# A Predictive Model and Socioeconomic and Demographic Determinants of Body Mass Index in Sudan

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# A predictive model and socioeconomic and demographic determinants of body mass index in Sudan

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**Abstract**: This paper aims at determining the socioeconomic and demographic determinants related to Body Mass Index (BMI) for children under-five years in Sudan. This study uses the Sudan Multiple Indicator Cluster Survey (MICS) conducted in the year 2014. The survey was conducted by the Central Bureau of Statistics in cooperation with several national institutions. The objective of the study is to identify the factors of BMI for under-five children. The multinomial logistic regression model was adopted. Results revealed that the prevalence of underweight for infant's under-five years was 86.3% for females and 85.3% for males, the proportion of the normal weight of infants under-five years of age for males is slightly higher than that of females; there is correlation amid geographic determinants; state, and BMI status. Also, there was a significant association between mother's education and body mass index status and the wealth index and body mass index status. The variables place of residence and sex did not show a statistically significant relationship with body mass index status for the children under-five years of age in Sudan. In addition, the risk factors significantly associated with body mass were the state, child ever breastfeeds, sex, mother's education, wealth index, and age in the month.

**Keywords**: BMI, malnutrition, proportional odds model. multinomial

## Background

Medically, Body Mass Index (BMI) is a main Index employed to connect weight and height. It is an individual's mass measured in kilograms (kg) divided by a person's highness in meters. Standard mass and obesity are identified by the National Institute of Health (NIH) based on BMI of 27.3 or over for females and 27.8 for males while obesity is considered a BMI of more than 30 for both genders [12].

Worldwide, it is predicted that 165 million under-five infants were stunned in 2011. This phenomenon occurred Africa (36%) and in Asia (27%); it remains a public health issue, but it is unnoticed. These percentages represent 90% of the glob's undersized infants [8]. [16] found no significant variations in percentage of hefty people. Being skinny was associated with age, number of banquets, level of parent schooling, origin of food, and quantity of stock possessed. [4] revealed that BMI was positively correlated with gender (females), but it was negatively connected to age and educational standard. Hefty, obesity and underweight amid Bulgarian infants and teenagers were connected to nurturing manner and gorge for both genders [13] was found to rise in the five distributions of fortune in both genders. BMI and fortune index were also found to be correlated [9] A lofty incidence of gross and obesity was strongly related to females. This indicates a relation between females, attending commercial schools, good socioeconomic position [2]. [18] concluded that infants under five, mass of an infant at birth, material's age; BMI; social status and area Affar, Dire Dawa, gambela, Harari & Somalia were factors considerably affect under-five infant's nutrition habits in Ethiopia. A study conducted in Khartoum State, Sudan revealed that 20.9% were badly sustained and 79.1% of them were well sustained, but approximately 15.4% of the infants were skinny, 8.8% of them were fairly skinny, and 6.6% were seriously underweight [14]. Another study conducted in Ghana by [6] showed that the occurrence of underweight, lavish, and undersize was 10.4%, 5.3%, and 18.4%, respectively. The infant's age was related to underweight, lavish, and undersize while gender was connected to lavish and undersize. Regular or overweight/obese, Mother BMI class, female's self-sufficiency, and middle class fortune index were related to smaller odd malnutrition [1]. The study conducted by [5] concluded that the incidence of overweight and obesity was 34% and 4.97, respectively. Women possessed a loftier frequency of overweight (38.3%) compared to (30%) among men. Obesity was more common among women (7.4%) than amid men (2.4%); most participants were healthy weight (50.9%). A study conducted by Sen, Mondal & Dutta (2013) found that the existence of overweight and obesity was noticed to be high among both genders; it was (23.67% and 9.67%) amid men and (20.33%% and 29.33%) among women. Gender, age, monthly revenue, spousal status, schooling, and alcohol intake were noticed to have considerable impact on obesity. Additionally, they had noticeable impact on joined overweight-obesity.

