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Review Article

Determinants of Under-Five Children Body Mass Index in Sudan; Application of Quantile Regression: A Systematic Review

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Abstract

Background: One of the health challenges in Sub-Saharan countries is child malnutrition. Body Mass Index (BMI) can be defined as a measure of nutritional status. Examining the determinants of under-five children's BMI is a significant subject that needs to be studied. For this study, quantile regression was used to identify the determinants of under-five children's BMI in Sudan.

Methods: We used the 2014 Sudan Multiple Indicator Cluster Survey (MICS) conducted by the Central Bureau of Statistics. Quantile regression was used.

Results: Place of residence, state, mother's educational level, gender, age of the child, and wealth index were an important effect significantly affecting under-five children's BMI at different quantile levels.

Conclusion: Taking measures on the nutritional status of mothers will accordingly resolve the nutritional status of their children. Therefore, the focus of policymakers should be on the influential significant factors which were found across all quantile levels to plan and develop strategies to enhance the normal or healthy weight status of under-five children in Sudan.

Keywords: Body mass index; Under-five; Multiple indicator cluster survey

Introduction

Body Mass Index (BMI) is a measure of weight accommodate for height, computed as weight in kilograms divided by the square of height in meters (kg/m^2). Furthermore, BMI is adopted as a checking mechanism to determine whether an individual is a healthy weight, underweight, overweight, or obese for their height. But, body fatness is not measured directly by BMI. In case that individual's BMI is away from the normal BMI area the possibility of sickness or death can enhance unquestionably. Children's BMI depends on age and gender, also is usually specified as BMI for age. A large amount of body fat in individuals or children may point to weight associated illness and other health matters and being underweight may also put a person at exposure for health problems (1, 2).

The burdens related to using BMI for adults also apply to children and adolescents. Other factors, including height and level of sexual maturation, have influenced the association between BMI and body fat amid children too. Furthermore, the accuracy of BMI varies substantially according to the person's child's degree of body fatness. Among obese children, BMI was a good signal of excess body fat. However, among overweight children, elevated BMI levels could be a result of expanded levels of either fat or fat-free mass. Similarly, among approximately slim children, differences in BMI are often due to differences in fat-free mass (3-5).

Sudan has been committed to the 2015 Millennium Development Goals (MDG) targeting to eliminate, intense famine, and malnutrition (6). The reduction of child malnutrition was one of the objectives of Sudan's National Health Sector Strategic Plan (NHSSP) 2012-2016, which is expected to curtail the prevalence of reducing malnutrition (underweight) from 32% to 16%. According to the Ministry of Health's annual statistical reports malaria, diarrhea, and malnutrition are the major causes of under-five illnesses and hospital admission. Multiple Indicator Cluster Survey (MICS) 2014 offers an opportunity to assess the status of child malnutrition in Sudan face to face MDG 2015 and the NHSSP 2012-2016 targets. Besides, it sets to provide baseline evidence-based prioritization of child malnutrition within the full Poverty Reduction Strategic plan and the development of a national multi-sector nutrition strategy. The purpose was to focus on targeting to reduce child acute malnutrition. According to the 2014 MICS report, 16.3% of children were weighed at birth. Relatively 32.3% of children born in the last two years, were predicted to weigh less than 2,500 g at birth. The prevalence of low birth weight differs by urban 27.9% and rural areas 33.9% (7).

Globally, an estimated 101 million under-five children were underweight (i.e. weight for age below -2SD) in 2011, a 36 percent decrease from an estimated 159 million in 1990. Although the prevalence of stunting and underweight among under-five years of age has decreased worldwide since 1990, overall progress is insufficient, and millions of children remain at risk (8, 9). Therefore, malnutrition is a considerable health problem that needs due attention because reducing malnutrition in children is equivalent to improving the health status of these children. This is equivalent to improving the health status of future generations of that society and is indispensable for the economic growth and development of the society under consideration. Children's BMI under the age of five at or above the 95th percentile, between the 85th and 95th percentile, and between the 5th and 85th percentile was classified as obese, overweight, and normal (healthy weight) respectively (10). The cut-off point for underweight of less than the 5th percentile is based on recommendations by the WHO Expert Committee on Physical Status. The percentiles are age-specific for children but not for adults (3).

