Multi-Level Analysis and Spatial Interpolation of Distributions and Predictors of Childhood Diarrhea in Nigeria

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ABSTRACT

BACKGROUND: Diarrhea is one of the health problems contributing to Nigeria's under-5 mortality rate, ranked as the eighth highest globally. As our search is concerned, there is limited evidence on the spatial distribution of childhood diarrhea in Nigeria. Therefore, this study aimed to examine the spatial distribution and predictors of diarrhea among under-5 children in Nigeria.

MATERIALS AND METHODS: Using data from the child's recode file of the 2018 Nigeria Demographic and Health Survey, a sample of 28 583 children of women of reproductive age was considered as the sample size for this study. The outcome variable used in this study was childhood diarrhea. We employed both multilevel and spatial analyses to ascertain the factors associated with childhood diarrhea as well as its spatial clustering.

RESULTS: The regional distribution of the prevalence of diarrhea among children in Nigeria ranged from 0% to 62%. The hotspots for childhood diarrhea were in Yobe, Bauchi, Gombe, Kano, Sokoto, Imo, and Taraba. The likelihood of a child having diarrhea in Nigeria was higher among women whose partners have secondary education and above [aOR = 1.18; 95%CI = 1.05-1.33], women currently working [aOR = 1.24; 95%CI = 1.13-1.35], women practicing Islam [aOR = 1.24; 95%CI = 1.04-1.46], and women who were exposed to mass media [aOR = 1.29; 95%CI = 1.18-1.42], compared to women whose partners had no formal education, women not currently working, women practicing Christianity, and those who were not exposed to mass media. Children born to mothers who reside in North East [aOR = 2.55; 95%CI = 2.10-3.10], and communities with medium socioeconomic status [aOR = 1.44; 95%CI = 1.09-1.91] were more likely to experience diarrhea compared to those born to mothers residing in the North Central and in communities with low socioeconomic status.

CONCLUSION: High proportions of childhood diarrhea among under-5 children in Nigeria were located in Yobe, Bauchi, Gombe, Kano, Sokoto, Imo, and Taraba. Policies and interventions that seek to reduce or eliminate diarrhea diseases among under-5 children in Nigeria should take a keen interest in the factors identified as predictors of childhood diarrhea in this study as this will help in achieving the aims of WASH, ORT corners, and SDG 3 by the year 2030.

KEYWORDS: Diarrhea, child Health, Nigeria, multilevel analysis, spatial analysis, public health

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Background

Diarrhea still remains a public health issue among many countries in the world due to unsafe drinking water, poor hygiene and sanitation practices, and poor nutritional practices.[1,2] A global report indicated that diarrhea among children under age 5 accounts for about 1.3 million deaths every year.[3] Out of this figure majority occur in low-and-middle-income countries (LMIC).[4] For instance, some scholars have reported in other parts of the world that despite efforts to control the spread of diarrheal disease, the burden continues to be high.[2,5] Some studies conducted in sub-Saharan Africa (SSA) countries such as Ethiopia and Ghana have also reported a high prevalence of diarrhea among children under 5.[6,7] Diarrhea is one of the health problems contributing to Nigeria's under-5 mortality rate, ranked as the eighth highest globally. Diarrhea occurs when a person frequently passes watery stools, usually 3 or more times within 24 hours.[8,9] Diarrhea is often experienced as a symptom of parasitic, viral, bacterial, or fungal infection of the intestinal tract.[8] A Nigerian study reported that diarrhea among under-5 children accounts for approximately 160 000 deaths among children below age 5.[10]

Diarrhea which has been identified as a preventable disease can pose severe health complications for the child. For example, diarrhea causes dehydration, leading to malnutrition, growth impairment, or death among children under age 5 who are most vulnerable to diseases at that young age.[11] More so, research has revealed that children who experience diarrhea before their second year are 5% more likely to be stunted compared to their peers who do not.[12,13] Aside from these, diarrhea diseases are related to chronic adverse mental outcomes and a reduced economic or work efficiency in later years of life.[14,15]

Despite the available interventions to eliminate diarrhea diseases among children under 5 in Nigeria, the phenomenon remains pervasive.[16,17] Given that diarrhea is a preventable disease, more concerted effort by government organizations and civil service entities could significantly reduce the associated mortality rates among children under age 5. Some previous studies have identified place of residence, mother's education, parental wealth, poor sanitation practices, source of drinking water, gender, father's education, family size, and sewage disposal methods as predictors of diarrhea among children.[17-20] However, breastfeeding and water chlorination were protective factors against diarrhea among under-5 children.[18] A critical appraisal of the available literature revealed that no study had examined the spatial distribution of diarrhea and the factors that predict diarrhea among children under age 5 using data sets that are up-to-date and nationally representative in Nigeria. This creates a void in literature which this study seeks to address. Therefore, the study examined the prevalence and predictors of diarrhea among under-5 children in Nigeria using spatial and multilevel analysis. The use of spatial analysis helps analyze the disparities in the distribution of childhood diarrhea and direct resources where needed.[21-23] Monitoring progress across geographical regions can determine if programs and policies benefit the poorest people and are implemented were most needed, thus contributing to improved and equitable health outcomes.[24] Multilevel analysis also helps account for the hierarchical structure of the demographic and health survey dataset.[25] Findings from the study could contribute to directing policies that would help in the fight against the raging prevalence of diarrhea in Nigeria, which is in line with Nigeria's Water Sanitation and Hygiene (WASH) and the implementation of Oral Rehydration Therapy (ORT) corners in hospitals[26] and the United Nations' (UN)[27]Sustainable Development Goal 3 (SDG 3) of ensuring healthy lives for all individuals irrespective of age by 2030 .

Materials and Methods

Data source

Data for this study were derived from the 2018 Nigeria Demographic and Health Survey (NDHS). The NDHS is a nationally representative survey that collects data on men, women, and children. Among the issues data are collected on for children is childhood diarrhea.[28] The NDHS utilizes a 2-stage sampling procedure to gather data from 36 administrative units and the Federal Capital Territory (FCT). The survey's primary sampling unit was made up of samples drawn at random from clusters. Using data from the child's recode file, after considering the variables of interest and other inclusion criteria, a sample of 28 583 children of women of reproductive age was considered as the sample size for this study since those were the respondents with the complete file on childhood diarrhea in 2018 NDHS. The sampling, pretesting and the general methodology of the 2018 NDHS has been published elsewhere.[29] In writing this manuscript, we adopted the guidelines for improving the reporting of observational studies in Epidemiology.[30] The dataset is available in the public domain and can be downloaded from https://dhsprogram.com/data/available-datasets.cfm.

