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Factors Affecting Malnutrition Among Children under Five Years of Age in Sudan

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ABSTRACT

This study aims to assess the nutritional status using anthropometric measurements, which include body mass index and other physical dimensions, in addition to the age of the child. The study emphasizes the need to compare anthropometric measurements with standard measures and analyze data using Cross tables to investigate the impact of economic and social factors on malnutrition. The results indicate that almost 34 of children under five years old suffer from moderate Underweight, with over 36.6 classified as moderately stunted, meaning they are significantly shorter than expected for their age. Furthermore, about 15.8 of children exhibit moderate wasting, indicating that they are thinner than expected for their height. The study reveals significant differences in malnutrition levels based on factors like the child's gender, urban versus rural living conditions, states and maternal education, as well as other indicators such as diarrhea, vitamin intake, and family wealth. These factors significantly impact malnutrition based on the indicators of underweight, stunting, and wasting.

1   INTRODUCTION

The nutritional status of children under five in developing countries significantly impacts the overall health and wellbeing of the community. A balanced diet containing essential nutrients helps prevent recurring diseases. Children who receive proper care reach their full growth potential, remain well-nourished, and are less likely to suffer from malnutrition. Globally, malnutrition contributes to more than half of child mortality rates, where children with poor nutrition are more likely to die from common childhood diseases. Survivors often experience recurring illnesses and growth disorders. Threequarters of children who die due to malnutrition suffer from mild or moderate malnutrition, often without any external signs of their weakened condition [1,2,11].

The United Nations' Millennium Development Goal aimed to halve the proportion of people suffering from hunger between 1990 and 2015. Reducing malnutrition rates can also help lower child

mortality rates. Nutritional status is influenced by prevailing social and economic conditions. The various methods used to assess nutritional status differ in their number and complexity depending on the purpose of their use. Typically, standardized physical growth indicators are calculated by measuring the height and weight of children under five and linking them to the child's age to determine their nutritional status [2-3]. These measurements are compared to recognized standards recommended by the World Health Organization (WHO) and compared to the reference community's indicators (Table 1). These include three main indicators:

i. Weight forage (Underweight): This indicator reflects both acute and chronic malnutrition and is more sensitive than the other two indicators.
ii. Height forage (Stunting): This indicator measures chronic malnutrition and reflects the long-term impact of insufficient food intake or recurring diseases, causing stunted growth.
iii. Weight for height (Wasting): This indicator represents acute malnutrition due to recent inadequate food intake or severe illness preventing the child benefiting from food. Wasting is often linked to seasonal changes in food availability or disease outbreaks [3].

Additionally, children whose weight for height exceeds the median of the reference population by two standard deviations are classified as overweight. However, this indicator falls outside the scope of this study.

These indicators are classified into moderate/severe for children below two standard deviations from the reference population median and severe for children below three standard deviations. For height forage, moderate stunting includes children below two standard deviations, while severe stunting includes those below three standard deviations. The same classifications apply to the other indicators.

This study explores the variation in these indicators according to demographic, social, and economic characteristics using data from the Fifth Multiple Indicator Cluster Survey (MICS) [1], which provides updated information necessary for assessing the status of children and women in Sudan and monitoring progress toward the Millennium Development Goals.

Importance: Malnutrition is a significant problem in many developing countries, including Sudan. The increase in the percentage of children suffering from malnutrition leads to an increase in the incidence of diseases. Children under five are the most vulnerable to nutritional issues and face higher risks of mortality. Malnutrition is also an economic and social issue with wide reaching effects [4,12].

Research Questions The research problem and questions focus on the following:
- Does the level of malnutrition differ by the child's gender and age?
- Does malnutrition vary based on the mother's education level?
- Is malnutrition affected by the family's economic status?
- Is malnutrition influenced by the incidence of diseases?

The aim of this study is to examine the impact of economic, social, and demographic factors on the level of malnutrition and, to determine the relative importance of each factor affecting malnutrition levels.

