

ASSESSMENT OF TEMPERATURE VARIABILITY AND HEAT RELATED DISEASES IN YOLA METROPOLIS

Godiya Bitrus, Abel A. Adebayo and Macbernard Nipona

Department of Geography, Modibbo Adama University, Yola

Email: godiyatizheterry@gmail.com

Abstract

This study assessed the effects of temperature variability on heat-related diseases in Yola Metropolis, Nigeria. Secondary data used for the study include maximum temperature data for 40 years (1985 - 2024) obtained from the Upper Benue River Basin Development Authority, Yola and reported cases of heat-related diseases and deaths (cerebral malaria, cerebral meningitis, cardiovascular diseases and heat stroke) were obtained from Modibbo Adama University Teaching Hospital, Yola (Former Federal Medical Center, Yola) for the period of 24 years (2001 - 2024). The data were subjected to trend analysis, correlation and regression analysis. Monthly pattern of temperature showed extreme heat between February and April, with March recording the highest average maximum temperature (39.23°C), before declining to a minimum in August (30.67°C). Correlation analysis showed that cardiovascular diseases ($r = 0.847$, $p < 0.01$), cerebral meningitis ($r = 0.756$, $p < 0.01$), and heat stroke ($r = 0.759$, $p < 0.01$) were strongly and positively associated with rising maximum temperatures, while cerebral malaria showed a weak and statistically insignificant negative correlation ($r = -0.390$, $p > 0.01$). Regression analysis revealed that maximum temperature was a strong and statistically significant predictor of heat stroke ($R^2 = .577$, $t = 3.69$, $p = .004$), cerebral meningitis ($R^2 = .571$, $t = 3.65$, $p = .004$), and cardiovascular disease ($R^2 = .718$, $t = 5.05$, $p = .001$). The findings affirm that temperature variability poses a critical public health challenge in Yola, intensifying disease burdens, especially among vulnerable populations. Based on these outcomes, the study recommends establishing a climate-sensitive disease surveillance system that integrates health and weather data for early warnings. It further suggests implementing seasonal health preparedness programs, institutionalizing climate-health risk assessments in public health planning, and launching community-based education initiatives to improve awareness and promote practical adaptation strategies.

Keywords: Cardiovascular, Heat stroke, Malaria, Meningitis & Temperature.

Introduction

Climate is a fundamental determinant of human health, shaping disease patterns, mortality rates, and the overall wellbeing of populations across the globe. Its stability and variability are critical for public health planning, particularly in rapidly urbanizing regions across developing countries where adaptive capacity remains limited. Urban climate-health systems encompass complex interactions between meteorological conditions, built environments, healthcare infrastructure, and population vulnerability that collectively determine health outcomes in cities. The strategic monitoring, spatial assessment, and management of temperature-related health risks determine not only the immediate response to extreme weather events but also the long-term resilience and sustainability of urban populations (Vicedo-Cabrera et al., 2021). However, in many African cities, including Yola in northeastern Nigeria, climate-health surveillance systems remain inadequate, poorly integrated, or unevenly implemented, resulting in spatial inequalities in health outcomes, delayed emergency responses, and unsustainable disease burden (Akinbami et al., 2022).

The concept of temperature variability assessment in public health planning involves the systematic use of meteorological data, epidemiological analysis, and decision-support systems to understand the relationship between thermal extremes and disease occurrence. In this context, heat-related diseases (HRDs) refer to a spectrum of health conditions, including heat exhaustion, heatstroke, cardiovascular complications, and dehydration, that result from the body's inability to maintain thermal homeostasis during periods of extreme or fluctuating temperatures. Temperature variability assessment enables public health practitioners to identify when and where heat-health risks are highest, which populations are most vulnerable, and how intervention strategies should be temporally and spatially targeted to reduce morbidity and mortality. According to Zhang *et al* (2023), the sustainability of urban health systems depends not only on healthcare availability but also on how well public health interventions are aligned with climatic patterns and demographic vulnerability profiles. This reinforces the need to integrate epidemiological surveillance with meteorological intelligence so that assessment efforts achieve both preventive effectiveness and equitable health protection, thereby promoting long-term population resilience.

Yola Metropolis, the capital of Adamawa State Nigeria, provides a compelling case for applying temperature-health assessment methods. Located in a region experiencing intensifying temperature extremes, Yola has witnessed temperatures exceeding 40°C during dry seasons, with recent data from Modibbo Adama University Teaching Hospital indicating alarming mortality rates, approximately 20 deaths per week during the peak heat periods of March and April 2024, attributed to heat-related diseases (Modibbo Adama University Teaching Hospital, 2024). The city exemplifies the convergence of multiple vulnerability factors: rapid urbanization creating heat island effects, limited healthcare infrastructure, inadequate public awareness of heat risks, and a large population of outdoor workers and vulnerable groups exposed to prolonged thermal stress. These challenges are compounded by broader climatic trends, as Nigeria's northern regions have experienced documented increases in both mean temperatures and the frequency of extreme heat events over recent decades (Akinbami *et al.*, 2022). Although the federal and state governments, alongside international health agencies, have initiated some climate-health awareness campaigns, the current response system remains largely reactive rather than anticipatory, and lacks the systematic temperature-disease surveillance needed for evidence-based intervention. The existing healthcare infrastructure was established without the benefit of contemporary climate-health assessment tools that account for temperature variability patterns, urban microclimate effects, and differential population vulnerability. As a result, health system capacity is often exceeded during heat extremes while preventive measures remain underdeveloped.

