

Epidemiological Study of Diurnal Temperature and Humidity Variability and the Resurgence of Meningococcal Meningitis in Three Contrasting Ecological Zones of Kaduna State, Nigeria

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Abstract

Meningitis remains a public health problem associated with high morbidity and mortality rates worldwide. Meningococcal meningitis is a contagious disease causing more number of deaths particularly in Sub-Saharan African region. Climate change remains the major threat to public health worldwide. This study aims at evaluating the association between the incidence of meningococcal meningitis and the diurnal temperature and humidity variability in Kaduna State, Nigeria. A longitudinal spatiotemporal epidemiological design was adopted in this study. The population of this study includes households located within the ecological zones and residents of the study area. A total of 213 participants were selected using multistage sampling technique. The data were collected using structured questionnaires and observation checklists. Data were analyzed by descriptive statistics using SPSS. The association between the incidence of meningococcal meningitis and the diurnal temperature variability and humidity was examined by correlation analysis. The results showed that most of the respondents (24.88 %) were aged between 30 and 34. The percentage of male and female respondents was 33.80 % and 66.20 %, respectively. It was observed that almost all the respondents (96.24 %) attended tertiary education. Most of the participants (63.85 %) in this study were living in urban areas. During dry season, more than half (53.05 %) of the respondents experienced high temperatures in their areas. Majority of the respondents (88.73 %) indicated that heat increased during certain months in their areas. According to more than half of the respondents (53.99 %) the humidity level in their areas is low. The occurrence and incidence of meningococcal meningitis was significantly associated with increase diurnal temperature and low humidity in the study area.

Keywords: Humidity, Kaduna state, Meningococcal meningitis, Temperature.

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INTRODUCTION

Meningococcal meningitis remains a significant burden of disease among children and young adults worldwide. Meningococcal meningitis is one of the major epidemic diseases, contributing substantially to the overall disease burden in Sub-Saharan Africa (Naghavi *et al.*, 2016). Meningococcus is primarily a commensal bacterium found in human nasopharynx causing meningitis when present in bloodstream (Asturias *et al.*, 2022). Approximately 80–85 % of all the bacterial meningitis outbreaks have been caused by meningococcal group (WHO, 2025). High incidence of

meningitis has been recorded in African meningitis belt comprising twenty-six sub-Saharan African countries (WHO, 2025). In sub-Saharan African countries, frequent meningitis outbreaks have been recorded in children between the ages 5–12 years with high incidence up to 1000 cases in 100,000 people (Mohammed *et al.*, 2017). In West African countries, about 400 million people are at risk to meningitis leading to 25,000 to 250,000 infected people every year (Ayanlade *et al.*, 2020). About fifty percent of the world meningitis cases in children aged below 5 years occurred in sub-Saharan African countries including Nigeria

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(GBD, 2019). High percentage of these cases might have been meningococcal meningitis (Wunrow *et al.*, 2023).

Climatic conditions and their variations remain the major threats to public health worldwide. Spatiotemporal association between meningitis cases and meteorological weather events has been described by many climatic models (Chen *et al.*, 2023; Tall *et al.*, 2022). Environmental factors have significant impacts on meningitis incidence and prevention of meningitis outbreaks (Dione *et al.*, 2022). Environmental risk factors for meningitis outbreaks remain consistent and relevant within the context of widespread meningococcal vaccines. The ability of meningitis vectors to spread depends on climatic factors (Henne *et al.*, 2018). Changes in climatic factors such as temperature, humidity, and rainfall significantly influence the incident and transmission of meningitis (Tall *et al.*, 2022; Akanwake *et al.*, 2022). Many meningococcal meningitis cases have been recorded in African countries due to increase in temperatures (WHO, 2025; Akanwake *et al.*, 2022). Increase in temperature variability was significantly associated with higher incidence of meningitis (Chen *et al.*, 2023).

Africa has been the largest region with the global burden of meningitis, with Nigeria recording significant burden of the disease (Koutangni *et al.*, 2018). Sub-Saharan African countries recorded the highest incidence of meningococcal meningitis in the world (Mazamay *et al.*, 2021). Meningococcal meningitis outbreaks have become more common across the Sub-Saharan African region, including Nigeria (WHO, 2024). The region might continue to face a risk of meningitis epidemics due to variability in climatic conditions (Chen *et al.*, 2023). Africa's meningitis belt encompasses about 26 countries including Nigeria. Nigeria has experienced resurgent outbreaks attributed to sero groups C, W, and X in 2015, 2017, and 2021–2022 (Mustapha *et al.*, 2016; NCDC, 2022). According to Nigeria Centre for Disease Control the 2017 outbreak affected 17 states with over 14,000 suspected cases and about 1,200 deaths (NCDC, 2017). Meningococcal meningitis outbreaks have been recorded in different communities in northern states of Nigeria and Kaduna was among the worst-affected states. Kaduna state, straddles three contrasting ecological zones which are Guinea savannah, Sudan savannah, and Sahel fringe. Meningococcal meningitis incidence and outbreaks have been recorded in all the three zones in the state. The weather condition in each zone is characterized by variable temperature, relative humidity, rainfall and dust. This ecological diversity caused the interest of the researchers to investigate the association between the incidence of meningococcal meningitis and the diurnal temperature variability and humidity in the state. This study aims at evaluating the association between the incidence of meningococcal meningitis and the diurnal

temperature variability and humidity in Kaduna State, Nigeria.

