

PREDICTING NUTRITIONAL STATUS IN NIGERIAN WOMEN OF REPRODUCTIVE AGE: A HYBRID MULTINOMIAL LOGISTIC REGRESSION MODEL AND NEURAL NETWORK APPROACH

ABDULAZEEZ, K. A¹, LASISI K. E², A. AHMED², I. A. ISHAQ², A. BISHIR² AND M. U. BAWA²

¹Federal College of Freshwater Fisheries Technology, Baga, Borno State, Nigeria.

²Department of Statistics, Abubakar Tafawa Balewa University, Bauchi, Nigeria

Corresponding Author: kazeemade2@gmail.com

DOI Link: <https://doi.org/10.70382/bejsmsr.v9i9.014>

ABSTRACT

This study developed a hybrid predictive model combining Multinomial Logistic Regression (MLR) and Neural Network (NN) Approach to assess and predict nutritional status among Nigerian WRA. Utilizing data from Multiple Indicator Cluster Survey 6 (MICS 6), the hybrid model evaluated the predictor variables of underweight, overweight and obesity using normal weight as the baseline category. Key determinants (predictor variables) include age, women education, access to mass media, availability of sufficient water when needed, iodized salt consumption, geo-political zone and ethnicity. Model evaluation performance indicated robust predictive accuracy of the hybrid model in this study which correctly predicted (APE) 87.3% of the outcomes in the training datasets while the Expected Prediction Error (EPE) provides a more realistic estimate of the model's performance on large datasets, as

Introduction

The global prevalence of malnutrition remains at persistently high rates and accounts for substantial increases in morbidity and mortality, particularly in lower and middle-income countries (GNP, 2020). Obesogenic factors and overweight are increasingly coexisting with high levels of undernutrition, causing a double burden in many developing nations (Ahmed *et al.*, 2020). According to global estimates, 9% of adults have a BMI of less than 18.5 kg/m², which is considered underweight (Dagnev and Asresie, 2020) while according to the World Health Organization's

opposed to Apparent Prediction Error (APE) which is based on the training data. It was revealed in this study that the hybrid model Expected Prediction Error (EPE) is expected to correctly predicted approximately 87.8% of the outcomes in new, unseen data with very low Standard Error of 0.003 which implies that variability of the estimate is low which is an indication of better performance of the hybrid model developed in this study for prediction over the traditional multinomial logistic regression model. The study provides insights for targeted nutritional interventions and policy formulation to improve health outcomes for WRA in Nigeria. It is recommended that collaboration among government agencies, international organizations and local stakeholders is very essential to ensure effective implementation of nutrition policies and programmes.

KEYWORDS: Nutritional Status, Women of Reproductive Age, Multinomial Logistic Regression, Neural Networks, Hybrid Model, Predictive Accuracy.

2021 report, being overweight or obese causes 2.3% of all disability-adjusted life years (DALYs) worldwide and at least 2.8 million deaths per year. A body mass index (BMI) of less than 18.5 kg/m² in adults is indicative of chronic energy deficiency, also known as underweight, a type of undernutrition (Dagnew and Asresie, 2020; Wubie *et al*, 2020).

Globally, 9.4% of WRA suffer from undernutrition; the prevalence is up to ten times higher in low- and middle-income countries than in high- and upper-middle-income countries, disproportionately affecting those in these countries (Dagnew and Asresie, 2020). For example, underweight is more common among younger and less educated women, whereas overweight or obesity is more common among older women and those with higher education levels, such as those at the university level and beyond (Ahmed *et al*, 2020; Mangemba and San, 2020).

In contrast to high-income nations, obesity and education have a positive correlation in low-income nations. This is ascribed to epidemiologic and nutritional shifts in low- and middle-income nations, such as urbanisation and socioeconomic status rises coupled with sedentary lifestyles, increased consumption of processed foods, and weight gain (Ahmed *et al*, 2020; Mangemba and San, 2020).

The nutritional status of WRA may be influenced by specific factors at the household level. Socioeconomic status and household wealth are two examples of such factors. Underweight women are more likely to be those who fall into the lowest wealth index (Dagnew and Asresie, 2020). With higher wealth indices, this positive correlation might not be as obvious (Song *et al*, 2020).

As per the World Health Organization (WHO)—malnutrition encompasses a combination of both over-nutrition or undernutrition leading to a transformation in

body composition, outcome, and/or reduced body function (WHO, 2021). The term malnutrition covers three comprehensive groups of conditions: undernutrition (*wasting, stunting, and underweight*); over-nutrition (*overweight and obesity*); and micronutrient-related malnutrition (King, *et. al.*, 2015). On the other hand, the double/dual burden of malnutrition (DBM) is characterized by the coexistence of both undernutrition and overweight/obesity in the same population. This can be within particular/respective individuals, households, and communities and can spread across the life-course (Sekiyama *et. al.*, 2015; Ramires *et. al.*, 2014).

Generally, in any context, the DBM becomes distinct in any population when reduction in one form of malnutrition becomes slower than the progression of the other form. This means that in any population, the DBM will be more apparent when the reduction rate of undernutrition is slower than the increasing rate of over-nutrition (Kiman *et. al.*, 2015).

Despite much improvements in many human development indexes, nearly one in three people around the world is living with at least one type of malnutrition (WHO, 2021). In 2014, almost 462 million adults globally were underweight, and another 1.9 billion were overweight or obese (NRF, 2016).

An adult woman's nutritional status is the culmination of nutrients intake, metabolism, and utilisation over the course of a lifetime, beginning with her nutritional status at birth. Weight at birth is a proxy indicator of nutritional status in the uterus and may be linked to health problems later in life, such as cardiovascular diseases, hypertension, and cancer. Poverty is related to poor nutritional status, usually due to factors limiting food access (NBS, 2015).