2   METHODOLOGY

The cross-sectional methodology was chosen for this study due to its ability to provide a comprehensive and immediate overview of malnutrition among children under five in Sudan. This design helps identify relationships between influencing variables, such as socioeconomic factors, healthcare services, and mothers' education, forming a basis for targeted interventions. In Sudan, where many communities face limited healthcare resources and high poverty rates, the findings of this study will be of significant importance. They offer reliable and concrete data for decision-makers and healthcare organizations to direct efforts toward the most affected regions and groups. Additionally, these findings can support the formulation of national strategies that improve children's nutritional status and reduce mortality rates associated with malnutrition.

This design was selected due to its effectiveness in evaluating relationships between different variables in large population-based studies, as demonstrated by [6].

The data collection tools included anthropometric measurements (weight, height, mid-upper arm circumference [MUAC], and head circumference), using standardized and calibrated measuring equipment. The World Health Organization (WHO) guidelines were followed in measuring and classifying the nutritional status, which have been widely adopted in similar studies, such as the work of [9]. The sample size consisted of 12,402 children under the age of five, for whom anthropometric measurements were collected to assess malnutrition indicators, including underweight, stunting, and wasting, based on internationally recognized standards [1]. However, the data for this research is limited to a one-year analysis from 2014. With additional data, the prediction model could be used to assess malnutrition indicators among children under five.

The nutritional status of children was classified using z-scores calculated through the WHO Anthro Software. This method is considered a globally reliable standard and has been successfully applied in studies such as [10].

Dependent Variable: Nutritional status, categorized as underweight, stunted, wasted, or normal. Independent Variables: Age, gender, socioeconomic status, maternal education level, and access to healthcare services.

In data analysis, descriptive statistics (means, standard deviations, frequencies, and percentages) were calculated to summarize the demographic and nutritional characteristics of the sample, while the Chi-Square Test was applied to analyze the relationship between nutritional status and independent variables such as age groups, gender. This method is widely used in epidemiological studies, as highlighted by [10, 13], who employed the same test to examine factors influencing malnutrition among children.

The Chi-square statistic was calculated using the following formula:

$$\chi^2 = \frac{\sum (O_i - E_i)^2}{E_i} \tag{1}$$

where, O_i is observed frequency in each category and E_i is expected frequency.
The test was conducted at a significance level of 0.05, with degrees of freedom determined as

$(r - 1) \times (c - 1)$, where r is the number of rows and c is the number of columns in the contingency table. This allowed the study to evaluate significant associations between the anthropometric measurements and other variables.

Table 1: Classification of malnutrition based on anthropometric measurements (weight-for-age, height-for-age, and weight-for-height)

Measurement	Moderate Malnutrition	Severe Malnutrition
Weight-for-age	WFAM: -2 to -3 SD	WFAS: Below -3 SD
Height-for-age	HFAM: -2 to -3 SD	HFAS: Below -3 SD
Weight-for-height	WFHM: -2 to -3 SD	WFHS: Below -3 SD

- These classifications are based on WHO growth standards and are used worldwide to assess child malnutrition and prioritize interventions [1].
- WFAM: Weight-for-age moderate malnutrition
- WFAS: Weight-for-age severe malnutrition
- HFAM: Height-for-age moderate malnutrition
- HFAS: Height-for-age severe malnutrition
- WFHM: Weight-for-height moderate malnutrition
- WFHS: Weight-for-height severe malnutrition.

3   RESULTS AND DISCUSSION

The analysis of malnutrition among children under five in Sudan focuses on three key indicators: 1underweight (weight-for-age), stunting (height-for-age), and wasting (weight-for-height). The findings are summarized below, with an emphasis on their statistical significance and implications. Approximately one in three children under five in Sudan suffers from underweight 34.0%, (Table 2). Additionally, 39.6% of children are moderately stunted, meaning they are significantly shorter than their age group (Table 3). Furthermore, 15.8% experience moderate wasting, indicating they are thinner than expected for their height (Table 4).

