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STATISTICAL ANALYSIS FOR INFECTIONS OF MALARIA IN THE RIVER NILE STATE (SUDAN) (2018-2022)

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Abstract

This article analyzes malaria cases in River Nile State (Sudan) during the period 2018-2022. It concludes that Malaria prevalence rates in River Nile State (Sudan) were very similar across the study years (2018-2022), reaching 17%, 16%, 15%, 14%, and 13%, respectively. This is very high compared to the global malaria prevalence rate (3.1%), but close to the African average (16.4%). There is a significant difference in malaria cases across the years. Due to the increase in the number of cases in recent years, there is no significant difference in cases between months during each study year, meaning that cases are similar throughout the year. However, cases increase in winter and decrease in summer, cases increased for all months in 2022 compared to 2018, especially in April, except for June and July, where they decreased by 3% and 8%. Overall infections increased by 27.6%

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from 2018 to 2022 and the predictive values showed an increase in the number of infections over the next five years. The article recommends that there should be an increase in mosquito control measures, especially during the winter months. Mosquito nets be provided, especially to those living in rural areas. They must be educated about water conservation. Necessary treatment be provided to reduce the number of deaths and study the reasons that led to the sharp rise in April 2022.

Introduction

Malaria is a life-threatening disease caused by Plasmodium parasites that are transmitted to people through the bites of infected Anopheles mosquitoes. There are five different types of parasites that infect humans: P. falciparum, P. vivax, P. ovale, P. malariae, and P. knowlesi. Of these, P. falciparum and P. vivax are the most prevalent, and P. falciparum is the most dangerous, with the highest rates of complications and mortality [1].

Malaria occurs mostly in tropical and subtropical areas of the world where people lack access to certain resources, such as housing with screens or medical facilities with proper testing and treatment capabilities. In many of the countries affected by malaria, it is a leading cause of illness and death. In areas with high transmission, the most vulnerable groups are young children, who have not developed immunity to malaria yet, and pregnant women, whose immunity has been altered by pregnancy. The costs of malaria - to individuals, families, communities, nations - are enormous (Health [2]).

Globally in 2023, there were an estimated 263 million malaria cases and 597000 malaria deaths in 83 countries. The WHO African Region carries a disproportionately high share of the global malaria burden. In 2023, the WHO African Region was home to 94% of malaria cases (246 million) and 95% (569 000) of malaria deaths. Children under 5 accounted for about 76% of all malaria deaths in the region (WHO [3]).

In Sudan, malaria remains a significant epidemic, it is estimated that more than 1.3 million malaria cases and over 850 deaths were confirmed in 2023, according to the World Malaria Report 2024. Children account for 22.3% of these cases and 16% of the estimated deaths (UNICEF [4]). Sudan is one of the countries with a high burden of malaria-related morbidity and mortality and this causes substantial negative effects on the nation's economy. Both federal and state health ministries have faced ongoing challenges in addressing the disease, which led to the establishment of a dedicated unit - the Malaria Control Department. This study examines malaria infections data from River Nile State (Sudan) spanning the years 2018 to 2022, as provided by the Ministry of Health - Malaria Control Department - River Nile State. The study is valuable in helping relevant authorities assess the anticipated infection rates and evaluate the effectiveness of current malaria control measures.

Material and Methods

Descriptive measures and graphical representations will be used to describe the data. Since the data are for more than two variables [5] (5 years, 12 months), analysis of variance (ANOVA) will be applied to test whether there is a significant difference between infections across the study years. ANOVA requires normality of data. Homogeneity of groups variances and samples should be independent [6]. If the ANOVA assumptions are not met, then the nonparametric Kruskal-Wallis test will be used instead https://datatab.net/tutorial/dependent-and-independent-samples. Forecasts for future years will also be made using general trend equation, trend is a pattern in data that shows the movement of a series to relatively higher or lower values over a long period of time. In other words, a trend is observed when there is an increasing or decreasing slope in the time series [7]. It can be written as follows: Trend $= a + b^{*}$ time, the coefficient b is the expected change in the trend in consecutive periods. The coefficient a is the intercept. https://towardsdatascience.com/understanding-time-series-trend-addfd9d 7764e/.