Maternal mortality in Nigeria accounts for an estimated 14% of global maternal deaths. Furthermore, Nigeria accounts for an estimated 9% of global first-day deaths, with less than 5% of the world's birth. Women are thus, vulnerable to malnutrition for social and biological reasons. A person's body mass index (BMI) is calculated by dividing their weight (W) in kilogrammes by their height (h) in meters-square (m)², resulting in an index known as body mass index (BMI). The extreme BMI to the right is used to distinguish between classes of overweight or obese individuals. A person with a BMI of <18.5 is underweight, 18.5 to 24.9 is said to be normal and 25 to 29.9 is overweight and obesity are identified with BMI of ≥ 30 according to current classification (CDC, 2010). A review of pooled data from 2005 to 2013 of women in 32 African countries, including Nigeria, Ghana, and Rwanda, revealed rising prevalence levels ranging from 5.6 to 27.7% for overweight and 1.1 to 23.0% for obesity (Neupane *et al.*, 2016).

Ezeama *et al.* (2022) worked on multi-level correlates of the nutritional status of Nigerian women of reproductive age using multinomial logistic regression analysis to determine predictors of nutritional status which revealed that a significant proportion

of the women had poor nutritional status and statistically significant factors associated with poor nutritional status were found at all three levels namely; individual level factors (age, education, parity, contraception), household/family level factors (inadequate health services, water and sanitation, wealth index status) and community level factors (residence, geo-political zone, employment) considered in their study which served as a leading paper in this study.

However, since not all predictor variables or factors have a linear relationship with the nutritional status of Nigerian women of reproductive age, hence, the need for this study to develop a robust statistical model so as to investigate the effects of these variables. This is necessary to ensure that the model developed in this study will capture non-linearity and complex relationships, as well as to improve model fitting and prediction accuracy.

Objectives of the Study

The main aim of this study is to assess the nutritional status of Nigerian women of reproductive age using a combination of statistical and machine learning techniques while specific objectives are;

1. to develop a predictive model using multinomial logistic regression and neural network for nutritional status categories (underweight, overweight, obesity and normal weight).
2. to examine the effect of selected predictor variables in the hybrid model associated with nutritional status of women of reproductive age in Nigeria.
3. to evaluate the performance of the hybrid model in predicting nutritional status and compare it to traditional statistical model.

Research Design

In order to concentrate on the actual topic of the research variables (Predicting Nutritional Status in Nigerian Women of Reproductive Age: A Hybrid Multinomial Logistic Regression Model and Neural Network Approach), from which the data were gathered, the survey research design was used in this study. The variables were chosen in accordance with the study topic in relation to the outcome and predictor variables. The National Bureau of Statistics (NBS) conducted the Multiple Indicator Cluster Survey (MICS) in 2021 as part of the Global MICS Program, and the United Nations Children's Fund (UNICEF) provided technical assistance. The study was published in August 2022, with government funding and financial support from UNICEF, Gavi, the Vaccine Alliance, and the Bill & Melinda Gates Foundation (BMGF).

Source of Data

The Multiple Indicators Cluster Survey (MICS 6, 2021–2022) report, the program website, and the Global Nutrition Publication (GNP, 2020) were the sources of the

secondary data used in this study. Computer-Assisted Personal Interviewing (CAPI) is used in MICS surveys. The CPro (Census and Survey Processing System) software, Version 6.3, which included a MICS-specific data management platform, served as the foundation for the data collection application. Standard programs and procedures created as part of the global MICS program were modified for use in the Multiple Indicators Cluster Survey (MICS) 2021 final questionnaires. Changes were made to the application and questionnaires in response to the CAPI-test results.

Population and Sample Size

Women of reproductive age in Nigeria (WRA) between the ages of 15 and 49 made up the study's target population. 38,806 Nigerian women of reproductive age were interviewed out of 40,326 women of reproductive age who were eligible for the National Bureau of Statistics' 2021 interview; this constituted the sample size and produced a 96.2% response rate among the households surveyed (NBS, 2022).

Sampling Technique

The purpose of the Multiple Indicators Cluster Survey (MICS), 2021, was to estimate a wide range of indicators pertaining to the status of women and children at the national, rural, and urban levels for 36 states, the Federal Capital Territory (FCT), Abuja, and Nigeria's six geopolitical zones. The primary sampling strata were determined to be states, and the household sample was chosen in two phases. A stratified two-stage cluster sampling technique was used in the survey.

Measurement of Variables

The considered variables in this study are outcome variable Y (the nutritional status; underweight, overweight, obesity and normal weight is baseline category) and the predictor variables are (i.e. X_1 = age, X_2 = women education, X_3 = access to mass media, X_4 = availability of sufficient water when needed, X_5 = iodized salt consumption, X_6 = geo-political zone and X_7 = ethnicity. Both outcome variable and predictor variables were categorically coded.

The Existing Model

The model in the context of this research will have the form as;

$$Y_i \sim \text{Multinomial}(n_i, \pi_j)$$

1.0

where $i = 1, 2$ and 3 for underweight, overweight and obese respectively

Y_i = the number of malnourished women of reproductive age.

π_j = denote the probability of malnourished women of reproductive age.

n_i = denote the number of women of reproductive age.

$$\text{Log} \left[\frac{\pi_j(x_i)}{\pi_k(x_i)} \right] = \beta_{0j} + \beta_{1j}x_{1i} + \beta_{2j}x_{2i} + \dots + \beta_{pj}x_{pi} \quad 1.1$$

Where $j = 1, 2, \dots, (k-1), i = 1, 2, \dots, n$. Since all the π 's adds to unity, this reduces to

$$\text{Log} \left(\pi_j(x_i) \right) = \frac{\exp(\beta_{0j} + \beta_{1j}x_{1i} + \beta_{2j}x_{2i} + \dots + \beta_{pj}x_{pi})}{1 + \sum_{j=1}^{k-1} \exp(\beta_{0j} + \beta_{1j}x_{1i} + \beta_{2j}x_{2i} + \dots + \beta_{pj}x_{pi})} \quad 1.2$$

For $j = 1, 2, \dots, (k-1)$, the model parameters are estimated by the method of ML.

