

Effect of Rainfall on Seasonality of Malaria Transmission Dynamics and Percentage Occurrence of mRDT Positives Around the Five Rural Health Facilities in Vihiga County, Kenya

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ABSTRACT

Background: The negative impact and concern of malaria is felt world over with 247 million cases reported in 2021. The cases were reported in 84 malaria endemic countries with high number of casualties experienced in Africa. Normally, malaria infection is influenced by climatic factors while its treatment and resilience to drugs is controlled by health interventions measures both at the hospital level and in the community. Malaria Rapid Diagnostic Tests (mRDTs) are recommended by WHO for malaria testing and are expansively used in rural set-ups. However, their success in performance is controlled by many factors. This study aimed at correlating the effect of rainfall patterns to malaria positive case as tested by mRDT in Vihiga County, Kenya.

Methodology: This study focused on the participation of 500 patients from a population of 18201 patients within a two (2) Kilometre radius of the five rural health facilities in Vihiga County. Facilities had poor infrastructure in terms of malaria testing and mostly relied on mRDT for malaria testing and surveillance. Data was collected from the five health facilities at the end of every month for a period of twelve months. The rain gauge reading was also collected daily by Vihiga metrological department from which the average monthly rainfall was computed. This was run from April 2022 and March 2023. Care start TM Rapid Diagnostic Tests were used to detect HRP2/3 proteins/antigens which are specifically responsive to *Plasmodium falciparum* antibodies.

Results and Data Analysis: Average rainfall for the period between April 2022 and March 2023 was 185mm; the average percentage prevalence of malaria during the same period in this region was 21.3%. This region experienced one peak of rainfall recorded at 360mm in the month of September; 2022. The month of April recorded the highest malaria prevalence of 38.4% with an average rainfall amount of 311.7mm while February recorded the lowest malaria prevalence of 7.16% with an average rainfall amount of 0.2mm. The data showed that there were more patients in the middle age category of between five (5) and eighteen (18) years. More women came to the facilities than men; hence more women were malaria positive than men. Linear regression analysis was performed which emerged that the average rainfall accounts for 28.37% variations in prevalence ($R^2=0.2837$). The model coefficient showed that average rainfall has a positive significant effect on prevalence ($\beta=0.0591$, $p<0.05$). This implies that malaria prevalence is determined by rainfall amount. Although the infection rate is on the downward trend, there was a constant of 10 from the model equation which is apparent that malaria infection is not dependent on

rainfall alone; there could be other factors as well.

Conclusion: This study reported fluctuating average rainfall throughout the year. There was fluctuating average malaria prevalence as well. When the average rainfall was high, average malaria prevalence was also high and the converse was true. Therefore, rainfall significantly caused the malaria infection in this region. High rainfall is a significant determinant of malaria prevalence.

Keywords: Malaria diagnosis, Pfhrp2/3 gene deletions and malaria RDT

INTRODUCTION

Malaria remains a devastating public health challenge not only in Africa but also the world as a whole^{1, 2}. This disease is caused by any of the five species-of the *Plasmodium* genus, namely: *Plasmodium vivax*, *Plasmodium malariae*, *Plasmodium ovale*, *Plasmodium knowlesi* and *Plasmodium falciparum*^{3, 4}. In the year 2020, the world recorded a total of 229 million malaria cases, a situation that has not changed for the last four years^{4, 5, 6}. Seventy percent (70%) of the total count of the malaria cases in the world was reported in Africa while Kenya registered about 3.5 million new clinical malaria cases of which 10,700 patients died annually^{7, 8}. Vihiga County is endemic to malaria and registers 20% cases of all outpatients' visiting health facilities in this region^{9, 10}.