Outcome variable

The outcome variable used in this study is childhood diarrhea. This was measured by asking the respondent if the child had diarrhea in the past 2 weeks. The variable had 2 response categories, "Yes" and "No," and these were coded as "1" and "0," respectively. The coding of the outcome variable was supported by previous literature.[31-33]

Independent variables

Based on theoretical and practical significance and the availability of the variables in the dataset, we considered both individual and contextual level factors in our study. The selection of the variables was influenced by their association with childhood diarrhea in several previous studies in Nigeria.[31-33]

Individual-level factors

The individual-level factors were the age of the child (0-11, 12-23, 24-35, 36-47, and 48-59 months), sex of child (male, female), source of drinking water (unimproved, improved), type of toilet facility (unimproved, improved), maternal age (15-24, 25-34, 35, and above), maternal educational level (no education, primary education, secondary, and above), and partner's educational level (no education, primary education, secondary, and above). Others were currently working (no, yes), parity (1, 2, 3, 4, and above), religious affiliation (Christianity, Islam, Traditionalists, and others), ethnicity (Hausa, Yoruba, Igbo, and others) and media exposure (no, yes).

Contextual level factors

The contextual level factors were wealth index (poorest, poorer, middle, richer, richest), sex of household head (male, female), region (North Central, North East, North West, South East, South South, and South West), place of residence (urban and rural), community literacy level (low, medium, and high), and community socioeconomic status (low, medium, and high).

Statistical analyses

We employed both spatial and multilevel analyses in analyzing the data. The use of spatial analysis helps in analyzing the disparities in distribution of childhood diarrhea and to direct resources where needed,[21-23] while multilevel analysis also helps account for the hierarchical structure of the demographic and health survey dataset.[25]

Spatial analysis

To analyze the spatial distribution (geographic variation of diarrhea), different statistical software like Excel, SaTScan, ArcGIS, and Stata 14 were used. The weighted frequency of outcome variable (diarrhea disease with the last 2 weeks yes/no) with cluster number and geographic coordinate data was merged in Stata 14. Among 1400 Enumeration Areas (EAs), 7 clusters (EAs) having longitude and latitude 0 were dropped. The data was exported to CSV delimited format to make ready data for ArcGIS 10.7 for spatial analysis.

Spatial autocorrelation analysis

To check whether there is a clustering effect in diarrhea disease in Nigeria, spatial autocorrelation analysis was done. This analysis result gives Global Moran's *I* value, *Z*-score, and *P*-value for deciding whether the data is dispersed or random or clustered. Moran's *I* value close to positive 1 indicates a clustering effect, close to negative 1 indicates dispersed and close to zero random. If the *P*-value is significant at .05 and the value of *I* is closer to the mean, that means diarrhea disease had a clustering effect in Nigeria.

Hot spot analysis (Getis-OrdGi statistic)*

The hot spot analysis tool gives Getis_Ord or Gi* statistics for a cluster in the dataset. Statistical values like *Z*-score and *P*-value are computed to determine the statistical significance of clusters. The analysis result with high GI* value means hot spot areas (high proportion of diarrhea disease) and low GI* value means cold spot areas (low proportion of diarrhea disease).

Spatial interpolation or prediction

Spatial prediction is one of the techniques of furcating unsampled areas based on sampled areas. In Nigeria, 1400 enumeration areas were selected as samples. A total of 7 clusters had no enumeration longitudes, and latitudes were dropped. Based on 1393 sample areas, it is possible to predict the remaining parts of Nigerian. Ordinary Kriging prediction methods were used for this study to predict diarrhea disease in unobserved areas of Nigeria.

Spatial scan statistical analysis

Bernoulli's purely spatial model was applied to identify diarrhea disease clusters using 1393 enumeration areas. SatTscan Software was used for the analysis. First, the dataset was managed as appropriate for SaTScan software. Children who are diarrhea disease were taken as cases, and women who did not have the disease as controls. The Cluster number, longitude, and Latitude data were obtained from the GPS dataset. The cluster size of less than 50% of the population was taken upper bound. A 999 Monte Carlo replication was used for this study. Based on the above criteria, Primary clusters were identified.

Multilevel analysis

A 2-level multilevel binary logistic regression model were fitted to evaluate the individual and contextual level factors linked to diarrhea among children under 5 in Nigeria. In the modeling, women were nested within households; then households were nested within clusters. To account for the unexplained variability at the contextual level, clusters were proposed as random effects. A total of 4 models were fitted. Firstly, we fitted an empty model, model I, which contained no predictors (random intercept). Model II only included individual-level variables, model III only included contextual level variables, and model IV included both individual-level and contextual level variables. The odds ratio and related 95% confidence intervals were provided for all models. These models were fitted by a Stata command "melogit" to identify predictors of childhood diarrhea. The log-likelihood ratio (LLR), Akaike Information Criteria (AIC) measure, and Schwarz's Bayesian Information Criteria (BIC) were used to compare models. The best fit model has the highest log-likelihood and the lowest AIC.[34] The multicollinearity test, which used the variance inflation factor (VIF), revealed no evidence of collinearity among the independent variables (Mean VIF = 1.77, Maximum VIF = 3.49, and Minimum VIF = 1.00). In individual sample weight (v005/1 000 000) was used in all analyses to account for over- and under-sampling, while the svy command was used to account for the complex survey design and generalizability of the results. All the analyses were carried out using Stata version 16.0 (Stata Corporation, College Station, TX, USA).

Results

Socio-demographic characteristics of respondents

A total of 28 583 women were included in the study. At an individual level, 20.99% of the respondent's children were 0 to 11 months, 50.79% of the children were male, 64.64% of the children lived in households with an improved source of drinking water, 51.74% of respondents were women aged 25 to 34 while at contextual level 61.06% of women reside in the rural area (These are geographical locations outside the cities), 6285 (21.99%) were from the poorest household, 36.16% were residing in North West, 34.10% were from a community with high literacy level, and 59.47% were from a community with low socio-economic status (Table 1).