Many studies related to malnutrition have been conducted globally. These studies have shown an increase in malnutrition with an increase in the age of the child and other demographic factors (11-13). Therefore, the main objective of this study was to use the quantile regression model to identify the factors affecting the under-five children's BMI.

Materials and Methods

The 2014 Sudan 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 were collected using completed interviews for 15,801 households taken from a sample size of 18,000 households from all states of Sudan. The response rate was found to be 98 percent. A total of 20,327 women ranging between 15–49 yr of age and 14,751 children under five yr 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 yr of age.

Study Variables

The response variable for this study is BMI for the under-five child in Sudan. The explanatory variables used in this study are the place of residence, state, mother's education, gender, age of the child, the child still breastfeeding, and wealth index. The socioeconomic and demographic factors used in this study were suggested by different researchers (11, 13-16).

Statistical model

Quantile Regression (QR) which was proposed by Koenker and Bassett, is an extension of linear regression used to model the conditional quantiles of the dependent variable like 25^{th} percentiles, 50^{th} percentiles, and 90^{th} percentiles or 0.90 quantiles. QR is especially appropriate when the amount of variation in the conditional quantile, asserted by the regression coefficients, relies on the quantile. Median regression is a special case of quantile regression when the quantile is 0.50 (17). The basic superiority of QR compared to MLR is its resiliency for studying data with heterogeneous conditional distributions. Data of this type appeared in various fields, such as econometrics, survival analysis, and ecology. QR brings accomplish illustrate of the effect of the variable when a group of percentiles is studied, and it assumes no distributional assumption about the error term in the model (18).

Let y be a random variable with a distribution function

1) $F(y) = \text{prob}(Y \leq y)$

The τ^{th} quantile of Y is defined as the inverse function

2) $Q(\tau) = inf\{y: F(y) \geq \tau\}$

Where $0 < \tau < 1$, we consider the Median as a special case $Q(0.5)$. Also, equation 2) can be extended as follows:

3) $Q_y(\tau \backslash x_1, x_2, \ldots\ldots, x_k) = \beta_0^{(\tau)} + \beta_1^{(\tau)} x_1 + \ldots\ldots + \beta_k^{(\tau)} x_k$

Where $0 < \tau < 1$, $\beta^{\tau} = (\beta_0^{(\tau)}, \beta_1^{(\tau)}, \ldots\ldots\ldots, \beta_k^{(\tau)})$ is the vector of the unknown parameters

Let $y_1, y_2, \ldots\ldots, y_n$ be a random sample of Y, the sample median is known as the minimum of the sum of the absolute deviations

4) $min_{\zeta \in R} \sum_{i=1}^{n} |y_i - \xi|$

Furthermore, the general τ^{th} sample quantile $\zeta(\tau)$ which is the analog of $Q(\tau)$, can be formulated for the optimization solution

5) $min_{\zeta \in R} \sum_{i=1}^{n} \rho_\tau |y_i - \xi|$

Where $\rho_\tau(z) = z(\tau - I(z < 0)), 0 < \tau < 1.$ Here $I(0)$ represents the indicator function. Like the sample mean which minimizes the sum of the square residuals.

6) $\hat{\mu} = argmin_{\mu \in R} \sum_{i=1}^{n} (y_i - \mu)^2$

Could be expanded to the linear conditional mean function $E(Y \backslash X = x) = x\acute{}\beta$

7) $\hat{\beta} = argmin_{\beta \in R^p} \sum_{i=1}^{n} (y_i - x\acute{}\beta)^2$

Similarly, linear conditional quantile function, $Q(\tau \backslash X = x) = x\beta\acute{}(\tau)$ can be estimated via solving the following equation

8) $\hat{\beta}(\tau) = argmin_{\beta \in R^p} \sum_{i=1}^{n} \rho_\tau (y_i - \acute{x}_i \beta)$

For any quantiles $0 < \tau < 1$. The portion $\hat{\beta}(\tau)$ is recognized as τ^{th} regression quantile, when $\tau = 0.5$ which minimizes the sum absolute residuals, coincides with median regression. The estimated model of the conditional quantile is given by

9) $\hat{Q}_\tau(y_i / x_i) = \acute{x}_i \hat{\beta}_\tau$

The interpretation of the estimated parameters in QR has the same way of interpretation as those of OLS as rates of changes (19). More details about QR can be found in different works of literature such as (20-23).

