Modeling the Predictors of Stunting in Ethiopia: Analysis of 2016 Ethiopian Demographic Health Survey Data (EDHS)

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Abstract

Background Despite the continued effort to address malnutrition, there is a minimal reduction in the rate of stunting in developing countries including Ethiopia. Nutritional and socioeconomic factors have not been assed using a rigorous analysis so far. Therefore, this study aims to model the effect of nutritional and socioeconomic predictors using 2016 Ethiopian Demographic health survey. Methods This study is a secondary of data analysis of the 2016 EDHS survey. 7909 children of age 6-59 months were included. Descriptive statistics using frequency and percentage for categorical data and mean and standard deviation for metric data were conducted. Linearity, confounding and multicolinearity were checked. Bivariable and multivariable logistic regression were carried out. Odds ratio and 95% confidence interval were calculated. Receiver operative curve was built to estimate the sensitivity and specificity of the model. Result The study identified as 39.2% of children included to this analysis were stunted. 76.47%, 84.27%, 92.62% of the children did not consume fruits and vegetables, legumes and lentils, and meat and its products respectively. Children aged 24 month to 59 months were at 9.71 times higher risk of being stunted compared to younger children of age 6-24 months old (AOR: 9.71; CI: 8.07, 11.6 children) with weights below 9.1 kilogram were at 27.86 odds of being stunted compared to those weight of 23.3 kg and above. Moreover, mothers below 150 cm tall (AOR: 2.01; CI: 1.76, 2.5), living in a rural area (AOR: 1.3, CI: 1.09, 1.54) and being male (AOR: 1.4; CI: 1.26, 1.56) were associated with stunting. Predictive ability of the model was 77% correctly such pair of observation. Conclusion The model indicates that being born male, being from a mother of short stature, living in the rural area, small child size, mother with mild anemia, being from a husband with no education or primary education only, having low weight, and reaching age above 24 months increases the likelihood of stunting. On the other hand, being born of an overweight or obese mother decreases the likelihood of stunting.

1. Introduction

Nutrition in children, compared to other populations, is critical because of the intense period of mental, physical, and cognitive growth and health. Childhood nutrition also reflects long- and short-term health outcomes. However, macronutrient and micronutrient deficiencies are common during childhood [1] with stunting, wasting, and underweight being the most common nutritional problems affecting millions of children worldwide [2].

Stunting is a global nutritional challenge which disproportionately affects developing nations [2]. It is manifested post-chronic malnutrition due to lack of adequate nutrient intake during the most critical periods of growth and development of children (i.e. first one thousand days) [3]. According to World Health Organization (WHO) definition, children with height-to-age z-score below minus two standard definition (-2SD) from the median WHO reference population are stunted and those below -3SD are considered to be severely stunted [4].

There is a huge variation in worldwide prevalence of stunting. It affects 151 million children worldwide with over 94% incidence in Asia and sub-Saharan Africa (SSA) [2]. According to a meta-analysis conducted in SSA in 2014, the prevalence ranges from 57.7% in Burundi to 16.5% in Gabon. According to the 2016 Ethiopian Demographic Health Survey [EDHS], the prevalence of stunting is 38% [5]. However, not only the burden of stunting is large but also it has shown a slow reduction and the rate has almost remained constant [6]. This high prevalence has various implications at individual, societal and national level.

Chronic malnutrition causes mortality and morbidities collectively called ‘stunting syndrome’ because long- and short-term effects. Long term negative health consequences including reduced economic potential, delayed cognitive development and educational achievement along with increased risk of metabolic syndrome.

Consequently, these syndromic effects lead to intergenerational and iterative effects which are challenging to circumvent as a stunted mother delivers a stunted child which perpetuates poverty and underdevelopment of a society/nation[7-12].

The factors associated with stunting are diverse and vary across different nations, regions, communities, and societies [6, 13-26,]. The factors associated with stunting are very complex and interconnected with each other. The factors can be classified as distant factors, like socioeconomic status of the household, followed by intermediate factors, such as environmental factors and health service-related characteristics and immediate factors such as maternal, child and nutritional characteristics [6,13-17]. A systematic review and meta-analysis of 21 studies in Africa found that the predictors of stunting were complementary feeding practice, maternal under nutrition, household food insecurity, economic growth, and maternal education, as principal determinants of stunting [6].

In Ethiopia, different studies identified different risk factors associated with stunting [13-16]. A study in northern Ethiopia found that being female, belonging to age group of 25–59 months, and birth weight of <2.5 kg, mothers' lack of antenatal visits, and mistimed complementary feeding initiation were positively associated with childhood stunting; whereas educational status of the mother showed negative association [13]. However, a study in northeast Ethiopia identified the factors associated with stunting as being male, increasing age, large family size, poor wealth status, illiterate mother, leftover food, living in a rural area, and experiencing less frequent feedings were significantly associated with stunting [14]. In addition, as study in northwest Ethiopia revealed that increased age of the child , and the family size of six and above were positively associated with stunting, while fathers with secondary school education, farmers as household heads, and self-employed parents as household head were found to be preventive factors [15]. A rigorous analysis of the 2011 EDHS [27], did not include nutritional factors and the predictors that might vary through time [18]. Most studies respecting stunting are cross-sectional with sample sizes and in specific localities which is limiting in fully understanding the breadth and complexity of this issue.

Although the government of Ethiopia has implement different intervention strategies to reduce stunting and malnutrition [28, 29], stunting prevalence has plateaued with minimal reduction [5]. There is an imperative to undertake a nationally representative contemporary study conducted on the sociodemographic and nutritional predictors of stunting using a rigorous analysis and modelling in order to fully understand the situation. Therefore, aim of this study is to determine the predictors associated with stunting in children of 6 month to 59 months using 2016 EDHS data and a best fit model in order to inform national efforts being made to address stunting syndrome in Ethiopia.