Microscopy, once considered the gold standard, has been used for malaria diagnosis for a very long time though other methods have been discovered as well. Malaria Rapid Diagnostic Tests (mRDTs) is one such method that is expansively used in rural areas in Vihiga County. They are mostly preferred because they are cheap and easy to interpret since they do not require highly specialized training. The use of mRDT does not also require electricity which lacks in most rural health facilities in Kenya^{4, 11, 12, 13}. Rapid Diagnostic Tests, technically use an immunochromatographic device that is coated with monoclonal antibodies (Mab) which are specific to *Plasmodium falciparum* Histidine Rich Proteins (*Pfhrp2/3*) antigens in the blood sample^{2, 4, 7, 14, 15}. These antigens are soluble proteins found circulating in the blood stream of a malaria infected individual but some are also found on the *Plasmodium falciparum* parasite^{5, 16, 17, 18}. The use of RDTs has improved malaria case management and surveillance in Kenya^{4, 19, 20, 21, 25}. They have a weakness of being influenced by seasonality of malaria transmission, asymptomatic cases in populations and parasite genetic factors and as a result of errors made by the end-users^{4, 23, 13}.

Seasonality is a key broad component that controls and affects rainfall patterns, temperature variations, formation of ponds and swamps and either sustains continuous flow or diminishes the flow of water in some rivers. All these parameters affect the malaria transmission cycles and consequently, the use of mRDTs^{4, 16, 22}. Heavy rainfall (1800mm to 2000mm) during both short and long rain seasons coupled with high humidity and temperature (14⁰C to 32⁰C) provides a good environment for faster breeding of the mosquito hence increased malaria transmission and infection^{4, 17, 24, 25, 26}. Low parasite detection rate has been linked to increased expression of *Pfhrp2/3* gene deletions and this has been attributed to super infection by the malaria parasites^{5, 27, 28}. This therefore implies that there should be more studies on how seasonality affects malaria intensity and distribution of *Pfhrp2/3* gene deletions which in turn affects RDTs.

To control the devastating effects of malaria, it is worth noting that it is a treatable disease if is diagnosed early followed by proper treatment of the patients^{16, 29, 30}. Since malaria occurrence and testing in endemic areas strongly follows the patterns defined by malaria seasonality, it is prudent to not the significance of mRDT towards detection of infection and its ultimate role to malaria control^{1, 4, 14, 15}. Therefore the objective of this study was to analyse effect of rainfall on seasonality of malaria transmission dynamics and percentage occurrence of mRDT positives around the five rural health facilities in Vihiga County, Kenya

METHODOLOGY

Study design:

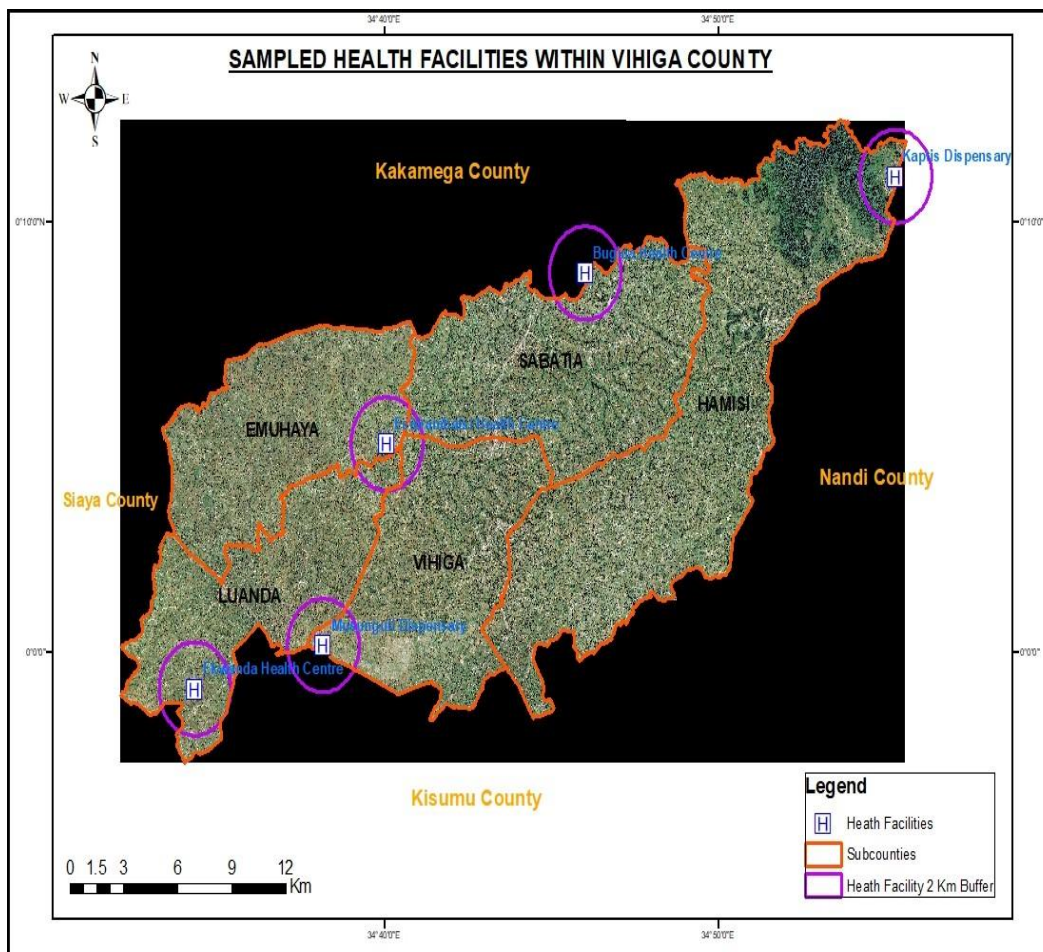
This study was a cross-sectional survey that utilized data on malaria positive cases from the five satellite health facilities in Vihiga County, Kenya.