The quantile regression goodness of fit to the given data at each quantile was assessed using pseudo-R-square as described by Koenker and Machao (24). Because the 2014 Sudan MICS was collected using multi-stage sampling, including the design effect is important. As a result, the sampling weights were included in the analysis to account for the complex sampling design. Ignoring the sampling design gives under or overestimated results. For the analysis, PROC QUANTREG in SAS 9.4 was used. The resampling method was used because the data set is large enough to use the resampling method (24) and to compute the quantile regression estimates. In addition, an interior algorithm was used. The goodness-of-fit and the equality of slopes are tested as given in Koenker and Machado. The use of the Wald test was applied to test the hypothesis for a pure location shift that fitted for the quantile regression model.

Ethical approval

Ethical approval for the study was granted by the Population Council's Institutional Review Board and the Ahfad University for Women's Research Committee. A written consent was obtained from all participants prior to the interviews and discussions and verbal ones were taken from illiterate respondents after approval from the research committee.

Results

The proposed Quantile model was applied to the 2014 Sudan MICS. Table 1 gives the BMI result for different quantile levels. As can be seen from the table, the median BMI has the same value as the 50th percentile or the second quantile (15.05) values. The 5^{th} percentiles have children with BMI less than 12.37. This value is considered underweight. Furthermore, children with a BMI from 13.98 to 16.45 (25^{th} to 75^{th} percentile) are considered as normal (healthy weight). But, children with BMI is 20.91 and considered overweight.

Table 1: Study result of under-five children BMI

Level	*BMI*
Median	15.05
5th Percentile	12.37
25th percentile, the first quantile (Q1)	13.98
50th percentile, the first quantile (Q2)	15.05
75th percentile, the third quantile (Q3)	16.45
90th percentile	20.91

Table 2 shows that 27.1% of the children were from Urban and 72.9% were from rural areas. Other data are presented in Table 2.

The combined test for equivalence of coefficients of the slop for the household data for the fitted quantiles 0.25, 0.50, 0.75, and 0.90 was significant (*P*-value<.0001). The result implies that the effects of explanatory variables on the household data are not similar for the different quantiles.

The result of the parameter estimation of the model is presented in Table 3. The interpretation of the model aimed to present any variable that is positively or negatively associated with under-five BMI. As can be seen in the table, factors that have a significant effect on all quantile levels and OLS are the State and age of a child.

Table 3 shows estimates of parameters using different model approaches. The OLS results showed that place of residence, state, and age of the child has a significant effect on under-five children's BMI. As the result indicates, under-five children's BMI is positively related to the place of residence. The under-five BMI increases by 1.6 for rural areas compared to urban areas by holding the other factors constant. On the other hand, child BMI is negatively related to State (Blue Nile, East Darfor, Gadafir, Gezira, Khartoum, Red Sea, South Darfor, West Darfor and West Kordofam). Furthermore, an under-five child's BMI is also negatively related to the age of a child in months. As the result indicates, the Child's BMI decreases by 0.09 for a unit change of the age of the child by holding the other factors constant.

At 0.25 quantile, Place of residence, State, gender, and age of the child has a significant effect on the BMI of under-five children. As Table 3 indicates, for a unit change of rural, BMI of under-five children decreases by 0.22. Concerning state, BMI is negatively related to some states. These states are Khartoum, North Darfor, and River Nile.

