FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 6 No. 4, August, 2022, pp 112 - 124
DOI: https://doi.org/10.33003/fjs-2022-0604-1056

SPATIAL DISTRIBUTIONS AND RISK FACTORS OF OVERWEIGHT AND OBESITY AMONG WOMEN IN NIGERIA USING STRUCTURED GEO-ADDITIVE REGRESSION MODELS: ANALYSIS OF 2018 NIGERIA DEMOGRAPHIC HEALTH SURVEY

[1]Chinenye Pauline Ezenweke, *[1]Isaac Adeola Adeniyi, [1]Helen Olaronke Edogbanya, [2]Waheed Babatunde Yahya

[1]Department of Statistics, Federal University Lokoja, P.M.B. 1154, Lokoja, Nigeria
[2]Department of Statistics, University of Ilorin, Ilorin, Nigeria

*Corresponding authors' email: **isaac.adeniyi@fulokoja.edu.ng; aizick.adeniyi89@gmail.com** Phone: +2348167919037

ABSTRACT
Overweight and obesity which are known to pose serious health problems are becoming increasingly prevalent in Nigeria which is a sub-Saharan African country. This study utilized the 2018 Nigeria Demographic Health Survey to examine demographic and socio-economic risk factors of overweight and obesity among Nigerian women aged 15-49 years. Exploratory analysis was used to provide basic description of the data while a semiparametric structured additive models was used to describe the relationship between the presumed factors and overweight and obesity status while also accounting for spatial effects at state level. The national prevalence of overweight and obesity among Nigerian women was found to be 27.4%. Increased risk of overweight and obesity among Nigerian women was found to be strongly associated with being older, high educational level, being rich, living in an urban area, having many children, being pregnant, and residing in southern part of Nigeria. In respect to ethnicity and religion, the Fulani tribe and Islamic religion were associated with lower prevalence of overweight and obesity. Overweight and obesity were found to be significantly more prevalent in the Southern parts compared to the Northern parts of Nigeria. The highest and lowest prevalence of overweight and obesity were observed in Anambra and Yobe states respectively. Prevalence of overweight and obesity was higher among Muslim women compared to Christian women since most Northern women are Muslims and most Southern women are Christians. Random (unstructured) spatial effects were significant indicating that overweigh/obesity was influenced by unobserved state specific factors.

Keywords: Overnutrition; Excess adiposity, Determinants, Reproductive age, Spatial epidemiology

INTRODUCTION
Overweight and obesity, which is the excessive accumulation of the total body fat which (World Health Organization (WHO), 2021), is known to be associated with chronic diseases such as hypertension, diabetes and fertility related issues (Ojofeitimi et al., 2007; Finucane et al., 2011). Individuals who are overweight or obese are more likely to be diagnosed with type 2 diabetes, hypertension, osteoarthritis, some cancers, gall bladder disease among others (Monlux & Nigg, 2011). Obesity usually occurs when an individual is unable to use up as much energy as he/she takes in (Romieu et al., 2017) leading to the individual developing excessive weight gain. Body mass index (BMI), which is calculated by dividing a person's weight in kilograms by the square of the person's height in meters, can be used to determine the quantity of body fat. BMI value of 30 kg/m^2 or more indicate obesity; BMI values ranging from 25 kg/m^2 to less than 30 kg/m^2 indicate overweight; the underweight category is defined by BMI less than 18.5 kg/m^2 while BMI values between 18.5 kg/m^2 and kg/m^2 is an indication of normal weight. In this study when a person has BMI greater than or equal to 25, we refer to the person as being overweight/obese.
In spite all the warnings from the World Health Organization (WHO) concerning the rise of obesity worldwide (WHO Consultation & World Health Organization, 2000), prevalence of obesity has been more than doubled between 1980 and 2008 (McLellan, 2002; Romieu et al., 2017). Recent reports from the World Health Organization (WHO) (WHO, 2021), showed that over 1.9 billion (39%) adults aged 18 years and above were overweight; while over 650 million (13%) of the world's adult population were obese. The reports also show that overweight or obesity are more prevalent in adult women (55%) compared to adult men (50%). Though overweight and obesity were thought of as problems of the western countries, its prevalence is on an increasing trend in developing countries especially in Sub-Saharan Africa. A report of the 2018 Nigeria Demographic and Health Survey (NDHS) (National Population Commission (NPC) [Nigeria] and ICF, 2019) put the prevalence of overweight or obesity among women at 28%. This is higher than previous estimates indicating that prevalence of overweight and obesity in women had been increasing over time. Tagbo et al. (2021) showed that there was an increasing trend in overweight and obesity in women from year 2008 to 2018. Overweight/obesity prevalence among women was estimated as 22.2%, 24.7% and 28% in 2008, 2013, and 2020 respectively. This trend could be explained by the decreasing physical activities due to sedentary lifestyle, and increased consumption of energy-dense foods, and saturated fats (Chigbu et al., 2018).
While overweight/obesity is primarily caused by consuming more calories than expended, there are genetic, socio-economic, socio-cultural, demographic and individual factors that are associated with overweight and obesity. Studies in Nigeria and other countries have shown that overweight/obesity among women are associated with age, locality, educational status, ethnic group, wealth status, and marital status (Tagbo et al., 2021; Chigbu et al., 2018; Asosega et al., 2021; Kamruzzaman et al., 2017; Abrha, 2016; Kandala & Stranges, 2014; Turi et al., 2013; Uthman, 2009).
In Nigeria, a non-communicable disease strategic plan (Non-Communicable Disease Control Programme & Federal Ministry of Health Abuja, 2013) in collaboration with world health organisation (WHO) was established in 2013, but this strategy was not adequately implemented due to lack of resources and enforcement on the part of the government (Juma et al., 2018).

Although, there are many studies on overweight/obesity in Nigeria, most of them are facility based while some that are based on national data did not take spatial distribution into consideration. Hence, this study aimed to characterize the spatial patterns, socio-economic and demographic determinants of overweight/obesity using data from the 2018 Nigeria Demographic and Health Survey (NDHS) (National Population Commission (NPC) [Nigeria] and ICF, 2019). Understanding the geographic distribution of overweight/obesity will prove useful for designing intervention strategy that will target high-risk areas and also create awareness concerning location based risk factors. Structured geo-additive regression models were used to examine the determinants and spatial effects. Descriptive statistics, map plots and Chi-squared tests of independence were used to carry out exploratory analysis.

