Undernutritional Status of Children in Ethiopia: Application of Partial Proportional Odds Model

Etiyopya'daki Çocukların Yetersiz Beslenme Durumu: Kısmi Oransal Odds Modelinin Uygulaması

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ABSTRACT Objective: Malnutrition is one of the most important causes for improper physical and mental development of children. The aim of the study was to describe severity status of children malnutrition and identify factors affecting the nutritional status for under age five Ethiopian children. **Material and Methods:** A partial proportional odds model was fitted using 2011 EDHS data by categorizing the undernutritional status into three levels in order of increasing of severity. The partial proportional odds models perform consistently better than the other two models (POM and BLR). By using partial proportional odds models, the interpretation of the parameters allows better insight concerning contributing factors, i.e., it revealed the increasing malnutrition severity due to age categories of children and incidence of diarrhea in the last two weeks before the survey. **Results:** The significant factors affecting the severity status of children malnutrition cover demographic, socio-economic, and health related factors: age of child, sex of child, birth order, education of mother and father, wealth status of household, place of residence, mother's nutritional status, incidence of diarrhea and fever. Mother's education level has been identified as the most significant factor influencing children malnutrition. **Conclusion:** Thus, based on these findings more efficient countermeasures can be developed to mitigate children malnutrition severity. Furthermore, the influence of these factors can be used in the development of strategies of intervention for reducing severity of child malnutrition.

Key Words: Child nutrition disorders; infant nutrition disorders; malnutrition

ÖZET Amaç: Beslenme bozukluğu çocukların uygun olmayan fiziksel ve ruhsal gelişiminin önemli sebeplerinden biridir. Bu çalışmanın amacı çocuklarda beslenme bozukluğunun önemini tanımlama ve beş yaşın altındaki Etiyopyalı çocuklar için beslenme durumunu etkileyen faktörleri belirlemektir. **Gereç ve Yöntemler:** Yetersiz beslenme durumunu şiddeti artan sırayla üç düzeye ayırarak 2011 EDHS verilerini kullanarak kısmi oransal odds modeli uygulanmıştır. Kısmi oransal odds modeli diğer iki modelden (POM ve BLR) daha tutarlı performans göstermiştir. Kısmi oransal odds modelini kullanarak parametrelerin yorumlanması, araştırmadan önceki son iki haftada ishal insidansı ve çocukların yaş kategorilerine bağlı olarak artan beslenme bozukluğu durumunu ortaya koyma gibi yardımcı faktörleri de dikkate alarak daha iyi tahmin edilmesini sağlar. **Bulgular:** Çocukların beslenme bozukluğunun önem durumunu etkileyen anlamlı faktörler demografik, sosyo-ekonomik ve sağlıkla ilgili faktörleri: çocuğun yaşı, çocuğun cinsiyeti, doğum sırası, anne va babanın eğitimi, ikamet yeri, annenin beslenme durumu, ishal ve ateş insidansını kapsamaktadır. Annenin beslenme durumu çocukların beslenme durumunu etkileyen en önemli faktör olarak belirlenmiştir. **Sonuç:** Dolayısıyla, bu sonuçlara göre çocukların beslenme bozukluğunun ciddiyetini azaltmak için daha etkili önlemler geliştirilebilir. Ayrıca, bu faktörlerin etkisi çocuklarda beslenme bozukluğunun şiddetini azaltmak için müdahale stratejilerinin geliştirilmesinde kullanılabilir.

Anahtar Kelimeler: Çocuk beslenme bozuklukları; bebeklerde beslenme bozuklukları; beslenme bozukluğu

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Malnutrition is one of the most important causes for improper physical and mental development of children that continues to be a growing problem in most developing countries.[1] It could be a consequence of unfavorable conditions that associate with poor development and disturbances in mental and intellectual capacity.[2] Furthermore, malnutrition in children is the consequence of a range of factors that are often related to poor food quality, insufficient food intake, and severe and repeated infectious diseases, or frequently some combinations of the three.

A child can be malnourished by being undernourished or overnourished, but in most parts of the world malnutrition occurs when people are undernourished. Primary reasons for undernourishment, especially of children, are poverty, lack of food, repeated illnesses, inappropriate feeding practices, lack of care and poor hygiene. A short period of inadequate nutrition together with illness can quickly make a child dangerously malnourished.[3]

Poor nutrition during childhood is one important factor impeding child physical and mental development which ultimately propagates the vicious cycle of intergenerational malnutrition. Thus issue of child malnutrition is critical because its effects are not limited to the boundary of childhood but rather persist into adulthood. Malnutrition at the early stages of life can lower child resistance to infections, increase child morbidity and mortality, and decrease mental development and cognitive achievement and nutritional status is the best global indicator of wellbeing in children.[4]

Malnutrition is the largest single underlying cause of death worldwide and is associated with over one-third of all childhood deaths. Worldwide, ten and a half million children of age under-five die every year, with 98% of these deaths reported to occur in developing countries.[5]