Against this background, the aim of this study is to assess the effect of temperature variability on heat related diseases in Yola Metropolis. Achieving this objective will provide an empirical basis for improving climate-health surveillance and emergency preparedness. The study will assist policymakers and health sector stakeholders in formulating evidence-based strategies to reduce heat-related morbidity and mortality, optimize healthcare resource allocation during extreme events, and promote climate-resilient health systems. Ultimately, the research will contribute to achieving Sustainable Development Goal 3 (Good Health and Well-being) and Goal 13 (Climate Action) by supporting climate-informed public health management in Yola Metropolis.

Methodology

Description of Study Area

The study was conducted in Yola Metropolis, comprising Yola North and Yola South Local Government Areas as shown in Figure 1. The metropolis is located between latitudes 9°06' N and

9°19' N, and longitudes 12°23' E and 12°37' E. Yola Metropolis consists of Jimeta (the state capital) and Yola town (the ancient city where the Lamido resides), occupying an area of 329.33 km² with a projected population of 552,747 people based on National Population Commission (2006).

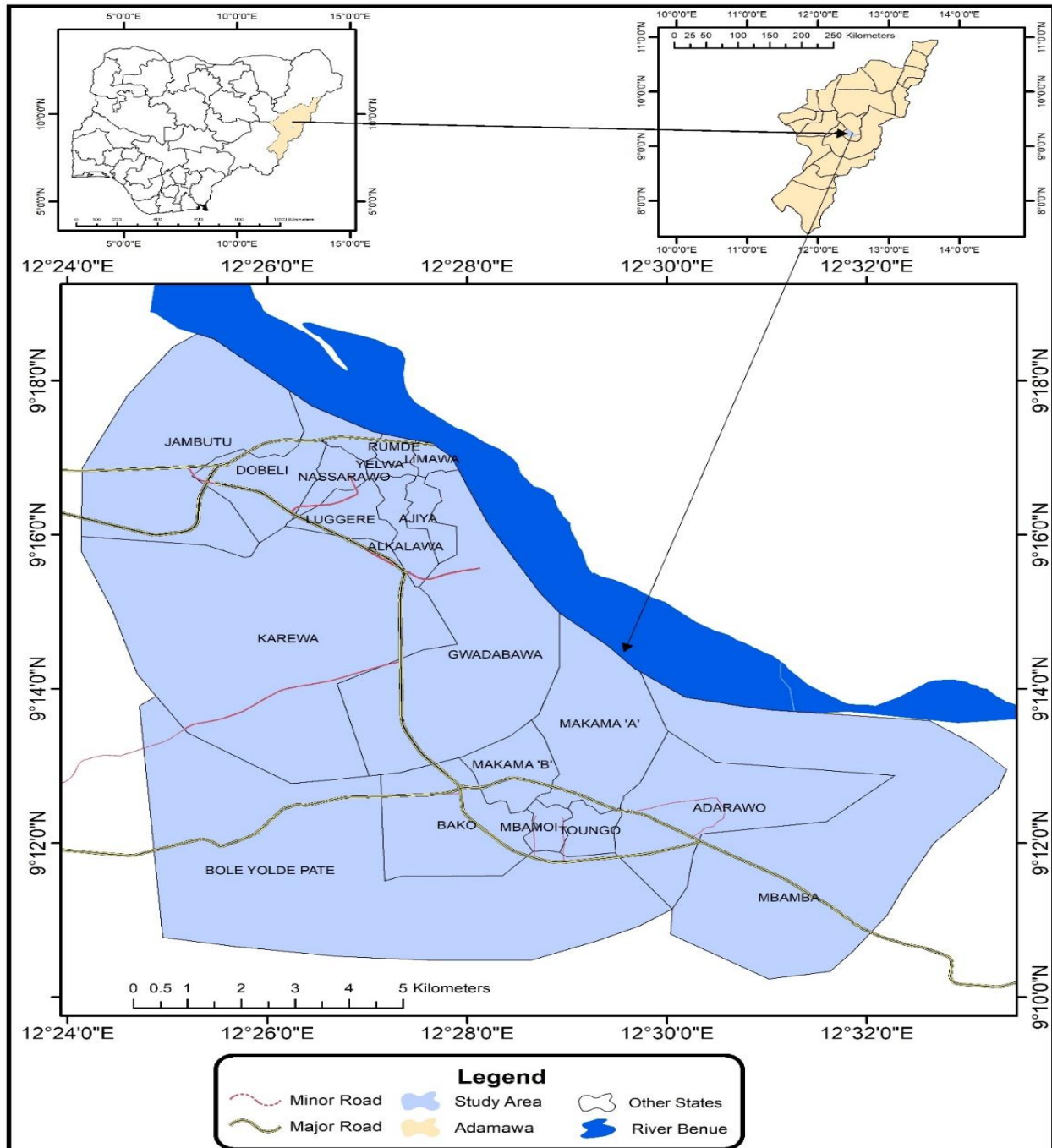


Figure 1: The Study area.

Source: Adamawa State GIS (2024)

Yola Metropolis has a tropical wet and dry climate, classified as Aw according to Köppen-Geiger classification. The dry season lasts from November to March, while the wet season spans from April to October. The average annual temperature is 28°C, with average annual rainfall of 933 mm. January is the driest month with no precipitation, while August records the highest rainfall (Zemba *et al.*, 2018). Temperature variability is evident in the significant differences between months, with April (the warmest month) averaging 32.1°C and December (the coldest month) averaging 25.9°C. Maximum temperatures exceed 40°C during March and April, creating conditions conducive to heat-related diseases such as heat exhaustion and heatstroke. Climate plays a critical role in this study, as temperature extremes directly affect human health, particularly among vulnerable populations.

The urban nature of Yola as Adamawa State capital has stimulated commercial activities including trading, banking, and small-scale manufacturing. Many residents engage in outdoor occupations such as farming, construction, and street vending, facing prolonged exposure to high temperatures, which increases their vulnerability to heat-related diseases.