The rest of the paper is organized as follows: Materials and Methods section which include the data and statistical methods employed; the data summary, exploratory analysis and geo-additive modelling results are presented in the Results section. Detailed discussions and concluding remarks are provided in the Discussions and Conclusion sections respectively.

MATERIALS AND METHODS

Data

The data used in this research were from the 2018 Nigeria Demographic and Health Survey (NDHS) 2018 (National Population Commission (NPC) [Nigeria] and ICF, 2019a) carried out by the National Population Commission (NPC) in Nigeria in 2018. The data for the survey were collected from 14th August to 29th December, 2018. The data collection design makes this study cross-sectional in nature.

The 2018 NDHS used a two stage stratified sampling technique. The first stage stratification involved dividing each of the 36 states and the Federal Capital Territory into urban and rural areas. The map of Nigeria showing the states and their respective geopolitical zones is displayed by Figure 1 (National Population Commission (NPC) [Nigeria] and ICF, 2019, p. xxxviii). A sample of 1400 enumeration areas (EAs) or clusters were selected in the first stage, after which 30 households were selected from each EA leading to a total of about 42,000 households. The selected households were visited and interviewed by trained staff. More details on the sampling technique are provided in the 2018 NDHS report (National Population Commission (NPC) [Nigeria] and ICF, 2019).

Women of reproductive age (15 to 49 years) were identified and interviewed in each household using a well-structured questionnaire. Some Biomarkers information including anthropometry measures and some biomarker information were collected for women and children during the survey. A total of 41821 women were interviewed. However, anthropometry measurements were available for only 13255 women.

Figure 1: Map of Nigeria showing states and geopolitical zones.

Note. Reprinted from "Nigeria Demographic and Health Survey 2018", by National Population Commission (NPC) [Nigeria] and ICF. 2019, October, p. xxxviii.

Study variables

In this study women who are obese or overweight are classified together as overweight/obese. The response variable considered in this study was the overweight/obesity status (overweight/obese and not overweight/obese) of a woman. Women with BMI greater than or equal to 25 were classified as overweight/obese.

The potential risk factors for overweight/obesity examined in this study include: age, highest education level; religion (Christian, Muslim, Others); household wealth index (poorer, poorest, middle, richer and richest); ethnic group; pregnancy status; employment status; and number of children ever born (birth count). Religion was reclassified by putting Christians and Catholics together as Christians while women who couldn't identify ethnic group to which they belong were put under "Other" category.

The households' wealth status classification is based on the DHS wealth index scheme (Rutstein & Kiersten, 2004) in which each household is classified as either Richest, Richer, Middle, Poorer or Poorest with each category comprising 20% of the population using household characteristics such as source of drinking water, toilet facilities, flooring materials, ownership of television, bicycle or car.

Data Analysis Techniques

In this study, a geo-additive semi-parametric binary logistic regression (Fahrmeir et al., 2013, Adebayo & Yahya, 2014) with a logit link function was adopted to model the effect of risk factors on the overweight/obesity status. Let $y_{ij} = 1$ if the ith woman from the jth state is overweight/obese and $y_{ij} = 0$ if otherwise, that is, y_{ij} follows a Beroulli distribution with parameter π_{ij}. Then, the model is given as

$$\eta_{ij} = \beta_0 + X_{ij}^T\beta + f_1(Z_{1ij}) + \cdots + f_k(Z_{kij}) + f^{str}(state_j) + f^{unstr}(state_j), \quad (1)$$

where,

$$\eta_{ij} = \frac{\pi_{ij}}{1-\pi_{ij}},$$

where, $\pi_{ij} = P(y_{ij} = 1)$ represents the probability that the ith woman from the jth state is overweight/obese; $X_{ij}(p \times 1)$ represents a vector of covariates corresponding to the ith case in region (state) j, $j \in (1,\ldots,R)$; β_0 is the unknown regression intercept; $\beta(p \times 1)$ is a vector of unknown regression coefficients representing linear fixed effects; Z_{lij}, $l = 1, \ldots, k$, is lth structured covariate corresponding to the ith case in state j; f_l $l = 1, \ldots, k$ functions of the covariates which are (not necessarily smooth); f^{str} and f^{unstr} are functions of correlated structured and unstructured spatial (states) effects respectively. The structured spatial effect $f^{str}(state_j)$ accounts for the assumption that states close in proximity are more likely to share some similar characteristics. However, the unstructured spatial effect $f^{unstr}(state_j)$ accounts for the random spatial variation due to effects of unmeasured state-level factors. The functions f_l usually are nonlinear effects of continuous predictors, time trends and seasonal effects, two-dimensional surfaces, varying coefficient models, random intercepts and slopes as well as spatial effects. It should be noted that the spatial factor is "state" (36 states of Nigeria and Federal Capital Territory Abuja).

The unknown nonlinear functions f_l in (1) and (2) were estimated by penalised splines (P-splines) (Eilers & Marx, 1996) using 20 knots and third degree splines. In this approach, the unknown functions are can be expressed as

$$f(Z) = \sum_{h=1}^{K} \gamma_h B_h(Z). \quad (2)$$

where, Z is expressed as equally spaced knots, $K = m + s$, m is number of knots and s is the degree, $\gamma_h = (\gamma_1, \ldots, \gamma_K)^T$ are unknown regression coefficients which are usually assigned first- or second-order random walk priors which are modelled by $\gamma_k = \gamma_{k-1} + u_k$ *and* $\gamma_k = 2\gamma_{k-1} - \gamma_{k-2} + u_k$ respectively where $u_k \sim N(0, \sigma^2)$ are Gaussian errors. In this study, $K = 23$.