The parameter β_j refers to the effect of x_i on the log odds that $Y=1$, controlling other x_i for instance, $\exp(\beta_j)$ is the multiplicative effect on the odds of a one-unit increase in x_i at fixed levels of other x_i .

The Hybrid Model

In this study, a new model is developed for nutritional status women of reproductive age in Nigeria from the traditional Multinomial Logistic Model in (1.2) by incorporating a Neural Network Component to capture non-linear relationships. Therefore, the hybrid model is written as:

$$\text{Nutritional Status} \sim \text{MNL}R(\text{age} + \text{women education} + \text{access to mass media} + \dots + \text{ethnicity} + \text{NN}(x)) \quad 1.3$$

Neural Network Component ($\text{NN}(x)$) is defined as: $\sigma(W2 * \sigma(W1 * x + b1) + b2)$ 1.3.1

where;

σ is the sigmoid function

$W1$ and $W2$ are weight matrices

$b1$ and $b2$ are bias terms

and x is the input layer (predictors).

Hybrid Model Equation developed in this study for prediction is of the form:

$$\text{Pr}(\text{Nutritional Status} = j) = \frac{\exp(X * \beta_j + \text{NN}(x)_j)}{\sum \exp(X * \beta_k + \text{NN}(x)_k)} \quad 1.4$$

where j indexes the nutritional status categories and k sums over all categories.

In this study, sigmoid function (σ) introduced non-linearity, allowing the model to learn complex relationships and maps the input to a value between 0 and 1 and also used for binary classification or probability output, bias terms ($b1$ and $b2$) help the model learn more accurate representations by allowing the activation functions to shift the input

values while weight matrices ($W1$ and $W2$) learn to transform inputs into higher-level representations, capturing complex relationships.

Data Analysis

This section outlines the analytical approach employed to model the nutritional status of women of reproductive age in Nigeria. Given the complex and non-linear relationships between the predictors and outcome variable, a hybrid multinomial logistic regression model and neural network approach was adopted. This innovative approach integrates the strengths of traditional logistic with adaptive learning capabilities of neural network, enabling the capture of subtle patterns and evaluation procedures to develop and validate the modified model. The data analysis was carried out using multinomial logistic model with MICS 6 datasets. The data was analyzed with the aid of STATA Software version 16.0.

Therefore, to model the nutritional status (outcome variable), we classified;

$$Y_i = \begin{cases} 1 & \text{if a woman has underweight} \\ 2 & \text{if a woman is overweight} \\ 3 & \text{if a woman is obese} \\ 4 & \text{if a woman has Normal – weight} \end{cases}$$

The present study used Body Mass Index (BMI), defined as the ratio of weight (in kg) to height (in m²) as an indicator to assess women's nutritional status as it provides a general indication of weight status and associated health risks while statistical significance was set at $\alpha < 0.05$.

RESULTS

Table 1 shows women background characteristics aged 15 – 49 years in Nigeria extracted from Multiple Indicator Cluster Survey report (MICS 6, 2021 - 2022) which were selected as predictor variables for the analysis. Women of reproductive age 15 – 19 years constituted the highest percentage of 21.9% while the least age distribution was 45 – 49. Women who attained senior secondary education were majority with 36.4% while WRA with senior technical education were the lowest (0.1%). WRA who watched television once in a week had highest percentage of 42.7% and least percentage regarding access to mass media was 5.0% for WRA who had access to three mass media. It is also clearly shown in Table 1 that percentage of non-availability of water from source for 75.7% WRA while 9.4% experienced too expensive water from source when needed and 94.4% being highest percentage consumed iodized greater than 0ppm while lowest percentage (0.1%) consumed non-iodized salt. Significant percentage of WRA (25.1%) in this study were from North-West geo-political zone while the least

percentage were South-East WRA (11.7%. Additionally, Yoruba WRA constituted the highest percentage of 26.7% while the least WRA in this study were Fulani (2.0%).

Table 1: Women Background Characteristics (aged 15 - 49)

	Weighted Frequency (N)	Weighted Percent (%)
Age		
15 – 19	8499	21.9
20 – 24	6322	16.3
25 – 29	5954	15.3
30 – 34	5310	13.7
35 – 39	5230	13.5
40 – 44	4209	10.8
45 - 49	3282	8.5
Women Education		
None	10303	26.6
Primary	5303	13.7
Junior Secondary	3376	8.7
Vocational Initiative Entrep. Pgm.	13	0.0
Senior Secondary	14106	36.4
Senior Technical	58	0.1
Higher/Tertiary	5647	14.6
Access to Mass Media		
Read Newspaper Once per Week	2872	7.4
Listen to Radio Once per Week	13349	34.4
Watch Television Once per Week	16570	42.7
All Three Media Once per Week	1940	5.0
Any Media Once per Week	4074	10.5
Availability of Sufficient Water When Needed		
Water not Available from source	29374	75.7
Water too Expensive	3848	9.4
Water not Accessible	5783	14.9
Iodized Salt Consumption		
No Salt	1630	4.2
No iodized salt	543	1.4
Iodized Salt greater than 0ppm	36632	94.4
Geo-political Zone		
North-Central	5859	15.1
North-East	5109	13.2

