of malaria parasites yet this is important in guiding bodies involved in malaria control to monitor the distribution of *Plasmodium* species that cause malaria in man and in monitoring various malaria vector strategies aimed at reducing malaria transmission. Modern

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accurate and reliable parasitological malaria diagnosis techniques recommended by WHO universally are microscopy and Rapid Diagnostic Tests (Graz *et al.*, 2011; Marycelina *et al.*, 2013 and PMI, 2014). Others include Enzyme-Linked Immunosorbent-Assay (ELISA) and molecular biomarker diagnosis such as polymerase chain reaction (D'Acremont *et al.*, 2009 and Yeda *et al*., 2016). Accurate diagnosis of malaria parasites species can reduce over- or under-estimation of malaria burden in a given area which can reduce unnecessary antimalarial treatment, help to remove the reservoirs of the malaria parasite and reduce antimalarial drug resistance in the population (Graz *et al.*, 2011 and WHO, 2015 (a)).

MATERIALS AND METHODS

The study site was Mbale town and its environs which is the headquarters of Vihiga County found within Vihiga and Sabatia sub-Counties, Western Kenya, along Kisumu-Kakamega Road. It is located at latitude 0° 0'54.0'N and longitude 34°43'17.0 E with an altitude of 1200 meters above sea level, rainfall of between 1800mm to 2000mm annually, highest in April (288 mm) and lowest in January (94 mm). The highest average temperature occurs in February (21.4^0C) and the lowest in July (19.1^0C) with an annual average temperature of 20.4^0 C. This study site was chosen because it was previously characterized for malaria transmission patterns and vector biology (Munyekenye *et al*, 2005 and Ndenga *et al*, 2016).

Fig. 1: A Map Showing the study site.
Source: the Republic of Kenya, Ministry of Public Health and Sanitation (May 2010) http://www.mudavadi2013.com/Western/Vihiga/Maps/Vihiga .

The study recruited 768 malaria patients from December 2019 to December 2020 who presented themselves at Mbale Provincial Rural Training Health Center. They were stratified according to age, and gender; 192 children below 5 years old, 192 children between 5-14 years old, 192 children between 14-18 years old and 192 adults. Malaria patients with; a history of allergy to antimalarial drugs, chronic infections such as H.I.V and persons treated for malaria within the preceding 2 weeks were excluded from the study. Blood sample collection for malaria screening was done by finger-pricking from malaria suspected patients and diagnosed by microscopy at the chosen health center. The area for finger-prick to collect blood was first swabbed with methylated spirit and allowed to dry before blood collection was done. A thin film was dried, fixed with methanol then stained with Giemsa stain, immersed in oil and used 100x microscopic objective to examine different *Plasmodium* species. A thick film was used to identify the parasitemia of malaria parasites. Written informed consent was signed by adult malaria patients and parents or guardians signed for malaria patients below 18 years old before the study commenced. The study was reviewed and approved by the both Ethics and Review Committee at Masinde Muliro University of Science and Technology (MMUST) and a permit issued by the National Commission for Science, Technology and Innovation before the study commenced. Data was entered in spreadsheets and analyzed using SPSS software version 17. Results are presented in frequency tables and bar graphs to compare the means of malaria parasite species in the study population. Linear regression was used to determine the effect of wards, gender, age and time trends (temperature and rainfall) on malaria infection in the study area where a p-value < 0.05 was considered statistically significant.

RESULTS

A total number of 768 malaria patients were recruited for the research from December 2019 to November 2020. Mbale town falls under three wards namely; Central Maragoli, Edzava and Lugaga/ Wamuluma. Samples of 64 malaria patients were collected every month and 16 every week for a period of 12 months to cover both long and short rain seasons. Four malaria patients were randomly picked from each age group weekly.

Out of 768 malaria patients who were recruited in the study,758 were infected with *Plasmodium falciparum* which accounted for (98.7%) followed by *P. malariae* with (6) 0.8%, *P. vivax* (3) with 0.4% and lastly *P. ovale* with (1) 0.1% malaria patients. From the results obtained, Lugaga/ Wamuluma had 346 (45.1%) malaria patients followed by Edzava with 278 (36.2%) cases and Central Maragoli had 144 (18.3%) malaria patients (Table 1). The distribution of *Plasmodium* species inwards was as follows; Central Maragoli had 143 malaria patients infected with *P. falciparum,* 1 with *P. malariae and P.ovale* and *vivax* none. Edzava word had 272 malaria patients infected with *P. falciparum,* 2 with *P. malariae, P.ovale* infected 1 malaria patient and *P. vivax* 3 patients. Lugaga/ Wamuluma had 343 *P. falciparum* malaria patients *P. malariae* 3 patients *and P.ovale* and *vivax* none. Edzava had all four *Plasmodium* species that infect human beings.