## Methods and materials

### Study variables

The response variable for this study is BMI for the under-five child in Sudan which is a multinomial variable. The independent variables used in this research are the place of residence, state, mother's education, gender, age of the child, the child still breastfeeding, and wealth index. The demographic and socioeconomic factors used in this study were proposed by different [10]; [17]; [7].

### Source of Data

For this study, the 2014 Sudan Multiple Indicator Cluster Survey (MICS) was used. The survey was carried out by the Central Bureau of Statistics in collaboration with several national institutions. For the survey, the data was collected using completed interviews for 15,801 households taken from a sample size of 18,000 households from all states of Sudan. The response percentage was found to be 98 percent. A total of 20,327 women ranging between 15-49 years of age and 14,751 children under-five years of age were included in the survey. This survey has basic information to track the progress of MDGs related to health and mortality. In general, 18,302 women aged 15-49 were interviewed from a sample of 16,801 households, and 14,081 questionnaires were completed for children under-five years of age.

### Statistical methods

The multinomial logistic regression models are an extension of the ordinary logistic models where we study a categorical response variable with more than two possible outcomes [3]. Let *J* represents the number of categories for the response *Y*. let $\pi_1$, $\pi_2$,……, $\pi_J$ represent the response probabilities, satisfying $\sum_{J=1}^{n} \pi_j$=1. With $n$ independent observations, the probability for the number of responses of the $J$ is multinomial distribution and can be expressed as follows:

$$\boldsymbol{P(Y_1, Y_2, \ldots\ldots, Y_j)} = \frac{\boldsymbol{N!}}{\prod_{j=1}^{J} \boldsymbol{Y_j}} \times \prod_{j=1}^{J} \boldsymbol{\pi_j^{y_j}} \quad , \tag{1}$$

The logit link function will be adopted for the multinomial logistic regression model. A response variable that has more than two nominal categories can be modeled adopting multinomial logistic regression. It is important to notice that whether the response variable is nominal or ordinal. Multinomial logit models together handle all pairs of categories by specifying the odds of the outcome in one category instead of another. For models of this section, the order of listing the categories is irrelevant, because the model treats the response scale as nominal (unordered categories).

Assume that Y can take on values coded as 0,1,2, ......., J. Later selects one of the response levels to assert J as the reference level. Suppose we have P covariates then the model can be expressed as follows:

$$LOG\left[\frac{\pi(Y=j/x_1,x_2,\ldots\ldots,x_J)}{\pi(Y=J/x_1,x_2,\ldots\ldots,x_J)}\right] = \beta_{j0} + \beta_{j1}x_1 + \beta_{j2}x_2 + \ldots\ldots\ldots + \beta_{jp}x_p \quad , \tag{2}$$

Where $j = 1,2,\ldots.,J-1$; $J$ is the outcome from the baseline category, which can be any category but is commonly the highest one: $\beta_{jo}$ represent the constants , and $\beta_{j1}x_1$, $\beta_{j2}x_2$, ….., $\beta_{jp}x_p$ are the coefficients of the multinomial regression model. As the model has $J-1$ comparisons, it estimates the $J-1$ logit function for each predictor [11].

To predict the multinomial logistic regression model, the maximum likelihood technique will be used. Regarding the nominal categories, one of the categories is considered as a reference or baseline category and the rest of the categories are compared with the reference category [3].

## Results

Firstly, bivariate tests were carried out, before performing the multinomial logistic regression analysis. The cross-tabulation, as a basic approach of descriptive analysis, was performed adopting the tests of chi-square to explore the association between the response of body mass index and many categorical socio-economic, demographic, and geographic variables at the 5% level of significance. Therefore, Table 1 displays the relationship between body mass index and selected socio-economic, demographic, and geographic categorical variables. There was a statistically significant association at the 5% level among geographic factors; state, and body mass index status (p-value < 0:0001). Among demographic variables and body mass index, a significant association was noticed, i.e., between mother's education and body mass index status (p-value < < 0.0001). Similarly, significant relationship was found between wealth index and body mass index status ((p-value < < 0.0001). In contrast, place of residence (p-value = 0.588) and sex (p-value=0.095) did not show a statistically significant association with body mass index status.