Spatial distribution of diarrhea disease in Nigeria

A total of 1400 clusters were initially considered for the spatial analysis of diarrhea disease in Nigeria. However, 7 clusters were dropped from the analysis because they had no measured longitude and latitude. Finally, a total of 1393 clusters were considered for the spatial analysis of diarrhea disease in Nigeria. Each point on the map represents 1 enumeration area with a proportion of diarrhea disease cases in each cluster. The prevalence of diarrhea disease among children in Nigeria ranged from 0% to 62%. The red color dot indicates areas with a high proportion of diarrhea disease in Nigeria, and it ranges from 25.01% to 62%, whereas the green color indicates EAs with a lower proportion of diarrhea disease and ranges from 0% to 9.38% (Figure 1).

Spatial autocorrelation

This study revealed that the spatial distribution of diarrhea disease was non-random in Nigeria with Global Moran's I 0.43 ($P < .0001$) (Figure 2).[35] The clustered patterns (on the right sides) show a high rate of diarrhea disease in Nigeria. The outputs have automatically generated keys on the right and left sides of each panel. Given the Z-score of 53.50, there is less than a 1% likelihood that this clustered pattern could result from random chance. The bright red and blue colors to the end tails indicate an increased significance level (Figure 2).

Hot spot analysis

The hot spot analysis result revealed the areas of the country where a high proportion of diarrhea disease (hot spot) and a low proportion of diarrhea disease (cold spot) are located. The red color indicates significant risky areas (high rate of diarrhea disease) located in Yobe, Bauchi, Gombe, Kano, Sokoto, Imo, and Taraba (Figure 3).

Interpolation or prediction of diarrhea in Nigeria

When we go from blue to red-colored areas, the predicted diarrhea disease over the area increases, the red color indicates the predicted diarrhea disease high-risk areas, and the blue color indicates the predicted low diarrhea disease risk areas. The predicted risk areas were located in Yobe, Bauchi, Gombe, Kano, Sokoto, Imo, and Taraba, in line with the hot spot area. Continuous images were produced by interpolating (Kriging interpolation method) diarrhea disease among children in the last 2 weeks before the survey (Figure 4).

Spatial SaTScan analysis of stillbirth Bernoulli based model

Most likely (primary), secondary, and tertiary clusters of diarrhea disease were identified. A total of 177 primary, 137 secondary, and 54 significant clusters were identified. The primary clusters spatial window was located in the Yobe, Bauchi, Gombe, Kano, and Jigawa, which was centered at (11.301940N, 10.466170E)/223.21 km, and Log-Likelihood ratio (LLR) of 290 and Relative Risk (RR) 2.10, at $P < .0001$. It showed that children within the spatial window had a 2.10 times higher risk of diarrhea disease than women outside the window. The secondary clusters spatial window was typically located in the central part of Plateau and Taraba. Which was centered at (11.704190N, 11.092290E)/213.03 km radius, and LLR of 290 and Relative Risk (RR) 2.23 at $P < .001$. It showed that children within the spatial window had a 2.23 times higher risk of diarrhea disease than children outside the window (Table 2, Figure 5).

Multi-level fixed effects (measures of associations) results

The significant predictors at the individual level were the age of the child, partner's educational level, working status, religious affiliation, ethnicity, and mass media exposure. The likelihood of diarrhea in Nigeria was higher among children born to mothers whose partners have secondary education and above [aOR = 1.18; 95%CI = 1.05-1.33], currently working [aOR = 1.24; 95%CI = 1.13-1.35], mothers practicing Islam [aOR = 1.24; 95%CI = 1.04-1.46], and mothers who were exposed to mass media [aOR = 1.29; 95%CI = 1.18-1.42], compared to children born to mothers whose partners have no education, those not currently working, mothers practicing Christianity, and those who were not exposed to mass media. Lower odds of a child having diarrhea was reported among mothers with children age 3 [aOR = 0.55; 95%CI = 0.48-0.62], and mothers who were from the Yoruba ethnic group [aOR = 0.64; 95%CI = 0.47-0.88], compared to mothers with children 0 to 11 months, and those from Hausa ethnic group.

At the contextual level, the significant predictors were wealth index, region, and community socioeconomic status. Children born to mothers who reside in North East [aOR = 2.55; 95%CI = 2.10-3.10], and medium community socioeconomic status [aOR = 1.44; 95%CI = 1.09-1.91] were more likely to experience diarrhea compared to those residing in the North Central and community with low socioeconomic status. Mothers who were within the richest wealth index [aOR = 0.47; 95%CI = 0.37-0.60], and those residing in South West region [aOR = 0.66; 95%CI = 0.49-0.89] were less likely

Table 1. Individual and contextual level characteristics of respondents (n = 28 583).

VARIABLE	WEIGHTED FREQUENCY	WEIGHTED PERCENTAGE
Individual-level		
Age of child (in months)		
0-11 months	6001	20.99
12-23 months	5664	19.82
24-35 months	5405	18.91
36-47 months	5716	20.00
48-59 months	5797	20.28
Sex of child		
Male	14 516	50.79
Female	14 067	49.21
Source of drinking water		
Unimproved	10 108	35.36
Improved	18 475	64.64
Type of toilet facility		
Unimproved	13 676	47.85
Improved	14 907	52.15
Maternal age		
15-24	6544	22.89
25-34	14 788	51.74
35 and above	7252	25.37
Maternal educational level		
No education	13 154	46.02
Primary education	4200	14.69
Secondary and above	11 229	39.28
Partner's educational level		
No education	10 344	36.19
Primary education	3987	13.95
Secondary and above	14 252	49.86
Currently working		
No	9244	32.34
Yes	19 339	67.66
Parity		
1	2937	10.24
2	5398	18.89
3	4971	17.39
4 and above	15 287	53.48
Religious affiliation		
Christianity	10 265	35.91

(Continued)

Table 1. (Continued)

VARIABLE	WEIGHTED FREQUENCY	WEIGHTED PERCENTAGE
Islam	18 162	63.54
Traditionalist and others	157	0.55
Ethnicity		
Hausa	13 045	45.64
Yoruba	3238	11.33
Igbo	3600	12.59
Others	8700	30.44
Media exposure		
No	10 971	38.38
Yes	17 612	61.62
Contextual level factors		
Region		
Urban	11 131	38.94
Rural	17 452	61.06
Wealth index		
Poorest	6285	21.99
Poorer	6269	21.93
Middle	5812	20.33
Richer	5306	18.56
Richest	4911	17.18
Region		
North central	3972	13.90
North East	5198	18.19
North west	10 335	36.16
South east	2819	9.86
South south	2443	8.55
South west	3816	13.35
Sex of household head		
Male	26 723	93.49
Female	1861	6.51
Community literacy level		
Low	9474	33.15
Medium	9362	32.75
High	9747	34.10
Community Socioeconomic status		
Low	17 000	59.47
Medium	1333	4.67
High	10 250	35.86

NDHS, 2018.