2. Methods And Materials

2.1 Participants, study setting and procedures

The data from 2016 EDHS which was collected from January 2016 to June 2016 in nine geographic regions and two administrative cities of Ethiopia. The survey collects data on demographic and health indicators of all household members with special emphasis on maternal and child health issues. The sampling frame is based on the Ethiopian Population and Housing Census conducted by the Central Statistical Agency in 2007. The sampling frame is a complete list of 84,915 Enumeration Areas (EA), with each EA comprised of 181 households. Sampling was stratified and conducted at two levels. Each region was stratified into urban and rural, producing 21 strata. Sample EA were selected independently from each stratum in two stages by using proportional allocation and implicit stratification.

In the first stage, a total of 645 EAs (202 in urban areas and 443 in rural areas) were selected with probability proportional to EA size (based on the 2007 Population and Housing Census) and with independent selection in each sampling stratum. In the second stage of selection, a fixed number of 28 households per cluster were selected with an equal probability systematic selection from the newly created household listing. Detailed sampling procedures and household selection are found elsewhere [5].

2.2 Data collection tool

Five questionnaires were developed in the 2016 EDHS. The Household Questionnaire, the Woman's Questionnaire, the Man's Questionnaire, the Biomarker Questionnaire, and the Health Facility Questionnaire. The questionnaire was developed in conjunction with the Demographic Health Survey (DHS) which are customized to an Ethiopian context. Since DHS recodes the original data into different databases, in this study, we used the children's recode because of intention to study children of aged 6 to 59 months.

The children's recode contains data mainly about the households' sociodemographic and other attributes of the children, mothers/caretakers/primary guardians, and fathers/husbands, as well as nutritional, environmental, and health service related characteristics.

2.3 Study variables

In this study, relevant variables were selected based on previous literature reviews, subject matter knowledge, and the objective of the study which was determining a best fit model on the nutritional and background factors associated with stunting. For model building, to determine factors associated with stunting, the maximum model was specified by considering a thoughtful causal diagram, reducing the number of predictor variables based on descriptive statistics, conducting correlations analysis to remove highly correlated variables, and creation of indices for some variables and conducting bivariable analysis. In addition, missing values above 15% were only described and not included in model building, the effect of continuous variables was also examined and continuous predictors were also tested for linearity.

Based on the above screening procedure, from the socio-demographic and maternal characteristics education of both husband/partner, respondent/ mother highest level of education, age of mother both in a continuous and grouped form, wealth index, residence, and sex of child time to get drinking water, body mass index (BMI) of mother, and weight of mother and height of mother. Education was categorized into no education, primary, secondary, and tertiary. Age of the respondent was initially categorized primarily into 7 5-year groups, but during analysis it was re-categorized into four groups (15-19, 20-29, 30-39, 40-49). Wealth index was classified into 5 groups: poorest, poorer, middle, richer, and richest. However, for the sake of analysis it is re-categorized in to 3 groups: poor, average and rich. Time to get drinking (potable) water was in a continuous form but categorized into less than 30 minutes or above or equal to 30 minutes. The details of EDHS variables code, including the transformation we made in this study and other details are explained in **Table 1**.

Regarding dietary intake of children, the data was based on 24-hr recall (day and night before the interview) by the mother who was asked if she had a child living with her who was born after 2014. If she was affirmative for this, the mother was asked if she gave the child certain food group selections. Based on this, in this analysis, we created four groups according to WHO indicators [30] which included: Fruits and vegetables (V414i +v414j+v414k+v414l); Grains, roots and tubers (v414f+v414E); Legumes and lentils (V414O); Dairy products (V414v+V414p); Meat and its products (V414M +V414N and/or V414H).

Table 1: EDHS variable codes, and explanation of variables included to this study

2.4 Data management and analysis

Data were cleaned and analyzed in SAS 9.4. Categorical variables were described using frequency and percentages. For continuous variables, mean and standard deviation (SD) were used. Cross-tabulations between some predictor variables and outcome variables were conducted. To check assumptions. Histograms and quartiles were used. For ordered variables, we used Spearman correlation and for continuous variables we used Pearson correlation to check correlation between independent predictors, $r>=0.7$ was the cut-off value for correlation. Multi-colineaity was checked using the variance inflation factor (VIF) with VIF <2.5 used as a cut-off point. Interaction and confounders were tested. Interaction was checked among pairs of variables that were suspected of having interaction based on prior knowledge and literature. A bivariable logistic regression analysis using an Unadjusted Odds Ratio (UOR) was carried out to select candidate variables with P-values of <0.25 for the multivariable logistic regression model building. In multivariable logistic regression analysis model building, backward elimination was used. Finally, variables with P-value of 0.05 with 95%confidence interval (CI) and adjusted odds ratio (AOR) were conducted. A receiver operative characteristics curve (ROC) with sensitivity and specificity was also depicted to determine the predictive ability of the model. Model fitness was assessed by using the Hosmer and Lemeshow test. Linearity was assessed by comparing the squared variable with un-squared variable significance; if the squared variable was significant, the variable was classified into plausible categories. A model selection for non-nested models was done using Akaike's Information Criteria (AIC) and a model with smaller values was selected.

3. Result

3.1 Participants and variables summary

The flow diagram below indicates participants and variables inclusion process and the final numbers included to the analysis. In the original recoded children data, there were10641 children under five and 1209 variables. On rigorous data cleaning and management process, finally 32 variables and 7909 children with mothers were included to the analysis. Details of the procedures and process are explained below (**Fig1**).

Variables present in the original EDHS, 2016 dataset (**n=10641**) and (variables=**1209**)

1069 variables were excluded on primary assessment because of missing values and not-relevant to the study objectives

At this stage there was no change in the number of study participants (women with their children).