METHODOLOGY

Study Area

This study was conducted in Kaduna State, North-West, Nigeria. The state lies within the northern Guinea and Sudan savannah ecological zones. Kaduna is bordered by seven states Zamfara and Katsina to the North, Kano to the North-East, Bauchi and Plateau to the East, Nasarawa and Abuja to the South, and Niger to the West. The state has a total of 23 Local Government Areas and is manufacturing center, housing Nigeria's largest textile industry, an oil refinery, and tobacco/agricultural processing plants. The state has a total population of 6,113,503 (2006 census) (NPC, 2006). The state is located between latitude 10°38'58" N and 10°25'36" N and to longitude 7°22'14" E and 7°32'00" E (Yusuf, 2015). The state is characterized by hot, humid, and cloudy rainy season and hot and partly cloudy dry season. Throughout the year, the temperature rarely falls below 50 °F or rises above 102 °F, usually ranging between 55 °F and 95 °F (Kaduna Climate, 2022). The state experiences dry season from November to April and wet season from May to October, with noticeable variations in temperature and humidity throughout the year. Kaduna State spans three main ecological and climatic zones; Northern Guinea Savanna, Sudan Savanna, and a Humid/Forest-Savanna transition zone. These zones vary greatly in rainfall, temperature, and plant life, affecting human and animals' health.

Study Design

The study adopted a longitudinal spatiotemporal epidemiological design. This design allows for the examination of the temporal trends in the incidence and transmission of meningococcal meningitis across the three ecological zones in the state. It also enables for the evaluation of relationship between the climatic factors and the incidence of the disease.

Study Population

The population of this study includes a total of 213 households located within and residents of the study area. A total 71 households and residents were selected from the Northern Guinea Savanna (Kaduna North, Kaduna South, Chikun, Kajuru, and Kachia), Sudan Savanna (Zaria, Sabon Gari, Makarfi, Ikara, and Kubau), and Humid/Forest-Savanna zone (Jema'a (Kafanchan), Sanga, Kgoro, and Zangon Kataf).

Sample and Sampling Technique

The sample size of this study was 213 participants comprising a households and residents within the study area. The participants were selected using systematic and purposive sampling technique. The sample size was calculated using standard epidemiological sample size formulas, based on existing prevalence estimates of meningococcal meningitis.

Instrument for Data Collection

Data were collected using questionnaire designed based on the purpose of the study. The questionnaire comprises two sections; socio-demographic information of the respondents and the climatic factors (temperature and humidity) influencing the incidence and transmission of meningitis. The instrument was designed by evaluating the study objectives and relevant literatures. A pilot study was conducted with 50 participants outside the sample to verify the instrument. Reliability of the instrument was tested using Pearson Product Moment yielding a 0.85 coefficient.

Data Analysis

The data were analyzed by descriptive statistics methods using SPSS. The association between the

incidence of meningococcal meningitis and the diurnal temperature variability and humidity was examined by correlation analysis. The results were presented as frequencies and percentages of the responses.

RESULTS

Socio-Demographic Information of the Respondents

Age Distribution of the Respondents

The age distribution of the respondents is shown in Figure 1. Most of the respondents (24.88 %) were aged between 30 and 34. The least percentage (1.41 %) of the respondents aged between 60 and 64. The high population of the youths in the study area could be responsible for the high percentage (24.88 %) of the respondents' age (30 – 34) class (Figure 1).

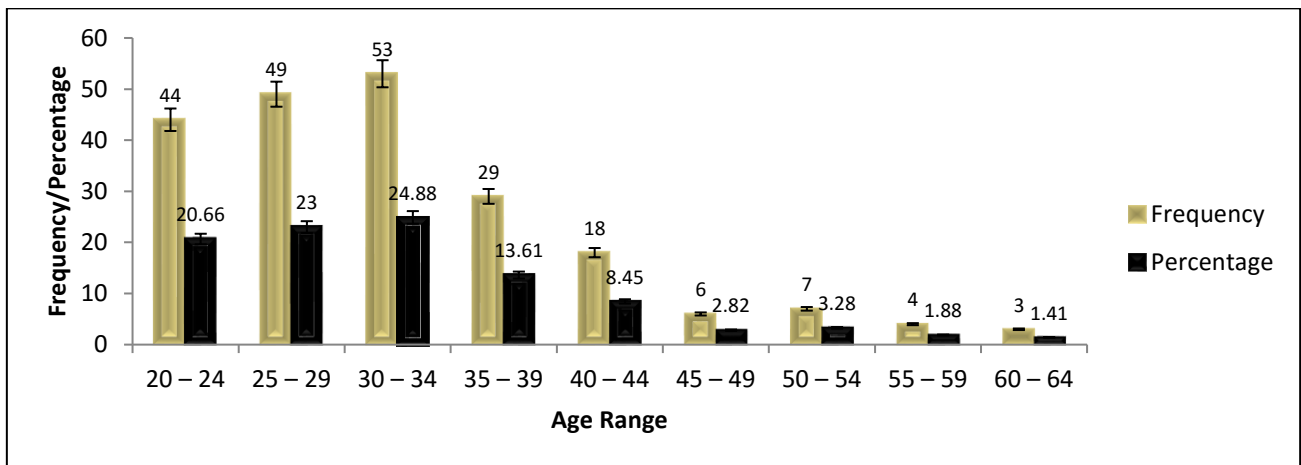


Figure 1: Age Distribution of the Respondents

Gender Distribution of the Respondents

Figure 2 shows the gender distribution of the respondents. The percentage of male and female respondents was 33.80 % and 66.20 %, respectively. The finding showed that the percentage of female

respondents (66.20 %) was high than that of the male respondents. The high proportion of female respondents might be due to the high population of female in the study area (Figure 2).