**Table 1 Association between body mass index and socioeconomic, demographic, and geographic variables**

| **Covariates** | **Classification for Body Mass Index** | | | | | | **Chi-square Test (P-Value)** |
|---|---|---|---|---|---|---|---|
| | **Under Weight** | | **Normal** | | **Overweight** | | |
| | **Number** | **%** | **Number** | **%** | **Number** | **%** | |
| **Place of residence** | | | | | | | 0.588 |
| Urban | 3171 | 85.3% | 210 | 5.7% | 335 | 9.0% | |
| Rural | 8599 | 86.0% | 530 | 5.3% | 870 | 8.7% | |
| **State** | | | | | | | **< 0.0001** |
| Northern | 194 | 84.80% | 13 | 5.70% | 22 | 9.40% | |
| River Nile | 339 | 87.40% | 14 | 3.60% | 35 | 9.00% | |
| Red Sea | 163 | 68.30% | 22 | 9.10% | 54 | 22.50% | |
| Kassala | 403 | 81.30% | 15 | 3.10% | 77 | 15.60% | |
| Gadarif | 642 | 85.20% | 64 | 8.40% | 48 | 6.40% | |
| Khartoum | 1592 | 92.50% | 53 | 3.10% | 77 | 4.50% | |
| Gezira | 1800 | 85.20% | 262 | 12.40% | 50 | 2.30% | |
| White Nile | 589 | 84.00% | 36 | 5.10% | 76 | 10.90% | |
| Sinnar | 467 | 84.80% | 16 | 2.90% | 68 | 12.30% | |
| Blue Nile | 626 | 92.10% | 36 | 5.40% | 17 | 2.50% | |
| North Kordofan | 730 | 81.70% | 42 | 4.70% | 121 | 13.60% | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| South Kordofan | 430 | 83.40% | 30 | 5.80% | 56 | 10.80% | |
| West Kordofan | 751 | 84.90% | 32 | 3.60% | 101 | 11.40% | |
| North Darfor | 952 | 86.30% | 25 | 2.30% | 126 | 11.50% | |
| West Darfor | 425 | 88.60% | 32 | 6.70% | 22 | 4.70% | |
| South Darfor | 1137 | 93.40% | 29 | 2.40% | 51 | 4.20% | |
| Central Darfor | 205 | 82.70% | 20 | 8.10% | 23 | 9.20% | |
| East Darfor | 451 | 92.70% | 11 | 2.20% | 25 | 5.00% | |
| **Sex** | | | | | | | 0.095 |
| Male | 5970 | 85.3% | 405 | 5.8% | 623 | 8.9% | |
| Female | 5800 | 86.3% | 335 | 5.0% | 582 | 8.7% | |
| **Mother's education** | | | | | | | **< 0.0001** |
| None | 5501 | 85.6% | 329 | 5.1% | 600 | 9.3% | |
| Primary | 3940 | 86.8% | 222 | 4.9% | 376 | 8.3% | |
| Secondary | 1671 | 85.0% | 125 | 6.4% | 169 | 8.6% | |
| Higher | 643 | 83.9% | 64 | 8.4% | 59 | 7.7% | |
| **Wealth Index** | | | | | | | **< 0.0001** |
| Poor | 5502 | 85.5% | 323 | 5.0% | 612 | 9.5% | |
| Middle | 2783 | 86.6% | 154 | 4.8% | 276 | 8.6% | |
| Higher | 3485 | 85.7% | 263 | 6.5% | 317 | 7.8% | |