Table 2: Distribution of covariates

Variable	*Number*	*Percentage*	*95% CI*	
			Lower	Upper
Place of residence				
Urban	3998	27.10	26.40	27.80
Rural	10753	72.90	72.20	73.60
State				
Northern	559	3.80	3.50	4.10
River Nile	600	4.10	3.80	4.40
Red Sea	443	3.00	2.70	3.30
Kassala	681	4.60	4.30	5.00
Gadarif	881	6.00	5.60	6.40
Khartoum	717	4.90	4.50	5.20
Gezira	822	5.60	5.20	6.00
White Nile	785	5.30	5.00	5.70
Sinnar	859	5.80	5.50	6.20
Blue Nile	1052	7.10	6.70	7.60
North Kordofan	799	5.40	5.10	5.80
South Kordofan	1120	7.60	7.20	8.00
West Kordofan	763	5.20	4.80	5.50
North Darfor	976	6.60	6.20	7.00
West Darfor	860	5.80	5.50	6.20
South Darfor	1017	6.90	6.50	7.30
Central Darfor	875	5.90	5.60	6.30
East Darfor	942	6.40	6.00	6.80
Gender				
Male	7506	50.90	50.10	51.70
Female	7245	49.10	48.30	49.90
Mother's education				
None	6885	46.70	45.90	47.50
Primary	4893	33.20	32.50	34.00
Secondary	2117	14.40	13.80	14.90
Higher	837	5.70	5.30	6.10
Age of child(yr)				
Under one	2983	21.20	20.50	21.90
One	2642	18.80	18.10	19.40
Two	2639	18.70	18.10	19.40
Three	3233	23.00	22.30	23.70
Four	2584	18.40	17.70	19.00
Child ever been breastfed				
Yes	7941	97.60	97.30	97.90
No	194	2.40	2.10	2.70
Child still being breastfed				
Yes	5173	65.20	64.10	66.20
No	2761	34.80	33.80	35.90
Wealth Index				
Poor	7313	49.60	48.80	50.40
Middle	3289	22.30	21.60	23.00
Higher	4149	28.10	27.40	28.90

Furthermore, the gender of the child (female) is negatively related to the BMI of the under-five child as compared to a male child's. In addition, the age of the child was negatively related to the BMI of the child. The result showed that for a unit change of age, BMI will increase by 0.01 by keeping the other factors constant.

Similarly, for 0.5 quantile result, state, mother's educational level, gender, age of the child, and wealth index has a significant effect on the BMI of the under-five child. In a closer look at the results, BMI is negatively related to some states.

Table 3: Parameter estimates using quantile regression

Covariates	*EST*	*P-value*	*EST*	*P-value*	*EST*	*P-value*	*EST*	*P-value*	*EST*	*P-value*
	OLS		0.25		0.50		0.75		0.90	
Intercept	25.29	<.0001	15.11	<.0001	16.34	<.0001	18.35	<.0001	100.13	<.0001