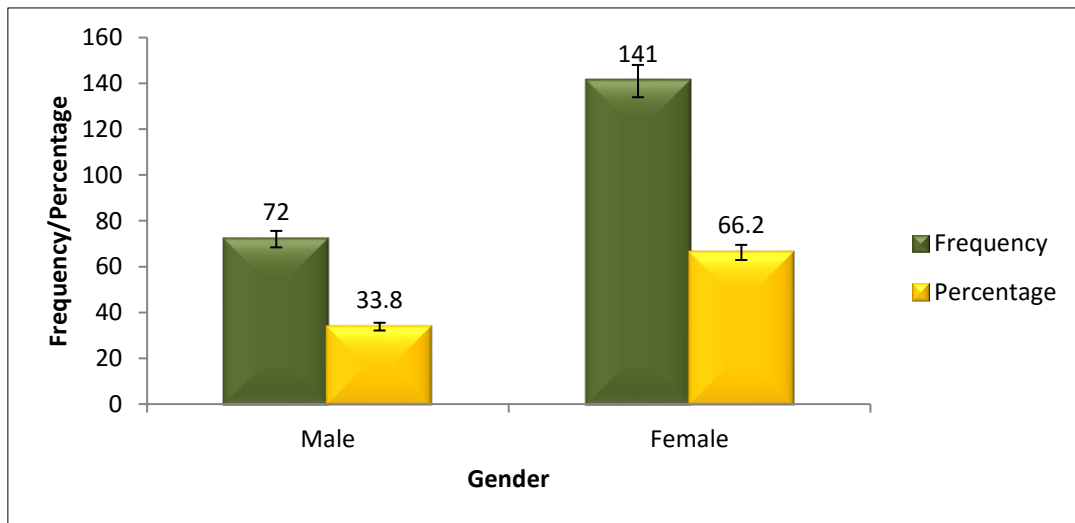


Figure 2: Gender Distribution of the Respondents

Educational Level of the Respondents

Figure 3 shows the educational level of the respondents. It was observed that almost all the respondents (96.24 %) attended tertiary education.

However, 2.35 % and 1.41 % of the respondents attended secondary and primary educations, respectively (Figure 3).

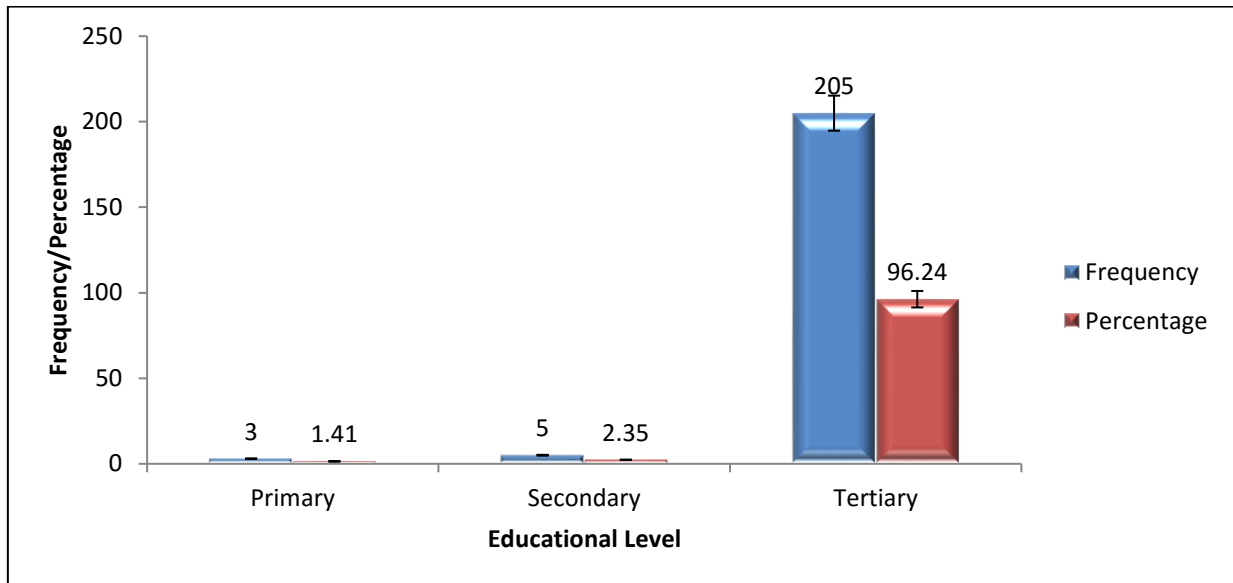


Figure 3: Educational Level of the Respondents

Occupation of the Respondents

The occupation of the respondents is indicated in Figure 4. The findings revealed that high percentage (21.13 %) of the respondents were civil servants

followed by business (15.02 %) and students (14.08 %). However, the least percentage (1.88 %) of the respondents were legal practitioners and unemployed (Figure 4).