8603 children left after children with age less than six month were excluded and **140** variables left.

Finally, after variables were removed by descriptive analysis, creation of new indices correlation and unconditional analysis **32** variables remain & included to analysis and **7909** children with mothers were analyzed after **694** children were excluded because outcome variable had incomplete information.

Fig 1: Study participants and variables selection process and outcome

3.2 Sociodemographic characteristics of 6-59 month old children

Regarding place of residence, more than 80% of the children resided in rural areas. Nearly half of the husbands/partners had no education and 4217(52%) were in the poor category of wealth status. See **Table 2** for details.

Table 2: Sociodemographic and economic characteristics of women and children (N=7909)

3.3 Description of nutritional characteristics of children with their mothers aged 6-59 months old

The prevalence of stunting in this population was 39.1%. A few (10%) children were given dairy products which included yogurt and cheese by their mothers/caretakers. The most common foods eaten were grains and tubers, which was consumed by almost half of the children. Less than a quarterof children consumed fruits and vegetables (23.53%), with the lowest food group consumed as meat (7.38%) and its products followed by legumes and lentils (15.73%). There were large missing values because mothers/caretakers were only asked for children born in 2014 or later and limited to one child per household . See details in **Table 3**.

Table 3: nutritional and clinical characteristics of mothers and children 6-59 months

3.4 Description of continuous variables

The average age of women participated in the survey was 29.4(6.5) and the average weight of child during the survey was 11.3(2.8) kilogram (see **Table 4** for details).

Table 4: Mean and standard deviation of continuous variables of children 6-59 months old in Ethiopia of 2016 EDHS,.

3.5 Correlation, and linearity of independent variables

Correlation test were conducted for all variables considered to be included in the analysis. Simple Pearson correlation was conducted for continuous variables. However, Spearman correlation was used for ordered categorical variables. Based on these tests significant correlation was not obtained. Correlation was considered significant if r was above 70%. Based on this level, there was no significant correlation among the independent variables (See **Annex 6.1** for details)

Linearity of selected independent variables was checked and of these weight of the child squared was found to be significant in the model. The quadratic form of the variable was significant and considering this the interaction term was included in the final model; however, it creates instability in the model due to high colinearity with the normal variable (unsquared weight child). Therefore weight of the child was categorized into quartiles (see **Table 5)**

Table 5: Linearity test of the selected variable weight child

3.6 Biavariable analysis and multicolinearity

Bivariable analysis showed that maternal height, age of the child, anemia level of the child, and mother, education of the mother and husband, weight of the child, sex of the child, BMI of the mother, weight of child, place of residence, and child’s size were significantly associated with stunting **(see Table 5).**

Table 5: Bi-variable analysis and cross-tabulation of the outcome variable versus the covariates in children of age 6month-59 months using 2016 EDHS dataset.

3.6.1 Multi-colinearty test result

Based on a restrictive multi-colineairty test values of ≥2.5, there was no multi-colineairty between the independent variables found in this study **(See Table 6).**

Table 6: Multi-colinearity test using variance inflation test for independent predictors included in the analysis

3.7 Predictors of stunting

After a rigorous screening steps to select candidate variables, mothers' education because of small number of observation in the third category and moderate correlation with husband education, all children food intake history(fruits and vegetables, grains, tubers and roots, lentils and legumes, meat groups and dairy products), birth interval and number of children were excluded because of large missing values. Based on this, after wealth and anemia of the child were excluded during model building, while maternal height, child size, husband education, age child, sex of child, residence, BMI of mother, anemia level of mother, and weight of child were all independent predictors of stunting in our study.

Mothers who were below 150 cm tall were at a 2.01 increased risk of having stunted children compared to mothers who were 150 cm or above (AOR: 2.01; CI: 1.76, 2.5). Age of the child and weight of the child during the interview were strong factors associated with stunting. Children aged 24 month to 59 months were at 9.71 times higher risk of being stunted compared to younger children of age 6-24 months old (AOR:9.71;CI:8.07,11.6). Similarly, children with weights below 9.1 kilogram were at 27.86 odds of being stunted compared to those weight of 23.3 kg and above. From the socio-demographic determinants, living in a rural area increases the odds of stunting by 30% than living in the urban areas (AOR: 1.3, CI: 1.09, 1.54). From the unavoidable factors, sex of the child, being male increases the odds of stunting by 40% than their female counterparts (AOR: 1.4; CI: 1.26, 1.56)[**see Table 5 for details**]. The steps of model building are attached as **Annex 6.2**.

Table 7: Multivariable analysis of variables included in the final model of children age between 6 months and 59 months included in 2016EDHS.

3.71. Result of Interaction test in the final model

As can be seen in the table below there was no a significant interaction found among the independent factors affecting stunting. Interaction was tested based on previous literature and knowledge of the subject matter. Interaction was tested between age of the child and weight of the child, education and anemia level, height of the mother and BMI**Table 8**).

Table 8: Interaction test result of some selected variables

3.72. Goodness of fit of the model

The model developed in this study fits the data well (P=0.85). We chose Hosmer and Lemeshow goodness fit test because our study contains too many categories and the number of unique profiles were 1823.

Table 9: Model fitness using Hosmer and Lemeshow Goodness-of-Fit Test

3.73. Predictive ability of the model

The AUC in our model was found to be 0.7688 which is equals to 77%. This means a randomly selected individual from the stunting group has a true test value larger than that for a randomly chosen individual from the non-stunted group 77% of the time. Or if pair of observations with stunted and non-stunted children were taken the model ranks 77% correctly such pair of observations (**See Figur w2**).