Study Area

The study area was Vihiga County, Kenya. It is located $0^{\circ}17'N$, $34^{\circ}74'E$, and receives rainfall ranging between 1800mm-2000mm with distinct long and short rainy seasons. The mean temperature is $23^{\circ}C$, ranging between $14^{\circ}-32^{\circ}C$. The altitude varies between 1300m and 1500m above sea level²⁵. Vihiga County has a population of 637,844 persons of which 52.5% are female and 47.8 % are male. The County has 144,000 households with a mean household size of 4.3 persons. It has the highest population densities in Kenya of 1,094 persons per square kilometre compared to the national average of 66 persons per square

kilometre³¹. In Vihiga County, malaria is endemic and with mosquito bites of over 300 per month, it (Malaria) is experienced throughout the year with peaks of transmission during long rains (April, May and July) and short rains (October, November and part of December). In Vihiga, the entomological inoculation rate (EIR) varies with specific location from 6.000-0.145 infective bites/person/night^{17, 24, 25}.

Fig: 1: Sampled rural health facilities within Vihiga County



Source: County government of Vihiga Geographical Information System (GIS) laboratory

Sampling procedure and data collection:

This study purposefully sampled five (5) health facilities from the five sub county administrative units of Vihiga County as shown if Fig 1. The health facilities of focus were Ekwanda, Bugina and Esiarambatsi from Luanda, Sabatia and Emuhaya Sub Counties respectively. The sample size calculation employed Taro Yamane (1967) formula revised in Anokye (2020)³² given as:

The adjusted Yamane’s formula is;

$$n = \frac{N}{1+Nd^2}$$

- N= The Population (Value of 18, 201)
- d= The precision
- n=The required sample size

Using a precision of d=0,05 at 95% confidence interval, the formula yielded an n value of 391. Similarly, with a d value of 0.04 at 96% confidence interval, the formula gave a sample size of 604. This therefore meant that from our population of 18,201 malaria patients, a sample of 500 respondents was appropriate. Beyond 96% confidence interval, the formula will give a sample population that will be uneconomically sustainable. This sample size of 500 was proportionately distributed as shown in Table 1.

Table 1: The proportionate distribution of the Sample size as per Health facility

NO	Health facilities	Population	Proportion
1	Bugina	3622	100
2	Ekwanda	4700	129
3	Esiarambatsi	5776	159
4	Musunguti	2525	69
5	Kaptis	1578	43
		N = 18201	n = 500

Data was collected from the five health facilities and it included the number of malaria positives from the suspected patients, the frequency of facility visits by the patients and the type of treatment administered. Sleeping under of treated mosquito nets and malaria vaccination for the under-five years was also assessed. The participants were randomly selected and consented to the study. They had come to the facilities with any of the following symptoms; high fever, nausea, headache, diarrhoea, vomiting, joint pains and prostration. Malaria positivity status was diagnosed with mRDT and confirmed by microscopy.