The structured component of the spatial effects $f^{str}(state_j)$ was modelled by a Markov Random Field (MRF) (Fahrmeir et al., 2013) which defines two states, $state_r$ and $state_s$ as neighbours if they share a common boundary. Suppose the connected geographical states are indexed by $s \in \{1, \ldots, R\}$, the spatial smoothness prior for the function $f^{str}(state_j)$ evaluations is given by

$$f^{str}(state_j) | f^{str}(state_{j'}), j \neq j', \sigma_{str}^2 \sim N\left(\frac{1}{N_j}\sum_{j' \in \theta_j} f^{str}(state_{j'}), \frac{\sigma_{str}^2}{N_j}\right), \quad (3)$$

where N_j is the number of adjacent states and $j' \in \theta_j$ denotes that state j' is a neighbor of state j. The variance component σ_{str}^2 acts as smoothing parameter and also describes the spatial variation between the states.

The random (unstructured) part of the spatial effects $f^{unstr}(state_j)$ was modelled by independent and identical Normally distributed random effects term, that is, $f^{unstr}(state_j) = b_j$ with $b_j \sim N(0, \sigma_{unstr}^2)$, $j = 1, \ldots, H$. In this case, $H = 37$ since there are 37 levels of the spatial factor (36 states and the federal capital territory).

The model in equation (1) is a structured additive regression model that includes the generalized linear models (GLMs), generalized additive model (GAMs), generalized mixed effects models (GLMMs) as special cases. The model also allows inclusion of spatial effects and nonlinear effects additively. The models were fitted based on the mixed effects model methodology (Fahrmeir et al., 2013; Adeniyi et al., 2018) in which the regression coefficients are estimated from penalized likelihood using restricted maximum likelihood technique while the variance components are estimated from their marginal likelihood (Harville, 1977; Fahrmeir et al., 2004). Additional information on structured mixed effects modelling techniques can be found in Fahrmeir et al. (2004) and Fahrmeir et al. (2013).

The data were prepared and cleansed using R version 4.1.0 (R Core Team, 2021) while the models were estimated using Bayes X version 3.0.2 (Belitz et al., 2015) through the

R2BayesX (Umlauf et al., 2015) R package. Descriptive and exploratory analysis were likewise carried out in R. The Akaike Information Criterion (AIC) (Sakamoto et al., 1986; Adeniyi et al., 2018) was used to determine the final model, selection of smoothing parameters, and determine if a spatial effect is necessary and which effect should be linear (fixed) or modelled structurally. The model with a lower AIC compared to another model is considered to be better. P values were computed for determining statistical significance at 5% significance level.

RESULTS

The final data used for this study after cleaning involved 13255 women aged 15 to 49 years. The women who are overweight or obese are classified together into the same category labelled overweight/obese. Table 1 presents the summary statistics on the data and prevalence (%) of overweight/obesity with respect to various socio-economic and demographic factors, as well as, chi-square statistics and p values corresponding to bivariate chi-square tests of association between overweight/obesity status and categorical variables.

Descriptive and Exploratory Analysis

The overall observed prevalence of overweight/obesity women in Nigeria was 27.4%. Women in urban areas were seen to be significantly (p value < 0.001) more overweight/obese with 36.1% prevalence compared to the women living in rural area (21.3%). The results also showed that there is a significant increase in prevalence of overweight/obesity with an increase in women's education level (p value < 0.001) and wealth class (p value < 0.001). Regarding educational level, the lowest prevalence (15.8%) and highest prevalence (48.9%) were observed among women with only primary education and higher education qualifications respectively. With respect to wealth class, prevalence of overweight/obesity was highest (47.3%) among women in the "richest" category while pregnant women in the "poorest" group yielded the lowest overweight/obesity prevalence (9.6%).

More so, it was observed that with increase in the age of women, there is a significant (p value < 0.001) increase in the prevalence of overweight/obesity. Women in the 15-19 years age group gave the lowest prevalence (7.8%) while highest prevalence of overweight/obese can be seen to be women in the 45-49 years age group. Also, prevalence of overweight/obesity was shown to be higher (36.0%) among women practicing Christianity religion compared to women practicing Islam (18.2%) and others (31.4%).

The results also showed that overweight/obesity in women was strongly associated (p value < 0.001) with number of children ever born by a woman. Women who had never given birth were observed to have the lowest overweight/obesity prevalence (15.2%) while women with 4-5 birth counts gave the highest prevalence (36.1%).

Furthermore, prevalence of overweight/obesity was strongly related to employment status (p value < 0.001). A higher prevalence (32.0%) was observed among employed women compared to unemployed women (18.7%). Also, overweight/obesity was significantly (p value = 0.03) related to current pregnancy status with pregnant women displaying higher prevalence (29.8%) compared to women who were not pregnant or unsure about their pregnancy status (27.2%).

From the results, overweight/obesity is strongly associated with ethnic group with the Fulani and the Ijaw/Izon tribes producing the lowest (11.0%) and highest (43.1%) prevalence respectively. The Kanuri/Beriberi and Igbos tribes had the second lowest (11.1%) and second highest (41.1%) overweight/obesity prevalence. The prevalence of overweight/obesity among the Yoruba, Hausa, Ibibio, Igala, Ekoi, Tiv and other tribes are 34.5%, 16.0%, 36.6%, 32.9%, 31.5%, 25.0% and 27.8% respectively

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Table 1: Demographic and social-economic summaries, and weight status of study participants

Factor	N (%)		χ^2 (p value)
	Not Overweight/Obese	Overweight/Obese	
Total	10792 (72.6)	4080 (27.4)	
Age (Mean=29.3, SD=9.5)			
15-19	2577 (92.2)	218 (7.8)	
20-24	1965 (83.1)	399 (16.9)	
25-29	1948 (72.6)	737 (27.4)	
30-34	1503 (66.0)	773 (34.0)	1179.9 (<0.001)
35-39	1251 (60.8)	808 (39.2)	
40-44	815 (59.5)	555 (40.5)	
45-49	733 (55.4)	590 (44.6)	
Type of Area of Residence			
Rural	6858 (78.7)	1859 (21.3)	394.0 (<0.001)
Urban	3934 (63.9)	2221 (36.1)	
Education			
No Education	4048 (84.2)	761 (15.8)	
Primary	1658 (70.0)	710 (30.0)	707.7 (<0.001)
Secondary	4317 (69.8)	1872 (30.2)	
Higher	769 (51.1)	737 (48.9)	
Wealth Class			
Poorest	2311 (90.4)	245 (9.6)	
Poorer	2376 (82.9)	491 (17.1)	
Middle	2475 (75.1)	820 (24.9)	1250.4 (<0.001)
Richer	2107 (64.5)	1158 (35.5)	
Richest	1523 (52.7)	1366 (47.3)	
Religion			
Christian	4878 (64.0)	2739 (36.0)	581.7 (<0.001)
Islam	5820 (81.8)	1298 (18.2)	