Place of residence (Ref. Urban)										
Rural	1.60	0.01	-0.22	0.0081	-0.11	0.1335	0.08	0.4543	0.43	0.3065
State (Ref.White Nile)										
Blue Nile	-8.14	<.0001	0.03	0.8172	0.07	0.6862	-0.28	0.2191	-80.65	<.0001
Central Darfor	-4.07	0.0526	0.10	0.541	0.08	0.647	0.29	0.4559	-75.36	<.0001
East Darfor	-7.70	<.0001	-0.07	0.651	-0.18	0.2005	-0.73	0.0006	-81.21	<.0001
Gadarif	-4.65	0.0009	-0.04	0.7622	0.04	0.8228	0.09	0.7233	-77.67	<.0001
Gezira	-8.44	<.0001	-0.28	0.0795	-0.24	0.1729	-0.40	0.0989	-80.08	<.0001
Kassala	3.04	0.0562	-0.26	0.0843	-0.26	0.1551	-0.24	0.6486	0.64	0.7926
Khartoum	-5.04	<.0001	-0.51	0.0006	-0.61	<.0001	-0.98	0.0001	-80.99	<.0001
North Darfor	-2.23	0.1132	-0.61	0.0002	-0.69	<.0001	-1.05	<.0001	-78.16	<.0001
North Kordofan	0.56	0.6954	0.19	0.2114	0.23	0.1937	-0.03	0.9191	0.02	0.995
Northern	-3.68	0.0717	-0.12	0.4546	-0.35	0.0303	-0.69	0.0136	-79.24	<.0001
Red Sea	9.66	<.0001	0.01	0.9701	0.26	0.2994	2.47	0.1579	1.61	0.4911
River Nile	-1.31	0.4494	-0.68	0.0001	-0.54	0.0028	-0.59	0.0262	-0.39	0.9849
Sinnar	-0.64	0.6741	-0.32	0.0474	-0.38	0.0133	-0.58	0.0241	0.46	0.9814
South Darfor	-6.86	<.0001	0.04	0.7776	-0.23	0.1631	-0.78	0.0011	-81.11	<.0001
South Kordofan	-0.91	0.5712	-0.06	0.6935	0.08	0.6589	0.18	0.5671	-74.59	0.01
West Darfor	-6.87	<.0001	-0.16	0.2862	-0.02	0.9142	-0.26	0.3385	-79.75	<.0001
West Kordofan	-4.95	0.0005	-0.10	0.6363	-0.25	0.1988	-0.42	0.1943	-80.48	<.0001
Educational Level (Ref. Secondary)										
Higher	1.64	0.1147	0.25	0.0829	0.25	0.1528	0.41	0.0951	0.28	0.6539
None	0.31	0.6904	-0.17	0.0644	-0.25	0.0181	-0.40	0.0055	-0.69	0.1386
Primary	-0.07	0.9199	-0.09	0.3348	-0.15	0.1558	-0.29	0.0343	-0.65	0.1133
Gender (Ref.Male)										
Female	-0.19	0.6876	-0.46	<.0001	-0.37	<.0001	-0.39	<.0001	-0.33	0.1609
Age of child in month	-0.09	0.0064	-0.01	0.0051	-0.03	<.0001	-0.05	<.0001	-0.07	<.0001
Still Breastfeeding (Ref.Yes)										
No	0.37	0.5877	-0.09	0.3539	-0.11	0.2331	0.02	0.8768	0.39	0.2496
Wealth index (Ref. Poor)										
Higher	-0.25	0.7549	0.17	0.0817	0.24	0.0258	0.08	0.6001	0.10	0.8191
Middle	-1.23	0.0733	0.00	0.9851	-0.02	0.8214	-0.19	0.1677	-0.25	0.4266