For this study, the proportional odds model was adopted to the 2014 Sudan Multiple Indicator Cluster Survey. The basis for outcomes with most multinomial regression models is the logit function. The distinction between logit and probit functions is found in small samples. This is because the probit link consider the normal distribution of the probability of an event. But the logit link assumes the logistic distribution. For the data derived from complex survey design, it is unsuitable to run the proportional odds model analysis for the ordinal response variable ignoring the design of survey sample. Disregarding the survey sampling information may provide biased estimates of parameters, incorrect variance, and parameter estimates. This is due to overestimated or underestimated parameters and variance estimates. For this kind of situation, a specialized method to obtain suitable estimates and standard errors for the ordinal outcome variable should be adopted. This technique includes the weight in the survey sampling design.

Therefore, the findings of the analysis are given in Table 2. Table 2 displays the results for the Multinomial logistic model. The log-likelihood value at each iteration steps displays that ordinal logistic regression uses maximum likelihood estimation method. The log-likelihood increases at each iteration because the purpose is to maximize the log-likelihood function. For the model to converge, the iterations have to be very small. The likelihood value of the fitted model was found to be 7923.67. This value was adopted in the likelihood ratio chi-square test of when all predictors' regression coefficients in the model are included at the same time zero and in tests of nested models. The likelihood ratio chi-square (LR $x^2$) examines if at least one of the explanatory's regression coefficient is not equal to zero. The p-value of the log-likelihood ratio Chi-square test with 50 degrees of freedom, LR $x^2(50)$ =500.55, was p-value < 0.0001. This value expresses that at least one of the logit regression coefficients of the predictors were statistically different from 0. Therefore, the full model with all predictors included gives a better fit than the null model.

The risk factors significantly associated with body mass index were found to be the state, child ever breastfeeds, sex, mother's education, wealth index, and age in the month (Table 2). Children of mothers who have attended secondary high school ((OR= 1.45, C.I. (1.03,1.04)) and higher education (OR=2.09, C.I. (1.42, 3.07)) were more likely to be underweight compared to mothers who have no education. Children from mothers who have not breastfed their children have an increased chance of being underweight compared to children who have been breastfed (OR=2.01, C.I. (1.2,3.13)). A unit increase in the wealth index of the household (OR=0.98, C.I. (0.967, 0.997)) and age of a child in a month (OR=0.096, C.I. (0.046, 0.201)) were associated with decreased odds of a child being underweight. Similarly, a unit increase in the wealth index of the household (OR=0.957, C.I. (0.94, 0.975)) and age of a child in the month (OR=0.111, C.I. (0.042, 0.294)) were associated with decreased odds of a child being normal weight. On the other hand, female under-five children were most likely having normal weight compared to male under-five children (OR=1.245, C.I. (0.990, 1.567)). Under-five children who lives in River Nile (OR=0.311, C.I. (0.154,0.627), Red Sea (OR=0.272, C.I. (0.140, 0.528)), Kassala (OR=0.080, C.I. (0.044, 0.146)), Gadarif (OR=0.150, C.I. (0.085, 0.265)), Khartoum (OR=0.377, C.I. (0.206, 0.693)), Sinnar (OR=0.260, C.I. (0.143, 0.473)), Blue Nile (OR=0.251, C.I. (0.138, 0.456)), South Kordofan (OR=0.222, C.I. (0.124, 0.400)), West Kordofan (OR=0.205, C.I. (0.117, 0.358)), North Darfor (0.488, C.I. (0.258, 0.924)), West Darfor (OR=0.248, C.I. (0.138, 0.446)) and East Darfor (OR=0.313, C.I. (0.171, 0.572)) states were less likely to be underweight compared to the Northern state. On the other hand, under-five children who live in White Nile (OR=4.643, C.I. (1.704, 13.454), North Kordofan (OR=4.788, C.I. (1.704, 13.454)) and South Darfur (OR=2.556, C.I. (1.055, 6.193)) were found to be more likely normal weight compared to the Northern region. In contrary, under-five children who lives in Red Sea (OR= 0.360, C.I. (0.136, 0.949)), Kassala (OR=0.404, C.I. (0.173, 0.945)), Gadarif (OR=0.268, C.I. (0.113, 0.634)), Blue Nile (OR=0.344, C.I. (0.142, 0.832)) and West Darfor (OR=0.323, C.I. (0.131, 0.794) were less likely to be normal weight compared to the Northern State.