Fig2: receiver operating characteristics curve for the model developed on stunting predictors

3.74. Comparing different non-nested models

Non-nested models were compared using AIC value for selectcontinuous variables like weight of the child versus weight of child (categorical, height of mother in meters versus categorized height of the mother, age of the child in months versus age in months categorized. We chose a model with the smaller AIC value which in this case was the categorized form of the variables.

4. Discussion

This analysis found that the prevalence of stunting in children of 6 month to 59 months to be 39.1%. Aim of this study was to model the predictors of stunting using a data that is representative of the nation and the findings could possibly be put in to practice. Therefore, we found that children age above 24 months, low weight of child, small child size, being male birth, short maternal stature, overweight and obese maternal status, rural residence, no education and primary education of husband, mild anemia were predictors of stunting. Among this child age, low weight of child and maternal stature were the strongest predictors with AOR above 2.

Child age above 24-59 months was a strongly associated with stunting because the AOR was above 2. A multitude of studies have found similar associations [13, 16, 18]. This corroborates the ideas that stunting is a malnutrition which starts during pregnancy and continues until the second year of life with most frequent appearance after the second year of life [12]. However, this finding does not mean intervening after the second year of life is not effective. Because there are different immediate avoidable factors that if intervened may reduce the effect of stunting after the second year of life. Study have shown that factors associated with stunting in late childhood and adolescence are different and there are other windows of opportunities to stop chronic malnutrition if the first 1000 years is missed [35]. Regardless, our study finding reaffirms that, to reduce stunting, intervention strategies should focus on age of the child before 24 months.

Current weight of the child was the strongest predictor of stunting according to the 2016 EDHS data. The continuous form of the variable has shown a non-linear relationship (quadratic) with stunting. Consequently, the variable is categorized into quartiles. There are no previous studies that assessed the effect of child weight on stunting directly. But studies have indicated that wasting (weight to height) is associated with stunting [21, 22] and low birth weight at birth is associated [13] and weight to age is an indicator which is a cumulative effect of wasting and stunting [5]. The association is very strong as there are a few children with a large weight and being stunted at same time; hence, this inflates the association. Child weight reflects body composition with a recent study finding that stunted mother have low body composition including small kidneys and other organs, are thin, and birth small infants [31]. The implication of this finding is that weight monitoring of children is critical in preventing and intervening stunting. Prospective future studies need to assess the effect of weight monitoring within the normal range over time on stunting incidence.

Maternal stature was one of the independent predictors of stunting. Different studies' findings were in line with our finding [26, 20] Maternal stature reflects the intergenerational effects of stunting, maternal malnutrition, and its consequences on childhood outcomes [12]. This implies focusing on mothers with short stature might help in improving birth outcomes and in following-up of children after birth. However, the maternal stature cut-off point we used was arbitrary because there is no an agreed cut-off point in the literature. Intuitively, the cut-off point should be locally derived as genetics may also have a role in determining one's height. This could be similarly applied to stunting's definition which might not be a perfect indicator of malnutrition because linear growth failure may be caused by different biological causes apart from an inadequate nutrition [32].

In addition, maternal BMI, rural residence, paternal education, being male, and child' size were important independent predictors. The findings are similar to those of recent literature [13,14,18,19, 23]. Although there is some contrasting evidence regarding association of sex with stunting [13], most studies' findings are inclined to male sex as more likely to affect stunting [14,15, 18, 25]. The reason could be biological and might be because of sex differences in energy metabolism [33] which suggests the need to give particular emphasis for male births.

Education is also a well-established factor for the likelihood stunning. Previous studies have found similar association [18, 25]. Stunting is a complex problem which is also correlated to the socioeconomic level of a society and a nation at large. Achieving the sustainable development goals is addressing the problem of stunting indirectly [34]. However, since stunting affects generations, there are hundreds of millions who are already stunted since childhood, and adolescence, so intervention strategies should focuses not only first 1000 years but also in these different segments of population groups to stop the stunting syndrome as there might be other windows of opportunities for intervention [35].

4.1 Strength and limitation of this study

To best of our knowledge, this is the first study that analyzed the 2016 EDHS and considered nutritional factors and dietary patterns, developed a model, and rigorously tested for its fitness. The model will open the door for future studies to be conducted and improve the AUC, sensitivity and specificity of the model by including other important factors that are not measured in this study.

The main limitation of this study is large missing data in some variables. Especially our main interest was to include all nutritional factors including dietary habits but there were missing data (almost 40%)in the EDHS data set hence leading to exclusion from analysis. Multiple imputation was beyond the scope this analysis. Moreover, AUC of the model we developed is not so high because of missing another unmeasured variables which implicates future supportive studies to improve its predictive ability. However, it evident from the descriptive statistics that,,on average, very few (i.e., one in five of children) received adequate and diverse nutrition which includes grains, animal and plant based proteins, fruits and vegetables.

4.2 Conclusion

Our model indicates that being born male, being from a mother ofshort stature, living in the rural area, small child size, mother with mild anemia, being from a husband with no education or primary education only, having low weight, and reaching age above 24 months increases the likelihood of stunting. On the other hand, being born of an overweight or obese mother decreases the likelihood of stunting.

The model fits the data very well with AUC 77%. Intervening the avoidable factors obtained in this study using short term and long term preventive strategies might reduce the burden of stunting.

Future studies are needed which focus on determining the association between body composition of the mother, medical conditions, and childhood stunting, finding another window of opportunity to minimize/reverse the consequences in already stunted children, and impact of low child weight should receive due emphasis on future endeavors of reducing chronic malnutrition. Moreover, we recommend the DHS to include more robust, and a contextually customized objective dietary/ nutritional patterns questionnaire in upcoming surveys.