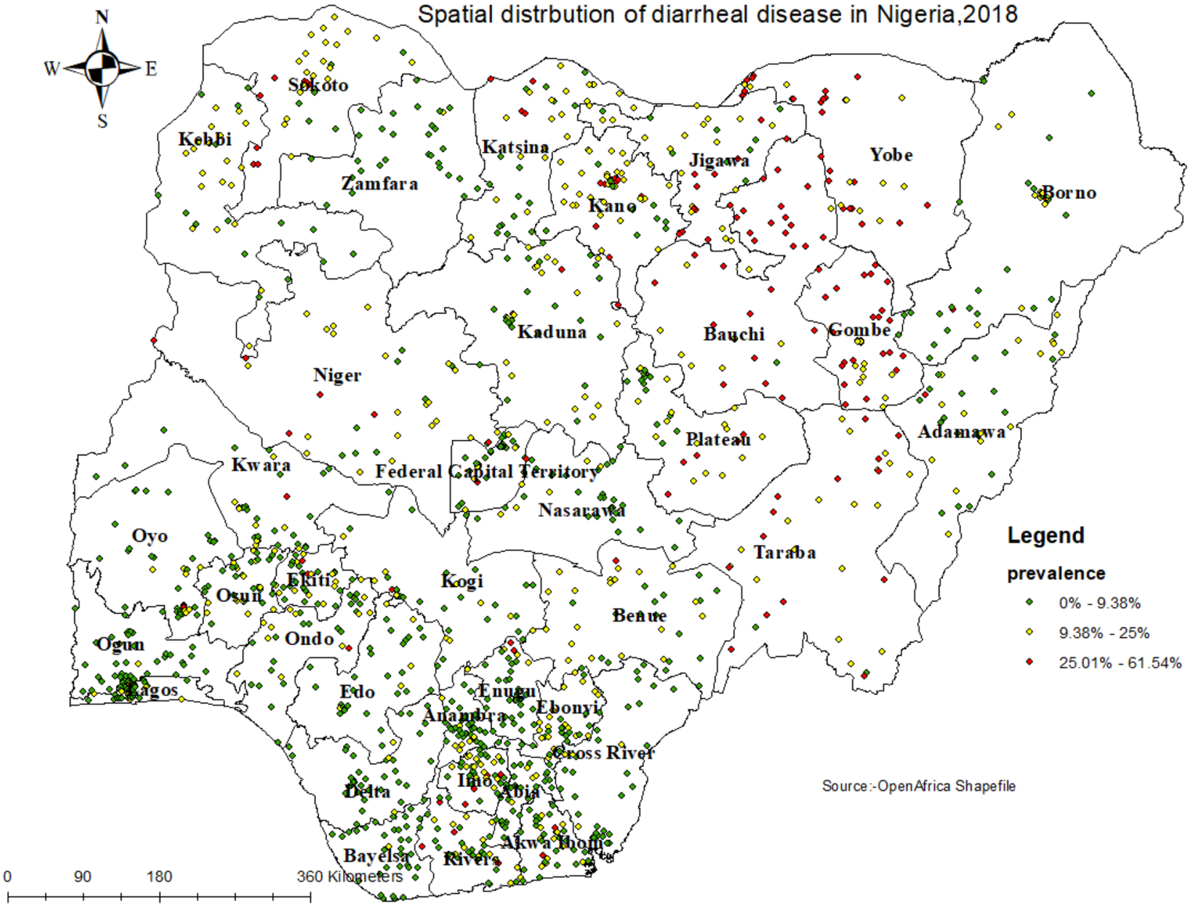

Figure 1. Spatial distribution of diarrhea disease among children in Nigeria, 2018.

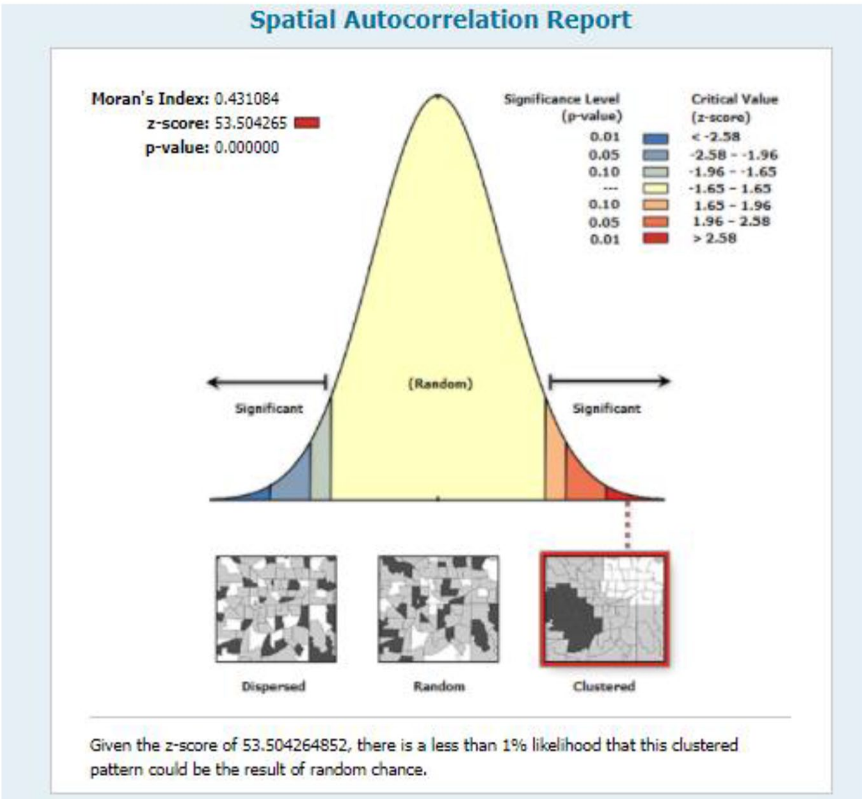

Figure 2. Spatial autocorrelation of results of diarrhea disease among children in Nigeria, 2018.