	Weighted Frequency (N)	Weighted Percent (%)
North-West	9740	25.1
South-East	4530	11.7
South-South	5663	14.6
South-West	7904	20.4
Ethnicity		
Hausa	2574	6.6
Igbo	6324	16.3
Yoruba	9143	23.6
Fulani	760	2.0
Kanuri	3890	10.0
Ijaw	3673	9.5
Tiv	3271	8.4
Ibibio	3385	8.7
Edo	2841	7.3
Other Ethnicity	2944	7.6

Source: Multiple Indicator Cluster Survey (MICS, 6; 2021 – 2022 Report

Table 2 shows the estimation of parameters for underweight women of reproductive age in order to examine the effects of selected predictor variables in the hybrid model associated with nutritional status of women of reproductive age (WRA) in Nigeria. Results of multinomial logistic regression model and neural network approach in Table 2 revealed that majority of the age distributions of WRA, those with no formal education, primary education, senior secondary and WRA with senior technical education were significantly associated with underweight. It was also clearly shown in Table 2 WRA who had access to reading of newspaper once in a week, listen to radio once in a week and those who watch television once in a week were also significantly associated with underweight. This implies that despite the accessibility of WRA to any of the mass media once in a week, there was significant association with underweight nutritional status among WRA in Nigeria who read newspaper, listen to radio and watching of television once in a week. Also significantly associated with underweight in the study were WRA who consumed no salt in food intake, those who consumed no iodized salt as well as WRA who experienced non availability of water from source when needed, those who bought expensive water for home use as well as WRA from geo-political zones in Nigeria and Hausa WRA being an ethnic group having obtained $p - value$ less than 0.05 with close margin of low standard error for each category of these predictor variables in this study.

On the other hand in Table 2, WRA within the age distribution 35 – 39, those with junior secondary and vocational initiative entrepreneurship skill and WRA who had access to all three media once in a week as well as majority of WRA from various ethnic groups in this study such as Igbo, Yoruba, Fulani, Kanuri, Ijaw, Tiv, Ibibio and Edo were not significantly associated with underweight having obtained $p - value$ greater than 0.05 for each categories of these predictor variables.

Table 2: Estimation of Parameters for Underweight Women of Reproductive Age at 95% CI

Predictor Variable	Coeff.	Std. Error	Wald	df	p – value	95% CI
Age						
15 – 19	-0.498	0.061	5.691	1	0.000	(0.539, 0.686)
20 – 24	-0.691	0.065	7.250	1	0.000	(0.441, 0.569)
25 – 29	-0.690	0.070	6.603	1	0.000	(0.437, 0.576)
30 – 34	-0.634	0.062	7.221	1	0.000	(0.469, 0.599)
35 – 39	-0.041	0.064	0.409	1	0.522	(0.847, 1.088)
40 – 44	-0.249	0.077	4.461	1	0.001	(0.671, 0.907)
Women Education						
None	-0.433	0.051	8.364	1	0.000	(0.586, 0.717)
Primary	-0.240	0.064	4.059	1	0.000	(0.694, 0.892)
Junior Sec.	-0.029	0.069	0.176	1	0.675	(0.848, 1.112)
Vocational Initi.						
Entrep. Pgm.	0.104	0.619	0.004	1	0.951	(0.309, 3.491)
Senior Sec.	-0.469	0.050	8.366	1	0.000	(0.567, 0.690)
Senior Tech.	-2.131	1.017	4.393	1	0.036	(0.016, 0.871)
Access to Mass Media 1ce/Wk.						
Read Newspaper	0.485	0.072	6.838	1	0.000	(1.409, 1.871)
Listen to Radio	-0.116	0.055	4.333	1	0.037	(0.799, 0.993)
Watch Television	-0.187	0.055	4.705	1	0.001	(0.745, 0.923)
All Three Media	-0.158	0.105	2.277	1	0.131	(0.696, 1.048)
Availab. of Suffic. Water						
Water not Available from source when Needed	-0.119	0.043	4.551	1	0.006	(0.816, 0.967)
Water too Expensive when Needed	0.304	0.057	5.012	1	0.000	(1.211, 1.517)
Iodized Salt Consumption						
No Salt	0.824	0.090	7.342	1	0.000	(1.909, 2.719)
No iodized salt	2.606	0.131	8.228	1	0.000	(2.484, 4.492)
Geo-political Zone						
North-Central	-0.489	0.072	6.223	1	0.000	(0.533, 0.706)
North-East	0.195	0.071	4.567	1	0.006	(1.058, 1.397)
North-West	-0.333	0.065	5.282	1	0.000	(0.631, 0.814)

Predictor Variable	Coeff.	Std. Error	Wald	df	p – value	95% CI
South-East	0.851	0.062	7.365	1	0.000	(2.074, 0.646)
South-South	0.161	0.062	4.708	1	0.010	(1.040, 1.327)
Ethnicity						
Hausa	0.222	0.080	4.724	1	0.005	(1.068, 1.460)
Igbo	0.028	0.067	0.169	1	0.681	(0.902, 1.172)
Yoruba	-0.013	0.064	0.043	1	0.836	(0.871, 1.178)
Fulani	-0.047	0.122	0.146	1	0.702	(0.752, 1.212)
Kanuri	-0.019	0.073	0.064	1	0.800	(0.850, 1.133)
Ijaw	0.034	0.074	0.214	1	0.644	(0.896, 1.195)
Tiv	-0.032	0.072	0.176	1	0.675	(0.834, 1.125)
Ibibio	-0.045	0.076	0.356	1	0.551	(0.824, 1.109)
Edo	0.019	0.078	0.057	1	0.811	(0.874, 1.188)
Constant	0.088	0.149	0.348	1	0.555	