**Table 2 Estimates of parameters using a proportional odds model with complex survey design**

| **Covariates** | **OR** | **P-value** | **95% C. I.** | | **OR** | **P-value** | **95% C. I.** | |
|---|---|---|---|---|---|---|---|---|
| | | | **Lower** | **Upper** | | | **Lower** | **Upper** |
| | **Overweight (base outcome)** | | | | | | | |
| | **Underweight** | | | | **Normal** | | | |
| **Place of residence (Ref. Urban)** | | | | | | | | |
| Rural | 1.021 | 0.860 | 0.808 | 1.291 | 1.043 | 0.799 | 0.757 | 1.437 |
| **State (Ref. Northern)** | | | | | | | | |
| River Nile | 0.311 | **0.001** | 0.154 | 0.627 | 0.742 | 0.539 | 0.286 | 1.925 |
| Red Sea | 0.272 | **0.000** | 0.140 | 0.528 | 0.360 | **0.039** | 0.136 | 0.949 |
| Kassala | 0.080 | **0.000** | 0.044 | 0.146 | 0.404 | **0.037** | 0.173 | 0.945 |
| Gadarif | 0.150 | **0.000** | 0.085 | 0.265 | 0.268 | **0.003** | 0.113 | 0.634 |
| Khartoum | 0.377 | **0.002** | 0.206 | 0.693 | 1.523 | 0.305 | 0.681 | 3.406 |
| Gezira | 0.560 | 0.113 | 0.274 | 1.147 | 0.731 | 0.531 | 0.274 | 1.949 |
| White Nile | 1.169 | 0.713 | 0.509 | 2.686 | 4.643 | **0.003** | 1.700 | 12.680 |
| Sinnar | 0.260 | **0.000** | 0.143 | 0.473 | 0.524 | 0.134 | 0.225 | 1.221 |
| Blue Nile | 0.251 | **0.000** | 0.138 | 0.456 | 0.344 | **0.018** | 0.142 | 0.832 |
| North Kordofan | 2.239 | 0.068 | 0.942 | 5.323 | 4.788 | **0.003** | 1.704 | 13.454 |
| South Kordofan | 0.222 | **0.000** | 0.124 | 0.400 | 0.596 | 0.217 | 0.262 | 1.356 |
| West Kordofan | 0.205 | **0.000** | 0.117 | 0.358 | 0.678 | 0.323 | 0.314 | 1.465 |
| North Darfor | 0.488 | **0.028** | 0.258 | 0.924 | 1.065 | 0.886 | 0.449 | 2.525 |
| West Darfor | 0.248 | **0.000** | 0.138 | 0.446 | 0.323 | **0.014** | 0.131 | 0.794 |
| South Darfor | 0.784 | 0.493 | 0.390 | 1.574 | 2.556 | **0.038** | 1.055 | 6.193 |
| Central Darfor | 0.553 | 0.065 | 0.295 | 1.037 | 0.738 | 0.504 | 0.303 | 1.798 |
| East Darfor | 0.313 | **0.000** | 0.171 | 0.572 | 1.265 | 0.568 | 0.565 | 2.835 |
| **Sex (Ref. Male)** | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Female | 1.020 | 0.819 | 0.863 | 1.204 | 1.245 | **0.061** | 0.990 | 1.567 |
| **Mother's education (Ref. No education)** | | | | | | | | |
| Primary | 1.285 | 0.251 | 0.838 | 1.970 | 0.703 | 0.218 | 0.402 | 1.231 |
| Secondary | 1.448 | **0.034** | 1.029 | 2.038 | 0.990 | 0.940 | 0.761 | 1.289 |
| Higher | 2.087 | **0.000** | 1.417 | 3.073 | 1.264 | 0.266 | 0.836 | 1.910 |
| **Child ever been breastfed (Ref. Yes)** | | | | | | | | |
| No | 2.010 | **0.002** | 1.290 | 3.130 | 1.142 | 0.697 | 0.585 | 2.227 |
| **Wealth Index** | 0.982 | **0.019** | 0.967 | 0.997 | 0.957 | **0.000** | 0.940 | 0.975 |
| **Age in month** | 0.096 | **0.000** | 0.046 | 0.201 | 0.111 | **0.000** | 0.042 | 0.294 |