Other	94 (68.6)	43 (31.4)	
Number of children ever born (Mean=3.2, SD=2.9)			
0	3186 (84.8)	571 (15.2)	
1	1284 (72.5)	487 (27.5)	
2-3	2320 (68.8)	1051 (31.2)	425.2 (<0.001)
4-5	1793 (63.9)	1014 (36.1)	
>5	2209 (69.8)	957 (30.2)	
Currently Pregnant			
Yes	1081 (70.2)	458 (29.8)	4.53 (0.03)
No/Unsure	9711 (72.8)	3622 (27.2)	
Employed			
No	4143 (81.3)	950 (18.7)	299.3 (<0.001)
Yes	6649 (68.0)	3130 (32.0)	
Ethnic group			
Yoruba	1351 (65.5)	713 (34.5)	
Igbo	1470 (58.9)	1025 (41.1)	
Fulani	860 (89.0)	106 (11.0)	
Hausa	2956 (84.0)	565 (16.0)	
Ibibio	192 (63.4)	111 (36.6)	
Igala	104 (67.1)	51 (32.9)	764.7 (<0.001)
Ijaw/Izon	275 (56.9)	208 (43.1)	
Kanuri/Beriberi	273 (88.9)	34 (11.1)	
Ekoi	74 (68.5)	34 (31.5)	
Tiv	276 (75.0)	92 (25.0)	
Other	2961 (72.2)	1141 (27.8)	
Geopolitical Zone			
North-Central	2006 (72.3)	770 (27.7)	
North-East	2158 (84.1)	407 (15.9)	
North-West	2753 (84.1)	520 (15.9)	753.8 (<0.001)
South-East	1300 (61.6)	810 (38.4)	
South-South	1160 (60.3)	764 (39.7)	
South-West	1415 (63.6)	809 (36.4)	

The results also pointed out that there is significant relationship between geopolitical zone and overweight/obesity status (p value < 0.001). From the results, one can observe that the South-South (SS) zone had the highest overweight/obesity prevalence (39.7%) while the North-East (NE) zone had the lowest overweight/obesity prevalence (15.9%). The prevalence of overweight/obesity in the South-West (SW), South-East (SE), North-Central (NC), and North-West (NW) zones are 36.4%, 38.4%, 27.7% and 15.9% respectively. This indicates that overweight/obesity prevalence increased as we move from the Southern to the Northern region of Nigeria.

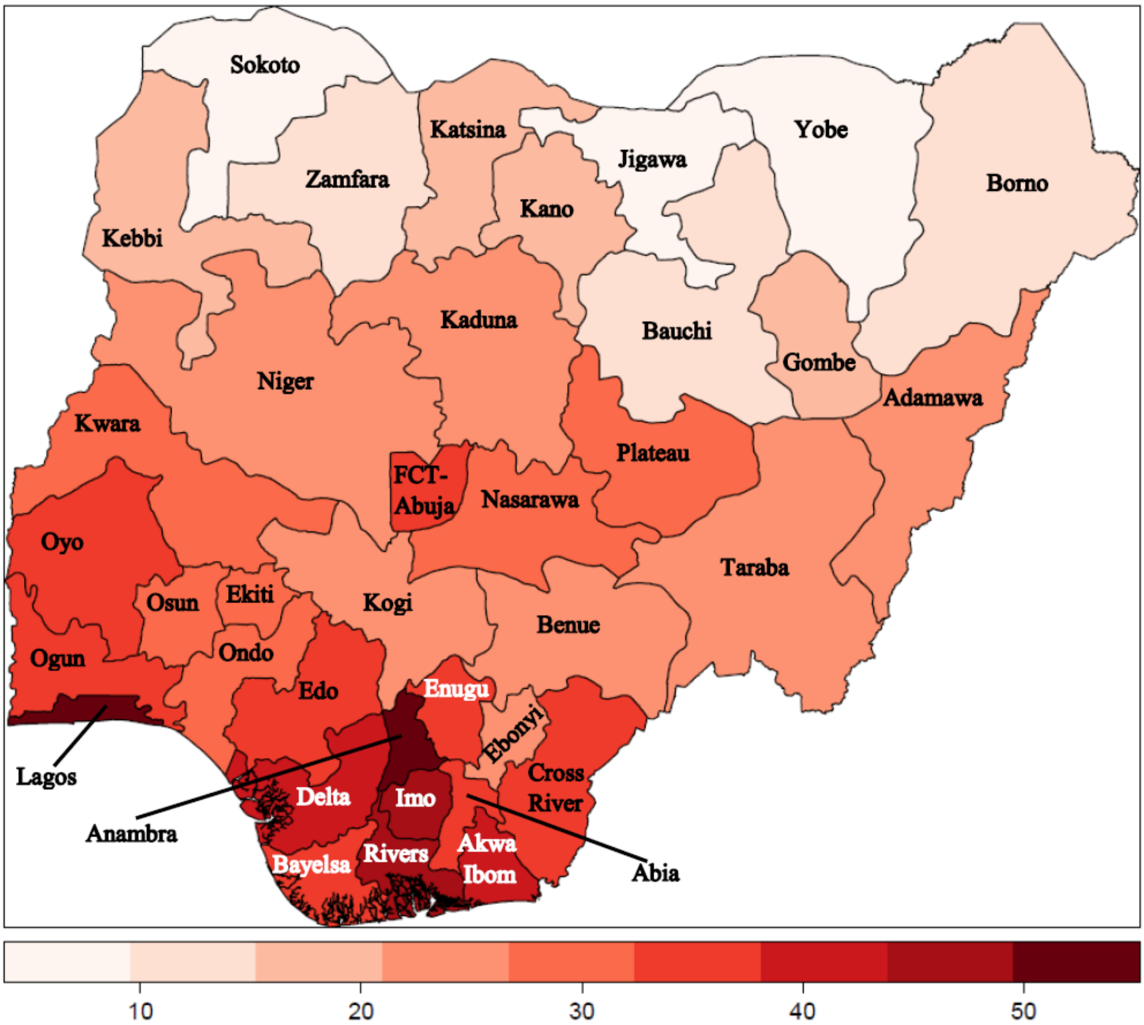

Figure 2: Prevalence of overweight/obesity in Nigerian women by state.