Abbreviations

AUC Area Under Curve

AIC Akaike Information criteria

BMI Body Mass Index

EDHS Ethiopian Demographic Health Survey

ROC Receiver Operating Curve

SD Standard deviation

SSA Sub-Saharan Africa

VIF Variance inflation Factor

Declaration

Competing interest

The authors declared there is no any competing interest.

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Authors' contributions

HGM: conceived the study, analyzed the data, wrote the draft manuscript and revised. HV: contributed in critical review and revision of the manuscript. CF: contributed in reviewing the manuscript, statistical review and edition. PP:participated in design, review and drafting the manuscript.

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Tables

Table 1: EDHS variable codes, and explanation of variables included to this study

Variable type	Variables code EDHS(if applicable)	Explanation	Type of variable	Newly Categorized	New variable name in this study
Outcome	HW70	Height-to-age of the children between age of 6 month and 59 months.	Nominal	Stunting, Yes, yes(1)/no(0)	Stunting
Main factors and confounders	V106	Highest education of women	Nominal	No education(0), primary(1), secondary(2), tertiary(3	Maternal education
	V012	Age of the respondent continuous	Scale(interval)	No	Age of mother
	V013	Age of respondent in 5-year space	Nominal	Yes, 15-19(1),20-29(2),30-39(3),40-49(4)	Age of mothercat
	V025	Type of place of residence	Nominal	No, urban(1), rural(2)	residence
	V115	Time to get drinking water	Scale	Yes, <30 min(1),≥30min(2)	Time to get water
	V137	Number of children(de jure)	Scale	Yes, one(1), two to four(2), ≥five(3)	Children alive
	V190	Wealth index	Nominal	Poor(1), average(2), rich(3)	Wealth index
	V437	Weight of mother	Scale	NO	NA
	V438	Height of mother	Scale	Yes, <150cm(1),≥150cm(2)	Maternal height
	V439	Height/age percentile of mother	Scale	No	NA
	V445	BMI of mother	Scale	Yes,<18.5(1), 18.5-24.9=(2), 25-29.9(3),≥30(4)	BMI
	V457	Anemia level of mother	Nominal	No, severe(1), moderate(2), mild(3), no anemia(4)	Anemia of mother
	V701	Husband/partner educational level	Nominal	No	Husedu
	B4	Sex of child	Nominal	male(1), female(2)	Sex
	B11	Preceding birth interval	Scale	Yes, <24=1,24=2	Birth interval
	M18	Size of the child	Nominal	Yes, Large(1), medium(2), small== (3)	Size child
	HW1	Child age in month	Scale	Yes,6-24 month(1), ≥24-59 month(2)	Age child
	HW2	Child weight in kilogram	Scale	NO	NA
	HW3	Child height in centimeter	Scale	NO	NA
	HW57	Anemia level of child	Nominal	No, severe(1), moderate(2),mild(3),	Anemia of child

				No anemia(4)	
	HW70	Height/age SD new (WHO)	Scale	Yes,≤2sd(1_,≥2sd(0)	Stunting
	HW2	Child weight	Scale	<9.1kg(1), 9.1 to 11.1kg(2),11.1 to 13.3kg(3),13.3kg(4)	
	V414I	Gave child pumpkin, carrot, squash	Nominal	Yes(1), No(0)	NA
	V414J	Gave child any dark green leafy vegetables	Nominal	Yes(1), No(0)	NA
	V414K	Gave child mangoes, papaya and other vitamin A fruits	Nominal	Yes(1), No(0)	NA
	V414L	Gave child any other fruit	Nominal	Yes(1), No(0)	NA
	V414V	Gave child yogurt	Nominal	Yes(1), No(0)	NA
	V414F	Gave child potato, cassava, other tubers	Nominal	Yes(1), No(0)	NA
	V414O	Gave child made from beans, lentils and nuts	Nominal	Yes(1), No(0)	No
	V414E	Gave child noodles, bread and other grains	Nominal	Yes(1), No(0)	NA
	V414P	Gave child cheese,yogurt,	Nominal	Yes(1), No(0)	NA
	V414M	Gave child liver, heart,other organs	Nominal	Yes(1), No(0)	NA
	V414N	Gave child fish, shellfish	Nominal	Yes(1), No(0)	NA
	N414H	Gave beef, pork lamb meat etc..	Nominal	Yes(1), No(0)	NA
Newly categorized variables	Dairy product	If the child took any dairy product by 24-recall	Nominal	Yes(1), No(0)	NA
	gratube	If the mother gave tubers, roots and grains	Nominal	Yes(1), No(0)	NA
	fruveg	If the mother gave any fruits and vegetables	Nominal	Yes(1), No(0)	NA
	meat	If the mother gave any meat	Nominal	Yes(1), No(0)	NA

		and, and its products			

Table 2: Sociodemographic and economic characteristics of women and children (N=7909)

Variable Name	Freq	%
Age of mother at delivery		
15-19	240	3.03
20-29	3933	49.73
30-39	3065	38.75
40-49	671	8.48
Time to get water (n=6503)		
<30 minutes	3748	57.63
≥30 minutes	2755	42.37
Missing	1406	
Paternal educational attainment		
No education	3592	48.21
Primary only	2484	33.34
Secondary	754	10.20
Tertiary	564	7.63
Age child(in months)		
6 to 24	2919	36.91
> 24 to 59	4990	63.09
Residence		
Urban	1452	18.36
Rural	6457	81.64
Maternal educational attainment		
No education	5092	64.38
Primary only	2021	25.55
Secondary	513	6.49
tertiary	283	3.58
Wealth index		
Poorest	2821	35.67
Poorer	1396	17.65
Middle	1161	14.68
Richer	987	12.48
Richest	1544	19.52
Sex of child		
Male	4454	51.26
Female	3855	48.74
Birth interval		
<24month	1533	24.14
≥24month	4817	75.86
Missing	1559	