Underweight reflects chronic energy deficiency, signifying long-term malnutrition. Stunting indicates prolonged nutritional deprivation and poor growth, while wasting represents acute malnutrition, often caused by recent illness or insufficient food intake.

The high prevalence of these indicators underscores the severity of malnutrition in Sudan. Stunting, the most widespread issue, highlights the extent of chronic malnutrition, while wasting points to the persistence of acute malnutrition, particularly in vulnerable subpopulations.

There are statistically significant differences between boys and girls in terms of underweight and stunting. The underweight rate is 35.1 for boys and 32.8 for girls (Table 2), while the stunting rate is lower among girls, at approximately 21, compared to 39 for boys (Table 3). For wasting, the rate is 8.0 for boys and 7.6 for girls (Table 4), with no significant difference between the genders in this regard.

Furthermore, we find statistically significant differences between rural and urban children for all three measurements. The underweight rate in rural areas is 38, compared to 24 in urban areas. The stunting rate is 43.9 in rural areas, compared to 28.6 in urban areas, and the wasting rate is 16.8 in rural areas, compared to 13.8 in urban areas (Table 4). All these indicators show that children in rural areas fare worse than those in urban areas (Figure 1).

The age pattern shows statistically significant differences among children in different age groups. It is observed that children in the first six months of life are the least likely to suffer from underweight, stunting, or wasting. The highest rate of underweight is 40.4 among children aged 24_35 months, compared to children who are either younger or older (Table 2). Stunting was 13.2 among children aged 05 months, compared to 51 among children aged 24_35 months (Table 3). The likelihood of children experiencing all three indicators increases as the child ages. This pattern is expected and is related to the age at which many children stop breastfeeding and are exposed to contaminated water, food, and the environment (Figure 2).
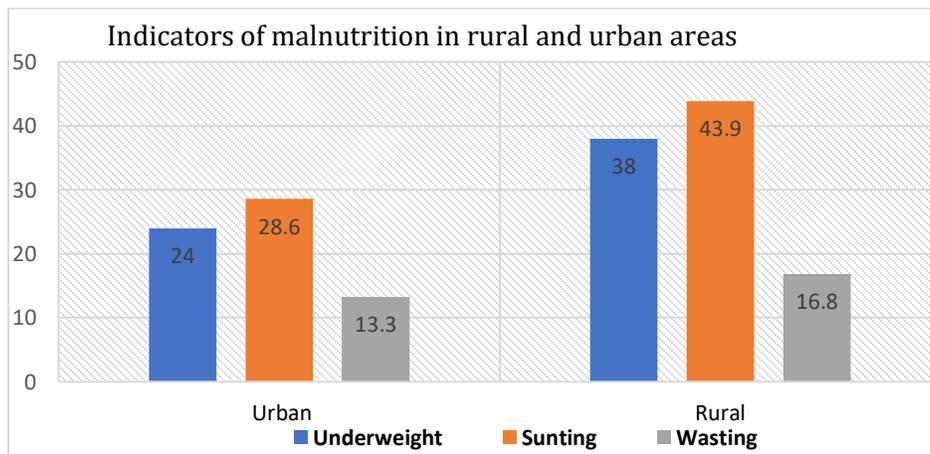

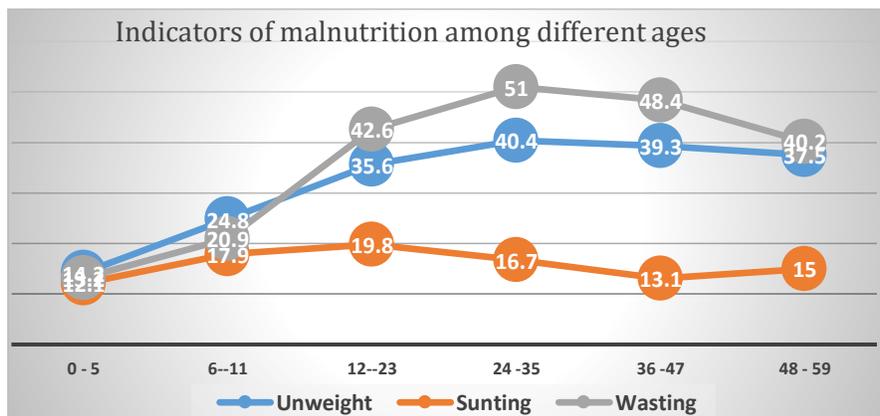Figure 1: Malnutrition status in rural and urban areas.