Table 1: Distribution of *Plasmodium* Species in the study site**.**

Count Ward	*Plasmodium* species				Total
	Plasmodium falciparum (P. falciparum)	*Plasmodium malariae (P. malariae)*	*Plasmodium ovale (P. ovale)*	*Plasmodium vivax (P. vivax)*	
Central Maragoli	143	1	0	0	144
Edzava	272	2	1	3	278
Lugaga/Wamuluma	343	3	0	0	346
Total	758	6	1	3	768

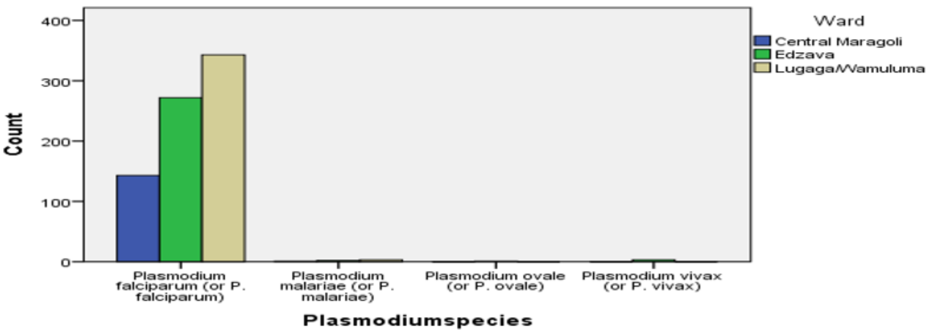

Fig.2: A Bar Graph Showing Distribution of *Plasmodium* Species in the Study Area

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From the results obtained 371 (49.3%), malaria patients were male while 397 (51.7%) were female as shown in table 3.2. Among females, 392 malaria patients had *P. falciparum*, 4 patients had *P. malariae*, and 1 patient had *P. vivax*. Among male malaria patients. 366 had *P. falciparum*, 2 patients had *P. malariae* 1 patient had *P. ovale* and 2 malaria patients had *P. vivax* recording all *Plasmodium* species (Table 2)

Table 2: Distribution of *Plasmodium* Species According to Gender in Study area**.**

Gender	*Plasmodium* species				Total
	Plasmodium falciparum	*Plasmodium malariae*	*Plasmodium ovale*	*Plasmodium vivax*	
MALE	366	2	1	2	371
FEMALE	392	4	0	1	397
Total	758	6	1	3	768

The results obtained showed a distribution of *Plasmodium* species as follows, among children below 5 years old, 188 patients had *P. falciparum*, 3 had *P. malariae*, *and* 1 patient had *P. vivax*, children aged 5-14 years old, had 189 patients with *P. falciparum*, 2 patients had *P. malariae* and1 patient had *P. ovale*. Among 14-18 years old, 191 patients had *P. falciparum* and 1 patient had *P. vivax.* Among adults, 190 patients were infected with *P. falciparum*, 1 with *P.* malariae and 3 patients with *P. vivax* (Table 3).

Table 3: Distribution of *Plasmodium* Species among different age groups found in the Study area.

Age	*Plasmodium* species				Total
	Plasmodium falciparum	*Plasmodium malariae*	*Plasmodium ovale*	*Plasmodium vivax*	
0-5 years old	188	3	0	1	192
5-14 years old	189	2	1	0	192
14-18 years old	191	0	0	1	192
Adults	190	1	0	1	192
Total	758	6	1	3	768

From the linear regression results obtained independent variables (wards, age and gender) generally had minimal effect of 0.7% on malaria infection with p = 0.136 (R^2 = 0.7, [F(3,764) = 1.854] , p < 0.136). Individual independent variables showed the following results; wards had a statistically significant effect on malaria infection (P = 0.034) while gender (P = 0.321) and age (P = 0.712) had a statistically insignificant effect on malaria infection (Table 4).

From the results obtained independent variables (time, rainfall and temperature) had 52.7% effect on malaria infection with p = 0.097 (R^2 = 0.527, [F (3,8) = 2.976], p < 0.097). Time trend (months) had a statistically significant effect (P = 0.036 < 0.097) on malaria infection in the study area. However different months had a different amount of rainfall and different temperatures which determined breeding sites for mosquitoes hence influencing malaria transmission while rainfall (p=0.310) and average temperature (p = 0.137) were statistically insignificant as shown in Table 5.