Table 3: Estimation of Parameters for Overweight Women of Reproductive Age at 95% CI

Predictor Variable	Coeff.	Std. Error	Wald	df	p – value	95% CI
Age						
15 – 19	-0.249	0.078	4.197	1	0.002	(0.669, 0.908)
20 – 24	-0.162	0.083	3.861	1	0.040	(0.723, 1.000)
25 – 29	-0.211	0.077	4.522	1	0.001	(0.696, 0.942)
30 – 34	-0.484	0.079	5.902	1	0.000	(0.529, 0.719)
35 – 39	0.245	0.077	4.235	1	0.002	(0.100, 0.485)
40 – 44	0.549	0.094	5.297	1	0.000	(1.441, 2.080)
Women Education						
None	0.195	0.050	4.214	1	0.000	(1.102, 1.340)
Primary	-0.394	0.057	5.015	1	0.000	(0.603, 0.754)
Junior Sec.	-0.149	0.062	5.856	1	0.000	(0.764, 0.972)
Vocational Initi.						
Entrep. Pgm.	-18.547	8602.020	0.000	1	0.998	(0.000, -)
Senior Sec.	-0.350	0.053	8.295	1	0.000	(0.635, 0.782)
Senior Tech.	-0.136	0.332	0.167	1	0.683	(0.455, 1.635)
Access to Mass Media 1ce/Wk.						
Read Newspaper	-0.035	0.079	0.198	1	0.656	(0.826, 1.128)
Listen to Radio	-0.070	0.057	1.492	1	0.222	(0.833, 1.043)
Watch Television	0.256	0.055	5.473	1	0.000	(1.159, 1.440)
All Three Media	-0.228	0.082	4.748	1	0.005	(0.678, 0.975)
Availab. of Suffic. Water						
Water not Available from source when Needed	0.544	0.054	7.230	1	0.000	(1.860, 2.497)

Predictor Variable	Coeff.	Std. Error	Wald	df	p – value	95% CI
Water too Expensive when Needed	-1.002	0.110	6.611	1	0.000	(0.296, 0.456)
Iodized Salt Consumption						
No Salt	0.768	0.075	7.519	1	0.000	(1.909, 2.719)
No iodized salt	-0.283	0.194	2.131	1	0.144	(0.515, 1.102)
Region						
North-Central	-0.251	0.089	4.894	1	0.005	(0.653, 0.957)
North-East	-0.034	0.096	0.124	1	0.725	(0.801, 1.167)
North-West	-0.011	0.079	0.018	1	0.894	(0.847, 1.156)
South-East	0.170	0.083	4.260	1	0.039	(1.009, 1.394)
South-South	-0.673	0.093	5.798	1	0.000	(0.425, 0.612)
Ethnicity						
Hausa	-0.004	0.088	0.002	1	0.962	(0.839, 1.132)
Igbo	0.104	0.071	2.147	1	0.143	(0.965, 1.275)
Yoruba	0.110	0.068	2.639	1	0.104	(0.978, 1.275)
Fulani	0.046	0.128	0.129	1	0.719	(0.814, 1.347)
Kanuri	-0.010	0.078	0.015	1	0.902	(0.850, 1.154)
Ijaw	0.053	0.079	0.448	1	0.503	(0.903, 1.231)
Tiv	0.088	0.081	1.202	1	0.273	(0.933, 1.279)
Ibibio	-0.014	0.081	0.029	1	0.864	(0.841, 1.156)
Edo	-0.086	0.085	1.016	1	0.313	(0.777, 1.084)
Constant	-6.037	0.606	9.360	1	0.000	

Furthermore, Table 3 above shows the estimation of parameters for overweight women of reproductive age in order to examine the effects of selected predictor variables in the hybrid model associated with nutritional status of women of reproductive age (WRA) in Nigeria.

The results of multinomial logistic regression model and neural network approach obtained in Table 3 revealed that there was significant association of all age distributions of WRA in this study with overweight. This implies that age is a significant predictor variable to be considered while investigating nutritional status of Nigerian women of reproductive age. It was also shown in Table 3 that WRA with no formal education, primary, junior secondary and senior secondary education had significant association with overweight as well as WRA who had access to watching of television once in a week and those who had access to all three media, namely; reading of newspaper once in a week, listen to radio once in a week and watching of television once in a week.

The study also revealed that there were significant associations of overweight with WRA who experienced non availability of water from source when needed, those who experienced too expensive water from source for when needed and WRA with no salt

intake in food consumption. Additionally, WRA from North-Central, South-East and South-South geo-political zones were also significantly associated with overweight having obtained p – value less than 0.05 with close margin of low standard error for each category of these predictor variables in this study.

On the contrary in Table 3, WRA with vocational initiative entrepreneurship programme, those who attained senior technical education had no significant association with overweight and those who read newspaper once in a week, those who listen to radio once in a week as well as WRA who consumed non iodized salt, North-East and North-West geo-political zones WRA and WRA from various ethnic groups in this study were not significantly associated with overweight having obtained p – value greater than 0.05 for each category of these predictor variables in this study.