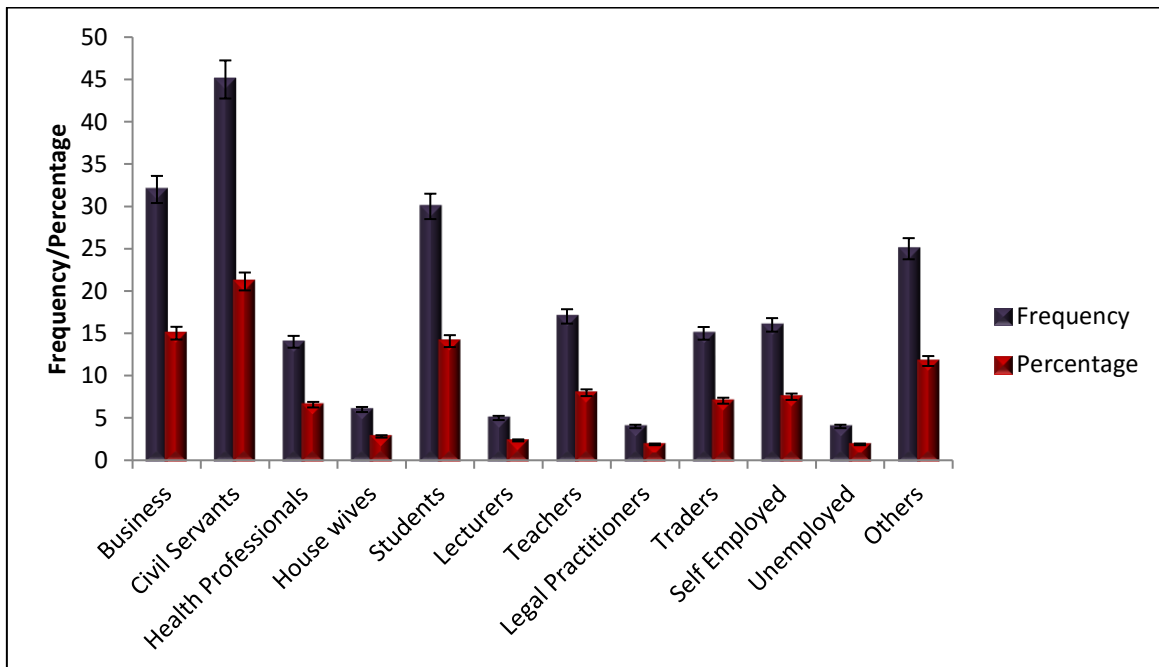


Figure 4: Occupation of the Respondents

Income Status of the Respondents

Figure 5 displays the income status of the respondents. More than sixty percent (60.56 %) of the respondents were in middle class income. About thirty

seven percent (36.62 %) of the respondents were in lower class income. However, only 2.82 % of the respondents were in high income level (Figure 5).

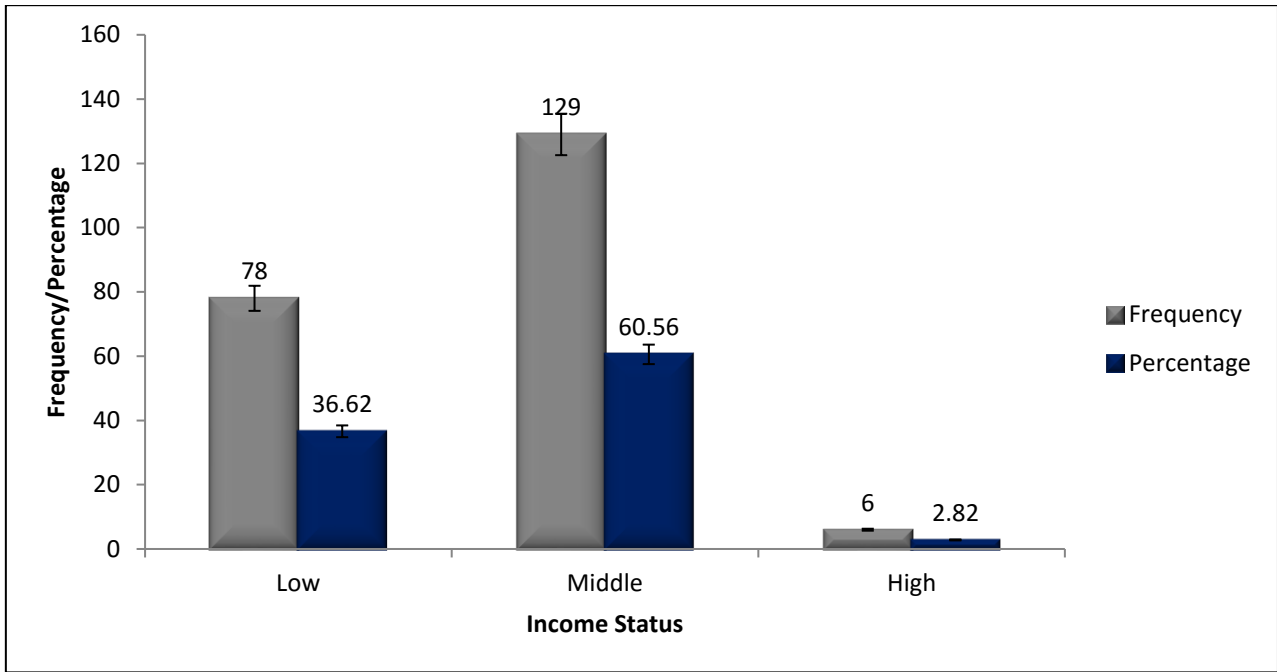


Figure 5: Income Status of the Respondents

Ecological Zone of the Respondents

The ecological zone of the respondents is shown in Figure 6. The results showed that most of the respondents (63.85 %) were living in urban areas.

However, the percentage of the respondents living in semi urban and rural areas was 26.29 % and 9.86 %, respectively (Figure 6).