Table 4: A Linear regression results showing the effect of Wards, Age and Gender on Malaria Infection in the Study area.

ANOVA[a]					
Model	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Regression	272804.862	3	90934.954	1.854	.136[b]
Residual	37475867.138	764	49052.182		
Total	37748672.000	767			
a. Dependent Variable: Malaria Infection					
b. Predictors: (Constant), Age, Ward, Gender					

Coefficients					
Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**T**	**Sig.**
	B	Std. Error	Beta		
(Constant)	351.207	39.242		8.950	.000
Ward	22.452	10.600	.076	2.118	.034
Gender	-15.893	16.006	-.036	-.993	.321
Age	2.637	7.153	-.013	.369	.712
a. Dependent Variable: Malaria Infection					
b. Predictors: (Constant), Ward, Gender, Age					

Table 5: A Linear Regression Showing Effect of Temperature, Rainfall and Months on Malaria Infection in Study area.

ANOVA[a]					
Model	**Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**
Regression	4200.926	3	1400.309	2.976	.097[b]
Residual	3763.991	8	470.499		
Total	7964.917	11			
a. Dependent Variable: Malaria Infection					
b. Predictors: (Constant), Month, Rainfall, Average temperature					

Coefficients					
Model	**Unstandardized Coefficients**		**Standardized Coefficients**	**T**	**Sig.**
	B	Std. Error	Beta		
(Constant)	590.995	238.779		2.475	.038
Average	-18.768	11.366	-.555	-1.651	.137
temperature	-.110	.101	-.269	-1.083	.310
Rainfall Month	-6.430	2.552	-.862	-2.520	.036
a. Dependent Variable: Malaria Infection					
b. Predictors: (Constant), Month, Rainfall, Average temperature					

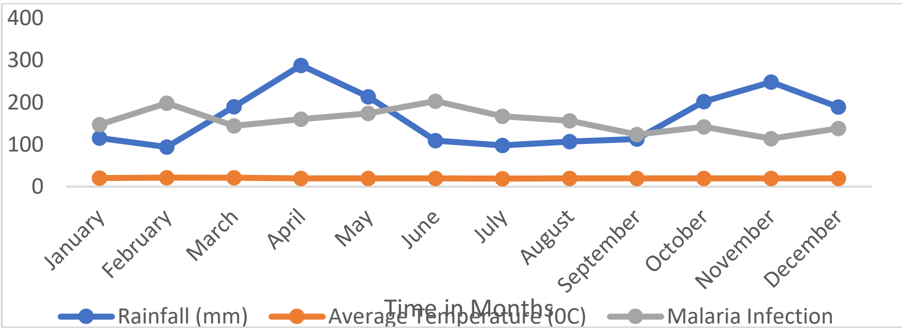
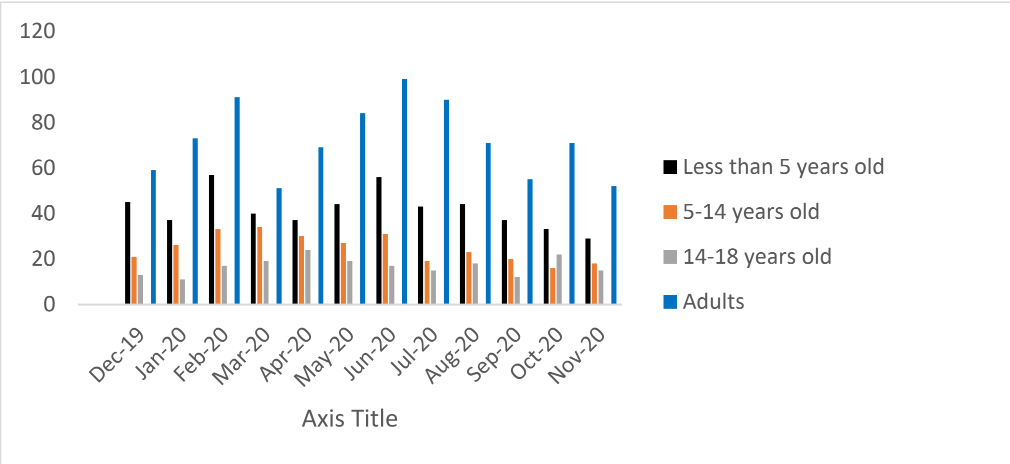


Fig. 3: Effect of Rainfall and Temperature on Malaria Infection in Study Area**:**