Data and Data Analysis

Table 1. Malaria infections in the River Nile State (Sudan) 2018-2022

	2018	2019	2020	2021	2022	Total	Average
January	14499	14814	20065	18820	19117	87315	17463
February	12892	13207	19245	18285	16432	80061	16012
March	15700	16015	16395	17403	18147	83660	16732
April	8542	8857	13895	12482	23821	67597	13519
May	14798	15113	12164	10308	17607	69990	13998
June	16835	17150	14736	11059	16710	76490	15298
July	15322	15637	16768	12635	14408	74770	14954
August	13162	13477	14236	16644	13880	71399	14279
September	11820	12135	11650	19698	13940	69243	13848
October	11524	11839	12825	19644	17213	73045	14609
November	12530	12845	12482	16669	16572	71098	14219
December	14245	14560	16493	19704	18700	83702	16740
Total	161869	165649	180954	193351	206547		
Average	13489	13804	15079	16112	17212		

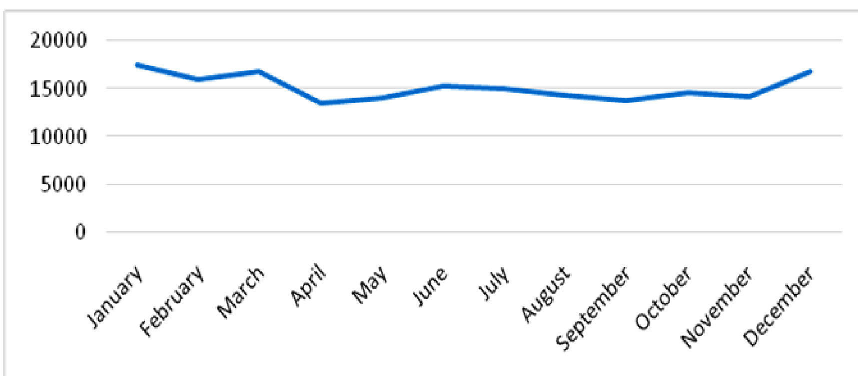

Figure 1. Malaria infections in the River Nile State (Sudan) by months (2018-2022).

Referring to Table 1 and Figure 1, the average highest incidences over the five-year period occurred in December, January, February, and March, the winter months when the weather is mild and mosquitoes are abundant. The remaining summer months are extremely hot, making mosquitoes inaccessible. The lowest incidences occurred in April and May (in these months, the temperature exceeds 40 Celsius).

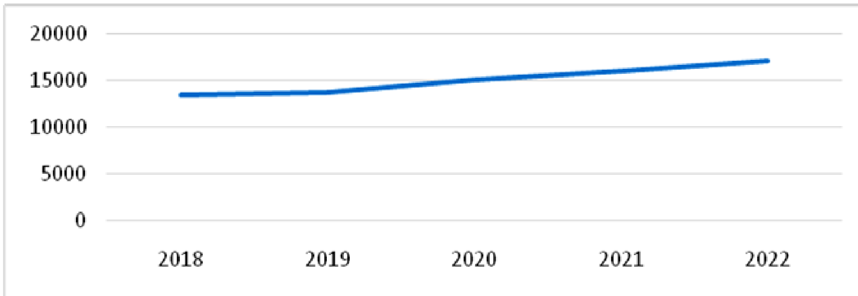

Figure 2. Malaria infections in the River Nile State (Sudan) by years (2018-2022).

From Table 1 and Figure 2, it is noted that the average number of infections over the five years is increasing, as the rate of increase in 2022 compared to 2019 was (28%) and compared to the previous year, 2021, was (7%) and the exchange rate from 2018 to 2022 is 27.6%.