Every hour and minute of every day, 300 and 5 children die because of malnutrition respectively. In the world today, one child in four is stunted due to malnutrition, and in developing countries this figure is as high as one in three and specifically in Africa two out of five children's would suffer with malnutrition.[4,6] This study focuses on Ethiopia, a country which registers one of the highest child malnutrition rates in Sub-Saharan Africa. In Ethiopia, child malnutrition is one of the most serious public health problem and the highest in the world.[8] As a result, it challenges to reach the child survival Millennium Development Goals (reducing child mortality by 3/4) with the current place of mortality reduction.[7] According to the 2011 Ethiopia Demographic and Health Survey (EDHS) 29 percent of children under-five are underweight (have low weight-for-age), 44 percent of children under age five are stunted and 10 percent of children are wasted. The figures show the extent to which how much of the country's future potential work force is challenged by malnourishment.

Health and physical consequences of prolonged states of malnourishment among children are: delay in their physical growth and motor development; lower intellectual quotient (IQ), greater behavioral problems and deficient social skills; susceptibility to contracting diseases.[8] The ultimate effect of malnourishment among children might be death of the children or it might propagate into the vicious cycle of intergenerational malnourishment.

In recognition of the burden of malnutrition among under-five children, four of the eight United Nations Millennium Development Goals (MDGs) are specifically directed towards improving child health outcomes in developing countries. In particular, a reduction in the mortality of children is a key MDG, and a reduction in malnourishment among children is an important indicator of progress towards that goal.

Given that good nutritional status is both a human right and a necessary component to address effectively the major children's health problem that Ethiopia faces, what needs to be done to ensure that all Ethiopian children are well-nourished? The first thing is to identify the causes of malnutrition and have a useful understanding of how the severity status of children malnutrition can be effectively analyzed in terms of socio-economic, demographic, health and environmental characteristics. Studies were conducted previously that attempted to identify the causes of malnutrition.[9-13]

Even though the problem of child malnutrition in Ethiopia has been sufficiently documented, the severity and the reasons behind it are still poorly understood. There is also inconsistency across studies regarding the determinant factors behind children malnutrition. The inconsistency may be due to inclusion and/or exclusion of some factors. Estimates may also differ depending on various factors including the nature of the data and estimating methodology.

Among various methods applied to uncover the factors of child malnutrition the most preferred method is logistic regression. It considers binary response (nourished and undernourished); consequently the binary logistic regression model was applied in all the cases. However, the nutrition level of a child is usually classified as nourished, moderately malnourished and severely malnourished. Since, the majority of the studies on child nutritional status have never taken into account the order of nutritional status in their analysis which might hide some important information about the severity of child malnutrition. As a result, little is known about the level (severity) of malnutrition in the area. Thus, the current study attempts to investigate major socio-economic, demographic, health related determinants of children malnutrition among under age five years old children in Ethiopia by considering the order of child nutritional status into account in the process of analysis.

Commonly determinants of malnutrition and severe malnutrition, two separate binary logistic regressions (BLR) models are required to develop by grouping the response variable into two categories.[14] This task is tedious and cumbersome due to estimation of more parameters. However, the researcher can consider the response variable as ordinal response and can apply ordinal logistic regression (OLR) for the same purpose.

MATERIAL AND METHODS

When examining literature it becomes clear that there is no unique approach in identifying the determinants of malnutrition. But, it is accepted that malnutrition is usually determined by several demographic, social economic and health related factors.

Authors had used different statistical methods to analyze determinants of malnutrition. These methods include descriptive and logistic regression analysis, Weighted Least Square and Fixed Effects models, probit model.[9-13]

Regression methods such as linear, logistic, and ordinal regression are useful tools to analyze the relationship between multiple explanatory variables. These methods also permit researchers to estimate the magnitude of the effect of the explanatory variables on the outcome variable. If researchers wish to study the effect of explanatory variables on all levels of the ordered categorical outcome, an ordinal regression method must be appropriately chosen to obtain the valid results.[15]

This study utilized ordinal regression method of analysis to meet the objectives set since the response variable in the study has three ordered categories (severely undernourished, moderately undernourished, and nourished) and the value of each category has a meaningful sequential order.

RESULTS

DESCRIPTIVE STATISTICS

This research utilized the national wide Ethiopia Demographic and Health Survey (EDHS) 2011 collected data on the nutritional status of children. The analysis presented in the study is based on 9,366 under-five children with complete weight-for-age anthropometric index as indicator of a children's nutritional and health status among other indices, since it is an excellent overall indicator of a population's nutritional and health status. Table 1, below, shows that the relative frequency distributions of the severity status of child malnutrition; 69.8% are nourished (Not malnourished), 20.4% are moderately malnourished and 9.8% are severely malnourished.