Table 4: Estimation of Parameters for Obese Women of Reproductive Age at 95% CI

Predictor Variable	Coeff.	Std. Error	Wald	df	p – value	95% CI
Age						
15 – 19	1.366	0.104	10.294	1	0.000	(1.196, 2.805)
20 – 24	1.542	0.108	11.665	1	0.000	(1.487, 3.773)
25 – 29	1.673	0.104	11.203	1	0.000	(1.351, 3.528)
30 – 34	0.968	0.105	8.078	1	0.000	(1.144, 2.235)
35 – 39	1.665	0.108	11.664	1	0.000	(1.292, 3.503)
40 – 44	1.719	0.122	11.100	1	0.000	(1.397, 3.079)
Women Education						
None	-0.345	0.052	6.957	1	0.000	(0.640, 0.784)
Primary	0.207	0.054	5.809	1	0.000	(1.107, 1.366)
Junior Sec.	-0.380	0.067	6.829	1	0.000	(0.599, 0.780)
Vocational Initi.						
Entrep. Pgm.	-18.949	0.000	-	1	-	(5.894E-009, 5.894E-009)
Senior Sec.	-0.468	0.052	8.559	1	0.000	(0.565, 0.964)
Senior Tech.	-0.824	0.425	3.763	1	0.062	(0.191, 1.009)
Access to Mass Media 1ce/Wk.						
Read Newspaper	0.215	0.074	4.378	1	0.004	(1.072, 1.435)
Listen to Radio	-0.072	0.055	1.744	1	0.187	(0.835, 1.036)
Watch Television	-0.454	0.055	8.990	1	0.000	(0.570, 0.708)
All Three Media	0.254	0.075	4.386	1	0.001	(1.112, 1.494)
Availab. of Suffic. Water						
Water not Available from						
source when Needed	0.544	0.054	7.230	1	0.000	(1.860, 2.497)
Water too Expensive						
when Needed	-1.002	0.110	6.611	1	0.000	(0.296, 0.456)

Predictor Variable	Coeff.	Std. Error	Wald	df	p – value	95% CI
Iodized Salt Consumption						
No Salt	0.693	0.078	8.073	1	0.000	(1.715, 2.332)
No iodized salt	0.050	0.180	0.077	1	0.782	(0.738, 1.497)
Geo-political Zone						
North-Central	0.070	0.089	0.611	1	0.434	(0.900, 1.278)
North-East	0.310	0.094	4.978	1	0.001	(1.135, 1.638)
North-West	0.377	0.081	5.775	1	0.000	(1.244, 1.707)
South-East	1.034	0.080	8.188	1	0.000	(2.404, 3.292)
South-South	-0.590	0.096	5.553	1	0.000	(0.459, 0.669)
Ethnicity						
Hausa	0.354	0.086	5.044	1	0.000	(1.204, 1.686)
Igbo	0.126	0.073	3.008	1	0.083	(0.984, 1.309)
Yoruba	0.195	0.069	4.986	1	0.005	(1.062, 1.391)
Fulani	-0.110	0.139	0.622	1	0.430	(0.583, 1.177)
Kanuri	-0.059	0.081	0.542	1	0.462	(0.805, 1.104)
Ijaw	0.083	0.081	1.056	1	0.304	(0.927, 1.274)
Tiv	0.026	0.084	0.093	1	0.761	(0.827, 1.149)
Ibibio	0.040	0.082	0.243	1	0.622	(0.887, 1.223)
Edo	0.096	0.085	1.269	1	0.260	(0.931, 1.301)
Constant	-3.560	0.235	11.358	1	0.000	

Table 4 shows the estimation of parameters for obese women of reproductive age in order to examine the effects of selected predictor variables in the hybrid model associated with nutritional status of women of reproductive age (WRA) in Nigeria.

The results of multinomial logistic regression model and neural network approach obtained in Table 4 revealed that there was significant association of age with obesity for all women of reproductive age irrespective of their age distributions (15 – 49) in this study. This implies that all the WRA 15 -49 considered in this study had significant association with obesity. It was also indicated that majority of WRA with respect to their educational attainments had significant association with obesity while WRA who had access to mass media such reading of newspaper, watching of television and combination of the three media (read newspaper, watch listen to radio and watch television) once in a week were not left out from having significant association with obesity.

Additionally, the study also revealed that there was significant association of obesity with WRA who experienced non availability of water from source and those who experienced too expensive water from source when needed as well as WRA who consumed no salt in food intake. It was equally found from this study that WRA from North-East, North-West, South-East and South-South regions had significant association

with obesity. Also significantly associated with obesity were Hausa and Yoruba WRA in Nigeria from this study having obtained $p - value$ less than 0.05 with close margin of low standard error for each category of these predictor variables.

In the contrary, Table 4 shows that WRA who attained senior technical education, those who listen to radio once in a week, those who consumed no iodized salt as well as WRA from North-Central geopolitical zone were not significantly associated with obesity nutritional status. Also not significantly associated with obesity in this study were majority of WRA from various ethnic group in this study which include Igbo, Fulani, Kanuri, Ijaw, Tiv, Ibibio and Edo having obtained $p - value$ greater than 0.05 for each category of these predictor variables.

Table 5: Evaluation of Model Performance

Multiple R	R Square	Adjusted R Square	Apparent Pred. Err.	Expected Pred. Err.	MSE	Std. Err.	N
0.356	0.127	0.127	0.873	0.878	0.003	38806	

In Table 5, considering the hybrid model's complexity and the number of parameters, a model with a lower AIC or BIC may not always be the best choice if it is overly complex, hence, the need for cross-validation of the new model which evaluates model performance and prevent overfitting. In this study, Table 5 shows 10 fold cross-validation technique for model performance from the analysis and values obtained for Multiple R (0.356), R square (0.127), Adjusted R square (0.127), Apparent Prediction Error (0.873) while Expected Prediction Error comprising of Mean Squared Error (0.878), Standard Error (0.003) with Number of Observations (38806) are clearly shown in Table 5.

DISCUSSION

This study predicted nutritional status of women of reproductive in Nigeria using hybrid multinomial logistic regression and neural network approach. The Global Nutrition Publication (GNP, 2020) reported that out of 46 million women of reproductive age in Nigeria, 7.3 million (15.9%) women were living obesity, 15.7% were undernourished and 16.8% were overweight WRA in Nigeria while 51.2% have normal weight body mass index.