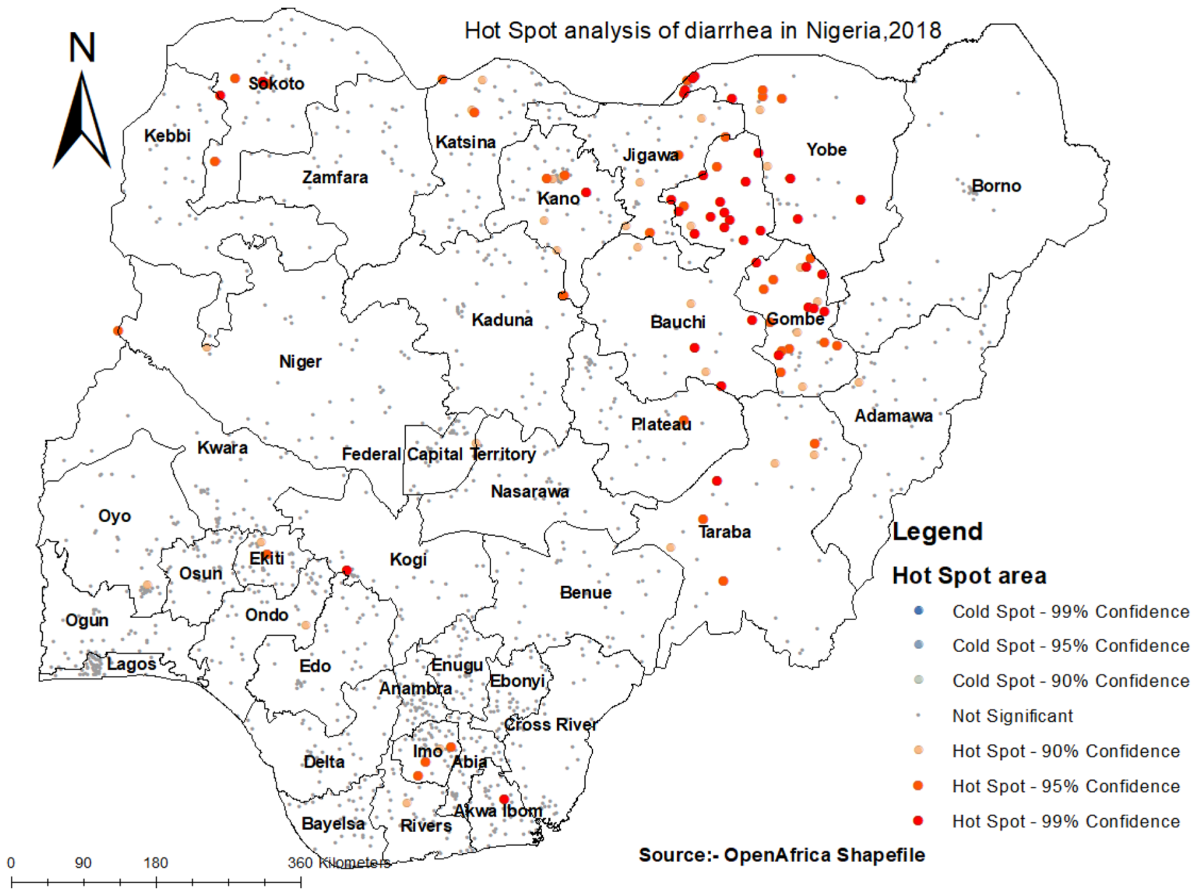

Figure 3. Hot spot analysis of diarrhea disease among children in Nigeria, 2018.

to have a child that experienced diarrhea compared to those who were poorest and those residing in North Central.

Random effects (measures of variations) results

The empty model (Model 0), as shown below in Table 2, depicted a substantial variation in the likelihood of childhood diarrhea in Nigeria across the Primary Sampling Units (PSUs) clustering [$\sigma^2 = 0.93$; 95%CI = 0.80-1.07]. Model 0 indicated that 22% of the variation in children experiencing childhood diarrhea in Nigeria was attributed to the variation between Intra-Class Correlation, i.e., (ICC = 0.22). The variation between-cluster decreased to 17% (0.17) in Model I (individual level only). At the contextual level only (Model II) and the complete model with both the individual and contextual level factors (Model III), the ICC decreased further to 13% at both models. This further reiterates that the variations in the likelihood of children experiencing childhood diarrhea in Nigeria are attributed to the variation in PSUs. The Akaike's Information Criterion (AIC) and Schwarz's Bayesian Information Criteria (BIC) values showed a successive reduction, which means a substantial improvement in each model over the previous model and affirms the goodness of Model III developed in the analysis. Therefore, Model III, the complete model with both the selected individual and contextual level factors, was selected to predict the likelihood of childhood diarrhea in Nigeria, as indicated in Table 3 below.

Discussion

The study examined the spatial distribution and predictors of diarrhea among under-5 children in Nigeria using the recent NDHS data conducted in 2018. We found that the low and high proportions of diarrhea disease among under-5 children in Nigeria ranged from 0% to 9.38% and from 25.01% to 61.54%, respectively. High proportions of diarrhea disease among under-5 children in Nigeria were located in Yobe, Bauchi, Gombe, Kano, Sokoto, Imo, and Taraba. A possible reason for this finding could be the incessant grazing where animals drink and defecate in water sources that are meant for human consumption, increasing the susceptibility of children leaving in such areas to the diarrhea disease.[19] Another plausible reason for this finding could be the low level of education and use of unimproved sanitation facilities, which tends to increases children's likelihood of having diarrhea disease.[2,36] This finding suggests that water sources and sanitation facilities in the locations identified as hotspots should be improved in order to eliminate or reduce diarrhea disease among under-5 children in Nigeria.