These states are Khartoum, North Darfor, River Nile, and Sinnar. The other significant effect of BMI is the educational level of the mother. As the result indicates, the educational level is negatively related to BMI. Similarly, the gender and age of the child have a negative effect on the BMI of the under-five child. But, the wealth index of the household is positively related to the BMI of the child (Table 3).

The result for 0.75 quantiles is given in Table 3. From the result, it can be observed that the state, mother's educational level, gender, and age of the child have a significant effect on the BMI of the under-five child. From the result, it can be seen

that BMI is negatively related to some states. These states are Khartoum, North Darfor, Northern, River Nile, Sinnar and South Darfor. The other significant effect of BMI is the educational level of the mother. As the result indicates, the educational level is negatively related to BMI. Similarly, the gender and age of the child have a negative effect on the BMI of the under-five child.
The other quantile level of the analysis is the 90th quantile. Compared to the other quantile levels, the 90th quantile level has the highest number of significant states on BMI of the under-five child. As given in Table 3, the significant effects are the state and age of the child. Both effects are negatively related to the BMI of the under-five child.
Fig. 1 and 2 present a summary of the quantile regression findings of the study variables. Each plot shows one coefficient in the quantile regression model, 95% confidence intervals represented in the shaded regions.

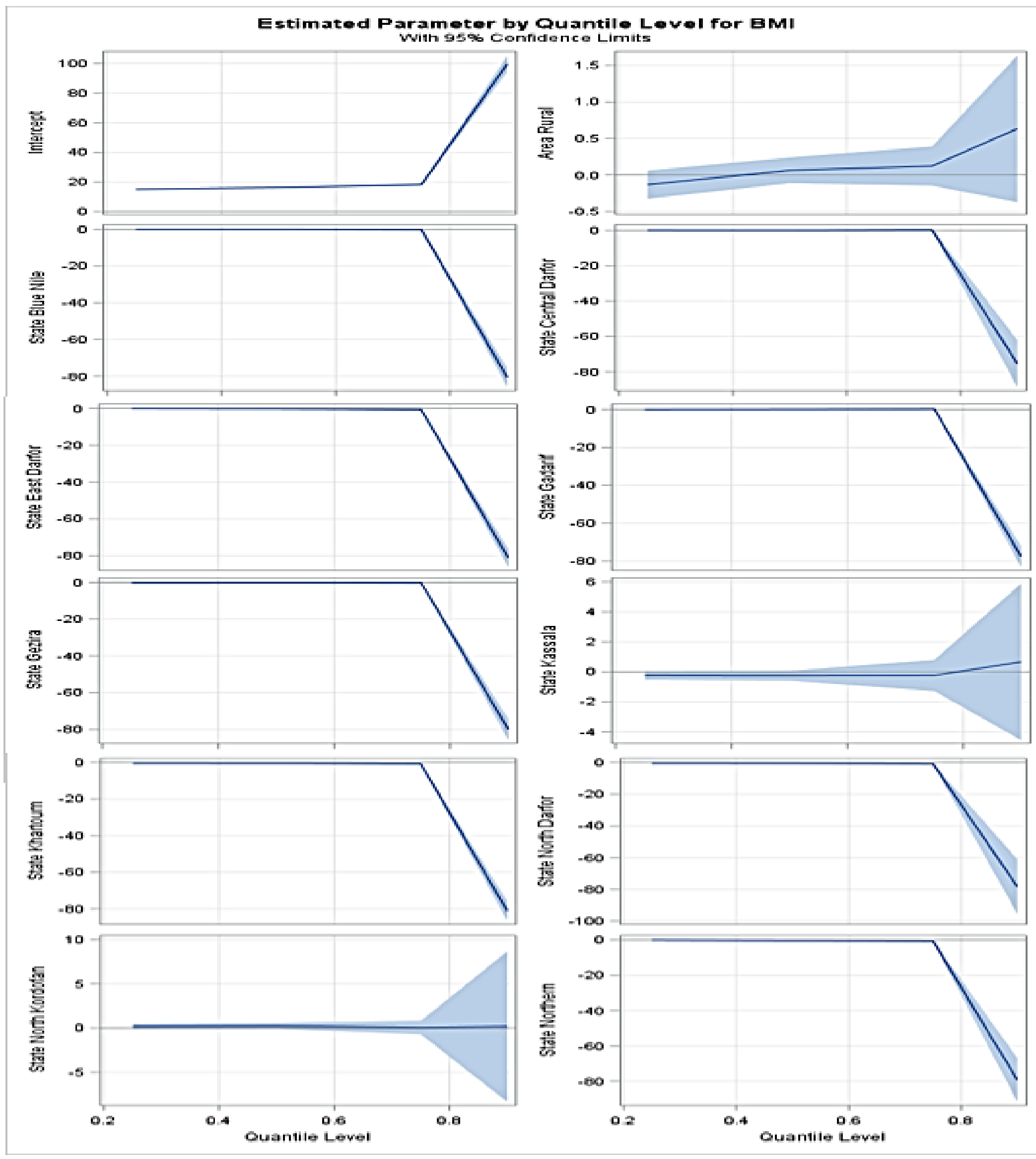

Fig. 1: Quantile processes with 95% confidence bands for state

The intercept of the model is represented in the first part of Fig. 1 and can be interpreted as the estimated conditional quantile function of the under-five children BMI for all possible quantile levels. The figure has a positive effect in the upper quantiles when compared to the lower quantiles. Besides, the graph indicates a positively upward sloped line across the quantiles. The second plot shows the effect of place of residence on under-five children's BMI has a positive effect, especially in the upper quantile's levels. The third plot shows the effect of the state in the model. The plot shows a negative effect across quantile levels except for Kassala state.

Figure 2 shows quantile processes for mother's education, gender, age, child breastfeeding, and wealth index. The first plot in the figure shows the mother's education. The effect of the mother's BMI in the model has a negative effect in the upper quantiles; the graph indicates a negatively descending sloped line across the quantiles. The other plots represent the gender of the under-five child. The figure shows an increasing pattern for upper quantiles. The next plot in the figure is the age of the child in a month. In contrast, this plot shows a negative relationship between age and BMI of under-five children. On the other hand, the wealth index of the household has a decreasing pattern.