Table 3: nutritional and clinical characteristics of mothers and children 6-59 months

Variable Name	Freq.	%
Stunting		
Yes	3101	39.21
No	4808	60.79
Dairy products(n=4770)		
No	3929	82.36
Yes	841	17.64
Missing	3139	
Grains,roots and tubers(gratube)(n=4770)		
No	2333	48.9
Yes	2437	51.1
Missing	3139	
Fruits and vegetables(Fruveg)(n=4770)		
No	3648	76.47
Yes	1122	23.53
Missing	3139	
Meat and its products(n=4770)		
No	4418	92.62
Yes	352	7.38
Missing	3139	
Legumes and Lentils (n=4770)		
Yes	750	15.73
No	4020	84.27
Missing	3139	
Size of child		
Large	2419	30.85
Average	3353	42.77
Small	2068	26.38
Missing	69	
Maternal height		
<150cm	776	9.81
>=150cm	7133	90.19
Anemia level of mother (n=7609)		
Severe	126	1.64
Moderate	730	9.48
Mild	1795	23.32
Not anemic	5046	65.56
BMI of mother		
< 18.5	1921	24.29
18.5-24.9	5174	65.42
≥25	722	9.13
Missing	92	1.16
Anemia level of the child		
Severe	300	3.94
Moderate	2455	32.22
Mild	1812	23.78
Not anemic	3052	40.06
Missing	290	
Weight child		
<9.1 kg	1948	2463
≥9.1-11.1kg	19642	2483
≥11.2-13.3 kg	2005	2535
≥13.3 kg	1992	2519

Table 4: Mean and standard deviation of continuous variables of children 6-59 months old in Ethiopia of 2016 EDHS,.

VARIABLE	MEAN	Sd
Age of mother in years (n=7909)	29.45	6.5
Time to get water(n=6503) in minutes	57.93	75.84
Number of children(n=7909)	1.85	0.81
Weight mother(n=7820) in kg	51.7	9.29
Height mother(n=7821) in m	1.58	0.68
BMI mother(n=7817) in kg/m^2	20.66	3.34
Weight child(n=7907) in kg	11.3	2.8
Heigchild(n=7909) in m	0.85	0.116

Table 5: Linearity test of the selected variable weight child

Analysis of Maximum Likelihood Estimates					
Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr > ChiSq
Intercept	1	-5.9841	0.4295	194.1247	<.0001
WEIGHTCHILD	1	1.2471	0.0808	238.2498	<.0001
HW2SQ	1	-0.0639	0.00369	300.5695	<.0001

Table 5: Bi-variable analysis and cross-tabulation of the outcome variable versus the covariates in children of age 6month-59 months using 2016 EDHS dataset.

Variable	Stunting		UOR	95%CI	P-value
	No, freq(%)	Yes, freq(%)			
Age of mother cat					
15-19	138(1.74)	102(1.29)	ref	ref	
20-29	2404(30.4)	1529(19.33)	1.16	0.89,1.51	0.22
30-39	1866(23.59)	1199(15.16)	1.15	0.88,1.5	0.33
40-49	400(5.06)	271(3.43)	1.09	0.80,1.47	0.91
Overall p-value=0.643					
Maternal height					
≥150cm	4461(56.4)	2672(33.78)	ref	ref	ref
<150cm	347(4.39)	429(5.42)	2.06	1.77-2.39	<0.0001
Anemia level of mother					
Severe	78(1.01)	48(0.62)	1.008	0.7,1.45	0.96
Moderate	428(5.56)	302(3.92)	1.15	0.98,1.35	0.07
Mild	1036(13.46)	759(9.86)	1.2	1.07,1.33	0.0011
Not anemic	3133(40.7)	1913(24.85)	ref	ref	ref
Anemia level of child					
Severe	135(1.77)	165(2.17)	2.2	1.73,2.79	<0.0001
Moderate	1425(18.7)	1030(13.52)	1.3	1.16,1.45	<0.0001
Mild	1075(14.11)	737(9.67)	1.23	1.09,1.39	0.0006
Not-anemic	1962(25.75)	1090(14.31)	ref	ref	ref
Overall P-value=0.0069					
Child size					
Large	1608(20.51)	811(10.34)	ref	ref	
Average	2059(26.26)	1294(16.51)	1.24	1.11,1.39	<0.0001
Small	1099(14.02)	969(12.36)	1.74	1.54,1.97	<0.0001
Paternal education					
No education	1993(26.95)	1599(21.63)	2.87	2.33,3.55	<0.0001
Primary	1537(20.79)	947(12.81)	2.2	1.78,2.74	<0.0001
Secondary	525(7.10)	229(3.10)	1.56	1.21,2.01	0.0005
Tertiary	441(5.96)	123(1.66)	ref	ref	
Maternal education					
No education	2899(36.65)	2193(27.73)	4.22	3.03,5.86	<0.0001
Primary	1281(16.26)	740(9.36)	3.22	2.3,4.5	<0.0001
Secondary	388(4.91)	125(1.58)	1.79	1.22,2.63	0.0026
Tertiary	240(3.03)	43(0.54)	ref	ref	
Age child					
6 to 24 months	2017(25.5)	902(11.4)	ref	ref	
≥ 24 to 59	2791(35.29)	2199(27.8)	1.76	1.6,1.94	<0.0001
Wealth index					
Poor	2321(29.35)	1896(23.97)	1.98	1.78,2.2	<0.0001
Average	695(8.79)	466(5.890	1.62	1.4,1.88	<0.0001
Rich	1792(22.66)	739(9.34)	ref	ref	
Sex of child					
Male	2400(30.35)	1654(20.91)	1.14	1.04,1.25	0.003
Female	2408(30.45)	1447918.3)	ref	ref	
Residence					
Urban	1076(13.6)	376(4.75)	ref	ref	
Rural	3732(47.19)	2725(34.45)	2.09	1.84,2.37	<0.0001
BMI of mother					
<18.5	1094(14)	827(10.58)	1.13	1.02,1.26	0.018
≥ 18.5-24.9	3107(39.75)	2067(26.44)	ref	ref	