Inclusion criteria

This study included consenting subjects of all ages who availed themselves for health services from the sampled rural health facilities in Vihiga County.

Exclusion Criteria

Patients who were non-permanent residents of Vihiga County, did not consent or their parents/Guardian did not consent to the study were excluded from the study.

DATA COLLECTION AND ANALYSIS

Both quantitative and qualitative data were analyzed to assess significance of rainfall patterns malaria transmission in the communities. Data was entered using access data base Microsoft software.

Data was analyzed using least square line regression model of $y = \alpha + \beta x$ where:

y = Average prevalence

α = Constant term

x = Average rainfall

β = Regression coefficient/The gradient

RESULTS AND ANALYSIS

Data on average monthly rainfall and average malaria prevalence was collected, harnessed analysed in this section in Table 2. Comparison between the average rainfall amount and average monthly malaria prevalence was made and presented in Fig 3.

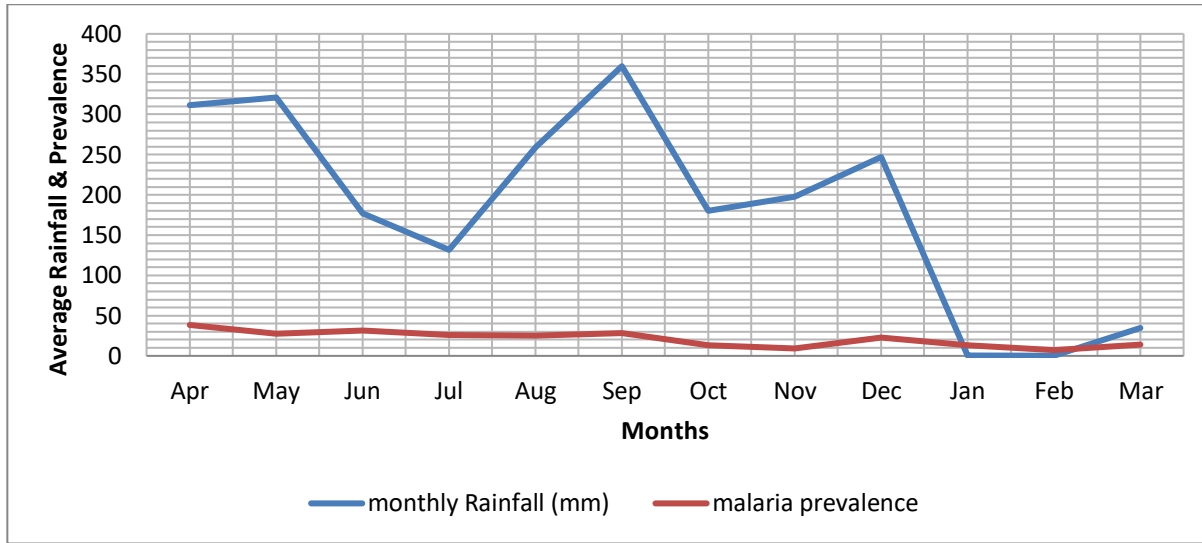
Table 2: Average monthly Rainfall against malaria prevalence for the five health facilities

Month	Average monthly Rainfall (mm)	Bugina H.C	Ekwanda H.C.	Esiarambatsi H.C.	Kaptis Disp.	Musunguti Disp	Average malaria prevalence
Apr	311.7	33.6	48.2	51.9	29.1	29.1	38.38
May	320.9	18.1	40.9	41.6	15.1	21.1	27.36
Jun	176.8	13	43.3	39.1	24.8	36.1	31.26
Jul	132	10.2	35	34.5	19.7	28.9	25.66
Aug	258.9	33	44.1	26.9	11.5	11.3	25.36
Sep	359.8	28.7	29.1	26.2	28.6	26.9	27.9
Oct	180	6.4	9.7	23	19.3	7.6	13.2
Nov	198	10.1	15	10.1	7.4	5	9.52
Dec	247	24.5	42.7	24.1	15.6	8.3	23.04
Jan	0.8	9.3	7.6	9.7	17.1	20.3	12.8
Feb	0.2	4.8	5.8	6.9	8.6	9.7	7.16
Mar	35	9.1	16.1	12	14.7	16.5	13.68