Types and Sources of Data

This study used quantitative and data from secondary sources to achieve its objectives. The historical temperature records spanning 40 years (1985 to 2024) were obtained from the Upper Benue River Basin Development Authority, Yola. While records of reported cases of heat-related diseases and deaths for 24 years (2001-2024) were obtained from Modibbo Adama University Teaching Hospital, Yola (Former Federal Medical Center, Yola).

Methods Data Analysis

Monthly pattern of temperature and diseases occurrence were analyzed using line graph while annual patterns were analyzed using Trend Analysis.

Pearson Product Moment Correlation and Regression were used to analyze the statistical relationship between temperature and the occurrence of heat-related diseases.

Results and Discussion

Monthly Pattern of Temperature and Heat Related Diseases

The pattern of monthly mean maximum temperature and heat related diseases in Yola metropolis is presented in Figure 2.

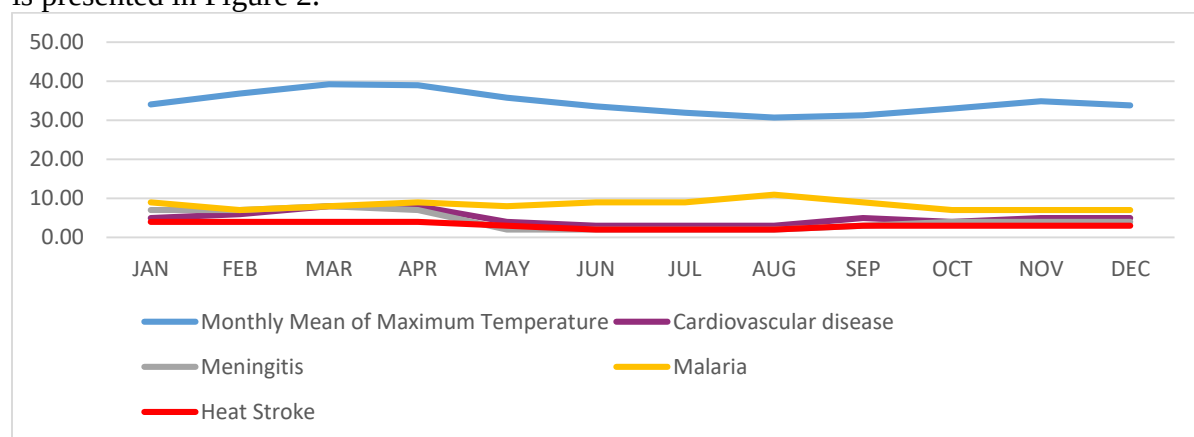


Figure 2: Monthly Pattern of Maximum Temperature and Heat Related Diseases

The mean maximum temperature rises steadily from January, peaking between March and April at about 39°C, before declining gradually towards August (around 30–31°C). A slight rise is again observed from September to November, after which temperatures stabilize.

The monthly mean for heat stroke also follows a somewhat similar trend, with slightly higher incidences observed during the hotter months of February to April and lower occurrences during the mid-year cooler months of June to August. This indicates a positive relationship between temperature and heat stroke, as higher temperatures correspond to increased heat stroke cases, which is consistent with existing studies linking extreme temperatures to heat-related morbidity (Huang *et al.*, 2021; Ogunjo *et al.*, 2020).

In contrast, cerebral malaria cases do not follow the temperature trend. Instead, incidence remains relatively steady at 7–9 cases for most months, with a notable peak in August (11 cases), coinciding with the lowest monthly mean temperature. This suggests that while temperature exerts some influence, cerebral malaria incidence is also shaped by other climatic and environmental factors such as rainfall, humidity, and mosquito breeding patterns. Previous studies have reported that malaria transmission intensity often correlates with seasonal rainfall and humidity patterns, rather than temperature alone, although temperature can still influence parasite development within mosquitoes (Mordecai *et al.*, 2019; Okunlola *et al.*, 2021).

The monthly pattern of cerebral meningitis in Yola metropolis is closely related to that of maximum temperature. The cases of cerebral meningitis are highest during the early part of the year (7–8 cases in February–April), coinciding with the hot and dry months, after which they sharply decline to their lowest point between May and August (2 cases). A slight rise is then observed from September through December (3–4 cases). This trend reflects the known epidemiology of meningitis, where outbreaks typically occur during the dry season with high temperatures, low humidity, and dusty conditions, and recede with the onset of rains (Agier *et al.*, 2017; Umuhoza *et al.*, 2020).

The pattern of cardiovascular disease in Yola Metropolis reveals a strong seasonal variation that suggests a close link between temperature fluctuations and heat-related health outcomes. The incidences of cardiovascular disease (CVD) are at peak (8 cases) in March and April, the hottest months while reaching the lowest values (3 cases) between June and August, which coincides with the peak of the rainy season and lower ambient temperatures. Similar findings have been reported in tropical and sub-tropical regions where temperature peaks directly correlate with higher hospital admissions for heat-related cardiovascular conditions (Achebak *et al.*, 2020).

Annual Trend of Maximum Temperature in Yola Metropolis between 1984 to 2024

Maximum temperature trends in Figure 3 shows an increasing trend with a low R^2 value of 0.0232, with temperatures fluctuating significantly between the mid-30s, with peaks in 2003 (37.5°C), 2004 (37.08°C), and 2017 (36.33°C). Although variability is evident, the general pattern suggests intermittent increases in extreme maximum values, consistent with regional heatwave intensification (Russo *et al.*, 2022).