As shown in (Fig. 3) incidences of malaria infection increase one to two months after rain seasons (Wafula, H and Mulinya C, (2018). Temperature and rainfall determine the prevalence of malaria and are hence used in zoning malaria infection (PMI, 2016). Stagnant water is a breeding ground for mosquitoes while vegetation such as bushes and grass (PMI, 2016) which depend on temperature and rainfall are resting sites for mosquitoes as they target to bite at dusk and dawn (CDC, 2019 and Wafula, H and Mulinya C, (2018). Rainfall leads to the collection of water in ditches, pits, tyre in car washing areas, empty containers and other openings on the earth which acts as a breeding ground for mosquitoes. (Wafula, H and Mulinya C, (2018). Malaria infection increases 1-2 months after the onset of rainfall (CDC, 2019). Malaria parasites take 8-10 days (Minoo, M. and Khodadad, S., 2016). to complete their life cycle in the *Anopheles* mosquitoes to be able to transmit malaria especially when the temperature is below 20 c^{o}. In addition, 7-30 days is the time interval taken between *Anopheles* mosquito bite and entry of merozoites into the bloodstream before the first malaria symptoms appear (CDC, 2020). The incubation period for *P. falciparum* is the shortest while that of *P. malariae* is the longest (CDC, 2019). Rainfall and high temperatures lead to an increase in humidity which favors the development of malaria parasites in the *Anopheles* mosquitoes (Minoo, M. and Khodadad, S., 2016).



Time in Months

Fig. 4: Shows Malaria Infections per Month among Different Age Groups in the Study area

Children have higher malaria infective incidences than adults but the duration of persistent malaria infection increases with age as malaria parasitemia decreases with age (Andrea *et al*, 2019). During the COVID-19 pandemic period, most parents were reluctant to take their children to hospitals in this region and this explains why the number of children below 5 years old who attended health facilities was less than that of the adults as shown in Figure 4. The community health workers in Vihiga County where the study area falls have been allowed to test for malaria using a rapid diagnostic test (RDT) and administer antimalarial drugs to malaria patients in their homes. Most mothers and guardians preferred to have their children treated at home for malaria infection by community health workers during the COVID-19 pandemic period which reduced the number of children below 5 years seeking treatment in health facilities as shown in Figure 3.

DISCUSSION

Parts of Edzava and Lugaga/Wamuluma wards fall under Mbale town while Central Maragoli is mainly found in the outskirts of Mbale town. The four *Plasmodium* species vary in their appearance, periodicity, geographical distribution and ability to relapse (CDC, 2019). All the three wards in the study area had more *falciparum* malaria which accounted for 98.7 % while the other three *Plasmodium* species accounted for 1.3%. In terms of gender, 51.7% of female and 48.3% of male patients had malaria infection in the study area. From the study that was carried out on gender and malaria in Kenya in 2915, it was observed that women and children were more vulnerable to malaria infection because of women's high work burden in mosquito prevalent areas, due to sociocultural norms and expectations from women which exposes them to mosquito bites (Kenya, Ministry of Health, Malaria control unit; Gender and Malaria in Kenya, 2015). From results obtained in this research in Mbale and its environs, the difference between males and women infected with malaria was insignificant. All three wards found in the study area had fish ponds and pits (tyre tracks) and old vehicle tyres found in car washing areas which provided breeding grounds for mosquitoes resulting in malaria transmission. Lugaga/Wamuluma ward had more malaria patients than the other two wards. Malaria patients in this ward were infected with mainly *P. falciparum* and 3 patients were infected with *P. malaria*. *Plasmodium ovale* and *Plasmodium vivax* was not identified among malaria patients in this ward. Malaria infection in Lugaga/Wamuluma ward was likely to have been due to poor drainage system and poor disposal of empty containers in Mbale town where the ward is located. Poor drainage systems encouraged stagnant water while empty containers held water providing good breeding grounds for mosquitoes. In Wamuluma/Lugaga ward there is Ehedwe valley with low and gentle slopes, a stream, pits formed by car washing tyres, bushes, swamps, brick making and gold mining which might have encouraged the breeding of mosquitoes hence transmission of malaria in this ward. In Edzava ward, malaria infection was likely to have been due to brick making and gold mining as well. Water collected in the burrow pits formed by brick making and gold mining provided breeding grounds for mosquitoes. All four *Plasmodium* species (*P. falciparum P. malariae, P. ovale* and *P. vivax*) were found in Edzava ward. The central ward was comparatively well drained and had few rocks which explained why malaria prevalence was fairly low compared to Lugaga/Wamuluma and Edzava wards. In the Central Maragoli ward malaria patients were infected mainly with *P. falciparum*, one patient had malariae malaria and there were no malaria infections caused by *P. ovale* and *P. vivax*.