In Vihiga County, the average rainfall for the period between April 2022 and March 2023 was 185.025 mm (Table 2). The records indicate high average rainfall though there is a general trend towards reduction of rainfall in this region^{24,25}. This trend could be attributed to global warming brought about by climate change³⁴. Naturally, 185.025 mm rainfall and warm temperatures is a recipe for proliferation of the arthropod vector which exacerbates the rate of malaria transmission and infection. The average percentage prevalence of malaria in this region is 21.3%; this percentage score is slightly higher than 20% initially reported in Vihiga^{5,8}. Malaria infection in this area has remained fairly high with a range of 31.223%

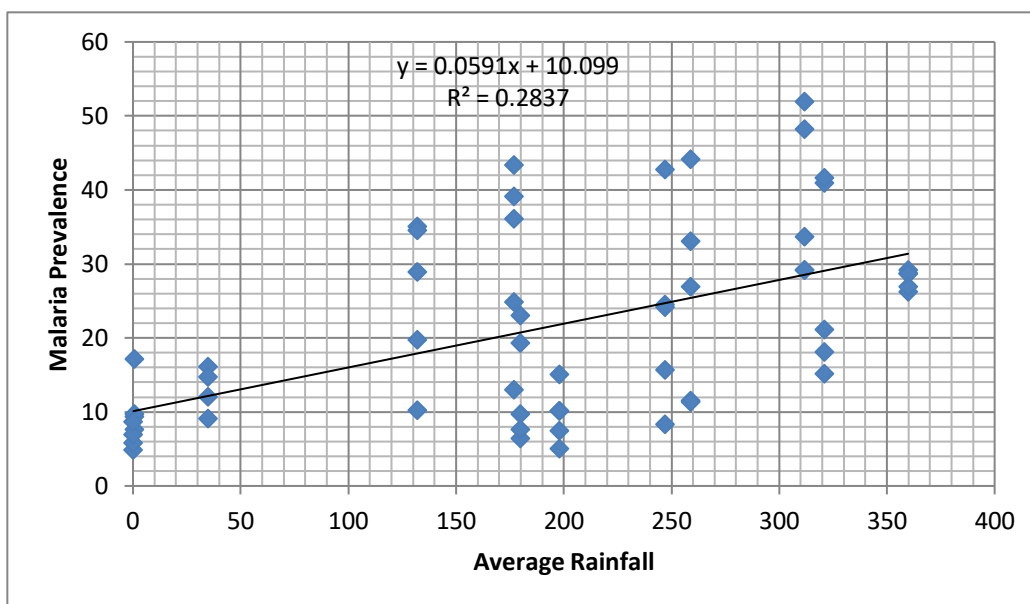
(Table 2)

Fig 2: Comparison between average monthly rainfall and average malaria monthly prevalence



During this period under study (twelve months), this region experienced one peak (360mm) of rainfall experienced in the month of September, 2022. The second and third highest months with high amount of rainfall were May and April with 321mm and 312mm respectively. This was a deviation from the historical bimodal peak of rainfall pattern in Kenya which is usually recorded in April and June then October and December⁵. April recorded the highest malaria prevalence (38.4%) as diagnosed by mRDT. The month of June had the second highest malaria infections (31.3%) while May had the third highest (27.4%). Incidentally, the month with the lowest amount of rainfall had a prevalence of 7.16%; which is less than the average prevalence of malaria positivity for the Vihiga County which stood at 21.3%. This malaria percentage prevalence was greater than the projected prevalence of 18.6% by Vihiga County annual malaria report by the County Government of Vihiga, Department of health³⁴.

Fig 3: Scatter plot Regression Analysis of Rainfall and Malaria prevalence in Vihiga County, Kenya



To analyze the linear relationship between the average amount of rainfall and average amount of malaria

prevalence, a scatter plot was designed from the data obtained and the line of best fit drawn.