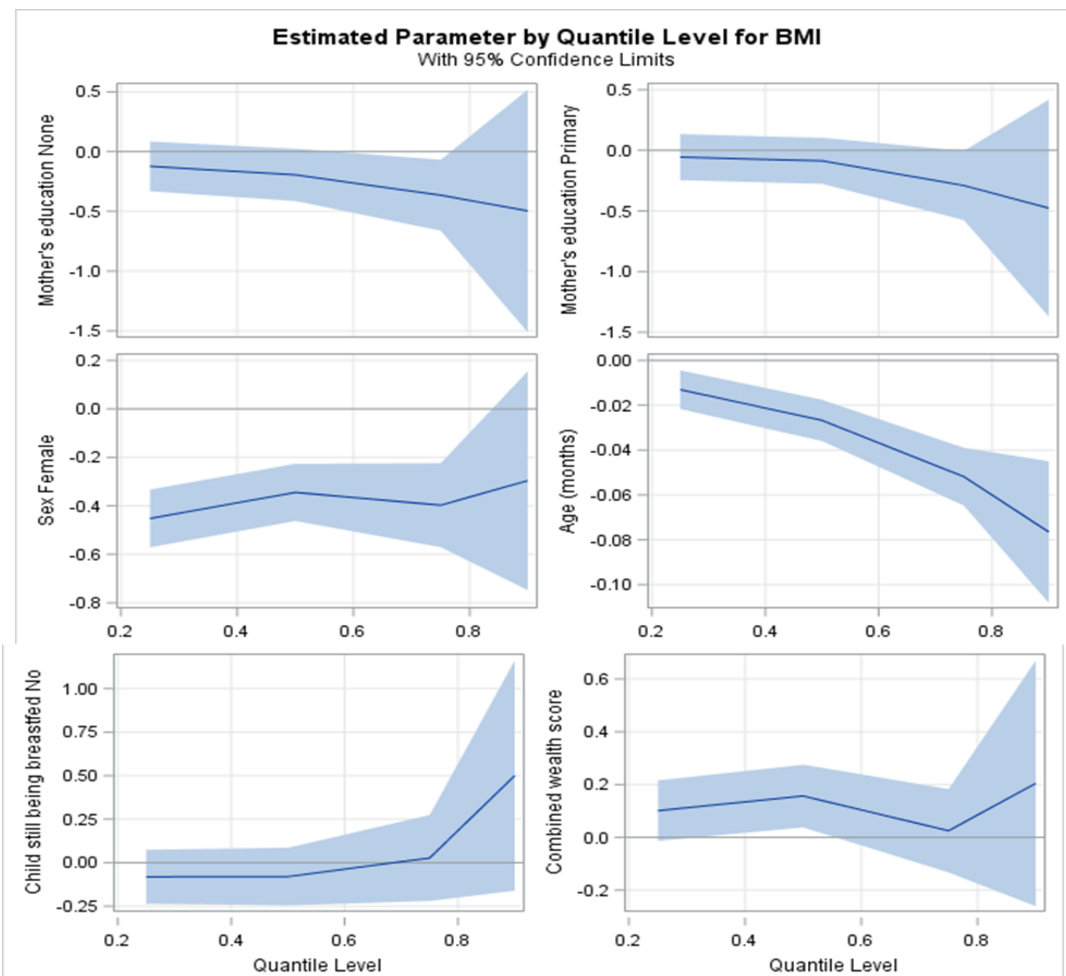

Fig. 2: Quantile processes with 95% confidence bands for mother's education, gender, age, child breastfeeding, and wealth index

Discussion

In the area of under-five malnutrition, different researchers have presented their findings. From these studies, it was observed that poor attitude and practice by parents and the poor environment surrounding them was one of the reasons (25). Moreover, in Ethiopia for children under the age of five, the current age of mother, mother's region, and weight of the child at birth were significantly affecting under-five children's BMI across quantile levels (16). From similar studies, age, gender, learning in classes, playing in the open air, reading books or use of the internet, current maternal smoking, television viewing (both with higher BMI), and frequent nut consumption (11-13).

For this study, the quantile regression was used for the analysis of under-five children's BMI using the 2014 MICS. The point estimates of quantile levels allowed us to identify the effects of predictors on various quantiles of the under-five BMI. Therefore, the result gave a full situation of the association between the outcome and explanatory variables. The evaluations across the different quantile levels gave us to study the influence of predictors on different quantile levels of the response variable (BMI of under-five children) and thus make available a complete picture of the association between the response and different covariates.

This study revealed that children under the place of residence, state, mother's education level, gender, age of the child, and wealth index were found to be an important effect significantly affecting under-five children's BMI at different quantile levels. Therefore, our findings supported the findings of previous studies.

Conclusion

Investigating BMI is an important public health issue among children under five yr of age in Sudan. Besides, not only education but also socioeconomic factors affect the under-five children's BMI. Therefore, taking measures on the nutritional status of mothers will accordingly resolve the nutritional status of their children. Therefore, the focus of policymakers should be on the influential significant factors which were found across all quantile levels to plan and develop strategies to enhance the normal or healthy weight status of under-five children in Sudan.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare that there is no conflict of interest.

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