Figure 3 shows adult malaria patients were more than malaria patients below 5 years old because most parents/ guardians were reluctant to take their children to health facilities during the COVID-19 pandemic period. Generally, there should have been more malaria patients among children below 5 years old than adults but the study was purposive that is why an equal number of malaria patients were taken from each age group. It is not well understood why naturally acquired immunity against malaria develops slowly (Gonzales *et al*., 2020). Children below five years old and old people have low immunity levels (CDC, 2019) and that is why they are easily infected with diseases including malaria. Immunity to various diseases including malaria is high among people who are 10-50 years old (Gonzales *et al*., 2020). Children build up their acquired immunity against malaria infection as they grow (Andrea, G. *et al.*, 2019). Immunity among children of 5-14 years old who were mainly nursery and primary school going children was high compared to that of children below 5 years old (Andrea, G. *et al*, 2017). Children between 14-18 years old are mainly secondary and tertiary going children who had more exposure to mosquito bites which led to malaria infection and this enabled them to develop more immunity to malaria infection (Andrea, G. *et al*., 2017). The immunity of children above 5 years old is high (CDC, 2019) and that is why their body immunity is able to fight malaria parasites. Children below 15 years old including school-age children tend to acquire *falciparum* malaria easily as opposed to adults and children below 5 years old have less duration of malaria parasites in their bodies as opposed to people above 5 years old (WHO, 2019).

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An indicator of malaria transmission risk is determined by the dynamics of the adult mosquito population (Omukunda *et al*., 2013). Temperature and rainfall had an impact on malaria infection in the study area (Wafula, H and Mulinya C, 2018) by providing more breeding grounds for mosquitoes during moderate temperatures and heavy rainfall (Wafula, H and Mulinya C, (2018). Heavy rainfall tends to wash away mosquito breeding sites hence reducing malaria transmission following heavy rainfall (Andrea, G. *et al*., 2017). Moderate rainfall tends to increase mosquito abundance which results in more malaria incidences (Andrea, G. *et al.,* 2017). As the monthly temperature increases the incidence rate of malaria increased significantly because an increase in temperature tended to accelerate the development of malaria parasites in the *Anopheles* mosquitoes (Minoo, M. and Khodadad, S., 2016). Malaria infections vary in different months due to changes in the amount of rainfall received and the different temperatures in different months (Wafula, H and Mulinya C, (2018). The effect of rainfall on malaria prevalence is observed 1-2 months after the rainfall because the time taken from an infective bite by *Anopheles mosquitoes* and the appearance of the first symptoms of malaria is 7 to 30 days depending on the *Plasmodium* species (CDC, 2019). Rainfall and temperature influences humidity which affects the developmental stages of the *Anopheles* mosquitoes which bite to transmit malaria (Minoo, M. and Khodadad, S., 2016). There was more malaria prevalence following the long rains season and relatively high temperature which enabled mosquitoes to breed in many sites of stagnant water, developed very fast and accelerated the development of malaria parasites in *Anopheles* mosquitoes (Minoo, M. and Khodadad, S., 2016). There was more malaria prevalence in the month of June due to the heavy rainfall that was observed in April because high rainfall increased breeding grounds for mosquitoes which increased malaria transmission. High humidity (moisture in the air) which is a result of heavy rainfall and high temperature accelerates the growth of malaria parasites in the *Anopheles* mosquitoes and enables the mosquitoes to live longer and bite human beings hence increasing malaria transmission (Minoo, M. and Khodadad, S., 2016). Malaria infection was less in September due to less rainfall and low temperature that was observed in July which decreased breeding grounds for mosquitoes (Alemu *et al*, 2013). Malaria infections during the rainy season are longer than those detected in a dry season because of a high density of mosquitoes during the rainy season (Andrea, G. *et al.,* 2019). Species temporal distribution showed that *Plasmodium falciparum* malaria occurred throughout the study period with few incidences of *P. malariae, and P. vivax* during rain seasons (Awe *et al.*, 2013).