This data was analyzed using least square line regression model and can be represented in the model equation (Line of best fit) as: $y=0.0591x + 10.099$ as shown in Fig 2 above. This meant that, a unit increase on average rainfall leads to an increase on prevalence by a magnitude of 0.0591 units hence average rainfall significantly impacts on malaria prevalence

When analyzed using the least square line regression model, it gave a value of $R^2 = 28.37\%$ which indicated that average rainfall has a positive ($\beta = 0.0591$, $p < 0.05$) which was represented in the model equation. The range for the percentage prevalence was 31.22%. which was high an indication that there were varied prevalence in malaria episodes which was reported by Centre for Disease Control-CDC which stood at 20%^{7, 9}.

From the findings, linear regression analysis was performed and it emerged that the average rainfall accounts for 28.37% variations in prevalence ($R^2=0.2837$). Using the model coefficient results, it was also found that the average rainfall has a positive significant effect on prevalence ($\beta=0.0591$, $p<0.05$). This implies that malaria prevalence is determined by rainfall amount. Although the infection rate is on the downward trend, there was a constant of 10 from the model equation which is apparent that malaria infection is not dependent on rainfall alone; there could be other factors as well.

DISCUSSION

Malaria is one of the diseases that is affecting the people of Vihiga County. Due to favorable geographical and climatic conditions that favors proliferation of the mosquito vector has made malaria endemic in Vihiga. The infection and prevalence of malaria is defined by seasonal peaks. The intervention measures towards control and management should also peak with equal measure. Malaria surveillance and reporting is therefore an imperative aspect of disease control since it helps to monitor seasonal variations and advise stakeholders on specific response mechanisms towards the same. The policies directed towards malaria control should be backed with well researched empirical data output/statistics stemming from seasonal malaria outbreaks. This study was designed to make rainfall pattern and malaria prevalence status as two strong pillars that either controls infection to the benefit host, vector or the *Plasmodium falciparum* parasite.

The knowledge on malaria seasonality and targeted intervention measures enhance cost effectiveness in managing malaria outbreak. Stakeholders in the health sector should use this information to advice, with precision, on whether to mitigate or combat the *Plasmodium* parasite. This team can also advice on Indoor Residual Spraying (IRS), giving intermittent preventive treatment to pregnant mothers/Infants (IPTp/IPTi) in anticipation of an outbreak and finally, health facilities can stock, in anticipation malaria outbreak, more anti-malarial drugs during the peak period to prevent wastage from drugs stocked beyond the 'sale-by- date' shelf-life^{2, 4, 24}.

In defining the status of malaria in this County, there is an indication that malaria transmission is on the downward trajectory, albeit gradual. This can be attributed to many parameters which do influence a decline in malaria infection. They include mosquito vector control measures, treatment of malaria patients and civic education on malaria control strategies among others^{5,35}. A drop in malaria transmission in this region, therefore, could be attributed to an increase in malaria intervention strategies which. by extension, influences malaria epidemiology in Vihiga County settings^{24, 35}.

This report relates seasonality of malaria to environmental parameters of rainfall and temperature since the two parameters have a strong influence to the lifecycle of malaria mosquito vectors and consequently the malaria infection rate in the population. This report correlated precipitation/rainfall patterns to malaria

transmission processes and it did not establish high malaria prevalence during heavy rainfall as earlier reported²⁵. In Vihiga, there are no distinct bimodal peaks of rainfall since the rainy season is fairly longer than dry spell. This region is also fairly watered by rain in most part of the year and has many rivers and ponds. In the period between April, 2022 and March 2023, these factors kept malaria transmission high at 23.68% of all suspected, tested and confirmed malaria positive patients visiting the health facilities.