≥25	556(7.11)	166(2.12)	0.44	0.37,0.53	<0.0001
Weight child					
<9.1	1117(14.12)	830(10.51)	3.81	3.28,4.42	
≥9.1-11.2	956(12.09)	1008(12.74)	5.4	4.66,6.27	
≥11.2-13.3	1068(13.5)	937(11.85)	4.5	3.88,5.21	
13.3	1667(21.08)	325(4.11)	ref	ref	
Continuous variables	**B-coefficient**	**CI**	**P-value**		
Age of mother	1.003	0.997,1.01	0.325		
Weight of child	0.983	0.981, 0.985	0.0001		
Height of mother	0.995	0.994,0.995	<0.0001		

Table 6: Multi-colinearity test using variance inflation test for independent predictors included in the analysis

Parameter Estimates								
Variable	**Label**	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	**Tolerance**	**Variance Inflation**
Intercept	Intercept	1	0.95720	0.06628	14.44	<.0001	.	0
WEALTH	Wealth status	1	-0.00766	0.00727	-1.05	0.2923	0.65479	1.52721
mstature	Maternal height	1	-0.15002	0.01767	-8.49	<.0001	0.99013	1.00997
V457	Anemia level of mother	1	0.00805	0.00737	1.09	0.2744	0.92282	1.08363
HW57	Anemia level of child	1	-0.00951	0.00610	-1.56	0.1192	0.85178	1.17401
weightchil	Weight of child	1	-0.22745	0.00692	-32.87	<.0001	0.46198	2.16462
B4	Sex of child	1	-0.06339	0.01061	-5.98	<.0001	0.98241	1.01791
V025	Type of place of residence	1	0.04256	0.01734	2.45	0.0142	0.66429	1.50537
childage	Age of child	1	0.50561	0.01548	32.66	<.0001	0.49409	2.02392
SIZECHILD	Size of child at birth	1	0.02910	0.00711	4.09	<.0001	0.96209	1.03940
BMI	Body mass index	1	-0.01773	0.00917	-1.93	0.0533	0.90286	1.10760
husedu	Husband education	1	-0.02683	0.00654	-4.10	<.0001	0.78995	1.26590

Table 7: Multivariable analysis of variables included in the final model of children age between 6 months and 59 months included in 2016EDHS.

Variable	AOR	95%CI
Maternal height		
≥150cm	ref	Ref
<150cm	2.01	1.76,2.5
Child size		
Large	ref	ref
Average	1.12	0.98,1.27
Small	1.38	1.19,1.59
Paternal education		
No education	1.79	1.39,2.3
Primary	1.62	1.25,2.1
secondary	1.32	0.99,1.77
tertiary	ref	ref
Age child		
6 to 24 months	ref	ref
>24 to 59 months	9.71	8.07,11.6
Sex of child		
Male	1.4	1.26,1.56
Female	ref	ref
Residence		
Urban	ref	ref
Rural	1.3	1.09,1.54
BMI of mother		
<18.5	1.02	0.9, 1.16
≥18.5-24.9	ref	ref
≥25-29.9	0.69	0.54,0.89
≥30	0.59	0.37, 0.94
Anemia level of mother		
Severe	0.73	0.48,1.11
Moderate	0.92	0.76,1.11
Mild	1.14	1.1,1.3
Not anemic	ref	ref
Weight of child		
<9.1	27.8	21.8,35.38
9.1 to 11.2	15.64	12.91,18.95
11.2 to 13.3	5.19	4.41,6.10
13.3	ref	ref

Table 8: Interaction test result of some selected variables

Type 3 Analysis of Effects			
Effect	DF	Wald Chi-Square	Pr > ChiSq
mstature	1	7.0937	0.0077
V457	3	9.2792	0.0258
weightchil	3	26.7638	<.0001
B4	1	37.7386	<.0001
V025	1	8.8256	0.0030
SIZECHILD	2	19.8752	<.0001
agechild	1	62.2701	<.0001
BMI	3	6.4923	0.0900
husedu	3	2.1284	0.5462
Stabmi(maternal height and BMI)	1	1.3604	0.2435
Huseanema(husband education and anemia)	1	1.4566	0.2275
Bmimheight(child weight and child age)	1	0.1137	0.7360

Table 9: Model fitness using Hosmer and Lemeshow Goodness-of-Fit Test

Hosmer and Lemeshow Goodness-of-Fit Test		
Chi-Square	DF	Pr > ChiSq
3.9964	8	0.8574