Figure 2: Malnutrition status for children under five years of age, age in months.

Table 2: Prevalence of underweight (weight-for-age below -2SD from the mean) among children under five years and associated demographic and social factors.

Category	Under -2 SD		Number (N)	Chi-square	Degrees of Freedom (df)	Significance (sig)
	N %	Mean (Z_Score)				
Total	34.00	1.48	11367			
Sex				**6.534**	**1**	**.011***
Male	35.10	1.51	5826			
Female	32.80	1.46	5541			
Area				**201.9**	**1**	**.000***
Urban	24.00	1.2	3224			
Rural	38.00	1.6	8143			
Age				**354.34**	**5**	**.000***
0-5 months	14.20	0.48	1286			
6-11 months	24.80	1.17	1265			
12-23 months	35.60	1.55	2248			
24-35 months	40.40	1.76	2161			
36-47 months	39.30	1.69	2433			
48 -59 months	37.50	1.72	1974			
Mother's Education				**287.56**	**4**	**.000***
None	41.10	1.71	4967			
Primary	32.70	1.45	3901			
Secondary	24.00	1.18	1767			
Higher	17.20	0.92	720			
Wealth Index				**325.58**	**4**	**.000***
Poorest	42.00	1.73	2325			
Second	40.00	1.67	2816			
Middle	34.70	1.51	2624			
Fourth	28.50	1.31	1978			
Richest	17.90	0.98	1624			
Child Had Diarrhea in Last 2 Weeks				**37.685**	**3**	**.000***
Yes	38.30	1.61	3226			
No	32.30	1.44	8079			
Child Took Vitamin A in Last 6 Months				**116.92**	**3**	**.000***
Yes	36.60	1.63	7887			
No	37.60	1.5	1504			

* The Chi-square statistic is significant at the .05 level

Table 3: Prevalence of stunting (height -for-age below -2SD from the mean) among children under five years and associated demographic and social factors.

Category	Under -2 SD		Number (N)	Chi-square	Degrees of Freedom (df)	Significance (sig)
	N %	Mean(Z_Score)				
Total	**39.60**	**0.81**	**12402**	**19.084**	1	**.000***
sex				**279.52**	**17**	**.000***
Male	41.60	0.83	6336			
Female	37.50	0.8	6066			
Area				**218.77**	**1**	
Urban	28.60	0.7	3351			
Rural	43.90	0.86	9051			
Age				**714.81**	**5**	**.000***
0-5 months	13.20	0.3	1199			
6-11 months	20.90	0.8	1280			
12-23 months	42.60	0.95	2384			
24-35 months	51.00	0.9	2378			
36-47 months	48.40	0.76	2846			
48 -59 months	40.20	0.93	2315			
Mother's education				**409.99**	**4**	**.000***
None	48.60	0.88	5781			
Primary	37.70	0.82	4128			
Secondary	27.20	0.7	1777			
Higher	18.60	0.55	701			
Wealth index quintile				**434.44**	**4**	**.000***
Poorest	46.80	1.01	2830			
Second	47.60	0.86	3258			
Middle	42.80	0.74	2725			
Fourth	31.80	0.75	1993			
Richest	20.10	0.59	1596			
child had diarrhoea in last 2 weeks				**10.882**	**3**	**.012***
Yes	42.00	0.91	3455			
No	38.60	0.78	8848			
Child take any Vitamine A during the last 6 months				**165.1**	**3**	**.000***
Yes	43.70	0.87	8718			
No	42.40	0.84	1786			

* The Chi-square statistic is significant at the .05 level

Table 4: Prevalence of wasting (weight-for- height below -2SD from the mean) among children under five years and associated demographic and social factors.