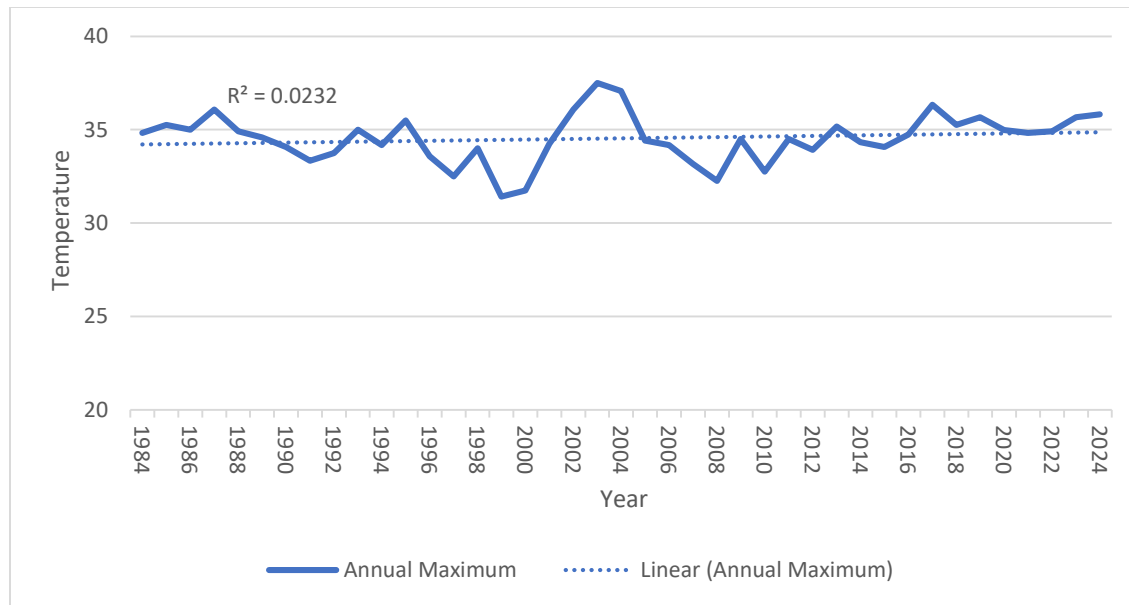


Figure 3: Annual Trend of Maximum Temperature in Yola Metropolis between 1984 to 2024

Annual Trend of Diseases Occurrence and Mortality

The annual trend of heat stroke in Yola Metropolis presented in Figure 4 shows a contrasting trajectory between occurrence and mortality rates. The result indicates a slight but statistically insignificant decline ($R^2 = 0.0036$) in the number of annual cases over time. The near-zero R^2 value further suggests that the decline is not strongly explained by time, pointing instead to variability in climatic and environmental conditions as well as possible improvements in preventive awareness and early treatment interventions (Ebi *et al.*, 2021). On the other hand, the mortality trend ($R^2 = 0.1516$) shows a gradual increase, with an average rise of about 0.15 deaths per year. Although the explained variance is modest, this upward pattern underscores a concerning rise in fatalities despite relatively stable or declining incidence.

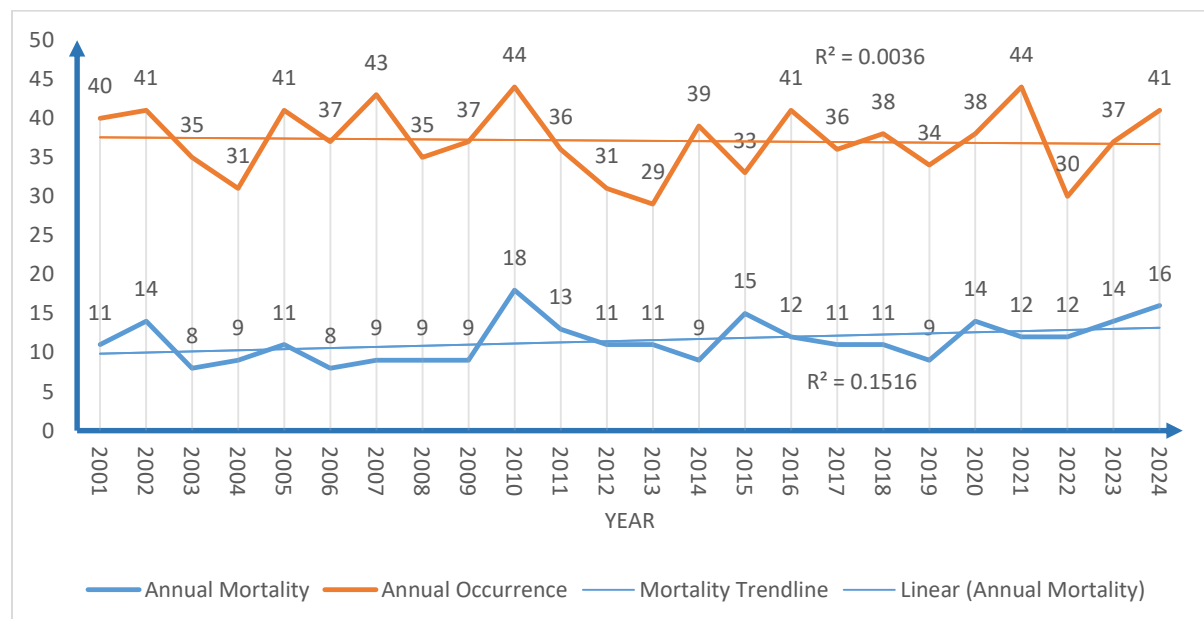


Figure 4: Annual Trend of Heat Stroke Occurrence and Mortality in Yola Metropolis from 2001 to 2024

Such a trend may be linked to increasing temperature extremes, delayed medical intervention, or higher vulnerability among populations such as the elderly and those with pre-existing conditions (Achebak *et al.*, 2019; Ogunjo *et al.*, 2022).