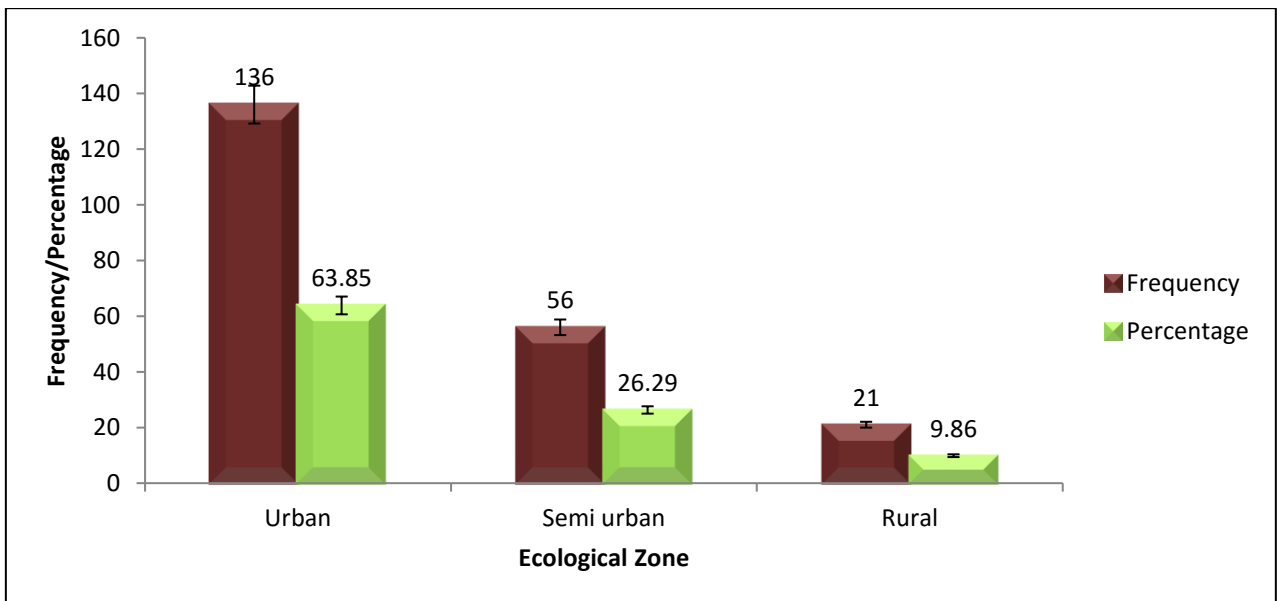


Figure 6: Ecological Zone of the Respondents

**Impact of Temperature and Humidity on the Incidence and Transmission of Meningitis
Temperature Level in the Respondents' Areas**

Figure 7 presents the responses of the respondents on the temperature level during dry season in their areas. More than half of the respondents (53.05 %) responded that the temperature level during dry

season in their areas is very high. Forty six percent (46.01 %) of the respondents responded that the temperature level during dry season in their areas is moderate. However, only 0.94 % of the respondents responded that the temperature level during dry season in their areas is low (Figure 7).

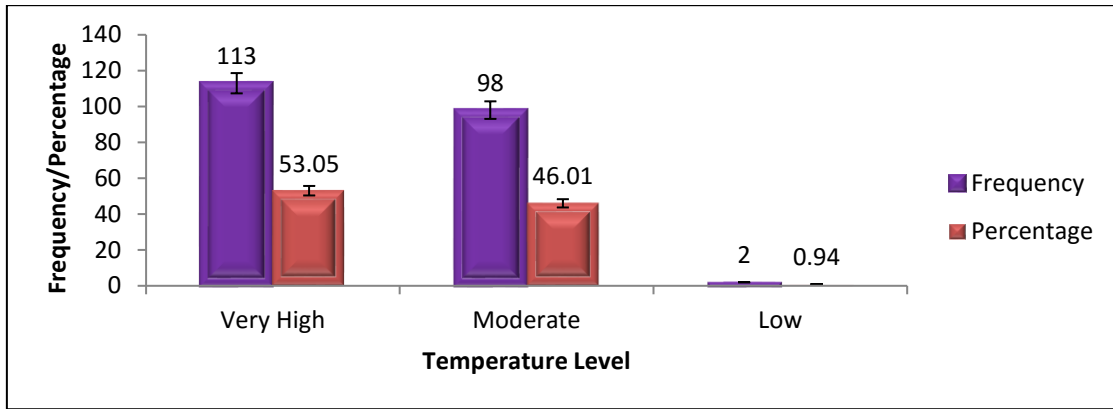


Figure 7: Temperature Level during Dry Season

Home Excessive Heat Feeling

The responses of the respondents on home excessive heat feeling are presented in Figure 8. The

results revealed that 46.01 %, 51.64 %, and 2.35 % of the respondents feel excessive heat always, sometimes, and rarely in their houses (Figure 8).

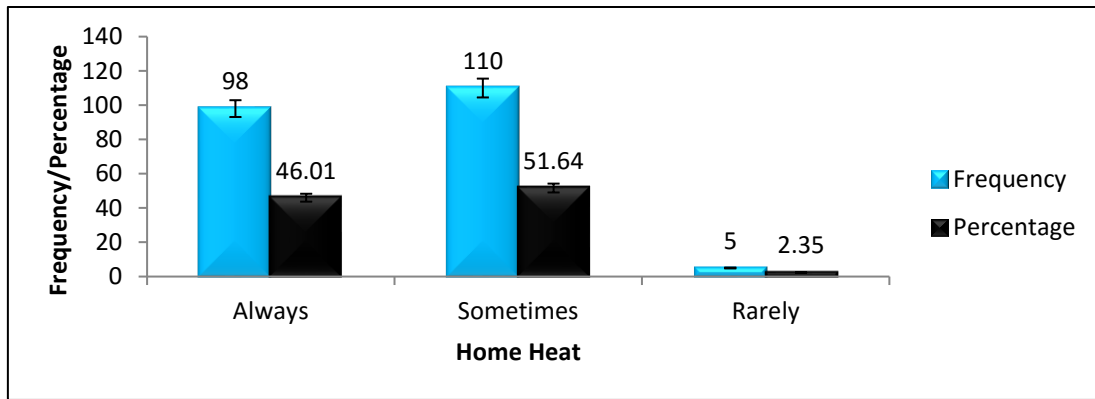


Figure 8: Home Excessive Heat Feeling

Humidity Level in the Respondents' Areas

Figure 9 shows the responses of the respondents on the humidity level in their areas. About forty two percent of the respondents (53.99 %) responded that the humidity level in their areas is low. Approximately, fifty