A heat map of Nigeria showing the prevalence of overweight/obesity among Nigerian women with respect to the 36 states and FCT Abuja is shown by Figure 2. The plot indicates that the prevalence of overweight/obesity was highest in Anambra state (57.5%) followed by Lagos state (56.6%) and then Rivers state (51.7%). On the other hand, the lowest overweight/obesity prevalence was observed in Yobe state (5.9%) followed by Jigawa (8.0%) and then Sokoto (8.3%) states.

Structured Geo-additive Modelling

Model Selection

In this research, structured geo-additive logistic regression models based on the GLMM framework were used to model the effects of various factors considered on overweight/obesity status which is a binary variable. A number of models were fitted and compared to determine which of the continuous covariate should be modelled as fixed linear effects or nonlinear effects and if spatial effects should be structured, unstructured or combination of both. Using the AIC, the results indicate that the effects of age should be considered as nonlinear effects for which were therefore estimated semi-parametrically by P-splines. It should be noted that the variable "geopolitical zone" was not included as a predictor in the model because spatial effects terms with respect to state were included in the model. The results are presented in Table 2 and Figures 3 and 4.

Fixed Effects

The results in Table 2 include estimates of the fixed effects, odds ratios (OR), with corresponding standard errors and p values, and structured and random spatial effects variance components. The term "ref" indicates the reference category. The results indicate that the effects of educational level, wealth index, ethnic group, number of children ever born and current pregnancy status on overweight/obesity are significant. Higher educational level, higher wealth class, being a Christian, higher birth counts, and being pregnant would lead to increased risk of overweight/obesity. The odds of overweight/obesity for women in the "middle" wealth class were about 2.2 (p value < 0.001) times that of women in the "poorest" while the odds of overweight/obesity for women in the "richest" class were about 4.7 times that of women in the "poorest" class. Similarly, the odds of overweight/obesity for women in the "poorer" and "richer" wealth class were about 1.5 (p value < 0.001) and 3.3 (p value < 0.001) times respectively that of women in the "poorest" wealth class. The odds of overweight/obesity for women with up to tertiary level education were about 1.7 (p value < 0.001) times that of women who had no education while the odds of overweight/obesity for women with only primary education were about 1.2 times that of women who had no education. The odds of overweight/obesity for women educated up to secondary level were about 1.4 (p value < 0.001) times that of women no education. Also, the odds of a woman living in an urban area being overweight/obese were significantly higher (OR = 1.2, p value = 0.001) than that of a woman living in a rural area. The odds of a Christian woman being overweight/obese were about 1.2 (p value = 0.031) times that of a Muslim woman.

In contrast to results from the bivariate analysis, the odds of overweight/obesity for employed women (OR = 1.06, p value = 0.294) were not significantly different from that of unemployed women. This observation can be explained by the fact that employment status is strongly associated with wealth status and education. Hence, after accounting for wealth status, education and other factors, the spurious effect of employment status on overweight/obesity was eliminated leading to non-significance of the marginal effect of employment status.

Furthermore, the results show that the odds of overweight/obesity for a pregnant woman were about 1.6 (p value < 0.001) times that of a non-pregnant woman. The risk of overweight/obesity for women who had given birth to six or more children was about 1.3 (p value = 0.021) times that of a woman who had never given birth. Also, women who had given birth once had significant higher odds of overweight/obesity (OR = 1.4; p value < 0.001) compared to women who had never given birth. Similarly, the odds of overweight/obesity for women had never given birth child were significantly lower than that of women who had given birth to 2 to 3 children (OR = 1.2; p value = 0.014) and those with 4 to 5 children (OR = 1.4; p value < 0.001).

Table 2: Results from Geo-additive model showing the estimated fixed effects on odds of overweight/obesity, odds ratio (OR) and corresponding standard errors (SE) and p value as well as variance parameters.

	Estimate (β)	**OR**	**SE**	**t value**	**P value**
(Intercept)	-2.966	-	0.154	-19.212	<0.001
Wealth Index (ref = Poorest)					
Poorer	0.423	1.526	0.090	4.705	<0.001
Middle	0.791	2.205	0.090	8.800	<0.001
Richer	1.193	3.298	0.095	12.566	<0.001
Richest	1.538	4.655	0.104	14.790	<0.001
Education (ref = No education)					
Primary	0.203	1.225	0.073	2.795	0.005
Secondary	0.304	1.356	0.073	4.168	<0.001
Tertiary	0.510	1.665	0.093	5.502	<0.001
Residential Area (ref = Rural)					
Urban	0.171	1.186	0.051	3.327	0.001
Religion (ref = Islam)					
Christianity	0.151	1.163	0.070	2.162	0.031
Traditionalist/Others	0.048	1.049	0.223	0.215	0.830
Currently Employed (ref = No)					
Yes	0.054	1.056	0.052	1.049	0.294
Currently Pregnant (ref = No)					
Yes	0.446	1.562	0.068	6.577	<0.001
Number of children ever born (ref = 0)					
1	0.321	1.379	0.084	3.805	<0.001
2-3	0.198	1.220	0.080	2.470	0.014
4-5	0.336	1.399	0.089	3.765	<0.001
>5	0.228	1.256	0.098	2.312	0.021
Ethnic Group (ref = Fulani)					
Yoruba	0.181	1.198	0.155	1.169	0.242
Igbo	0.728	2.072	0.161	4.519	<0.001
Hausa	0.228	1.256	0.128	1.779	0.075
Ibibio	0.525	1.690	0.206	2.547	0.011
Igala	0.762	2.143	0.242	3.155	0.002
Ijaw/Izon	1.000	2.719	0.203	4.927	<0.001
Kanuri/Beriberi	0.070	1.073	0.235	0.299	0.765
Tiv	0.839	2.315	0.216	3.888	<0.001