Category	below -2 SD		Number (N)	Chisquare	Degrees of Freedom (df)	Significance (sig)
	N %	Mean (ZScore)				
Total	**15.80**	**0.81**	**12402**			
Sex				**1.407**	**1**	**0.236**
Male	16.20	0.83	6336			
Female	15.40	0.8	6066			
Area				**22.125**	**1**	**0.000***
Urban	13.30	0.7	3351			
Rural	16.80	0.86	9051			
Age				**63.38**	**5**	**0.000***
0-5 months	12.10	0.3	1199			
6-11 months	17.90	0.8	1280			
12-23 months	19.80	0.95	2384			
24-35 months	16.70	0.9	2378			
36-47 months	13.10	0.76	2846			
48 -59 months	15.00	0.93	2315			
Mother's Education				**27.564**	**4**	**0.000***
None	17.20	0.88	5781			
Primary	15.70	0.82	4128			
Secondary	13.30	0.7	1777			
Higher	11.60	0.55	701			
Wealth index quintile				**51.468**	**4**	**0.000***
Poorest	19.00	1.01	2830			
Second	16.90	0.86	3258			
Middle	14.60	0.74	2725			
Fourth	14.70	0.75	1993			
Richest	11.60	0.59	1596			
Child Had Diarrhea in Last 2 Weeks				**19.845**	**3**	**0.000***
Yes	18.20	0.91	3455			
No	14.90	0.78	8848			
Child Took Vitamin A in Last 6 Months				**11.183**		**0.011***
Yes	15.70	0.87	8718			
No	18.10	0.84	1786			

* The Chi-square statistic is significant at the .05 level

Table 5: Malnourished status (Underweight, Stunting, wasting) of the proportion children under five years in the states.

STATS	Underweight below -2 SD		Stunting below -2 SD		Wasting below -2 SD	
	N %	Mean (Z_Score)	N	Mean (Z-Score)	N	Mean (Z-Score)
Total	34.00	1.48	39.60	0.81	15.80	0.81
Northern	22.30	1.11	22.90	0.7	12.20	0.7
River Nile	32.90	1.5	30.30	0.99	20.30	0.99
Red Sea	34.70	1.56	47.60	0.53	14.10	0.53
Kassala	44.60	1.79	51.80	0.97	19.80	0.97
Gadarif	38.00	1.58	45.80	0.72	15.30	0.72
Khartoum	22.40	1.17	21.00	0.84	14.10	0.84
Gezira	29.50	1.25	41.00	0.38	13.00	0.38
White Nile	31.00	1.43	36.90	0.78	15.10	0.78
Sinnar	34.80	1.55	38.00	0.92	15.30	0.92
Blue Nile	33.80	1.48	45.00	0.63	10.60	0.63
North Kordofan	32.80	1.47	39.30	0.77	14.20	0.77
South Kordofan	35.20	1.52	40.10	0.73	14.40	0.73
West Kordofan	36.00	1.41	39.90	0.91	16.50	0.91
North Darfor	43.80	1.82	45.60	1.36	27.70	1.36
West Darfor	29.50	1.3	36.30	0.89	19.20	0.89
Central Darfor	31.50	1.56	34.30	1.04	16.50	1.04
East Darfor	39.20	1.65	48.30	0.63	15.50	0.63

As for the mother's educational level, there are statistically significant differences among the different education levels. Children whose mothers have attained secondary education or higher are less likely to suffer from underweight, stunting, and wasting compared to children whose mothers have not received any form of education.

Children whose mothers attained secondary education had a lower rate of underweight at 17.2, compared to 41.1 among children whose mothers had no education (Table 2). Similarly, the stunting rate was 18.6 among children whose mothers had secondary education, compared to 48.6 for children whose mothers had no education (Table 3). For wasting, children of mothers with secondary education had a rate of 11.6, compared to 17.2 for children whose mothers had no education (Table 4). This is because more educated mothers are generally more aware of proper nutrition practices [5-8, 14].