In 2005 the percentage of undernourished children was 33% and 10% were severely undernourished. Though the percentage of undernour-

TABLE 1: proportion of severity status of children malnutrition.

severity status of child malnutrition	Freq.	Percent
Nourished	6,540	69.83
Moderate malnourished	1,906	20.35
Severe malnourished	920	9.82
Total	9,366	100.00

ished children reduced a little in 2011 (29%), the levels are still very high.[15]

The prevalence of child malnutrition according to selected background characteristics are shown in Table 2. The proportion of severely malnourished and moderately malnourished children were found higher among the children aged 12-23 months (11% and 21%), being male (10% and 22%), having 4-6 birth order (12% and 22%), with illiterate (11% and 22%) and acutely malnourished (thinness or BMI<18.5) mothers (14% and 25%), who resides in rural (11% and 22%), and experienced with several diseases like diarrhea, and fever (near about 38% malnourished separately). More-

TABLE 2: Children's nutrition status according to selected independent variables.

Covariate		Nutrition status according to weight-for-age z-score (WAZ): Severely Malnourished (WAZ<-3.00)	Moderately Malnourished (-3.00 ≤ WAZ ≤ -2.01)	Nourished (Adequate) (WAZ ≥ -2.00)	Total	Pearson chi-square (p-value)
Age of child in months	0-11	5.61	10.71	83.68	1,924	227.652 (p<0.001)
	12-23	10.94	20.66	68.40	1,728	
	24+	10.90	23.50	65.59	5,714	
Sex of child	Female	9.36	18.87	71.77	4,595	16.613 (p<0.001)
	Male	10.27	21.78	67.95	4,771	
Birth order of child	1-3	8.14	19.22	72.64	4,740	46.360 (p<0.001)
	4-6	11.87	21.84	66.29	3,008	
	7+	10.94	20.89	68.17	1,618	
Mother's highest educational level	No education	11.44	22.29	66.27	6,540	187.501 (p<0.001)
	Primary	6.82	17.73	75.45	2,375	
	Secondary	3.04	7.43	89.53	296	
	Higher	0.65	3.23	96.13	155	
Husband/partner's education level	No education	12.29	22.76	64.96	4,908	188.431 (p<0.001)
	Primary	7.93	19.67	72.40	3,457	
	Secondary	5.15	12.08	82.77	621	
	Higher	2.89	8.95	88.16	380	
Household wealth status	Poor	12.72	23.82	63.46	4,614	239.504 (p<0.001)
	Medium	9.76	21.26	68.98	1,557	
	Rich	5.67	14.90	79.44	3,195	
Place of residence	Rural	10.82	22.03	67.15	7,875	169.522 (p<0.001)
	Urban	4.56	11.47	83.97	1,491	
Mother's nutritional status (MBI)	Thinness	14.29	24.88	60.84	2,464	212.082 (p<0.001)
	Normal	8.69	19.64	71.67	6,361	
	Overweight	2.77	8.13	89.09	541	
Incidence of diarrhea in the last two weeks	No	8.69	20.09	71.22	7,898	81.963 (p<0.001)
	Yes	15.94	21.73	62.33	1,468	
Incidence of fever in the last two weeks	No	8.64	19.91	71.45	7,498	70.987 (p<0.001)
	Yes	14.56	22.11	63.33	1,868	
Total		9.82	20.35	69.83	100%	

over, near about 37 percent of the total number of children who lived in poor households were most vulnerable to malnutrition. All the selected independent variables were significantly associated with the children's nutrition status (Chi-square statistics and p-values are mentioned in Table 2).

ORDINAL LOGISTIC REGRESSION ANALYSIS

This section focuses on regression analysis undertaken to test the relative predictive power of demographic, socio-economic and health related covariates with severity status of children malnutrition.

In this study ordinal logistic regression is selected for analyzing the nutritional data using the explanatory variables associated with the dependent variable. In order to appropriately address all factors that, through extensive research performed, are believed to affect the level of malnutrition, the following was done. In our initial selection of variables, we looked for risk factors that clearly demonstrated in different previous extensive research performed and also for variables significant for bivariate analysis with Pearson chi-square association measure. After these factors were identified, the ordinal logistic regression procedure was used in combination with the stepwise selection method. This enabled us to select those significant variables which contribute to malnutrition. Accordingly, age of child in months (AGCH), sex of child (SECH), birth order of child (BOCH), mother's highest educational level (EDU), husband/partner's education level (HEDU), household wealth status (WI), place of residence (RES), mother's nutritional status or Mother's BMI (BMI), incidence of diarrhea (DIARRHEA) and incidence of fever in the last two weeks (FEVER) are included in the model.

Partial proportional odds model with logit function was developed for nutrition status of children. To identify the risk factors of child malnutrition and to estimate their effect, the study fitted partial proportional odds models by a user-written program gologit2.[16] For comparison, POM and Separate Binary Logistic Regressions were also fitted. At first competence of the models are described and then the results of the models are interpreted.