Ekoi	0.466	1.593	0.293	1.588	0.112
Other	0.496	1.643	0.130	3.826	<0.001
Variance Parameters					
σ^2_{str}	0.01	-	-	-	-
σ^2_{unstr}	0.08	-	-	-	-
σ^2_{Age}	0.004	-	-	-	-

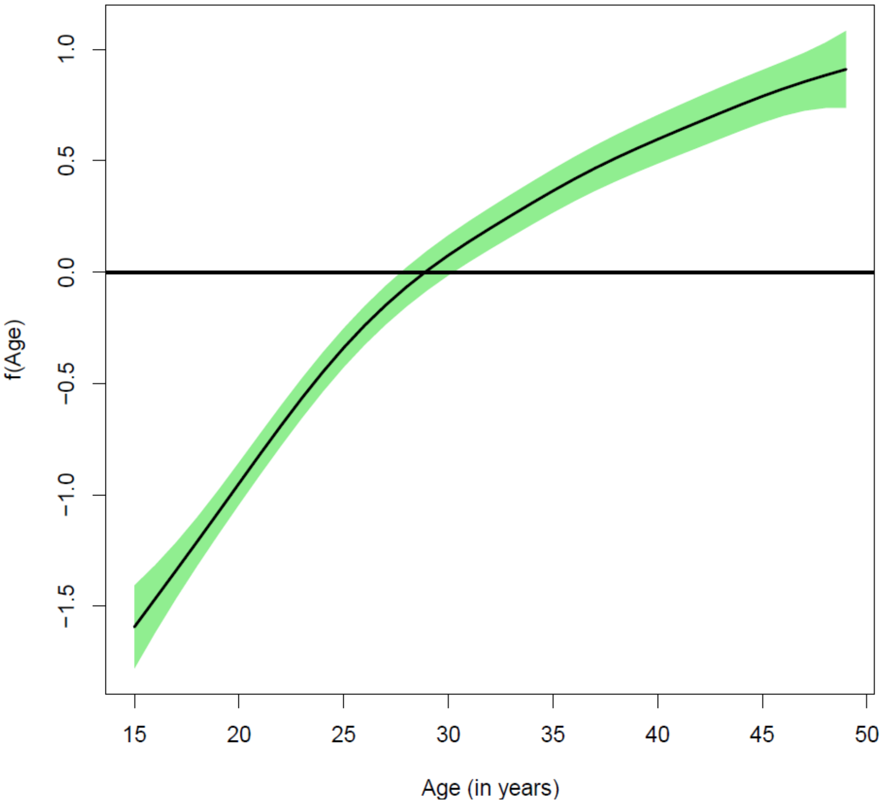

Figure 3: Estimated nonlinear effects of age on odds of obesity. The green band represents the 95% CI.

The odds of overweight/obesity for women from the Igbo, Igala, Tiv, Ibibio, and Ijaw/Izon ethnic groups were 2.1 (p value < 0.001), 2.1 (p value = 0.002), 2.3 (p value < 0.001), 1.7 (p value = 0.011), and 2.7 (p value = 0.001) times that of Fulani women respectively. Though not significant, the odds ratio of overweight/obesity in Yoruba, Hausa, Kanuri/Beriberi, and Ekoi women in comparison with Fulani women were 1.2 (p value = 0.242), 1.2 (p value = 0.075), 1.1 (p value = 0.916) and 1.6 (p value = 0.11) respectively. Women from tribes other than those identified were significantly more at risk of overweight/obesity compared to Fulani women (OR = 1.6, p value < 0.001).

Nonlinear Effects

Figure 3 depicts the nonlinear effects age on odds of overweight/obesity and corresponding 95% confidence intervals (CIs) represented by the shaded blue band. The plot indicate odds of overweight/obesity increased with increase in age. The CIs do not include zero for most of the effects estimates indicating that the effect of age is strongly significant.