The likelihood of a child having childhood diarrhea was high among women whose partners had secondary education

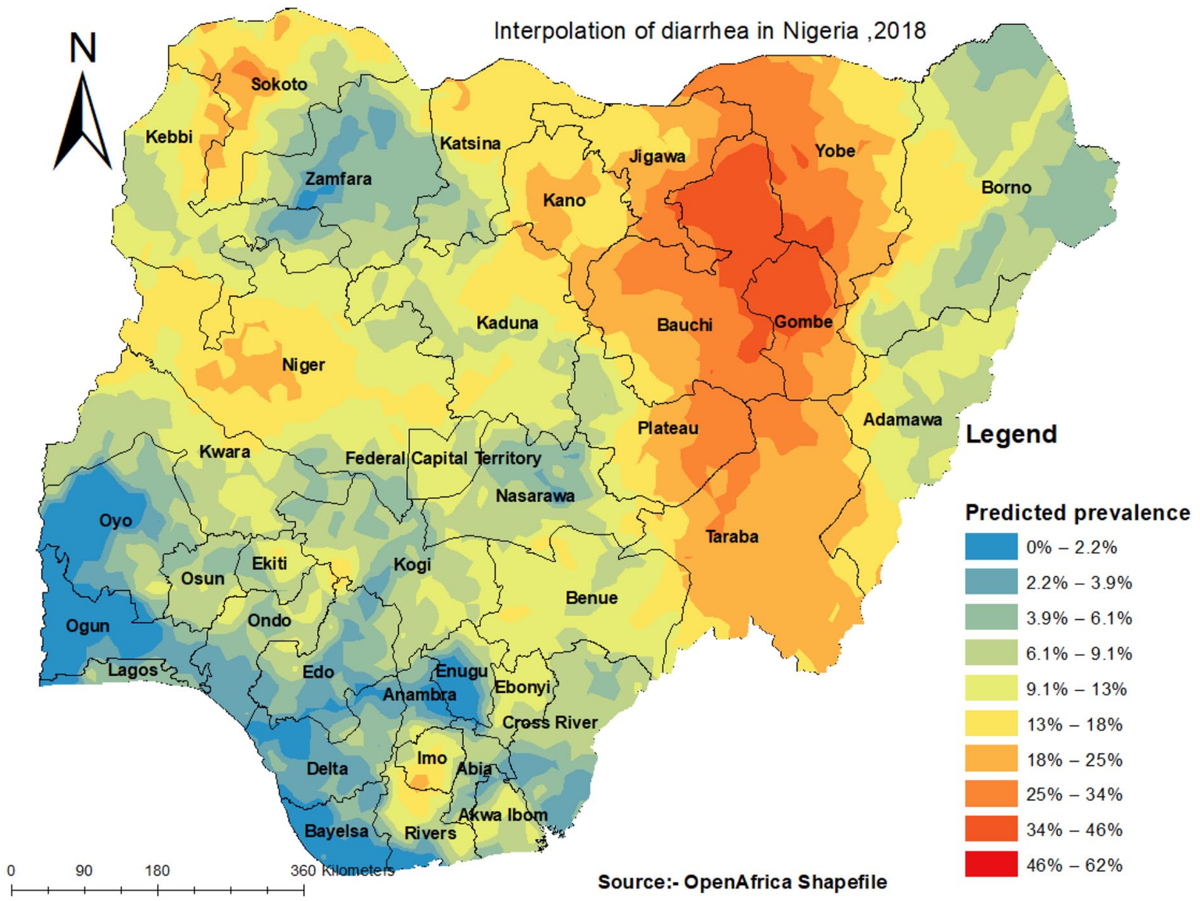

Figure 4. Spatial prediction of childhood diarrhea disease in Nigeria, 2018.

Table 2. SaTScan analysis result of diarrhea disease among children in Nigeria, 2018.

CLUSTER	ENUMERATION AREA (CLUSTER) IDENTIFIED	COORDINATE/RADIUS	POPULATION	CASE	RR	LLR	*P*-VALUE
1	177	(11.301940N, 10.466170E)/223.21 km	5676	1527	2.10	290	<.001
2	137	(11.704190N, 11.092290E)/213.03 km	3932	1178	2.23	290	<.001
3	54	(8.347721N, 10.408740E)/166.95 km	1043	233	1.41	14.3	.0014

and above, and women currently working compared to women whose partners had no education and women not currently working. A possible reason for these findings could be that women whose partners have attained some levels of education are no more paying much attention to the hygiene practices of their spouses, the sanitation facilities, and quality of water that are given to their children, increasing the children's possibility of having a diarrhea disease.[37,38] It is also possible that women who are currently working may also be experiencing financial difficulties securing quality drinking water and improved sanitation facilities that could potentially protect their children from diarrhea disease.[39,40] Further studies to explain the causes of these findings are warranted.

The likelihood of a child having childhood diarrhea was high among women practicing Islam, women exposed to mass media compared to women practicing Christianity, and those not exposed to mass media. The findings of this study contradict the findings of other previous studies.[41,42] A possible reason for these findings could be that some practices or frameworks in the Islamic religion increase children whose mothers practice Islam compared to those who practice Christianity.[41,43] Another plausible reason for these findings could be that mothers' exposure to mass media no more reduces their children's chances of having diarrhea disease.[41]

Akin to the findings of other previous studies,[44,45] the study found that low odds of a child having diarrhea was reported among mothers with children of age 3 years and women who were from Yoruba ethnic group compared to women with children less than a year, and those from Hausa ethnic group. An acceptable reason for these findings could be that women who