Figure 5 shows the annual trend of cerebral malaria occurrence and mortality in Yola Metropolis between 2001 and 2024; it reveals a fluctuating but relatively stable pattern with a slight upward trajectory in cases and a gradual decline in deaths. The trend line ($R^2 = 0.069$) suggests a weak positive trend in annual occurrence, indicating that while cases of cerebral malaria have not significantly increased, there is a slow rise over time. This marginal growth in incidence aligns with climatic and environmental dynamics in tropical regions where rising temperatures and erratic rainfall patterns influence malaria transmission cycles (Oladipo *et al.*, 2021). Conversely, annual mortality has generally decreased ($R^2 = 0.2044$), dropping from 23 deaths in 2001 to 9 in 2024.

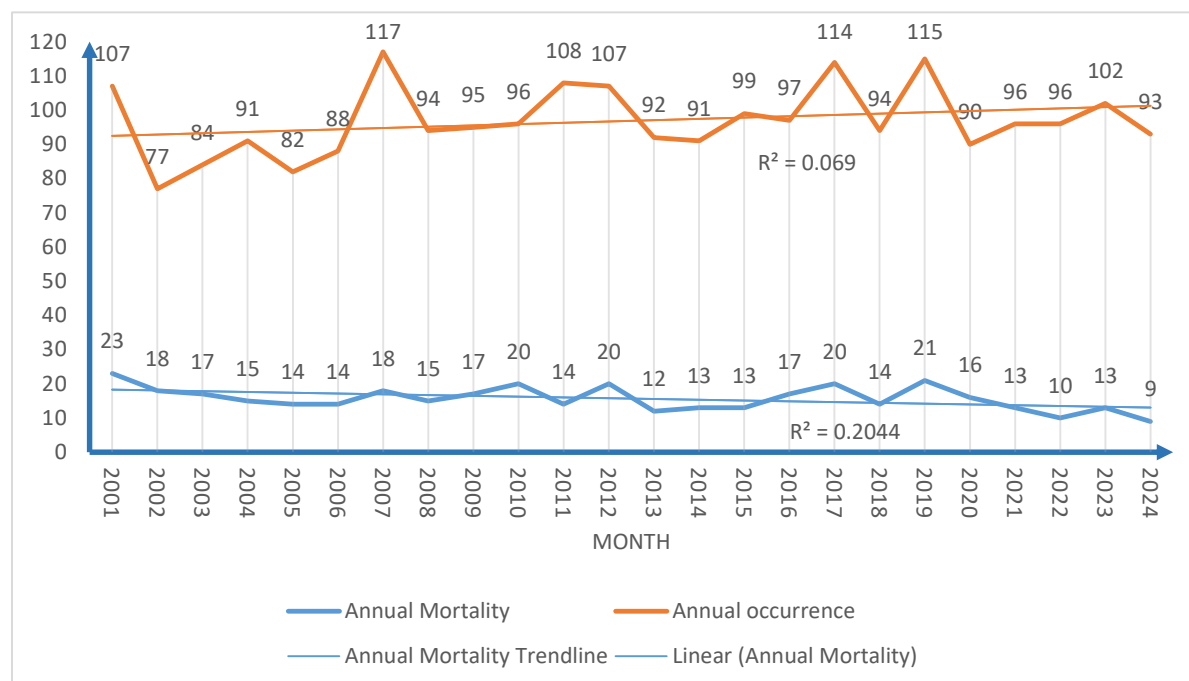


Figure 5: Annual Trend of Cerebral Malaria Occurrence and Mortality in Yola Metropolis from 2001 to 2024

The trend of cerebral meningitis in Yola Metropolis over the period 2001–2024 shown in Figure 6 reveals a fluctuating but generally increasing pattern in both annual occurrence and mortality. The trend line suggests a modest upward trend, though the low ($R^2 = 0.0679$) value indicates that year-to-year variations are not strongly explained by the linear model. Nevertheless, the observed increase in peak years, particularly in 2004, 2012, 2019, and 2020, reflects surges that correspond with climatic variability, especially elevated temperatures and dusty dry-season conditions known to intensify meningitis outbreaks in the region (Okello *et al.*, 2021; Agbo *et al.*, 2022). Similarly, mortality exhibits an upward trajectory ($R^2 = 0.1782$), with deaths rising more steadily in recent years, reaching a peak of 22 in 2024.