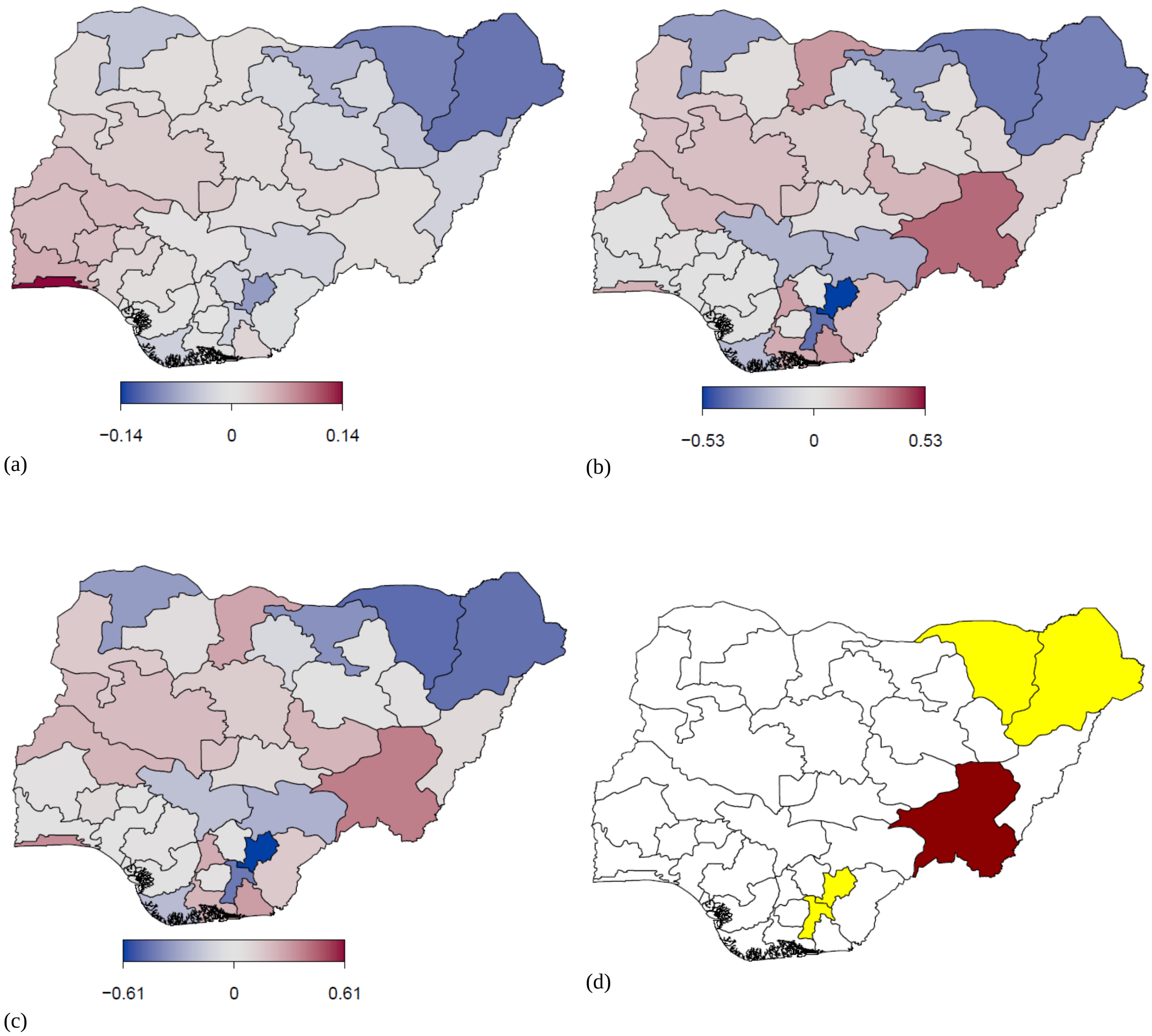

Figure 4: Maps of Nigeria showing (a) structured spatial effects, (b) unstructured spatial effects, (c) total spatial effects, (d) 95% CI of the unstructured spatial effects on odds of overweight/obesity.

Spatial Effects

Table 2 contains estimates of the variance components of the spatial effects in the Model while Figure 4 displays map plots of the spatial effects with respect to Nigerian states. From the plots, estimates of the total spatial effects ranged from about -0.61 to 0.39.

The estimates of the structured components of the spatial effects ranged from -0.11 to 0.14 with a variance component of 0.03 while unstructured (random) spatial effects ranged from about -0.52 to 0.37 with a variance component of about 0.07. Figures 4(a), 4(b) and 4(c) represent structured, unstructured and total spatial effects on odds of overweight/obesity respectively for all 37 states. In the map plots, darker colours (red or blue) indicate stronger spatial effect. The map plot for the total spatial effects is similar to that of the unstructured spatial effects because the random spatial effects were more dominant than that of the structured effects. States with lower prevalence of overweight/obesity were associated with negative spatial effects represented by blue colour while states with high prevalence had positive spatial effects represented by red colour.

Figure 4(d) indicates which of the unstructured spatial effects were significant based on 95% CI. There is no 95% CI plot for structured spatial effects because no state had a significant structured spatial effect. The spatial effect is significant if its CI doesn't include 0. The States with dark red colour are associated with significant positive spatial effects while those coloured yellow are associated with significant negative spatial effects. Only Taraba state was associated with significant random positive spatial effects on overweight/obesity while Yobe, Borno, Ebonyi and Abia states had significant negative random spatial effects. The non-significance of the structured spatial effects may be due to the presence of ethnicity since many states share ethnicity with some other states. During our analysis, excluding ethnicity from the model made the structured spatial effects to become significant.

DISCUSSION

This study analyzes determinants and spatial distributions of overweight and obesity among Nigerian women aged 15-49 years in Nigeria using the 2018 NDHS dataset. Women who are overweight or obese were classified together as overweight/obese. Exploratory analyses including the Chi-squared tests of association were carried out to provide descriptive summaries and show bivariate associations between overweight/obesity and various demographic and socio-economic factors. A structured semi-parametric geoadditive binary logistic regression model was fitted to examine the effects of factors considered on overweight/obesity status of Nigerian women while accounting for unobserved spatial effects. The final model was selected based on the BIC.

The national prevalence estimate of overweight/obesity among Nigerian women was 26.9% which is higher than those reported in most previous population based studies in Nigeria (Tagbo et al., 2021; Uthman, 2009; Okoh, 2013; Kandala & Stranges, 2014). This findings suggest that there is an increasing trend of overweight/obesity among Nigerian women. On the other hand, the estimated prevalence value is lower than estimates from most previous facility or locality based studies (Abubakari and Bhopal,2008; Desalu et al., 2008; Adedoyin et al., 2009; Amira et al., 2011; Oyeyemi et al., 2012; Chukwuonye et al., 2013). The estimated lower prevalence compared to previous facility or locality based studies can be attributed to variations in demographic, socio-economic, socio-cultural and geographical factors. For example, the average age of the women in this study was 29.8, whereas most of the facility or locality based studies were targeted at middle-aged individuals, among whom overweight/obesity prevalence is projected to be higher since our analysis showed that the highest prevalence of overweight/obesity was observed for women within 35-39 years age group.

Results from bivariate analyses showed that overweight/obesity among Nigerian women is strongly associated with woman’s age, education, wealth index, religion, type of residential area, employment status, number of children ever born, ethnicity, region and current pregnancy status. However, results from the geo-additive modelling showed that, after accounting the effect of other factors, religion and employment status were not significantly associated with risk of overweight/obesity. As observed by previous studies (Tagbo et al., 2021; Kandala & Stranges, 2014; Balarajan & Villamor; 2009, Uthman, 2009; Neuman et al., 2011; Poehlman, 1993), increase in age resulted to increase in risk of a woman being overweight and obese. This could be due to age-related increase in weight which can be caused by reduction in physical activities, since younger women are likely more engaged in physical activity compared to older women. Pregnancy and child birth are age related factors that could also lead to increased weight.