four percent (41.78 %) of the respondents responded that the humidity level in their areas is moderate. However, only 4.23 % of the respondents responded that the humidity level in their areas is high (Figure 9).

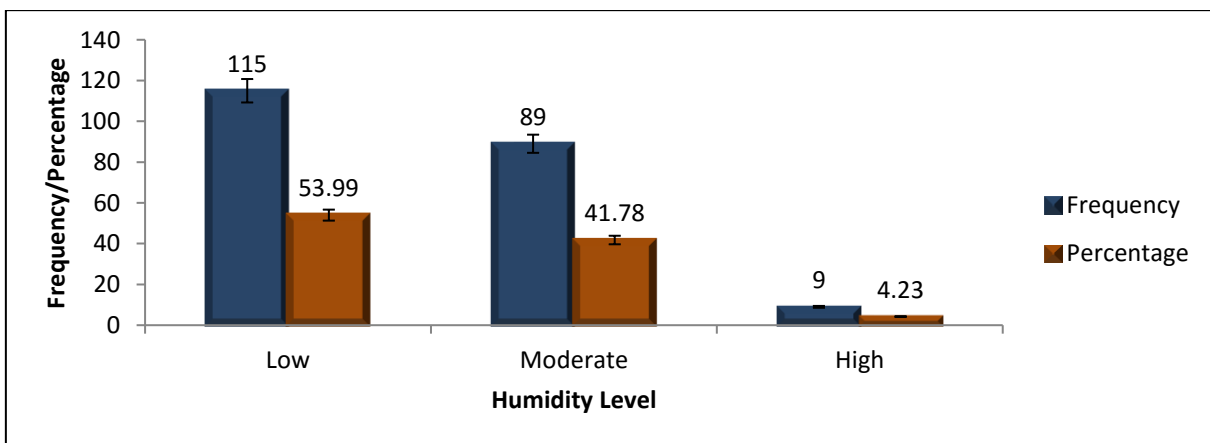


Figure 9: Home Humidity Level

Increase in Meningitis Cases during Hotter Months

The responses of the respondents on the increase in meningitis cases during hotter months are indicated in Figure 10. Majority (65.73 %) of the

respondents responded that meningitis cases increase during hotter months. However, the least percentage (5.63 %) of the respondents responded that meningitis cases are not increase during hotter months (Figure 10).

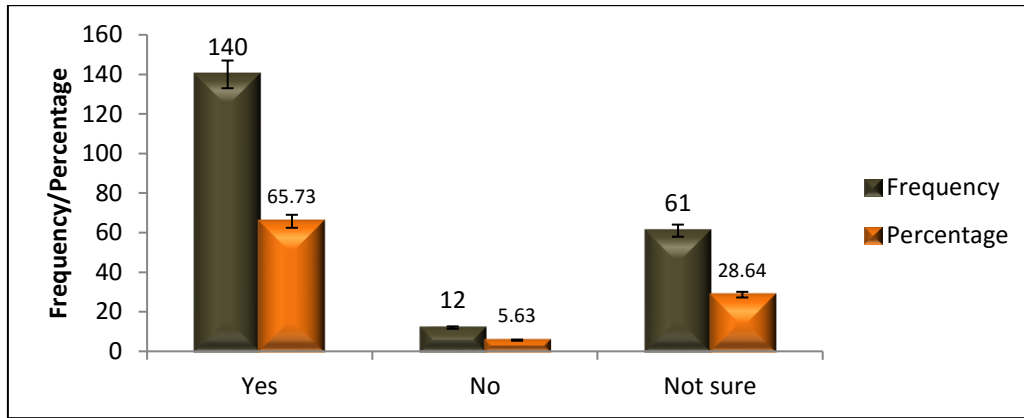


Table 10: Increase in Meningitis Cases during Hotter Months

Other Related Factors Impacting the Incidence and Transmission of Meningitis

Table 1 shows the responses of the respondents on other related factors impacting the incidence and transmission of meningitis. The findings showed that majority of the respondents (88.73 %) responded that heat increased during certain months in their areas. More

than half of the respondents (51.64 %) experienced frequent dry air or dust in their areas. About sixty three percent (62.91 %) of the respondents experienced frequent dust storms in their areas. High proportions of the respondents (64.79 %) applied measures to reduce heat in their houses (Table 1).

Table 1: Other Related Factors Impacting the Incidence and Transmission of Meningitis

Item	Frequency		Percentage (%)	
	Yes	No	Yes	No
Increased Heat during Certain Months	189	24	88.73	11.27
Frequent Dry Air / Dust Experience	110	103	51.64	48.36
Frequent Dust Storms in Your Area	79	134	37.09	62.91
Changes in Temperature Over the Years	192	21	90.14	9.86
Application of Measures to Reduce Heat	138	75	64.79	35.21

Association between the Incidence of Meningococcal Meningitis and the Diurnal Temperature and Humidity Variability

Figure 11 shows the association between the incidence of meningococcal meningitis and the diurnal

temperature. The linear regression plot showed a positive significant ($p < 0.05$) association between the increase in the temperature and the meningitis incidence in the respondents' areas with regression coefficient (r) and p-value of 0.9991 and 0.0269, respectively (Figure 11).