This study found association of selected predictor variables which include age, women education, access to mass media once in a week, availability of water when needed, iodized salt consumption, geopolitical zone and ethnicity with underweight, overweight and obesity. Similar to previous literature; majority of the age distributions of WRA,

those with no formal education, primary education, senior secondary and WRA with senior technical education were significantly associated with underweight in this study which aligned with Mtumwa *et al.* (2016) whose results showed that women aged 15-19 and 40-49 years were mostly affected of underweight, with a prevalence of 18% and 12% respectively. This also supported the findings of Song *et al.* (2020) in China found that higher level of education was associated with lower prevalence of overweight and obesity and attributed their findings to women of higher education having greater health awareness and diet management which protects them from over-nutrition.

Despite the accessibility of WRA to mass media once in a week, there was significant association to underweight nutritional status among WRA in Nigeria who read newspaper, listen to radio and watching of television once in a week. Also, WRA who experienced non availability of water from source when needed, those who bought expensive water for home use as well as WRA from all regions in Nigeria and Hausa WRA being an ethnic group had significant association with underweight. This implies that irrespective of geo-political zone WRA belong to in Nigeria, significant association of underweight with geo-political zone was found in this study.

Furthermore, statistically significant association of all age distributions of WRA in this study with overweight was found which aligns with Song *et al.* (2020) findings in China who found that higher level of education was associated with lower prevalence of overweight and attributed their findings to women of higher education having greater health awareness and diet management which protects them from over-nutrition.

This study also shows that despite the accessibility of WRA to reading of newspaper once in a week, listen to radio once in a week and watching of television once in a week, there was signification association of accessibility to mass media with overweight as well as WRA with no salt intake by WRA in this study while no salt intake consumption that had significant association with overweight could be attributed to consumption of certain salty fish.

Additionally, there was significant association of age with obesity for all women of reproductive age irrespective of their age distributions (15 – 49) in this study as well as with the majority of WRA with respect to their educational attainments which supported Song *et al.*(2020) findings in China who found that higher level of education was associated with lower prevalence of overweight and attributed their findings to women of higher education having greater health awareness and diet management which protects them from over-nutrition. It was equally found from this study that WRA from North-East, North-West, South-East and South-South geo-political zones as well as Hausa and Yoruba WRA had significant association with obesity in Nigeria. This finding aligns with Ezeama *et. al.* (2022) who stated that region and ethnic group were significantly associated with high body mass index.

In contrast, this study revealed that WRA within the age distribution 35 – 39, those with junior secondary and vocational initiative entrepreneurship skill and WRA who had access to all three media once in a week as well as majority of WRA from various ethnic groups in this study were not significantly associated with underweight. Women of reproductive age with vocational initiative entrepreneurship skill, those who attained senior technical education and those who read newspaper once in a week, those who listen to radio once in a week as well as WRA who consumed non iodized salt, North-East and North-West geo-political zones WRA and all WRA from various ethnic groups in this study were not significantly associated with overweight while WRA who attained senior technical education, those who listen to radio once in a week, those who consumed no iodized salt as well as WRA from North-Central geo-political zone were not significantly associated with obesity nutritional status and also majority of WRA from various ethnic group in this study which include Igbo, Fulani, Kanuri, Ijaw, Tiv, Ibibio and Edo.

In general, each regression coefficient's significance in the model is gauged by the Wald statistic. A chi-squared distribution with one degree of freedom is what the Wald statistic adheres to. The coefficient is statistically significant if the Wald statistic is higher than the chi-squared distribution's critical value, which is typically 3.84 for a 2-tailed test at the 0.05 significance level.

This suggests that all the predictor variable coefficients in Tables 2, 3, and 4 that were greater than 3.84 were statistically significant in the hybrid model developed for this study, whereas the predictor variable coefficients that were less than 3.84 with regard to WRA's nutritional status were not. A *p – value* of less than 0.05 indicates a significant relationship between the predictor variables and the outcome variables (underweight, overweight, obese, and normal weight).

The Apparent Prediction Error (APE) of 0.873 in Table 5 indicates that the hybrid model in this study correctly predicted 87.3% of the outcomes in the training datasets. On the other hand, Expected Prediction Error (EPE) provides a more realistic estimate of the model's performance on large datasets, as opposed to Apparent Prediction Error (APE) which is based on the training data. It could be observed that the Expected Prediction Error (EPE) of 0.878 indicates that the hybrid model is expected to correctly predict approximately 87.8% of the outcomes in new, unseen data. This is also a relatively good result, suggesting that the hybrid model has good generalizability with very low Standard Error of 0.003 which implies that variability of the estimate is low which is an indication of better performance of the hybrid model developed in this study for prediction over the traditional multinomial logistic regression model. This hybrid model also prevented overfitting of the training data as data partitioning to prevent overfitting in this study was 70:30, this implies that 70% of datasets for training while 30% for testing.

CONCLUSION

In summary, this study effectively illustrated how to fit and predict the nutritional status of Nigerian women of reproductive age using a Multinomial Logistic Regression Model and a Neural Network Approach. In order to improve nutrition outcomes, it is crucial to address sociodemographic, economic, and health-related factors. The study's conclusions have important ramifications for public health policy and intervention strategies. The hybrid model's better performance and capacity to capture intricate relationships highlight how advanced statistical modelling techniques can be used to address complex health issues in environments with limited resources.

The nutritional status of women of reproductive age (WRA) is significantly impacted by a few predictor variables, according to the study's findings. This study concludes that women's nutritional status should be improved based on these and other relevant findings. The majority of the predictor variables chosen for this study had an impact on mothers' nutritional status, which in turn had an impact on children's nutritional status. Additionally, it was discovered that there is a strong correlation between the nutritional status of the mother and her child as well as between the mother's nutritional status and birth weight.