This region, does not, only show variations in amount of rainfall between consecutive months but there are variations in malaria monthly prevalence as well. The rainfall was experienced throughout the year and had only one peak (September, 2022) and malaria prevalence was also observed in one peak (April, 2022). Historically, rainfall in this region peaks in March or April but during 2022, it peaked in February³³. A deviation in rainfall amount from the historical trend may have been caused by adverse changes in the climate hence resulting to global warming and a consequent change in rainfall patterns. This may have affected malaria infection patterns by converting the once dry months to wet ones. This exacerbates malaria infection challenges. Global warming has interfered with the traditional climatic status hence rainfall, temperature, and malaria outbreak can longer be predictable in this region^{27, 36}. The stakeholders should therefore re-strategize and think over new policies directed towards malaria control, diagnosis and treatment in lieu of the above. In fact, the stakeholders should have a complete paradigm shift from the traditional trends of malaria infections and have modern mechanisms of fighting malaria infections.

Information on start, progression and decline for malaria infection is very significant to the health stakeholders if they are to participate effectively and efficiently in malaria control processes. It also advises on planning and mitigation strategies for combating malaria disease. This will include management of the malaria parasite vector (female anopheles mosquito), malaria diagnosis and treatment of the patients. When spatio-temporally mapped, the information can guide or put in place tracking procedures to manage the infections at the point of detection in the human host³⁷. This can be achieved by mapping, by way of geo-referencing, malaria patients and buffering out malaria hot-spots for close monitoring and reporting²⁴. Climate change has also distorted routine malaria infection peaks in this endemic region. It has disrupted the usual malaria predictable patterns of infection. Consequently, predictability in mitigation measures has also been disrupted^{14, 33}. To understand this better and have a fairly reliable set of data to guide on the above, this study delved into looking at the correlation between the amount of rainfall and its influence to malaria infection processes.

In following up with the effect of seasonality to malaria prevalence, this study partly concurred with other report findings that there is a strong correlation between rainfall and the malaria infection rate^{25, 33, 38}. Three health facilities failed to concur with a study done on rainfall and malaria infection rate by registering negative correlation status (**Table 2**)²⁵. This study sustained mRDT activities for a period of 12 months which aimed at understanding the rainfall patterns and pointing out malaria positive subjects. This is because prevention of malaria and subsequent treatment is an expensive venture³⁹.

Meanwhile, there is an average prevalence for mRDT positive cases from the five selected health facilities was 23.68%. This value was higher than the 10% reported from a survey done in children and adults along the coastal region in Kenya and 20% reported by world health organisation^{5, 9}. Management of malaria is so involving and time consuming (to both patients and caregivers) that some people seek for extra man-hours off their work stations to attend to malaria patients¹². While at home or even in the health facilities, the victims require funds for diagnosis, management and general care. Malaria infection is preventable and if infected, it is treatable, both factors that are under our control. Therefore, all stakeholders including the community, caregivers, health workers and even the County government have a role to play in managing the malaria challenge. If not controlled, the negative effect of malaria causes a negative multiplier effect to the poor households but if contained, the government can re-direct the Malaria funds to other activities that are beneficial to the residents of Vihiga, Kenya..

CONCLUSION

This study reported fluctuating average rainfall throughout the year. There was fluctuating average malaria prevalence as well. When the average rainfall was high, average malaria prevalence was also high and the converse was true. Therefore, rainfall significantly caused the malaria infection in this region. High rainfall is a significant determinant of malaria prevalence. Understanding proper timing of the rainfall and accurate prediction of the malaria infection patterns is very important in contemplating and planning for control of malaria transmission. This information will can be used by stakeholders to re-design malaria control policies and give direction to proper protocol for the deployment of malaria drugs for both treatment and prevention. The stakeholders are made to understand malaria transmission dynamics and subsequent malaria control measures that can be applied to protect populations from the malaria scourge.

RECOMMENDATIONS

- There should enhanced surveillance and accurate mapping of patients to make it easy for follow ups to improve monitoring, evaluation and reporting on impact of malaria in the
- More studies are needed to look at applicability of malaria seasonality as a strategy for managing disease

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AUTHOR CONTRIBUTIONS

John Khamala Ongonda collected coalesced data and drafted the manuscript under the guidance of Cyrus Ayieko from Maseno University and Elly Munde from Kirinyaga University. Stephen Miheso from Maseno University helped organize the data. He also guided on the statistical analysis for this work.

Competing interests

The authors declare no competing interests

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