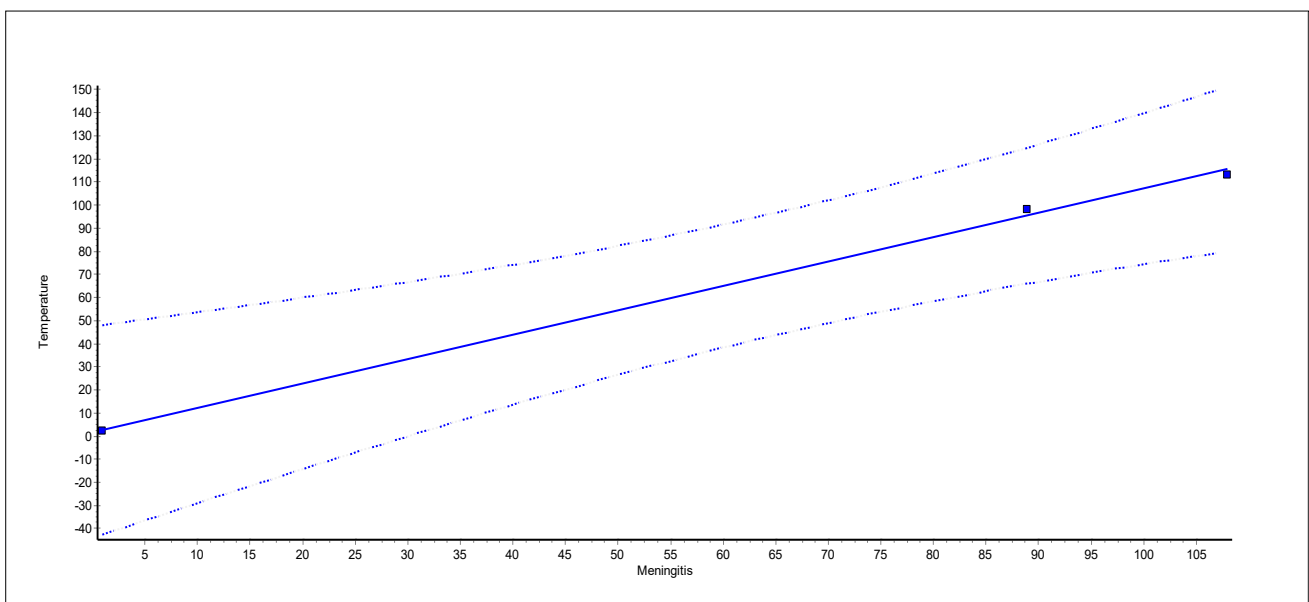


Figure 11: Association between the Incidence of Meningococcal Meningitis and the Diurnal Temperature Variability

The relationship between the incidence of meningococcal meningitis and humidity variability is shown in Figure 12. The regression analysis of the incidence of meningococcal meningitis and humidity in the study area yields a linear plot displaying positive

significant ($p < 0.05$) relationship between the low humidity and the meningitis incidence in the respondents' areas. From the linear plot, the association between the variables was indicated with r (0.9975) and p -value (0.0448) (Figure 12).

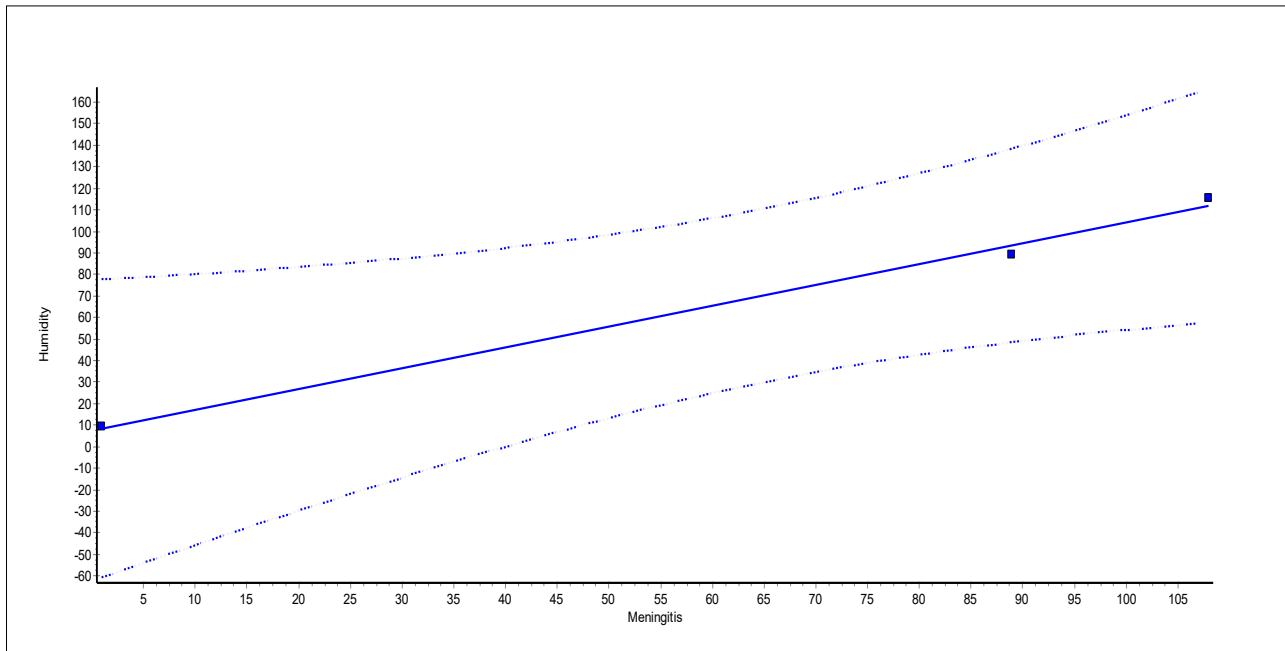


Figure 12: Association between the Incidence of Meningococcal Meningitis and Humidity Variability