The population size of the state during the study period did not change much, as its average was 1,212,000 people. Accordingly, the prevalence rates for the years 2018-2022 are 17%, 16%, 15%, 14% and 13%, respectively, which is very high compared to the global prevalence rate in 2022 (3.1%), where the number of infected people was estimated at 274 million [8] and the population was 7.9 billion people [9]. While it was very close to the prevalence rate in Africa (16.4%) where the population was 1.421 billion [10] and the number of infections was 233 million [11]. Therefore, it can be said that the spread of malaria in River Nile State was not abnormal compared to African countries, which are considered home to malaria.

The change rates from the base year 2018 to the current year 2022 for the infections in each month fluctuate as in Table 2 and Figure 3.

Table 2. Change rates from the base year 2018 to the current year 2022 for the infections in each month

Month	January	February	March	April	May	June	July	August	September	October	November	December
Change rate	29%	24%	13%	129%	17%	-3%	-8%	3%	15%	45%	29%	28%

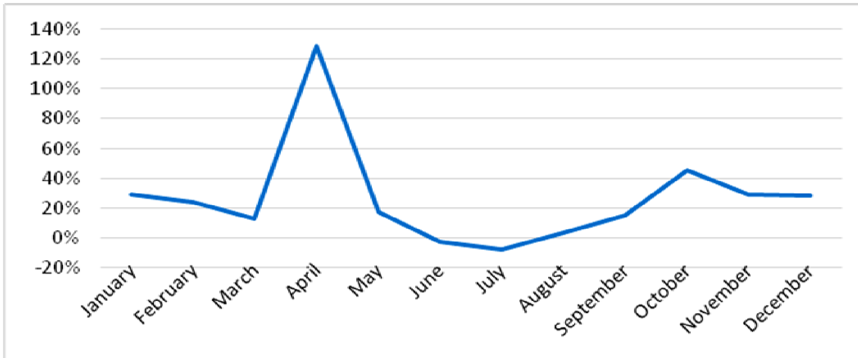

Figure 3. Change rates from the base year 2018 to the current year 2022 for the infections in each month.

Rates of change fluctuate widely throughout the year, with both positive and negative months. Of the twelve months, ten show an increase in the number of cases (January-May and August-December), while only two months, June (-3%) and July (-8%), record both a decrease and an improvement in the number of cases, indicating that most months experience an increase in cases with a slight decrease in early summer. The highest increase is observed in April (129%), a sharp rise that stands out as much larger than all other months, this calls for an investigation into the reason for this sudden increase in infections in April 2022 compared to infections in the same month in previous years. while the lowest decrease occurs in July (-8%). Several months show moderate and stable growth, including January (29%), February (24%), March (13%), May (17%), September (15%), November (29%), and December (28%). A seasonal pattern is clear: winter (January-March) shows a moderate, steady increase between 13% and 29%; spring (April-May) sees a significant increase in April followed by a moderate increase in May; summer (June-August) declines in June and July before recovering slightly in August; autumn (September-November) sees a strong rebound, particularly in October (45%), and December maintains a strong increase at 28%. Overall, the April increase is an anomaly, reflecting a seasonal effect as it acts as a buffer between summer and autumn, while the mid-year decline indicates a slowdown, as mosquitoes are fewer in autumn and more numerous in the period immediately following autumn.

For data of the 5 years: To test the normality of the data over the five years, the Kolmogorov-Smirnov results showed significant values of 0.09 for the years 2019, and 0.2 for the years 2018, 2020, 2021 and 2022, which are values greater than 0.5, indicating the normality of the data. Homogeneity of variance across the five-year incidences was tested, and the *p*-value was 0.088, which is greater than 0.05, indicating homogeneity of variance across the data. Therefore, the conditions for using a moderated analysis of variance and homogeneity of variance were met. Analysis of variance was used to test whether there was a significant difference between infections in the five years. The *p*-value was 0.007, which is less than 0.05, indicating that there was a significant difference between infections in the five years, meaning that the increase in infections is considered important.