PROPORTIONAL ODDS MODEL (POM)

The results of the proportional odds model are given in Table 3. Having fitted proportional odds model, a test procedure was run to see whether the fitting of a proportional odds model is appropriate for the data.[17] Brant's (1990) test procedure produced a significant chi-square value of 37.48 with 18 degree of freedom (p-value=0.005) indicating that a parallel lines assumption is no longer appropriate for the evidence that we see in our data. After conducting the Brant test of the parallel regression (proportional odds) assumption for status of children malnutrition, we identified two important predictors, age of child (for 24+) and incidence of diarrhea in the last two weeks before the survey, which were found to violate the proportional odds assumption. Hence, the proportional odds model was not appropriate to analyze the severity status of children malnutrition. The results of Brant tests are shown in the last column of Table 3 which reveals that all the variables except age of child in months and incidence of diarrhea in the last two weeks were found insignificant.

As a consequence, a partial proportional odds model was fitted. Without making a final decision we proceed to analyze the data using separate binary logistic regressions for the dichotomized response. Such analysis is required to assess the correct functional form of the covariates to build models with adequate goodness-of-fit.[18]

SEPARATE BINARY LOGISTIC REGRESSIONS (BLR)

Results of two separate binary logistic regression models are shown in Table 4. Hosmer-Lemeshow test for both models indicate that both fit the data adequately (p-value > 0.36). The regression coefficients and odds ratios in the two separate models for all the categories of each of the covariates are found homogeneous. Age of children and incidence of diarrhea in the last two weeks that failed to satisfy the proportional odds assumption have significant influence on both models. However, significance levels varied for some covariates in the two BLR models. In the first BLR model with response variable "at least moderate malnutrition" all the variables are found to be significant. On the other hand,

TABLE 3: Results of POM using children nutrition status as three ordered response categories.

Covariate		Regression Coefficient	P-value	Estimated OR	95% CI for OR	Brant test (p-value)
Age of child in months [0-11 as ref]	12-23	0.829	0.000	2.291	1.951, 2.691	0.084
	24+	1.031	0.000	2.805	2.448, 3.213	0.004
Sex of child [Female as ref]	Male	0.173	0.000	1.189	1.087, 1.302	0.131
Birth order of child [1-3 as ref]	4-6	0.155	0.003	1.167	1.054, 1.293	0.131
	7+	0.047	0.467	1.048	.923, 1.191	0.307
Mother's educational level [higher as ref]	No edu	1.424	0.001	4.155	1.767, 9.771	0.760
	Primary	1.258	0.004	3.518	1.502, 8.244	0.822
	Secondary	0.859	0.065	2.361	.9491, 5.871	0.668
Husband/partner's education level [higher as ref]	No edu	0.556	0.002	1.743	1.221, 2.489	0.567
	Primary	0.374	0.038	1.453	1.021, 2.069	0.891
	Secondary	0.162	0.422	1.176	0.792, 1.746	0.606
Household wealth status [Rich as ref]	Poor	0.443	0.000	1.558	1.378, 1.762	0.487
	Medium	0.242	0.002	1.274	1.096, 1.482	0.736
Place of residence [Rural as ref]	Urban	-0.231	0.011	0.794	0.664, 0.949	0.414
Mother's nutritional status [Normal as ref]	Thinness	0.440	0.000	1.553	1.407, 1.713	0.551
	Overweight	-0.772	0.000	0.462	0.347, 0.616	0.984
Incidence of diarrhea [No as ref]	Yes	0.388	0.000	1.473	1.296, 1.675	0.012
Incidence of fever [No as ref]	Yes	0.315	0.000	1.370	1.219, 1.539	0.154
/cut1		4.083		-	-	-
/cut2		5.549		-	-	-

Over all brant test of parallel regression assumption: Chi-square = 37.48, df = 18, p-value = 0.005
Goodness-of-fit test of overall model (Likelihood Ratio): Chi-square = 878.48, df = 18, p-value = 0.000, Pseudo R2 = 0.0584

sex of child, mothers' highest educational level, and place of residence are found insignificant in the other BLR model with response variable "at least severe malnutrition". Thus the covariates show similar result with some differences in significance level. Since these regression models do not consider the restriction of ordinal response and consider more parameters, we proceeded to construct PPOM, which represents a joint model of the response categories, a powerful method based upon maximum likelihood procedures for ordinal response.[19,20]

PARTIAL PROPORTIONAL ODDS MODEL (PPOM)

The results of STATA command GOLOGIT2 are similar to the series of binary logistic regressions and can be interpreted in the same way. The main problem with the results of both processes is that they include many more parameters than POM. These methods free all the variables from the parallel-lines constraint, even though the assumption may be violated only by one or a few of them. So the study used AUTOFIT option with GOLOGIT2 to fit partial proportional odds models, where the parallel-lines constraint is relaxed only for those variables where the assumption was not justified and parallel-lines constraint is considered for the other variables which satisfy the assumption.[21]

Parallel-lines assumption for each variable was tested using a series of Wald tests to see whether its coefficients differ across equations. The variables, age of child in months (p-value < 0.0139) and incidence of diarrhea in the last two weeks (p-value < 0.0010) were found significant i.e., the proportional odds assumption is violated. Partial proportional odds model with logit function was fitted with these variables changing across equations while other variables were imposed to have their effects meet parallel-lines assumption.