## Discussion

The study aimed, to identify the socioeconomic and demographic determinants of body mass index for children under five years in Sudan. The prevalence of underweight was 86.3% for females and 85.3% for males. There was insignificant difference between males and females underweight. The proportion of the normal weight of males is slightly higher than that of females. This result is contradicted with the result obtained by [16]. The results of the study showed that there is an association between geographic factors; state, the status of body mass index status. A significant relationship between mother's education and body mass index status. Also, a significant association was found between the wealth index and body mass index status. From the other side, place of residence and sex did not show a statistically significant relationship with body mass index status. The risk factors significantly associated with body mass index were found to be the state, child ever breastfeeds, sex, mother's education, wealth index, and age in the month. This result is in the same line as [15].

Under-five children who live in River Nile, Red Sea, Kassala, Gadarif, Khartoum, Sinnar, Blue Nile, South Kordofan, West Kordofan, North Darfor, West Darfor, and East Darfor states were less likely to be underweight compared to the Northern state. On the other hand, under-five children who live in White Nile, North Kordofan, and South Darfur were found to be more likely normal weight compared to the Northern region. On the contrary, under-five children who live in the Red Sea, Kassala, Gadarif, Blue Nile, and West Darfur were less likely to be normal weight compared to the Northern State. This result may due to the variation between Sudanese states in terms of resources, size, location, …etc. Also, the community values and habits could affect the behaviors of individuals inside these states

## Conclusion

This study shows that the factors associated with body mass index of Sudanese children under five age were child ever breastfeed, sex, mother's education, wealth index, age in the month, and states. Also. There was a high percentage of underweight children under five age in most Sudanese states. Evidence revealed that the body mass index is associated with a wealth index. The findings of this study will help policymakers to focus on the important factors to improve policies that develop the normal status of under-five children in Sudan. Furthermore, the paper recommends that developing the nutritional status of mothers helps to enhance the malnutrition status of under-five children. Therefore, the government of Sudan needs a crucial implementation of programs focused on the states of Red Sea, Kassala, Gadarif, Blue Nile, and West Darfur to enhance the policies of developing the good nutritional status of under-five children in Sudan.

## Abbreviations

BMI: Body Mass Index; MICS: Multiple Indicator Cluster Survey; NIH: National Institute of Health; LR: likelihood Ratio; OR: Odd Ratio; C.I: Confident Interval


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## Authors' contributions

Ahmed wrote the main manuscript text, Mohammed prepared theoretical statistics and literature Dawit did the statistical analysis and prepare results. All the three authors reviewed the manuscript.


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This research has no funds from any institution. It has been done by authors depending on their efforts.


## Availability of data and materials

All data analyzed were included in the submission. The datasets generated and/or analyzed during the current study are not publicly available due to their not owned by authors, it's owned by UNICEF, so authors haven't a right to disseminate these data. But are available from the corresponding author on reasonable request.

**Ethics approval and consent to participate**

Data used in this study were the 2014 Sudan Multiple Indicator Cluster Survey (MICS) The survey was carried out by the Central Bureau of Statistics of Sudan in collaboration with several national institutions. There is no direct or indirect involvement of participants.

**Consent for publication**

Not applicable

**Competing interests**

Not applicable

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