DISCUSSION

Socio-Demographic Information of the Respondents

Africa continent has the largest share of the global burden of bacterial meningitis, with Nigeria contributing substantially to this impact (Koutangni *et al.*, 2018). Meningitis remains severe, with case fatality rates reaching up to 30 % even with timely antibiotic management, and about 20 % of survivors experiencing psychomotor disabilities (Ibrahim *et al.*, 2026). In this study, most of the respondents were aged between 30 and 34. Similar research showed that youth ages are the most affected age group with meningitis (Dartey *et al.*, 2020). This age group is socially active, often exposed to risk factors such as overcrowded living conditions, and may experience waning immunity to meningococcal strains (Ibrahim *et al.*, 2026). Consequently, they should be prioritized in preventive mass immunization, targeted health education, and reactive vaccination campaigns (Ibrahim *et al.*, 2026).

The results of the present study showed that most of the respondents were living in urban areas. Similar research stated that people residing in cities are at higher risk of meningitis than those in rural areas (Abdussalam, 2014). Relevant research showed that across rural districts in Africa, suspected bacterial meningitis are infrequently confirmed as a result of limited access to laboratory and hospital diagnostic facilities (Mazamay *et al.*, 2020). In Nigeria, over 200 districts have been affected by a meningitis outbreak

(Cliff *et al.*, 2026). Many LGAs in the north-west senatorial zone share porous borders with Niger Republic. This facilitates social interactions and population movement that may promote cross-border transmission. This movement might contribute to increased reported cases of meningitis, paralleling Niger's outbreak (Oduoye *et al.*, 2023).

Impact of Temperature and Humidity on the Incidence and Transmission of Meningitis

Meningitis incidence has been documented to be influenced by hot, dry, and dusty weather conditions (Abdussalam and Qaffas, 2016). In this study, more than half of the respondents experience high temperature in their areas especially during dry season. This finding also displayed that increase in temperature is associated with increase in meningitis incidence in the respondents' areas. This finding is in agreement with that of Abdussalam (2014) who showed that temperature affected the occurrence and transmission of meningitis in the North-Western part of Nigeria. This result also agreed with that of Ayanlade *et al.*, (2020), who reported a weak positive relationship between temperature and meningitis outbreaks in all tropical ecological zones. Similar study showed that many communities in Northwestern zone of Nigeria attributed the endemic nature of meningitis to harsh environmental and climatic factors such as high temperatures (Omoleke *et al.*, 2018). The study observed a significant positive relationship between maximum temperature and meningitis cases (Omoleke *et al.*, 2018).

Relevant study on the relationship between climate and meningitis epidemics in Niger showed that extreme temperature is a risk factor that drives the outbreak of Meningitis (Jusot *et al.*, 2017). In a relevant study, the majority of respondents indicated that the study area's higher temperatures led to an increase in meningitis cases (Ahmed *et al.*, 2024). Similar research in the Democratic Republic of the Congo revealed that higher temperatures create ideal conditions for the emergence of meningitis outbreaks in the country (Mazamay *et al.*, 2020). This finding is also consistent with that of Greenwood (2013), who demonstrated that the incidence of meningitis has a substantial positive correlation with the highest mean temperature.

The present findings showed that majority of the respondents indicated that heat increased during certain months in their areas. It has been reported that mean monthly temperature has a strong influence on the incidence of meningitis in the study area (Alemaka *et al.*, 2021). The current finding agrees with the results of similar studies which showed that temperature levels are at peak in certain months characterized by fatigue, dehydration and dryness which increase susceptibility to meningitis in the study area (Alemaka *et al.*, 2021; Auwal *et al.*, 2014). However, it has been reported that meningitis cases were recorded in almost all the months of the year (Akanwake *et al.*, 2022).

In this study, according to more than half of the respondents (53.99 %) the humidity level in their areas is low. The present finding indicated a positive association between the meningitis cases and humidity level in the respondents' areas. This finding is in line with the results of similar study by Dukić *et al.*, (2012) who revealed that low relative humidity influenced spatial and temporal variability of meningitis. Relevant research showed that low absolute or relative humidity increases incidence and transmission of meningococcal meningitis especially during the dry season in the African meningitis belt (Junjun *et al.*, 2023). In a relevant study, it was observed that humidity demonstrated high correlation factor with *Neisseria meningitidis* loads up to -0.43 (UCAR, 2008). However, it was found that higher humidity enhances the carriage of bacterial meningococci and decrease the incidence of meningococcal meningitis (Mueller *et al.*, 2008).

CONCLUSION

Majority of the respondent indicated that increased in their residential areas especially during dry season and the area were characterized by low humidity. High incidence of meningococcal meningitis was recorded in the respondents' areas. The occurrence and incidence of meningococcal meningitis was significantly associated with increase diurnal temperature and low humidity in the study area.

Conflict of Interest

The authors declared that there was no conflict of interest.

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