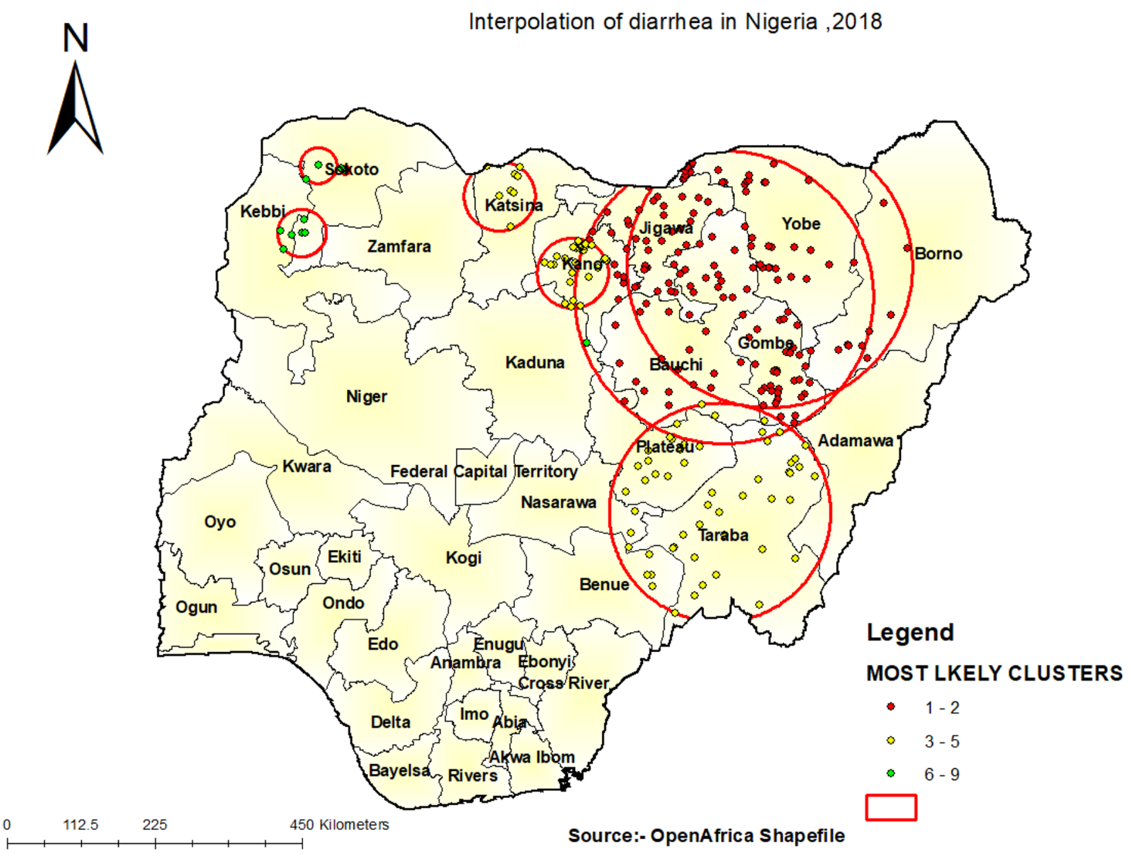

Figure 5. The SaTScan analysis map of diarrhea disease among children in Nigeria, 2018.

have children age 3 years practice better hygiene and sanitation practices, decreasing their children's likelihood of having episodes of diarrhea.[46] Another acceptable explanation for these findings could be that some practices in the Yoruba ethnic group protect children from having episodes of diarrhea, hence reducing children of Yoruba mothers' chances of having diarrhea disease.[45]

Children whose mothers resided in North Eas, and medium community socioeconomic status were more likely to experience diarrhea compared to those whose mothers were residing in the North Central and community with low socioeconomic status. The finding of the study agrees with the finding of another previous study.[47] A possible reason for these findings could be that mothers residing in the North East region of Nigeria are not able to afford quality drinking water and improved sanitation facilities for their children, increasing their likelihood of having the diarrhea disease.[47] Another possible reason for this finding could be that mothers living in communities with medium socioeconomic status may lack the affordability for quality drinking water, improved sanitation facilities and hygiene services, increasing their children's possibility of having episodes of diarrhea.[48]

Similar to the finding of previous studies,[19,44] that women who were within the richest wealth index and those residing in South West region were less likely to have a child that experienced diarrhea compared to those who were poorest and those residing in North Central. A possible reason for these findings could be that women from wealthy homes have the financial capacity to construct boreholes that are well protected from contaminations from animals, making their children less susceptible to unwholesome drinking water.[19,44] Another acceptable explanation for these findings could be that women residing in the South West region of Nigeria are more educated. Hence, they are better informed about water treatment practices and options that would protect their children from diarrhea diseases.[36] These findings suggest that providing women with well-paid jobs could help reduce the rate of diarrhea among children under age 5.

Policy and Public Health Implications

The findings of this study are relevant to policy and public health. The differences in the prevalence of childhood diarrhea based on the spatial analysis results emphasize the need to consider interventions for reducing childhood diarrhea for hotspot regions. Moreover, the socio-economic disparity in the likelihood of childhood diarrhea shows that children born to women with low socio-economic status need to be given much attention by public health providers in their programs and interventions.

Strengths and Limitations

Our study has several strengths. First, the use of nationally representative data boosts the capacity of our findings to be

Table 3. Multilevel logistic regression models for individual and contextual level predictors of childhood diarrhea in Nigeria.

VARIABLES	MODEL 0	MODEL I	MODEL II	MODEL III
N = 28 583		AOR (95%CI)	AOR (95%CI)	AOR (95%CI)
Fixed effects results				
Individual-level variables				
Age of child (in months)				
0-11 months		RC		RC
12-23 months		1.55*** (1.39-1.72)		1.54*** (1.39-1.71)
24-35 months		0.93 (0.83-1.05)		0.93 (0.83-1.05)
36-47 months		0.55*** (0.48-0.62)		0.55*** (0.48-0.62)
48-59 months		0.38*** (0.33-0.43)		0.37*** (0.33-0.43)
Sex of child				
Male		RC		RC
Female		0.97 (0.91-1.05)		0.97 (0.90-1.05)
Source of drinking water				
Unimproved		RC		RC
Improved		0.93* (0.84-1.03)		1.04 (0.94-1.15)
Type of toilet facility				
Unimproved		RC		RC
Improved		0.88 (0.80-0.97)		0.96 (0.87-1.07)
Maternal age				
15-24		RC		RC
25-34		0.86** (0.76-0.96)		0.91 (0.81-1.02)
35 and above		0.82** (0.71-0.95)		0.89 (0.77-1.02)
Maternal educational level				
No education		RC		RC
Primary education		0.97 (0.85-1.10)		1.06 (0.93-1.21)
Secondary and above		0.81** (0.70-0.92)		0.97 (0.84-1.12)
Partner's educational level				
No education		RC		RC
Primary education		0.99 (0.86-1.13)		1.03 (0.90-1.18)
Secondary and above		1.08 (0.96-1.21)		1.18** (1.05-1.33)
Currently working				
No		RC		RC
Yes		1.25*** (1.14-1.37)		1.24*** (1.13-1.35)
Parity				
1		RC		RC
2		0.88 (0.76-1.02)		0.87 (0.75-1.01)
3		0.96 (0.82-1.12)		0.94 (0.80-1.09)

(Continued)

Table 3. (Continued)