Figures

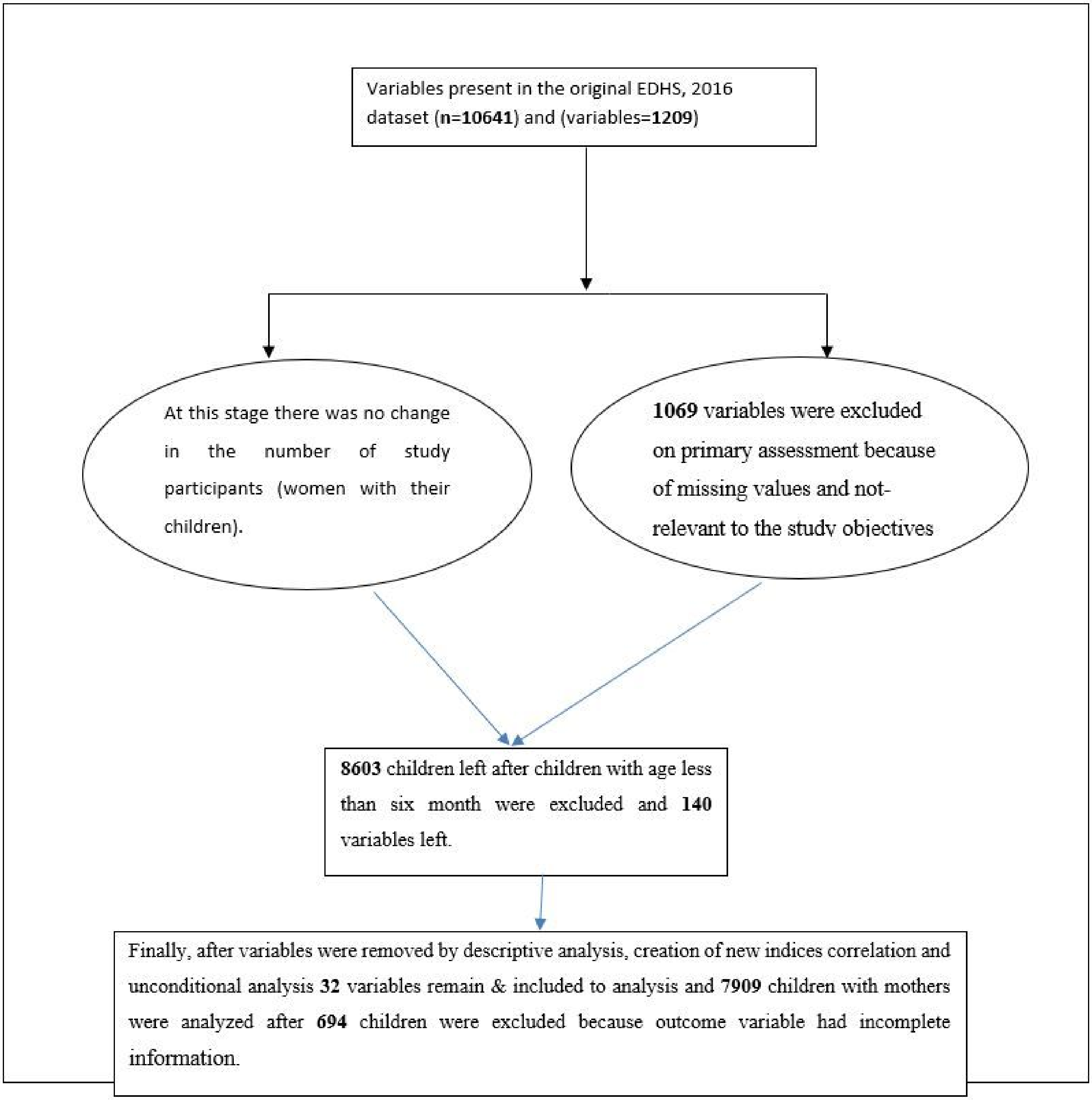

Figure 1

Study participants and variables selection process and outcome

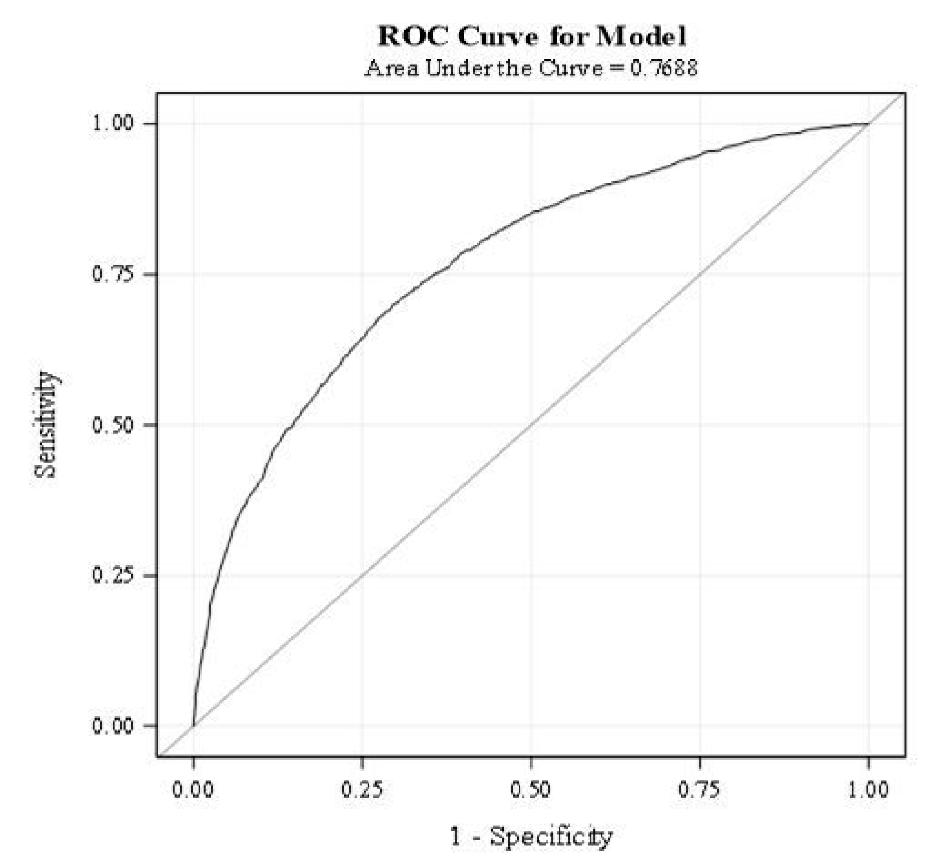

Figure 2

receiver operating characteristics curve for the model developed on stunting predictors