CONCLUSION

Malaria can be prevented, reduced and cured if all malaria patients can have access to prompt and correct malaria diagnosis and treatment. Specific malaria parasite species can also be eliminated in a given geographical area with continuous malaria prevention measures together with correct and complete treatment of malaria infection. The study area had high incidences of malaria with all the four *Plasmodium* species identified with many breeding grounds for mosquitoes which increased malaria prevalence. The malaria control units which include community health workers should inform people in the villages they serve that the type of land use activities they choose can lead to an increase in malaria transmission. Wamuluma/Lugaga had many breeding grounds for mosquitoes which explained why the ward tended to have had more malaria incidences than the other two wards. Results from the research showed community health workers assisted in reducing cases of malaria mortality by testing and treating malaria patients, especially young children in their homes besides advising people on strategies used to control malaria infection. The Kenyan government should also carry out regular monitoring and evaluation research on spatio and temporal distribution of malarial parasites to assess whether malaria prevalence is increasing, decreasing, or remaining the same in different regions and at different time trends to provide adequate strategies for malaria intervention programs.

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REFERENCES

Adesanmi, T.A., Okafor, H.U., Okoro, A.B., Mafe, A.G., (2014). Diagnosis of malaria parasitaemia in children using a rapid diagnostic test. *Nigerian Journal of Clinical Practice*; 14(2):195-200. doi: 10.4103/1119-3077.84015

Ageep, T.B., Cox, T., Moawa, M.H., Knols, B.G.I., Mark, Q.B., Malcolm, A.C, Babikar, A. and Sayed, B.E (2009). Spatial and temporal distribution of malaria mosquito *Anopheles arabiensis* in Northern Sudan. Influence of environmental factors and implications for vector control. *Malaria journal*, 8:123. https:/doi.org/10.1186/1475-2875-8-123.

Alemu K., Alamayehu, W. and Berhane, Y., (2013). Malaria infection has spatial, temporal and spatio temporal heterogeneity in unstable Malaria transmission areas in Northwest Ethiopia. *Plos one*, https://doi.org/10.1371/journal.pone.0079966

Amexo M, Tolhurst R, Barnish G, Bates I (2004). Malaria misdiagnosis: effects on the poor and vulnerable. *Lancet*, 364(9448): 1896–1898. doi: 10.1016/s0140-6736 (04) 17446-1.

AMREF, (2013). African Medical and Research Foundations. *Champions Community Case Management of Malaria.* http://amref.org/ news/ amref-champions.. malaria-of-managemen - case-community.

Andrea G., Buchwald, John D., Sorkin,Alick Sixpence, Mabvuto Chimenya, Millius Damson, Mark L., Wilson, Karl Seydel, Sarah Hochman, Dan Mathanga, Terrie E., Taylor (2019):Association Between Age and Plasmodium falciparum Infection Dynamics. *American Journal of epidemiology*, 188(1), 169-176.

Andrea, G., Buchwald, Jenna E. Coalson. Miriam,K. Laufer.(2017). Insecticide-treated net effectiveness at preventing P. falciparum infection. *Malaria Journal*, 16, Article number; 32 (2017) https//malaria journal. biomedcentral.com

````
````

Arora, B.A. (2005). Medical Parasitology, 2nd. Edition. New Delhi. Page 76-8. Asian Pharmacy Press All Right Reserved. *Asian Journal* of *Research* in *Pharmaceutical Sciences*, 1(1)*: Jan.-Mar. 2011; Page 09-16*

Awe Gneme,Wamdaogo M., Guelbeogo and Kenneth D., Vernick. (2013). Plasmodium species occurrence, temporal distribution and interaction in a child-aged population in Burkina Faso. *Malaria Journal*,12, Article number 67 (2013).

Ayele, G.D., Zewator, T.T, Mwambi, G.H, (2013). Spatial distribution of malaria problem in 3 regions of Ethiopia. *Malarial journal*, Biomed center. https:// malariajournal. Biomedcentral. com/articles/10.1186/1475-2875-12-207

Bloland, P. B. (2001. Drug resistance in malaria WHO/CDS/CSR/ DRS/ 2001.4.

Centers for Disease Control and Prevention, (2015). *Malaria.* 770-488-7788. http://www.cdc.gov/malaria/biology/life cycle htm. malaria @ cdc,gov.

Centers for Disease Control and Prevention, (2019). Malaria disease. cdc.gov/ malaria/about.

Chemtai, A.K., (2007). Immunology. Third edition Published by The Jomo Kenyatta Foundation, Nairobi, Kenya. Printed by Icons Printers Limited, Pg 35-60.