The results for the partial proportional odds model with logit function are presented in Table 5 with Wald test of parallel-lines assumption. Global

TABLE 4: Results of two separate multiple binary logistic regression models using child nutrition status as binary response.

		Nourish vs. (moderately & severely malnourished)			(Nourish & moderately malnourished) vs. severely malnourished		
Covariate		B_1	OR_1	p-value	B_2	OR_2	p-value
Intercepts		-4.068	-	<.0001	-5.854	-	<.0001
Age of child	12-23	0.838	2.311	<.0001	0.647	1.910	<.0001
	24+	1.050	2.859	<.0001	0.777	2.175	<.0001
Sex of child	Male	0.191	1.211	<.0001	0.095	1.100	0.1817
Birth order of child	4-6	0.142	1.153	0.0081	0.251	1.285	0.0018
	7+	0.037	1.038	0.5774	0.128	1.137	0.1976
Mother's educational level	No edu	1.420	4.135	0.0011	1.707	5.514	0.0958
	Primary	1.261	3.530	0.0037	1.473	4.364	0.1499
	Secondary	0.837	2.310	0.0717	1.255	3.510	0.2383
Husband education level	No_hedu	0.533	1.704	0.0037	0.704	2.022	0.0345
	Primaryh	0.374	1.454	0.0392	0.415	1.515	0.2107
	Secondaryh	0.144	1.155	0.4777	0.312	1.367	0.3928
Household wealth status	Poor	0.437	1.547	<.0001	0.501	1.650	<.0001
	Medium	0.239	1.270	0.0023	0.277	1.319	0.0275
Residence	Urban	-0.242	0.785	0.0086	-0.131	0.878	0.3971
Mother's nutritional status	Thinness	0.434	1.544	<.0001	0.474	1.607	<.0001
	Overweight	-0.767	0.464	<.0001	-0.772	0.462	0.0046
Incidence of diarrhea	Yes	0.347	1.415	<.0001	0.554	1.740	<.0001
Incidence of Fever	Yes	0.296	1.344	<.0001	0.406	1.501	<.0001

Hosmer and Lemeshow Goodness-of-Fit Test: p-value = 0.5186 p-value =0.3652

Wald test for the final model indicates that the final model does not violate the proportional odds assumption with high p-value (0.5375). Also the marginal effects for the model are reported in Table 6. From Table 4 and Table 5 we can see that there are only 21 unique β coefficients or odds ratios need to be explained in PPOM compared to the 36 coefficients produced by separate BLR models.

Results of PPOM show that all the covariates have significant influence on the response variable. In addition, the deviance (defined as the difference in the likelihood ratios between POM and PPOM) is chi-square = 23.19 (901.67-878.48) with 3 d.f. (21-18), favoring the PPOM as a better fit to the data than POM.[22] The pseudo R^2 of POM (0.0584) and PPOM (0.0600) also reflect the same result.

MARGINAL EFFECTS

Table 6 presents the marginal effects which are computed at a representative value, i.e., at the mode values of dummy variables. Table 6 shows that in general, the marginal effects have larger magnitudes of impact on the first two outcomes, nourished and moderate level of malnourishment, and smaller impact on the last outcome, severe level of malnourishment.

Table 6 shows that mother's highest educational level (EDU) variable has the largest magnitude of marginal impact on the outcome probabilities. A child born to a mother with no education experienced a larger increase in the probability of having a moderate level of malnutrition, i.e., an increase by about 16 percent, while the probability of having a severe level of malnutrition increases by about 9 percent.

DETERMINANTS OF SEVERITY STATUS OF CHILDREN MALNUTRITION

In PPOM, all independent variables in the model were found to be significant predictors of child malnutrition. The covariates were also found significant in both separate BLR models except sex of

TABLE 5: Results of PPOM using child nutrition status as response with three ordered categories.

		Nourish vs. (moderately & severely malnourished)			(Nourish & moderately malnourished) vs. severely malnourished		
Covariate		**B_1**	**OR_1**	**p-value**	**B_2**	**OR_2**	**p-value**
Intercepts		-4.075	-	<0.001	-5.569	-	<0.001
Age of child	12-23	0.815	2.258	<0.001	0.815	2.258	<0.001
	24+	**1.043**	**2.838**	<0.001	**0.877**	**2.404**	<0.001
Sex of child	Male	0.173	1.188	<0.001	0.173	1.188	<0.001
Birth order of child	4-6	0.155	1.168	0.003	0.155	1.168	0.003
	7+	0.046	1.047	0.481	0.046	1.047	0.481
Mother's educational level	No edu	1.432	4.186	<0.001	1.432	4.186	<0.001
	Primary	1.264	3.541	0.004	1.264	3.541	0.004
	Secondary	0.857	2.356	0.065	0.857	2.356	0.065
Husband education level	No_hedu	**0.535**	**1.707**	0.003	**0.679**	**1.973**	<0.001
	Primaryh	0.375	1.456	0.037	0.375	1.456	0.037
	Secondaryh	0.160	1.174	0.427	0.160	1.174	0.427
Household wealth status	Poor	0.443	1.557	<0.001	0.443	1.557	<0.001
	Medium	0.243	1.276	0.002	0.243	1.276	0.002
Residence	Urban	-0.233	0.792	0.011	-0.233	0.792	0.011
Mother's nutritional status	Thinness	0.440	1.552	<0.001	0.440	1.552	<0.001
	Overweight	-0.775	0.461	<0.001	-0.775	0.461	<0.001
Incidence of diarrhea	Yes	**0.336**	**1.400**	<0.001	**0.582**	**1.789**	<0.001
Incidence of Fever	Yes	0.311	1.365	<0.001	0.311	1.365	<0.001