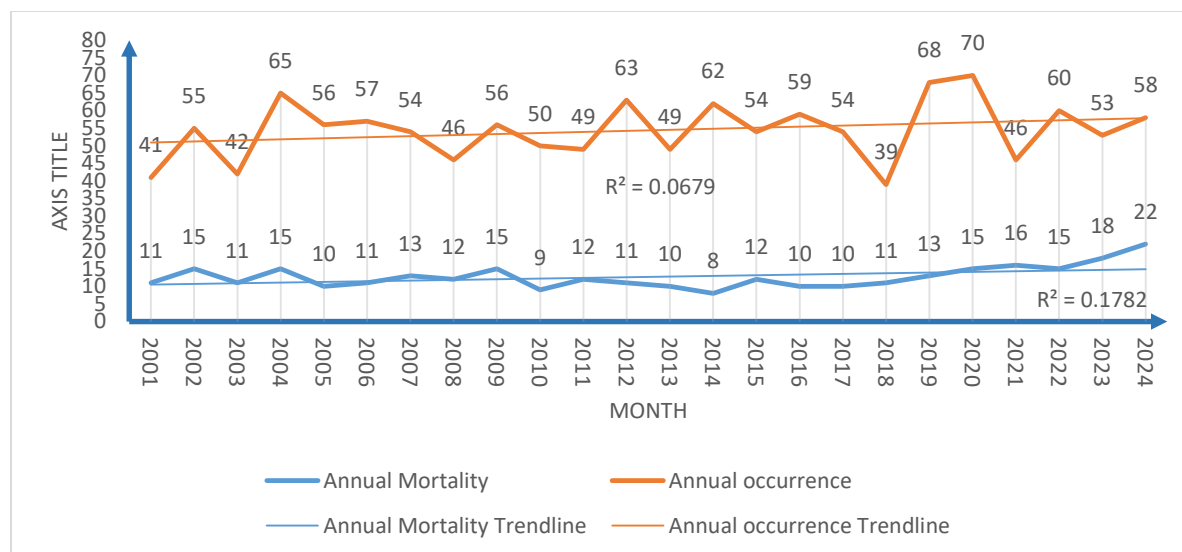


Figure 6: Annual Trend of Cerebral Meningitis Occurrence and Mortality in Yola Metropolis from 2001 to 2024

The annual trend of cardiovascular disease (CVD) occurrence and mortality in Yola Metropolis presented in Figure 7 shows a mixed pattern over the study period (2001–2024). The trend line for annual occurrence ($R^2 = 0.0432$) indicates a marginal increase in reported cases, suggesting that the incidence of CVD has increased with only slight fluctuations over the years. The data shows intermittent peaks, such as in 2009 (67 cases) and 2016 (67 cases), followed by declines, which aligns with observations that climatic stressors like extreme heat events can cause short-term surges in cardiovascular morbidity, but long-term records may show oscillating rather than linear increases (Achebak *et al.*, 2019). The mortality trend ($R^2 = 0.0272$) suggests a gradual rise in deaths associated with CVD, moving from an average of about 10 deaths in the early 2000s to 12–16 deaths in the later years.

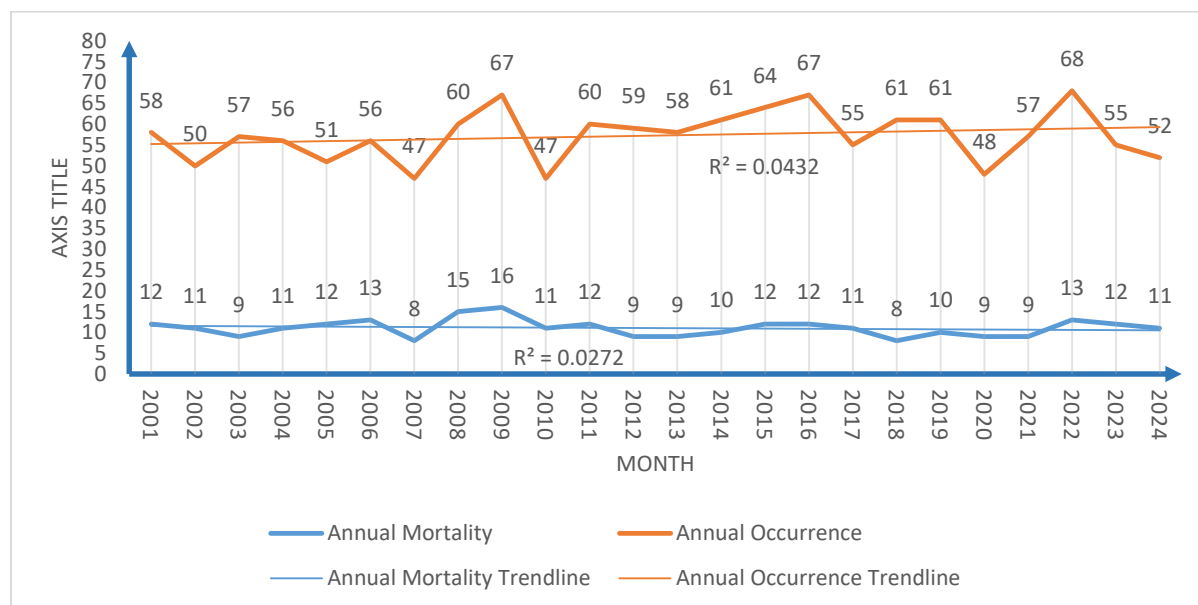


Figure 7: Annual Trend of Cardiovascular Disease Occurrence and Mortality in Yola Metropolis from 2001 to 2024

Relationship between Temperature and Occurrence of Heath Related Diseases

Table 1: Correlation between Maximum Temperature and Heat Related Diseases

Disease	Maximum Temperature	p-value
Cardiovascular	0.847*	0.01
Cerebral Meningitis	0.756*	0.01
Cerebral Malaria	-0.390	0.32
Heat Stroke	0.759*	0.01

*Significant at 0.01

The Pearson product moment correlation between maximum temperature and heat-related diseases in Yola Metropolis presented in Table 1 reveals varying degrees of association, indicating differential sensitivity of disease occurrence to rising temperatures. The results show that cardiovascular diseases ($r = 0.847$, $p = 0.01$) have a very strong positive correlation with maximum temperature, suggesting that their incidence significantly increases as temperature rises. Similarly, cerebral meningitis ($r = 0.756$, $p = 0.01$) and heat stroke ($r = 0.759$, $p = 0.01$) exhibit strong positive correlations, underscoring the vulnerability of these conditions to heat extremes. These findings are consistent with previous research highlighting the role of extreme heat in aggravating cardiovascular stress, impairing thermoregulation, and promoting the spread of meningitis pathogens under elevated temperatures (Schifano *et al.*, 2021; Gasparrini *et al.*, 2022). In contrast, cerebral malaria shows a weak negative correlation ($r = -0.390$, $p = 0.32$), suggesting a decreasing trend with rising temperatures, though this relationship is not statistically significant. This may be attributed to the complex ecology of malaria transmission, which is influenced not only by temperature but also by rainfall patterns, vector breeding habitats, and human adaptive measures (Okunlola *et al.*, 2022). Overall, the correlation results demonstrate that while most heat-related diseases exhibit increasing trends with rising maximum temperature, cerebral malaria follows a different pattern, reflecting the multifactorial nature of its epidemiology in Yola Metropolis.