RECOMMEDATIONS

Based on the findings from this study, the recommendations were made as follows;

- i. Government and stakeholders should prioritize the implementation and scaling up of nutrition programmes, such as Maternal, Infant, Youth Child Nutrition (MIYCN) programmes, to reach more women of reproductive age in Nigeria.
- ii. Health care systems should be strengthened to provide comprehensive and child health services, including nutrition counselling and support.
- iii. Further research and data collection are needed to inform policy and programmatic decisions aimed at improving the nutritional status of women of reproductive age in Nigeria.
- iv. Collaboration among government agencies, international organizations and local stakeholders is very essential to ensure effective implementation of nutrition policies and programmes.

REFERENCES

- Ahmed, K. Y, Rwabilimbo, A. G, Abrha, S. (2020). Factors Associated with Underweight, Overweight and Obesity in Reproductive Age Tanzanian Women. PLoS ONE 2020; 15(8): 1-16
- Centre for Disease Control (2010): Prevalence of obesity (class I, II and III) Among Adults Aged ≥ 20 years, by Age Group, and Sex. National Health and Nutrition Examination Survey (US, 2007- 2008), Found at <http://www.cdc.gov/mmwr/preview/mmwr.html/mm5917a9.htm>. Accessed on 30th May, 2012.

- Dagnew, G. W and Asresie, M. B (2020). Factors Associated with Chronic Energy Malnutrition among Reproductive-Age Women in Ethiopia: An Analysis of the 2016 Ethiopia Demographic and Health Survey Data. *PLoS ONE* 2020; 15(12): e0243148.
- Ezeama, N. N, Okunna, N and Ezeama, C. O (2022): Multi-Level Correlates of the Nutritional Status Nigerian Women of Reproductive Age. *Journal of Community Health Equity Research & Policy*, 44(1) 109 – 121.
- Global Nutrition Publication (2020): Global Nutrition Publication: Action on Equity to End Malnutrition. Bristol: Development Initiatives; July, (1).
- Kimani, M. E.W, Muthuri, S. K, Oti, S. O, Mutua, M. K, Van De Vijver, S., Kyobutungi C. (2015): Evidence of a Double Burden of Malnutrition in Urban Poor Settings in Nairobi, Kenya. *PLoS One*. 10: e0129943. doi: 10.1371/Journal.Pone.0129943
- King FS, Burgess A, Quinn VJ, Osei, A. K. (2015): Nutrition for Developing Countries. University of Oxford, UK: **Oxford University Press**.
- Lasisi, K. E., Nwaosu, S. C. and Abdulhamid, B. M. (2015): "Bayesian Regression Method with Gaussian and Binomial links for the Analysis of Nigerian Children Nutritional Status (Stunting)". *Global Journal of Science Frontier Research: F Mathematics and Decision Sciences*, 15(4)1, 111-118.
- Mangemba, N. T and San S. M (2020). Societal Risk Factors for Overweight and Obesity in Women in Zimbabwe: A Cross-sectional Study. *BMC Public Health*; 20(1): 1–8.
- Mtumwa, A. H, Paul, E. and Vuai S. A. H (2016): Determinants of Undernutrition among Women of Reproductive Age in Tanzania Mainland. *S Afr J Clin Nutr* 29(2):75-81.
- National Bureau of Statistics (NBS) and United Nations Children's Fund (UNICEF). (2022): Multiple Indicator Cluster Survey 2021, Survey Findings Report, Abuja, Nigeria: National Bureau of Statistics and United Nations Children's Fund.
- National Bureau of Statistics (2015): National Nutrition and Health Survey. Report on the Nutrition and Health Situation of Nigeria, 2015.
- National Research Foundation (2016): Trends in Adult Body-Mass Index in 200 Countries from 1975 to 2014: A Pooled Analysis of 1698 Population-Based Measurement Studies with 19.2 Million Participants. *Lancet*. 387:1377–96. doi: 10.1016/S0140-6736(16)30054-X
- Neupane S, Prakash K. C and Doku D. T. (2016): Overweight and Obesity among women: Analysis of Demographic and Health Survey Data from 32 sub-Saharan African Countries. *BMC Public Health*; 16(30): 1–9.
- Ramirez, Z, M, Kroker, L. M. F, Close, F. R., Kanter, R. (2014): The Double Burden of Malnutrition in Indigenous and Nonindigenous Guatemalan Populations. *Am J Clin Nutr*. 100:1644S–51S. doi: 10.3945/ajcn.114.083857
- Sekiyama, M., Jiang, H. W, Gunawan, B., Dewanti, L., Honda, R, Shimizu-Furusawa, H. (2015): Double Burden of Malnutrition in Rural West Java: Household-Level Analysis for Father-Child and Mother-Child pairs and the Association with Dietary Intake. *Nutrients*. (2015) 7:8376–91. doi: 10.3390/nu7105399.
- Song J, Zhang J and Fawzi, W. (2020): Double Burden of Malnutrition among Chinese Women of Reproductive Age and their Social Determinants. *Nutrients*; 12(10): 1–12.
- World Health Organization. (2021). Malnutrition: Key Facts. Available at: <https://www.who.int/news-room/fact-sheets/detail/malnutrition>.

World Health Organisation. Body mass index. <https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/body-mass-index> (2021, accessed 14 September 2021).

Wubie A, Seid O and Eshetie S. (2020). Determinants of Chronic Energy Deficiency among Non-Pregnant and Non-Lactating Women of Reproductive Age in Rural Kebeles of Dera District, North West Ethiopia, 2019: Unmatched Case Control Study. PLoS ONE; 15(10): e0241341.