The results show statistically significant differences among children across wealth index categories, which measure income and wealth inequality between the poor and the rich. The likelihood of children suffering from underweight, stunting, and wasting increases among the poorest groups, with 42.0 and 40.0 of children from the poorest and poor groups suffering from underweight,

respectively (Table 2). Stunting rates are 47.8 and 46.6, respectively, in these same groups (Table 3), and wasting rates are 19.6 and 16.9, respectively (Table 4). The rates of these indicators are lower among children from wealthier families, as malnutrition is more strongly associated with poverty (Figure 3) [3-8, 15].

Malnutrition is linked to diseases, and the results show statistically significant differences between children who had diarrhea and those who did not during the two weeks preceding the survey across the three indicators [16].

The results show statistically significant differences between children who took vitamins and those who did not. Among those who took vitamins, 38.3 were underweight compared to 32.3 of children who did not take vitamins (Table 2). For stunting, the figures were 42.0 and 38.6, respectively, (Table 3). While 18.2 of children who took vitamins and 14.9 of those who did not were categorized as wasted (Table 4). Most of the children suffering from malnutrition according to the three indicators had taken vitamins.

We find that there are statistically significant differences between children in the states for the three indicators. The probability of children suffering from underweight increases in Kassala State by 44.6, followed by South Darfur by 43.8, and the lowest state is Khartoum by 22.4 (Table 5). As for dwarfism (short stature), it is highest in Kassala State by 51.8, followed by Central Darfur by 48.3, and the lowest state is Khartoum by 21.0 (Table 5). The percentage of children suffering from emaciation is highest in South Darfur by 27.7 (Table 5). The high incidence of malnutrition is due to conflicts in some states.

The overall trend in the nutritional status of children under five from 2006 to 2014:
Nutrition has been on the rise during the years 2006 (SHHS), 2010 (SHHS), and 2014 (MICS), with the percentage of underweight children being 31, 32.2, and 33, respectively. Stunting rates were 32.2, 35, and 38.2, respectively. For wasting, the rates were 14.8, 16.3, and 16.3 (Figure 4).
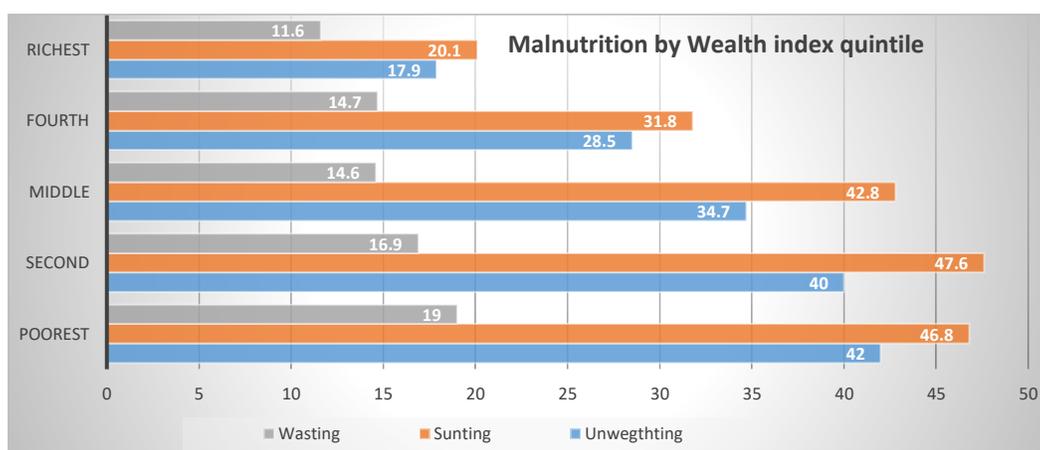