VARIABLES	MODEL 0	MODEL I	MODEL II	MODEL III
N = 28583		AOR (95%CI)	AOR (95%CI)	AOR (95%CI)
4 and above		0.98 (0.84-1.15)		0.94 (0.80-1.10)
Religious affiliation				
Christianity		RC		RC
Islam		1.68*** (1.44-1.97)		1.23* (1.04-1.46)
Traditionalist and others		0.52 (0.84-1.15)		0.62 (0.30-1.29)
Ethnicity				
Hausa		RC		RC
Yoruba		0.40*** (0.32-0.50)		0.64** (0.47-0.88)
Igbo		0.59*** (0.47-0.75)		0.85 (0.60-1.21)
Others		0.80** (0.70-0.91)		0.75*** (0.65-0.87)
Media exposure				
No		RC		RC
Yes		1.16** (1.06-1.27)		1.29*** (1.18-1.42)
Contextual level factors				
Region				
Urban			RC	RC
Rural			0.93 (0.80-1.09)	0.98 (0.84-1.14)
Wealth index				
Poorest			RC	RC
Poorer			0.96 (0.86-1.08)	0.92(0.81-1.03)
Middle			0.89 (0.78-1.03)	0.79** (0.68-0.92)
Richer			0.76** (0.63-0.90)	0.63*** (0.52-0.77)
Richest			0.57*** (0.46-0.71)	0.47*** (0.37-0.60)
Region				
North central			RC	RC
North east			2.70*** (2.25-3.25)	2.55*** (2.10-3.10)
North west			1.35** (1.13-1.62)	1.07 (0.87-1.32)
South east			0.67** (0.52-0.85)	0.65* (0.44-0.96)
South south			0.56*** (0.43-0.72)	0.59*** (0.52-0.77)
South West			0.61*** (0.48-0.77)	0.66** (0.49-0.89)
Sex of household head				
Male			RC	RC
Female			1.09 (0.921.30)	1.07 (0.90-1.27)
Community literacy level				
Low			RC	RC

(Continued)

Table 3. (Continued)

VARIABLES	MODEL 0	MODEL I	MODEL II	MODEL III
N = 28 583		AOR (95%CI)	AOR (95%CI)	AOR (95%CI)
Medium			0.88 (0.75-1.03)	0.88 (0.75-1.04)
High			0.83 (0.67-1.02)	0.86 (0.69-1.08)
Community socioeconomic status				
Low			RC	RC
Medium			1.46** (1.10-1.92)	1.44* (1.09-1.91)
High			1.13 (0.93-1.37)	1.12 (0.92-1.37)
Random effects results				
PSU variance (95%CI)	0.93 (0.80-1.07)	0.69 (0.59-0.81)	0.50(0.42-0.60)	0.81 (0.68-0.98)
ICC	0.22	0.17	0.13	0.13
LR test	$\chi^2 = 1232.58$, $P < .001$	$\chi^2 = 791.15$, $P < .001$	$\chi^2 = 495.80$, $P < .001$	$\chi^2 = 429.18$, $P < .001$
Wald χ^2	Reference	867.18***	474.43***	1136.77***
Model fitness				
Log-likelihood	−10296.41	−9829.99	−10075.29	−9699.42
AIC	20 596.83	19 709.98	20 184.58	19 478.83
BIC	20 613.33	19 916.23	20 324.84	19 808.85
Number of clusters	1388	1388	1388	1388

Abbreviations: AIC, Akaike's information criterion; AOR, adjusted odds ratios; BIC, Schwarz's Bayesian information criteria; CI, confidence interval; ICC, intra-class correlation; LR Test, likelihood ratio test; PSU, primary sampling unit; RC, reference category.
Weighted NDHS, 2018.
Exponentiated coefficients; 95% confidence intervals in brackets.
Model 0 is the null model, a baseline model without any determinant variable.
Model I is adjusted for individual-level variables (Age of child, Sex of child, water source, toilet facilities, maternal age, women's education, partner's education, working status, parity, religious, ethnicity, exposure to mass media).
Model II is adjusted for contextual level variables (Place of residence, wealth index, region, sex of household head, community literacy level, community socio-economic status).
Model III is the final model adjusted for individual and contextual level variables.
*$P < .05$. **$P < .01$. ***$P < .001$.

generalized to women in Nigeria. Additionally, the Geographical Information System (GIS) analysis in the analysis of the spatial distribution enabled us to identify the hotspots of childhood diarrhea in Nigeria, which is a major contribution to the web of literature on childhood diarrhea in Nigeria. Moreover, identifying these childhood diarrhea hotspots would benefit program designers and implementers in their design on context-specific and population-targeted interventions to alleviate childhood diarrhea. Nevertheless, the study was not without some limitations. A major limitation to this study was that the data used was cross-sectional in design, limiting us from establishing causality. Also, the data was self-reported, making it highly susceptible to recall bias and social desirability bias since childhood diarrhea in itself is not socially acceptable.

Conclusion

The study examined the spatial distribution and predictors of diarrhea among under-5 children in Nigeria using the recent NDHS data conducted in 2018. We found that the low and high proportions of diarrhea disease among under-5 children in Nigeria ranged from 0% to 62%. High proportions of diarrhea disease among under-5 children in Nigeria were located in Yobe, Bauchi, Gombe, Kano, Sokoto, Imo, and Taraba. Factors that predict episodes of diarrhea diseases among under-5 children in Nigeria identified were the age of the child, partner's educational level, working status, religious affiliation, mass media exposure, region, and community socioeconomic status. Policies and interventions that seek to reduce or eliminate diarrhea diseases among under-5 children in Nigeria should take a keen interest in the factors identified in this study as this will help in achieving the aims of WASH, ORT corners, and SDG 3 by the year 2030.

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Author Contributions

OAB developed the study's concept and performed the analysis. AS, BOA, OAB, and JBF drafted the study's abstract, introduction, materials and methods, and discussion sections; ZTT performed the spatial analysis. All authors contributed intellectually to the overall development of the manuscript and approved the manuscript's final version for submission.

Data Availability

The datasets utilized in this study can be accessed at https://dhsprogram.com/data/available-datasets.cfm.

Ethical Approval

Since the authors of this manuscript did not collect the data, we sought permission from the MEASURE DHS website and access to the data was provided after our intent for the request was assessed and approved on the 10th of March 2021. The DHS surveys are ethically accepted by the ORC Macro Inc. Ethics Committee and the Ethics Boards of partner organizations in different countries, such as the Ministries of Health. The women who were interviewed gave either written or verbal consent during each of the surveys.

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