D'Acremont, V., Lengeler, C., Mshinda, H., Mtasiwa, D. and Tanner M, (2009) Time to move from presumptive malaria treatment to laboratory-confirmed diagnosis and treatment in African children with fever. *PLoS Medicine,* 6(1): e252. doi: 10.1371/*journal.pmed*.0050252.

Dhimal, M., O'Hara, R.B., Karki, R., Thakur, G.D. and Ahrens, B, (2014). Spatio-temporal distribution of malaria and its association with climatic factors and vector-control interventions in two high-risk districts of Nepal. *Malaria Journal* ,2014 13:457.

Gonzales,S. Jakes, Raphel A.,REYES, Ashley E.,Braddom, Gayani Batugedara, Sebastiaan Bol and Eveliene M.,Bunnik (2020). Naturally Acquired Humoral Immunity Agaist *Plasmodium Falciparum* Malaria. *Frontiers in Immunlolgy B cell Biology,* Vol.11. https://doi.org/ 10.3389/ fimmu.2 020.594653.

Graz, B., Merlin, W., Szoless and Rongemont, A. (2011). Test and Treat or Presumptive treatment of malaria in high transmission situations? A reflection on the latest World Health Organization guidelines. *Malaria Journal*, 2011; 10:136.http://www,malariajournal . com/context.

Kenya National Malaria Strategy 2009–2017. Published by: Division of Malaria Control Ministry of Public Health and Sanitation PO Box 19982 KNH Nairobi 00202, Kenya Email: head.domc@domckenya .or.ke http://www.nmcp.or.ke iii 2009—2017.

Kenya, Ministry of Health, Malaria control unit (2015). Gender and Malaria in Kenya. *Malaria Control Unit Ministry of Health*. January 2015.https;//www.measureevaluatio.org.Last review January 4, 2019. http://www.cdc.gov/ malaria / biology htm. malaria@cdc,gov

Lin,H., Liang, L.,Linwei, T, Shuisen, Z., Wu, H, Yau, B, Ho, C. H and Liu, Q (2009). Spatial and temporal distribution of falciparum malaria in China. *Malaria journal,* 2009 8:130. https://doi.org/10 1186/ 1475-2875-8-130

Lubell, Y.H., Reyburn, H., Mbakilwa, H., Chonya, S., Whitty, C.J.M. and Mills, A. (2008). The impact of response to the results of diagnostic tests for malaria: cost-benefit analysis. *BMJ*2, 008, 336: 202-205. PubMed Abstract. http:// www. malariajournal. com/ pubmed/18199700.

Marycelina, M., Mubi, D., Kakoko, D., Ngasala, B., Premji, Z., Peter, S., Anders, B. and Martensson, A. (2013). Malaria diagnosis and treatment practices following introduction of rapid diagnostic tests in Kibaha District, Coast Region, Tanzania. *Malaria Journal*, 2013; 12: 293.Published online 2013 Aug 26. doi: 10.1186/ 1475-12-293-293. PMCID: PMC3765530.

Minakawa, N., Sonye, G., Mogi, M., Githeko, G and Yan, G. (2002). The effect of climate factors on the distribution and abundance of malaria vectors in Kenya. *Journal of medical entomology*,2002; 39 (6): 833-841.

Minoo Mohammadkhani and Khodadad Sheikhzadeh (2016). The relationship between climatic factors and malaria incidence in Kerman, South East of Iran. *Parasite Epidemiology and control*. volume 1, September 2016, page 205-210. https//doi. org/10;1016//.parepi.2016.06.010.

Munyekenye OG, Githeko AK, Zhou GF, Mushinzimana E, Minakawa N, et al. (2005) Plasmodium falciparum spatial analysis, Western Kenya highlands. *Emerging Infectious Diseases*, 11: 1571–1577. doi: 10.3201/eid1110.050106.

Ndenga B.A., Mulaya1, N.L., Musaki, S.K, Shiroko, J.N., Dongus, S. and Ulrike Fillinger3,4 (2016), Malaria vectors and their bloodmeal sources- in an area of high bed net ownership in the western Kenya highlands. *Malaria Journal*, volume 15, Article number: 76

Ndenga, B., Githeko, A., 1, Omukunda, E., 1, Munyekenye, G., 1, Atieli, H.,1, Wamai, P.,1, Mbogo, C., 2, Minakawa, N.,3, Zhou, G.,4 and Yan, G.,4. (2006). Population Dynamics of Malaria Vectors in Western Kenya Highlands. *Journal* of *Medical Entomology*, 43(2): 200Ð206 (2006).