Score test for the proportional odds assumption: Chi-square = 13.84, df = 15, p-value = 0.5375
Goodness-of-fit test of overall model (Likelihood Ratio): Chi-square = 901.67, df = 21, p-value = <0.001, Pseudo R2 = 0.0600.

TABLE 6: Marginal effects for severity status of children malnutrition based on PPOM.

		Nourished		Moderately malnourished		Severely malnourished	
Covariate		**MER**	**p-value**	**MER**	**p-value**	**MER**	**p-value**
Age of child	12-23	-.178867	<0.001	.1037724	<0.001	.0750944	<0.001
	24+	-.196775	<0.001	.1360182	<0.001	.0607571	<0.001
Sex of child	Male	-.034553	<0.001	.0218251	<0.001	.0127276	<0.001
Birth order of child	4-6	-.03143	0.003	.0197196	0.003	.0117114	0.004
	7+	-.009223	0.484	.005806	0.481	.0034165	0.487
Mother's education level	**No edu**	**-.247715**	<0.001	**.1603736**	<0.001	**.087341**	<0.001
	Primary	**-.278624**	0.005	**.1550713**	<0.001	**.1235524**	0.023
	Secondary	-.196084	0.088	.1076851	0.037	.0883993	0.163
Partner's education level	No_hedu	-.106290	0.003	.0563028	0.014	.0499873	<0.001
	Primaryh	-.076754	0.040	.0477988	0.037	.0289556	0.047
	Secondaryh	-.03306	0.440	.0205301	0.432	.0125299	0.453
Household wealth status	Poor	-.088751	<0.001	.0558237	<0.001	.0329276	<0.001
	Medium	-.050483	0.002	.0312353	0.002	.0192474	0.003
Residence	Urban	.044955	0.008	-.028871	0.009	-.016085	0.006
Mother's nutritional status (BMI)	Thinness	-.091875	<0.001	.0563568	<0.001	.0355184	<0.001
	Overweight	.130258	<0.001	-.087014	<0.001	-.043244	<0.001
Incidence of diarrhea	Yes	-.070673	<0.001	.0197331	0.102	.0509397	<0.001
Incidence of fever	Yes	-.064873	<0.001	.0399815	<0.001	.0248916	<0.001

Note: MER = Marginal effects computed at a representative value, i.e., at mode values of dummy variables.

TABLE 7: Model specification tests.

Tests	Results
Wald chi-square test	p-value <0.001
General model specification test	
i. Not malnourished: _hatsq	p-value = 0.290
ii. Moderately malnourished: _hatsq	p-value = 0.128
Threshold parameter test	
i. Alpha_1	p-value = <0.0001
ii. Alpha_2	p-value = <0.0001

child, place of residence, and mother's highest educational level in the 2nd BLR model with the response variable "at least severe malnutrition". The results support the use of PPOM instead of BLR models to determine the predictors of child malnutrition as well as severe malnutrition.

The results of POM reveal that the risk of having worse malnutrition status were 2.29 and 2.80 times higher among the children belonging to the age group 12-23 and 24+ months respectively, when compared with the infants(age group 0-11) (Table 3). Since the proportional odds assumption is violated for the variable, this interpretation may be invalid. However, from separate BLR models and PPOM it is clear that the odds ratios for the children aged 12-23 months and 24+ months compared to infants were about 2.26 and 2.84 respectively when nourished state is compared with moderate and severe malnutrition states implying that children belonging to the age group 12-23 and 24+ months had 2.26 and 2.84 times greater risk of being moderately or severely malnourished respectively compared with infants (age group 0-11) (Table 5). When nourished and moderate malnutrition states are compared with severe malnutrition state, the odds ratios were found about 2.26 and 2.40 respectively for children belonging to age group 12-23 and 24+ months compared to infants implying that children belonging to the age group 12-23 and 24+ months had 2.26 and 2.40 times greater risk of being severely malnourished respectively compared with infants (Table 5).