Table 2: Regression of Heat Related Diseases and Maximum Temperature

Dependent Variable	R	R ²	Adj. R ²	F(1, df2)	B (Constant)	B (Temperature)	B	T	p value	Interpretation
Heat Stroke	.759	.577	.534	13.62 (1,10)	-4.379	0.216	.759	3.69	.004	Strong positive, significant
Cerebral Malaria	.390	.152	.067	1.80 (1,10)	14.284	-0.172	-.390	1.34	.210	Weak negative, not significant

Meningitis	.75 6	.57 1	.52 8	13.3 2 (1,1 0)	-17.297	0.627	.75 6	3.6 5	.004	Strong positive, significant
Cardiovascu lar Disease	.84 7	.71 8	.69 0	25.4 8 (1,1 0)	-13.251	0.527	.84 7	5.0 5	.001	Very strong positive, highly significant

B = unstandardized coefficients; β = standardized coefficient.

The regression analyses in Table 2 highlight notable differences in the relationship between temperature and health outcomes. Maximum temperature was a strong and statistically significant predictor of both heat stroke ($R^2 = .577$, $t = 3.69$, $p = .004$) and meningitis ($R^2 = .571$, $t = 3.65$, $p = .004$), consistent with evidence that extreme heat directly increases risks of heat-related illnesses and facilitates meningitis outbreaks in hot and dry climates (Gasparrini et al., 2017; Molesworth et al., 2003). The association was even stronger for cardiovascular disease, where temperature explained over 70% of the variance ($R^2 = .718$, $t = 5.05$, $p = .001$), indicating that high temperatures exert significant physiological stress on the cardiovascular system through dehydration, blood viscosity changes, and increased cardiac load (Basu, 2009; Xu et al., 2022). In contrast, the model for cerebral malaria revealed a weak and statistically non-significant relationship ($R^2 = .152$, $t = -1.34$, $p = .210$), suggesting that malaria dynamics are influenced by a broader set of climatic and ecological factors, particularly rainfall and humidity, which shape mosquito breeding habitats and parasite development (Paaijmans et al., 2009; Caminade et al., 2014).

The regression analysis reveals that maximum temperature exerts varying effects on heat-related diseases. For heat stroke, the regression equation $Y_1 = -4.379 + 0.216X$ shows that a one-degree rise in temperature increases cases by 0.216 units, reflecting a strong positive and significant relationship. Similarly, meningitis, with equation $Y_2 = -17.297 + 0.627X$, responds even more strongly, as each degree rise leads to a 0.627-unit increase, also statistically significant. Cardiovascular disease follows a comparable trend, with equation $Y_3 = -13.251 + 0.5273X$ indicating a 0.527-unit rise per degree, and this effect is highly significant. Overall, the results demonstrate that heat stroke, meningitis, and cardiovascular disease are highly sensitive to rising temperatures, whereas cerebral malaria shows no significant association.

Conclusion

The findings of this study affirm that temperature variability poses a serious and growing public health challenge in Yola Metropolis. The consistent occurrence of heat-related diseases such as cerebral malaria, cerebral meningitis, cardiovascular diseases, and heat stroke highlights the relationship between climate dynamics and human health in the Yola Metropolis. While not all diseases respond uniformly to temperature fluctuations, the study clearly indicates that extreme heat is a significant stressor on the human body, exacerbating existing health vulnerabilities and creating new risks for the population. This study confirms that the health impacts of rising temperatures are not isolated events but part of a broader pattern of environmental change that requires urgent attention. The observed links between high temperatures and increased cases of cardiovascular diseases and cerebral meningitis emphasize the direct physiological consequences

of thermal stress. The weak correlation between temperature and cerebral malaria underscores the multifaceted nature of disease ecology, where temperature acts alongside other environmental and structural factors.

Recommendations

Based on the findings of the study, the following recommendations were made;

- i. There is a need for the Yola Metropolis health authorities to establish a climate-sensitive disease surveillance system. This system should integrate temperature and weather monitoring with health data to enable early warning for heat-related disease outbreaks. Hospitals and clinics should also maintain detailed records of temperature-related illnesses to guide timely interventions during high-risk periods.
- ii. Government at all levels and health stakeholders should implement seasonal health preparedness programs, especially between January and April when the highest occurrences of heat-related diseases such as heat stroke and meningitis are recorded. These programs should include heat emergency response teams, mobile clinics for remote communities, and public health advisories tailored to specific climatic periods.
- iii. Given the identified link between rising temperatures and diseases like cardiovascular illness and cerebral meningitis, climate-health risk assessments should be institutionalized in Yola's public health planning. This requires collaboration between the Nigerian Meteorological Agency (NiMet), health ministries, and urban planners to develop localized heat action plans.