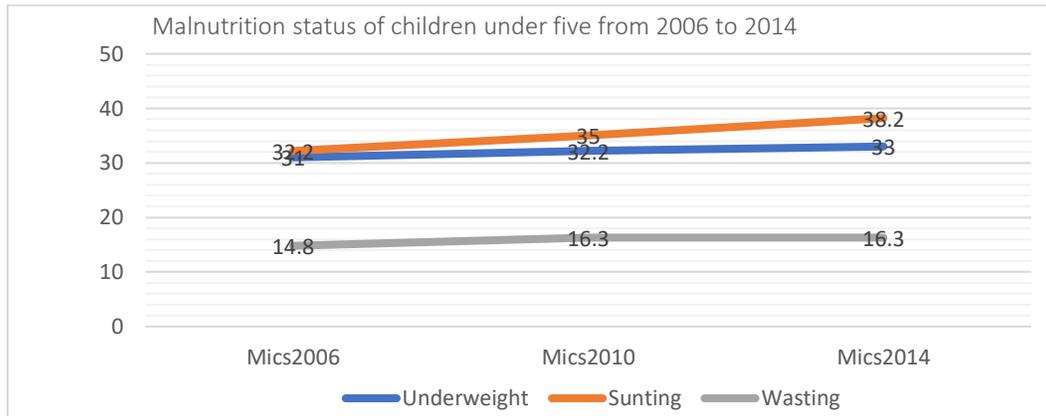Figure 3: Malnutrition status of children under five years according to the wealth index.

Malnutrition status of children under five from 2006 to 2014

Figure 4: Malnutrition status in children under five years of age from 2006 to 2014.

4   CONCLUSION AND RECOMMENDATIONS

4.1   Conclusion

This study demonstrates that malnutrition among children under five in Sudan remains a major public health challenge, with significant disparities based on gender, geographic location, maternal education and economic status. The results reveal that boys, rural children and those from poor households are disproportionately affected by underweight, stunting and wasting. Maternal education also plays a critical role in mitigating malnutrition, with children of educated mothers showing significantly lower rates of malnutrition.

The findings underscore the importance of targeted interventions, particularly in rural areas, to address the underlying economic, social and health factors that contribute to malnutrition. Promoting maternal education and improving access to health care, clean water and sanitation are key strategies for reducing malnutrition rates.

If there is a priority for policymakers to intervene in Sudan's states, it should be allocated to the states with the highest rates of stunting observed in the region. Specialized research is needed to investigate the specific causes that contribute to the high rates of stunting in this region, which will enable more effective and localized interventions.

In addition, the study highlights the need for specific interventions, especially during the weaning period when children are most vulnerable. Addressing these challenges requires coordinated efforts from policymakers, health professionals, and community leaders to ensure that every child in Sudan receives adequate nutrition and health care, ultimately reducing child mortality and improving overall health outcomes.

In conclusion, this research provides valuable insights into the key factors affecting child malnutrition in Sudan, providing a basis for future studies and practical policy interventions aimed at improving children's nutritional status and ensuring a healthier future for the next generation.

4.2   Recommendations

The following recommendations are based on a comprehensive analysis of the causes of malnutrition in children under five and aim to improve the health, social, and economic conditions in Sudan. The recommendations include:

♦   Improve access to healthcare services in rural areas by investing in medical infrastructure.

♦   Enhance maternal education through literacy programs and nutrition awareness campaigns.

♦   Implement economic empowerment programs for poor families, such as cash transfers and social safety nets.

♦   Strengthen supplementary nutrition programs by distributing nutritional supplements in affected areas.

♦   Improve water, sanitation, and hygiene (WASH) services to prevent diseases that exacerbate malnutrition.

♦   Targeted interventions in the most affected states, such as Kassala and Darfur.

♦   Use statistical models and machine learning algorithms to predict malnutrition cases based on relationships between different variables.

♦   Conduct longitudinal studies for continuous monitoring and evaluation of program effectiveness.

♦   Analyse root causes through qualitative studies to understand social and economic factors.

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