Nyaguara, A, Nabie, B., Hamel, M., Kim, A. Gimming, J.E., Frank Odhiambo, F., Kayla, F. L., Slutsker,L., Smith, T. and Penelope Vounatsou (2012). Spatial and temporal dynamics of malaria transmission in rural Western Kenya. *Parasite Vectors*, 2012 Apr 28;5:86. doi: 10.1186/1756-3305-5-86. 2012

Omukunda, E., Githeko, A., Ndong'a1, M.F., Emmanuel Mushinzimana, E., Atieli, H. & Peter Wamae1 (2013). Malaria vector population dynamics in highland and lowland regions of western Kenya. President's Malaria Initiative. Kenya Malaria Operational Plan FY 2016 Malaria Operational Plan. Financial year 2016 (FY 2016).

President's Malaria Initiative, Kenya (PMI, 2014/Kenya). Malaria Operational Plan. Financial year 2014 (FY 2014).

Republic of Kenya MALARIA Indicator Survey (2010). Division of Malaria Control Ministry of Public Health and Sanitation Kenya National Bureau of Statistics ICF Macro July 2011.https:// dhsprogram.com/pubs/MIS7/MIS 7.pdf.

Republic of Kenya, Vihiga County. First County Integrated Development Plan 2013-2017. Kenya Vision 2030. Towards a Globally Competitive and Prosperous Nation. http://cog.go.ke/images/ CIDPS/Vihiga.pdf-pop.

````
````

Rowe, A.K., Rowe, S.Y., Snow, R.W., Korenromp, E.L., Schellenberg, J.R., *et al*. (2006). The burden of malaria mortality among African children in the year 2000. *International Journal of Epidemiology,* 35: 691–704. doi: 10.1093/ije/dyl027.

Tawanda M., Chimbani, M. J, Macherera, and Mukaratirwa, S (2016). Micro-spatial distribution of malaria and control strategies in Gwanda district, Matabeleland, South Zimbambe. *Malaria Journal,* 2016 16 :476

Ubydel, H., Toshihika, S and Glass, E. G (2011). Malaria prevalence risk factors and spatial distribution in hilly forest area of Bangladesh. *PLoS One,* 21;6(4):e18908. doi: 10.1371/journal.pone.0018908

Wafula, H and Mulinya C, (2018). Impact of climate change on spread of malaria in Vihiga County, Kenya. www.iosrjournals.org. doi:10. 9790/2402-1201011626.

World Health Organization (2008). Task Shifting: Rational Redistribution of Tasks among health workforce teams; global recommendations and guidelines. ISBN 978 924 1596312. (NLB classification. WC 503.6)

World Health Organization (2011). World Malaria Report. Cataloguing-in-Publication.

World Health Organization (2015). Guidelines for The Treatment of Malaria. Third edition. World malaria report 2015. 1.Malaria - prevention and control. 2 Malaria - economics. 3.Malaria - epidemiology. 4.National Health Programs - utilization. 5.Insecticide-Treated Bed nets. 6.Antimalarials - therapeutic use. 7.Drug Resistance. 8.Disease Vectors. 9.Malaria Vaccines. 10.Annual Reports. I. World Health Organization. ISBN 978 92 4 156515 8 (NLM Classification: WC 765)

World Health Organization. (2010). Guidelines for treatment of malaria (2nd edition). No.8. ISNB97892 41547925.NLM Classification WC770. Pg 1-3.

world health organization. (2020). world malaria report 2020.20 years of global progress and challenges. 30 November global report ISBN: 978.92 4-001579-1(electronic version) ISBN 978-92 4-001580-7 (print version) www.who.int/ publication/Reports

Yadar, K., Suni, D, Bipul, R, Saikia, P.K. and Veera, V, (2014). Socio-economic determinands for malaria transmission in an endemic primary health center in Assam, India. Infectious diseases of poverty 2014 3:19. Biomed centre Ltd, 2014.

Yeda, R. Ingasia, L.A., Cheruiyoit, A.C, Okudo, C., Chebon, L.J. and Cheruiyoit, J. (2016). The Genotypic and Phenotypic Stability of *Plasmodium falciparum* Field Isolates in Continuous *In Vitro* Culture. *PLoS ONE*, 11(1): e0143565. doi: 10. 1371/journal.pone.0143565.

Zhou,G., Afrane, Y.A., Vardo-Zalik, Atieli,H., Zhong, Wamae *et al* (2011). Changing pattern of malaria Epidemiology between 2002 and 2011 in Western, Kenya. the fall and raise of malaria. *PLoS ONE,* 6 (5): e20318.doi:/journal. Pone.0020318.