Also, findings from this study, in agreement with previous studies (Asosega et al., 2021; Tagbo et al., 2021; Kandala & Stranges, 2014; Uthman, 2009), show that highly educated women and women from richer households were more likely to be overweight/obese compared to poorer and less educated women respectively. This may be explained by the fact that affluent women in Nigeria are more likely to have a diet filled with processed and energy-dense food. This can also be said of highly educated women as there is strong positive correlation between wealth status and education. Though preliminary analysis showed that women who were employed were significantly more probable to be overweight/obese compared to unemployed women as had been reported by some previous studies (Uthman, 2009), the observed difference due to employment status seemed to be spurious and may actually be caused by the strong correlation between wealth class and employment status. This was supported by the results of the geo-additive modelling which showed that employment status was not significantly associated with overweight/obesity after accounting for other factors.

The results also indicate that prevalence of overweight/obesity is significantly higher among women living in urban areas compared to women living in rural areas as also reported by previous studies in Nigeria (Tagbo et al., 2021; Kandala & Stranges, 2014; Uthman, 2009). This could be as a result of how prone people in urban areas are to eating processed and energy-dense food while people who live in rural areas eat more natural food as they are more into farming and easily have access to fresh natural food from farm (Akinyemi et al., 2021). Also, people in urban areas use automobiles more for movement compared to rural people who walk distances to farm and places with no access road leading to increased physical activity.

The results suggested that Muslim women were associated with significantly lower prevalence of overweight/obesity compared to Christian women. This could be due to the fact that religion in Nigeria is differentiated by ethnicity and geographical regions, for example, Fulani and Hausas are mostly Muslims while Igbos, Ijaws and Ibibios are mostly Christians. Similarly, people from the North-Eastern and North-Western part of Nigeria, where prevalence of overweight/obesity is lowest, are predominantly Muslims.

Additionally, the risk of overweight/obesity for women increases with number of children ever born. This finding could be attributed to weight gain associated with pregnancy which many women do not lose after giving birth. Also, women with more children are older and more likely to have larger BMI. The results from this study also indicate that overweight/obesity is more prevalent among pregnant women than in non-pregnant women. This is expected since women generally gain weight when pregnant.

The results from this study also show that prevalence of overweight/obesity among women strongly varied between the six regions (geopolitical zones) of Nigeria with the North-Eastern and North-Western parts of Nigeria exhibiting significantly lower prevalence and South-Southern part showing the highest prevalence. Similarly, women from the Fulani, Kanuri/Beriberi and Hausa tribes were found to be significantly less likely to be overweight/obese compared to women from other tribes. Women from the Ijaw/Izon and Igbo tribes were associated with significantly higher risk of overweight/obesity. One of the major reasons for this could be due to the dietary differences between tribes, and then between the southern and northern part of Nigeria. Also, individuals from the Northern part of Nigeria especially Hausas and Fulani mostly lead lives that require rigorous physical activity such as farming which probably makes them have slender stature throughout their lives. Also, the slender stature of the Hausas and Fulani seem to be genetic as they are rarely fat.

The results from the analyses showed clear spatial variability in prevalence of overweight/obesity among the 37 states in Nigeria with Anambra, Lagos and Rivers states exhibiting the highest prevalence while Yobe, Jigawa and Sokoto states having the lowest prevalence. All the states with high prevalence of overweight/obesity are in the southern part of Nigeria while the states with low prevalence are in Northern part.

Furthermore, after accounting for socio-economic, demographic and other factors considered in this study, the analyses showed that there are significant unobserved spatial factors at state level associated with overweight/obesity. The non-significant structured correlated spatial effects suggest that overweight/obesity is not influenced by unobserved geographical and environmental factors that transcend boundaries of the states. This also implies that state-level effect on odds of overweight/obesity was not similar among states. On the other hand, the random spatial effects of Anambra, Rivers, Akwa-Ibom, Adamawa, Katsina, Yobe, Jigawa, Ebonyi and Abia states on risk of overweight/obesity was significant indicating that there are unobserved variables that are peculiar to the women in these states that could be associated with overweight/obesity.

The significant spatial effects may be due to unobserved factors not captured by the covariates in the data and models, and identifying them may only be based on speculation. The geographical variation in lifestyle, diet and infections, such as HIV, malaria, hookworms, and helminths, could be one cause of such spatial variation. For instance, people from Anambra state eat a lot of food derived from cassava.

CONCLUSION

This study has provided insight into spatial distribution of the prevalence of overweight and obesity among Nigerian women while also examining associations with demographic and socio-economic factors. Overweight and obesity in Nigerian women were found to be strongly associated with age, educational attainment, wealth index, religion, employment status, area of residence, number of children ever born, pregnancy status and region of residence. Geo-additive structured models showed that being older, high educational level, affluence, not being a Fulani, living in an urban area, having many children, being pregnant, and living in the southern part of Nigeria were associated with increased risk of overweight and obesity. Prevalence of overweight and obesity was also more in Muslim women compared to Christian women. Overweight and obesity prevalence among Nigerian women was highest in the South-Southern part of the country and Anambra state produced the highest prevalence of overweight and obesity. On the other hand, the North-Eastern and North-Western parts of Nigeria showed the lowest overweight/obesity prevalence with Yobe producing the lowest prevalence in Nigeria. The significant random (unstructured) spatial effects indicate that overweight and obesity intervention programmes may be designed differently from state to state. A limitation of this study is its inability to incorporate other potential factors of overweight and obesity such as dietary information, information on physical activities, and individual biomarkers and genetic information due to unavailability of data, hence, future studies could consider these factors.

ACKNOWLEDGEMENT

We are grateful to the Demographic Health Survey (DHS) program/ICF international and the National Population Commission (NPC) [Nigeria] for providing access to the data used in this study.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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