References

- Achebak, H., Devolder, D., & Ballester, J. (2019). Trends in temperature-related age-specific and sex-specific mortality from cardiovascular diseases in Spain: A national time-series analysis. *The Lancet Planetary Health*, 3(7), e297–e306. [https://doi.org/10.1016/S2542-5196\(19\)30090-7](https://doi.org/10.1016/S2542-5196(19)30090-7)
- Agbo, S., Okonkwo, C., & Yusuf, A. (2022). Climate variability and meningitis incidence in northern Nigeria: Emerging public health threats. *International Journal of Infectious Diseases*, 118, 34–41. <https://doi.org/10.1016/j.ijid.2022.02.041>
- Agier, L., Deroubaix, A., Martiny, N., Yaka, P., Djibo, A., Broutin, H. (2017). Seasonality of meningitis in Africa and climate forcing: Aerosol impacts. *Epidemiology and Infection*, 145(4), 714–721. <https://doi.org/10.1017/S0950268816002692>
- Akinbami, J. F. K., Oluseyi, P. O., & Babatunde, S. O. (2022). Heat stress and urbanization in Nigeria: The case of Lagos. *International Journal of Environmental Studies*, 79(4), 553–570.
- Caminade, C., & Kovats, S. (2019). Climate change impacts on vector-borne diseases in Africa: Implications for public health. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 113(5), 241–250. <https://doi.org/10.1093/trstmh/trz018>
- Ebi, K. L., Capon, A., Berry, P., Broderick, C., de Dear, R., Havenith, G., & Wijeratne, S. (2021). Hot weather and heat extremes: health risks. *The Lancet*, 398(10301), 698–708. [https://doi.org/10.1016/S0140-6736\(21\)01208-3](https://doi.org/10.1016/S0140-6736(21)01208-3)
- Gasparrini A, Guo Y, and Hashizume M, (2017). Mortality risk attributable to high and low ambient temperature: a multicountry observational study. *Lancet*; 386: 369–75

- Gasparri, A., Vicedo-Cabrera, A. M., Guo, Y., Sera, F., Huber, V., Tong, S., Armstrong, B. (2022). Projections of temperature-related excess mortality under climate change scenarios. *The Lancet Planetary Health*, 6(7), e521–e531. [https://doi.org/10.1016/S2542-5196\(22\)00135-3](https://doi.org/10.1016/S2542-5196(22)00135-3)
- Huang, C., Barnett, A. G., & Xu, Z. (2021). Managing the health impacts of heatwaves. *International Journal of Environmental Research and Public Health*, 18(2), 733. <https://doi.org/10.3390/ijerph18020733>
- Ogunjo, S. T., Nwofor, O. K., & Adejuwon, J. O. (2022). Characterizing temperature and rainfall extremes over Nigeria using recent observational datasets. *Weather and Climate Extremes*, 35, 100418. <https://doi.org/10.1016/j.wace.2022.100418>
- Ogunjo, S. T., Rotowa, O. J., & Akinyemi, M. L. (2020). Temperature variability and heat-related health impacts in West Africa. *Theoretical and Applied Climatology*, 142(3–4), 1097–1109. <https://doi.org/10.1007/s00704-020-03319-8>
- Okello, C., Jjuuko, J., & Musa, J. (2021). Heatwaves, dust storms and the dynamics of meningitis outbreaks in the African Sahel. *Science of the Total Environment*, 770, 145262. <https://doi.org/10.1016/j.scitotenv.2021.145262>
- Okunola, O. A., Oyeyemi, O. T., & Adeleke, M. A. (2021). Climate variability and malaria transmission in sub-Saharan Africa: A review of evidence and implications for public health. *Parasite Epidemiology and Control*, 13, e00206. <https://doi.org/10.1016/j.parepi.2021.e00206>
- Okunola, O. E., Oyeyemi, A. L., & Adebayo, O. O. (2022). Climate variability and malaria transmission in sub-Saharan Africa: A systematic review. *Environmental Research*, 207, 112176. <https://doi.org/10.1016/j.envres.2021.112176>
- Oladipo, O. G., Adefalo, B. A., & Luka, M. (2021). Climate change and malaria incidence in Nigeria: Evidence from time-series analysis. *Journal of Environmental and Public Health*, 2021, 1–9. <https://doi.org/10.1155/2021/6653921>
- Russo, S., Sillmann, J., & Sterl, A. (2022). Humid heat waves at different warming levels. *Nature Climate Change*, 12(6), 547–553. <https://doi.org/10.1038/s41558-022-01326-y>
- Schifano, P., Davoli, M., & Michelozzi, P. (2021). Heat and cardiovascular diseases: Evidence from epidemiological studies and implications for public health. *International Journal of Environmental Research and Public Health*, 18(22), 12079. <https://doi.org/10.3390/ijerph182212079>
- Umuhzo, T., Nyandwi, E., Niyonzima, F., & Muvunyi, C. M. (2020). Climatic variability and its association with meningitis epidemics in the African meningitis belt. *Scientific African*, 9, e00511. <https://doi.org/10.1016/j.sciaf.2020.e00511>
- Vicedo-Cabrera, A. M., Scovronick, N., Sera, F., Royé, D., Schneider, R., Tobias, A., & Gasparri, A. (2021). The burden of heat-related mortality attributable to recent human-induced climate change. *Nature Climate Change*, 11(6), 492–500. <https://doi.org/10.1038/s41558-021-01058-x>

- Xu, Z., Fitzgerald, G., Guo, Y., Jalaludin, B., & Tong, S. (2020). Impact of heatwave on mortality under different heatwave definitions: A systematic review and meta-analysis. *Environment International*, 134, 105275. <https://doi.org/10.1016/j.envint.2019.105275>
- Zemba, A. A., Umar, Y., & Binbol, N. L. (2018). Climatic information as evidence of desertification processes in northern Yobe State, Nigeria: Implications for agriculture and ecosystem. *Global Journal of Pure and Applied Sciences*, 24(1), 117–124.
- Zhang, Y., Li, Z., Wang, X., & Huang, J. (2023). Global patterns of temperature variability and its socio-economic impacts: A multi-sectoral assessment. *Environmental Science & Policy*, 137, 243-255