Similarly, for incidence of diarrhea within last two weeks before the survey the proportional odds assumption was violated .Thus the interpretation with POM reveals that the risk of having worse malnutrition status were 1.47 times higher among children who experienced diarrhea compared with children having no such problems within last two weeks before the survey (Table 3) may be misleading. However, from separate BLR models and PPOM it is clear those children who experienced diarrhea within last two weeks before the survey had 40% higher risk of being malnourished compared with the children having no such problems (Table 5). Moreover, the severity increased for children experienced with diarrhea when nourished and moderate malnutrition states are compared with severe malnutrition state. This means among children under age five who had diarrhea in the two weeks preceding the survey, there has been a noticeable increase in the chance of getting worse malnutrition which was masked using the PO model as shown in Table 3. The marginal effects also showed that incidence of diarrhea in the last two weeks before the survey (Yes vs no) had positive effects on severe level of children malnutrition (0.051). Since all other covariates did not violate the proportional odds assumption and PPOM performed better than POM as well as separate BLR models, the results for other covariates are described from Table 5 and 6.

Mother's highest educational level (EDU) was identified to be the most significant positive factor for the contributions to decrease of children malnutrition. In this study, the different forms of mother's educational level were tested for investigating their effect on severity status of child malnutrition, which include no education, primary education, secondary education, and higher. The results showed that children having mothers with low level of education, specifically mothers with no education, levels of malnutrition tended to be more severe (Coef. = 1.43; *p*-value = 0.001). In other word, the risk of having worse malnutrition status was found highest for children having mothers with no education (about 4.2 times) compared with higher level educated mothers' children. These results were confirmed by the positive marginal effects for moderate and severe malnutrition as shown in Table 6. Similarly, the risk of having worse malnutrition status was found highest for the children having father's with no education (about 1.71 times) compared with higher level educated fathers' children.

The risk of having severe malnutrition compared to nourished and moderately malnourished was found significantly higher for male children compared to female children, i.e. the risk of male children being severely malnourished compared to nourished and moderately malnourished had 19% higher risk of being malnourished compared to females.

Children having birth order 4-6 had 1.17 times greater risk of having worse malnutrition status compared with children having 1-3 birth order (Table 5).

Compared with children from rich households, the chances of having worse malnutrition status was found to increase with decrease of household wealth condition (1.6 for children from poor households and 1.3 for those from medium households).

The risk of having worse malnutrition was found significantly higher for the children in rural areas compared to those in urban areas. From Table 6 the negative marginal effect for urban residence (-0.016) confirms that children in rural areas are more likely to be malnourished than children in urban areas.

Mother's nutritional status had a significant effect on malnutrition severity of children. Compared to children with normal level (nourished or BMI 18.5-24.9) mothers, children belonging to acutely malnourished (thinness or BMI<18.5) mothers were 1.55 times more likely to be malnourished moderately or severely. That means, children with acutely malnourished mothers had 1.55 times greater risk of being malnourished compared to those of nourished mothers. However, children belonging to overweighed/obese mothers (BMI≥25) were less likely to be malnourished moderately or severely.

Experiencing fever within last two weeks before the survey had significant effect on children malnutrition severity. Children who experienced fever within last two weeks before the survey had 1.37 times higher risk of being malnourished compared with children having no such problems.

MODEL SPECIFICATION TESTS

This section checks for the adequacy of the PPOM in terms of how well the model fits the data. These tests, as listed in Table 7, are imperative as an inappropriately specified model leads to misleading inferences.

The Wald chi-square test is a test of the PPOM's overall goodness-of-fit. It tests for the null hypothesis that all the coefficients in the model are simultaneously equal to zero, i.e., having no effect on the dependent variable. The significant p-values as shown in Table 7 indicate that the null hypothesis is strongly rejected, i.e., at least one of the coefficients in the model has an impact on nutrition status of children.

The general model specification test, also known as a link test, is a test of appropriate functional form of the model. This test is the nonlinear counterpart of Ramsey's (1969) RESET test for linear regression models. If a model is properly specified, then no nonlinear functions of the explanatory variables, such as the quadratic function, should be significant when added to the model. Here, the nonlinear functions of the explanatory variables are represented by the '_hatsq' variable. This variable is tested insignificant for each J–1 equation, i.e., the insignificant p-values. This indicates no functional form misspecification.

As mentioned in the Chapter 3, the alpha terms in a PPOM are cut points or threshold parameters along the continuum of the unobserved propensity to malnutrition. With three outcome categories, there are two cut points to be tested. The results of the threshold parameter test indicate that the two cut points are significant at the 1 percent significance level. That is, the two cut points are relevant to the model, indicating that the three observed outcome categories are indeed ordinal in nature and are well-placed along the continuous scale of the unobserved propensity to malnutrition. The significant cut points also suggest that the three outcome categories should not be collapsed into two categories.

DISCUSSION

In this study an attempt has been made to develop a method that can help to identify factors that affect the severity status of children malnutrition. Accordingly, Proportional odds model, Separate binary logistic models and Partial proportional odds model were fitted.

At first sight the POM becomes inappropriate model for analyzing the considered data since the p-value of chi-squared Brant test for overall model is significant at 5% level of significance indicating proportional odds assumption is violated, but all of the considered variables were found significant in the POM.