For data of months in the 5 years: Homogeneity of variance across infections over the five years was tested, and the value was 0.23, which is greater than 0.05, indicating homogeneity of variance across the data. Therefore, the conditions for using a moderated analysis of variance and homogeneity of variance were met. To test the normality of the data over the five years, Kolmogorov-Smirnov results showed significant values of 0.165, 2, 2, 2, 2, 0.131, 2, 0.124, 0.185, 2, 0.07 and 2, respectively, indicating the normality of the data. So, analysis of variance was used to test whether there was a significant difference between infections in the months during the five years. The *p*-value was 0.511, which is greater than 0.05, indicating that there was no significant difference between infections in the months during the five years, indicating the presence of malaria throughout the year and in numbers that were almost equal during all months.

To predict the number of infections in the coming 5 years, general trend equation (GTE) is used. The forecasts are as in Table 3.

Table 3. Malaria infections forecast in the River Nile State (Sudan) 2023-2027

Month	2023	2024	2025	2026	2027
January	21435	22759	24083	25407	26732
February	19659	20875	22091	23307	24523
March	18940	19622	20304	20986	21669
April	23756	27174	30592	34011	37429
May	14241	14323	14404	14485	14567
June	13395	12761	12127	11493	10895
July	13505	13022	12539	12056	11573
August	15660	16121	16581	17041	17502
September	17389	18570	19750	20930	22111
October	20363	22282	24200	26118	28037
November	17791	18982	20173	21364	22555
December	20956	22361	23767	25172	26578
Total	217090	228852	240611	252370	264171

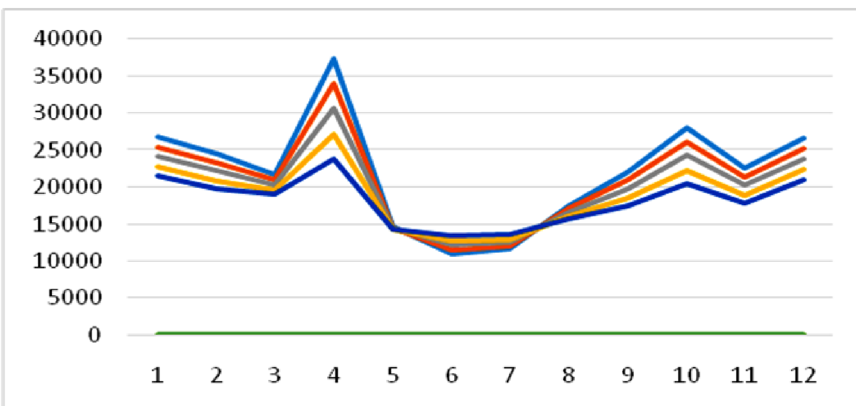

Figure 4. Malaria infections forecast in the River Nile State (Sudan) 2023-2027.

Predictions indicate an expected increase in infections during April and October, necessitating increased precautions during these two months. The lowest infections are expected in June and July, so authorities should not treat all months with the same level of precautions.

Conclusions

(1) Malaria prevalence rates in River Nile State (Sudan) were very similar across the study years (2018-2022), reaching 17%, 16%, 15%, 14%, and 13%, respectively. This is very high compared to the global malaria prevalence rate (3.1%), but close to the prevalence of malaria in African (16.4%).

(2) There is a significant difference in malaria cases across the study years, due to the increase in the number of cases in recent years.

(3) There is no significant difference in cases between months during each year, meaning that cases are similar throughout the year.

(4) In general, cases increase in winter and decrease in summer.

(5) Cases increased for all months in 2022 compared to 2018, especially in April, except for June and July, where they decreased by 3% and 8%.

(6) Overall infections increased by 27.6% from 2018 to 2022.

(7) Predictive values showed an increase in the number of infections over the next five years.

Recommendations

(1) Increase mosquito control measures, especially during the winter months.

(2) Provide mosquito nets, especially for those living in rural areas, and educate them about water conservation.

(3) Provide necessary treatment to reduce the number of deaths.

(4) Study the reasons that led to the sharp rise in April 2022.

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