Since, the proportional odds assumptions for overall model was violated, by using Brant test for each covariate, we have assessed for which covariate the assumption was violated. The Brant test for each covariate shows that the assumption is violated for age of child and incidences of diarrhea in the last two weeks before the survey. This condition was also checked with separate BLR models which indicate the coefficients and the odds ratios for each age and incidence of diarrhea categories varied in the models.

In the case of all other variables, coefficients and odds ratios are not identical but almost close. In PPOM, coefficients and odds ratios for the variables 'age of child' and 'incidence of diarrhea in the last two weeks before the survey' are almost same with the result of BLR models. However, the coefficients and odds ratios for other covariates in PPOM are slightly different compared to separate binary logistic regression models, but almost identical with those of POM. Moreover, all the variables are significant in PPOM but in the separate binary logistic regression models few of them found to be insignificant.

Generally speaking in comparing separate binary logistic regression models and partial proportional odds models for two main outcomes of children malnutrition, we found that the results were quite similar, but the partial proportional odds model was preferred due to the more parsimonious model principle, and as a result for easier interpretation of models in terms of fewer parameters. Due to that we stick our discussion with PPOM results as follows.

Mother's highest educational level (EDU) was identified to be the most significant factor to reduce the occurrence of children malnutrition. The findings of this study showed that there is a significant difference in the severity status of malnutrition in children by mothers' educational level. The risk of worse level malnutrition is significantly higher for children whose mothers have no education and primary education level than children whose mothers have secondary and higher level of education. This finding seemed to be consistent with other studies.[23,24] They indicated that education improves the ability of mothers to implement simple health knowledge and facilitates their capacity to manipulate their environment including health care facilities, interact more effectively with health professionals, comply with treatment recommendations, and keep their environment clean. Furthermore, educated women have greater control over health choices for their children. Similarly, the risk of having poor malnutrition status was found highest for the children having father's with no education when compared with higher level educated fathers' children.

In addition, our study revealed that the chances of having poor malnutrition status was found to increase with decrease of household wealth condition, i.e. under-five children from poor households are at a higher risk of malnutrition than children from rich households. This finding is consistent with other studies.[10,11] They indicated that better off households have better access to food and higher cash incomes than poor households, allowing them quality diet, better access to medical care and more money to spend on essential nonfood items such as schooling, clothing and hygiene products.

Age of child is also one important determinant associated with status of children malnutrition in

Ethiopia. Children up to 11 months (infants) have better nutrition status than other age groups. This could be because of breastfeeding in the early stages of child growth, mother's ability to care for the child and also due to the care that parents give to older children that may decline especially if there are younger children in the family.[25]

Another important demographic factor which affects status of children malnutrition in Ethiopia is sex of child. The risk of having worse malnutrition was found significantly higher for male children compared to female children, i.e. male children had 1.19 times higher risk of being malnourished compared to females. Similar results are also reported from other studies.[9,26,27] They argued that this could be due to genetic differences between male and female children and, due to girls' greater access to food through their gender-ascribed role in contributing to food preparation.

CONCLUSION

Despite some differences in the results of the fitted models, the result of PPOM is reasonably comparable with those of separate BLR models. PPOM fitted the data adequately in predicting severity status of child malnutrition, due to the nature of the response variable (grouped continuous variable). Furthermore, PPOM had a better fit better for the data than POM. Consequently, from the results of PPOM we have drawn the following conclusions.

The study examined the demographic, socioeconomic and health related determinants of child malnutrition in Ethiopia. The findings based on PPOM of the study showed that factors such as age of child, sex of child, birth order of child, mother's educational level, partner's educational level, household wealth status, child place of residence, mother's nutritional status, incidence of diarrhea and fever have statistically significant effect on the status of malnutrition.

High educational level was identified to be a very significant factor for the occurrence of children malnutrition in Ethiopia. Children younger than 11 months (infants) had better nutrition status than other age groups. This could be because of breastfeeding in the early stages of child growth.

The risk of having worse malnutrition was found significantly higher for male children compared to female children. It is observed that the risk of having poor malnutrition was found significantly higher for the children in rural areas compared to those in urban areas.

Mother's nutritional status had significant effect on children malnutrition severity. Compared to children belonging to nourished mothers, children belonging to acutely malnourished mothers were more likely to be malnourished moderately or severely. Children who had diarrhea are significantly vulnerable to malnutrition than those who did not. A similar result was also obtained for children who had fever.

RECOMMENDATIONS

We learn from this study that in addition to the efforts being made to reduce the frequency of malnutrition in general, specific attention should be given to reduce the prevalence of malnutrition by giving different priorities to different children age categories, residence category, family background in terms of their mothers/fathers education level, wealth status to curb the severity level of children malnutrition. Since we have shown that children in rural areas are more likely to be malnourished than children in urban areas, special attention should be given for the residence difference. Further study can be made on the area of malnutrition at different level by considering detail and accurate information on various variables.

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