Addis Ababa University
College of Health Sciences
School of Public Health

Maternal undernutrition indicators as proxy indicators of their offspring’s undernutrition: Evidence from 2011 Ethiopia Demographic and Health Survey

Research paper

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Table of Contents

Abbreviations/Acronyms

AUC	Area Under Receiver Operating Curve
BMI	Body Mass Index
CI	Confidence Interval
DALYs	Disability Adjusted Life Years
EA	Enumeration Area
EDHS	Ethiopia Demographic and Health Survey
ETB	Ethiopian Birr
GNP	Gross National Product
HAZ	Height for Age Z-score
IRB	Institutional Review Board
MUAC	Mid Upper Arm Circumference
NRERC	National Research Ethics Review Committee
SGA	Small for Gestational Age
UNICEF	United Nations Children's Fund
WAZ	Weight for Age Z-score
WHO	World Health Organization
WHZ	Weight for Height Z-score

List of tables and figures.

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Abstract

Background: The intergenerational continuity of undernutrition is influenced by shared genetic, household socio-economic and cultural resources which will be associated with the mother and the child nutritional status, possibly to the same degree. Provided that this assumption is valid, assessing maternal nutritional status will provide an effective screening tool for their children nutrition status.

Objective: To examine whether maternal undernutrition indicators can be used as a proxy indicator of their offspring's undernutrition.

Methods: Data were obtained from the 2011 Ethiopia Demographic and Health Survey (EDHS 2011). An analytical sample of 8,505 children whose mothers are not pregnant and live with their biological mothers was included. The bivariate associations between nutritional indices of the mother and the children were analyzed with Pearson correlation coefficients. The sensitivity, specificity, predictive values and area under Roc curves were calculated. We performed ROC regression analysis to determine factor that affects the accuracy of maternal underweight as a screening tool. We further performed rocreg postestimation to determine where exactly the test performed best.

Results: Mean BMI of mothers with stunted children was 20.01 (95% CI: 19.86–20.16), whereas that mothers with no stunted children was 20.46 (95% CI: 20.31– 20.62). Similarly, children who experienced underweight or wasting had mothers who had consistently lower BMI than those who did not (p <0.001). The sensitivity of maternal underweight (defined by BMI < 18.5 kg/m^2) as a predictor of child's nutritional status (<-2 z-scores) is low, failing to reach 50% for any of the child nutrition indices. In the roc regression analysis, maternal BMI(<18.5 kg/m^2) became a more accurate predictor of wasting among children whose mother are older (β = -0.014, p=0.002) and higher parity(β= -0.035, p <0.001), and among children who are not currently breastfeeding (β= -0.042, p = 0.006) and from richer households (β= -0.037, p <0.001).

Conclusion: Our study provides evidence that maternal undernutrition indicators are less informative in predicting their offspring's undernutrition, although maternal BMI (<18.5kg/m^2) may be a better measure of wasting among children whose mothers gave birth to four children and among children from richest households.

1. Introduction

1.1. Background

Maternal and child malnutrition are universal problems that can cause death, acute and chronic diseases. It can also cause significant consequences for healthy development and economic output of individuals and societies[1]. Malnutrition refers to undernutrition as well as obesity or overconsumption of specific nutrient. On the other hand, undernutrition is a condition when inadequate food intake and frequent infections result in one or more of the following: underweight for age, short for age (stunted), thin for height (wasted), and functionally deficient in vitamins and/or minerals[2].

Malnutrition is caused by a range of interrelated factors including dietary inadequacy or excess, infections, and socio-cultural factors. Among these determinants, maternal nutritional status is one of the important determinants of childhood nutritional status[3, 4]. The nutritional status of mothers both at conception and during pregnancy affects the growth and development of the fetus. These factors, together with nutritional status in the first 1000 days of life determine both undernutrition in childhood and obesity and related diseases in adulthood[1].

Emerging evidence has also suggested that shared genetic, social and environmental factors influence the nutritional status of parents and their offspring. Consequently, the intergenerational association between maternal and child nutritional status are more determined by shared genetic, household socio-economic and cultural resources [5-8]. For instance, shared environment that is deficient in adequate nutrition will possibly affect parents and offspring in a similar way[8].

Association between maternal and child nutritional status [4, 9, 10] emphasizes the significance of addressing maternal and young child nutritional status as a single factor[10]. Considering the association between maternal and child nutritional status, anthropometry can also be useful in assessing the nutritional status of a household based on the anthropometric indicator of an individual household member[11]. If anthropometric indicators of the mother are strongly correlated with that of the child, the anthropometric indicators of the mother can be used to tell us something about the occurrence of malnutrition among her offspring.

1.2. Statement of the problem

Globally, at least 165 million, 101 million and 52 million children less than five years are stunted, underweight and wasted in 2011 respectively[12]. Undernutrition among adult women (BMI less than 18·5 kg/m²) has decreased globally though it remains higher than 10% in Africa and Asia[1]. Together, maternal and child undernutrition is considered the root cause of 3.5 million deaths, 35% of the disease burden in children younger than 5 years and 11% of total global DALYs[13].

The prevalence of stunting among children under-five years of age is highest in Africa (36% in 2011) and still it's a public health problem which most of the time goes unrecognized. Although the global prevalence of underweight decreased for the last two decades, still considerable proportion (18% in 2011) of children under-five years of age in Africa are affected. It's estimated that 8.5% of children are also acutely affected by undernutrition. These children are at high risk of severe acute malnutrition and death[12].

The Ethiopia undernutrition picture is relatively similar to that of Africa with 44%, 29% and 10% of children of under-five of age being stunted, underweight and wasted respectively in 2011. Under nutrition among adult women is also high compared with other African countries with almost 27% of adult women are thin (BMI less than 18·5 kg/m²)[14].

Measuring nutritional status of children of under-five years of age assumes an immediate priority for relief organizations and researchers doing epidemiological investigations. However, sometimes it can be difficult to deal with them in terms of assessing their nutritional status and often times subject to many errors. Therefore, could there be a quick, accurate and simple way of measuring nutritional status of these children? In simple terms can anthropometric indices (i.e BMI and height) of mothers used as a proxy indicator for child undernutrition? The answer to this question will depend on the strength of correlations in nutritional status of mothers and their offspring at house-hold level.

Few studies tried to examine the use of individual anthropometric measurement in a household to predict the occurrence of malnutrition among other family members[15, 16]. However, these studies did not find strong epidemiological associations. The absence of the association was due to the fact that their study populations were too homogenous in terms of socioeconomic, environmental and behavior to bring about the association. Therefore, this study aims at finding stronger correlation by analyzing a heterogeneous study population from a nationally representative sample.

1.3. Rationale of the study

The study will try to examine if a correlation exists between mothers and children nutritional status. If strong correlations are found, it will have implications for the use of anthropometry for screening nutrition status of children less than five years of age. In other words, screening programs and researchers doing epidemiological studies may perhaps have accurate, timely and cost efficient means of identifying children with malnutrition.

2. Literature Review

Nutritional status of children under five years of age has been used as a proxy index of food security by many aid organizations despite the fact that other factors may affect their nutritional status. To put it differently, identification of malnourished children was used to predict the occurrence of malnutrition in the household. This assumption of targeting households according to the nutritional status of their members may hold true in the situation of less extreme shortages[11]. On the other hand, there is also an assumption that maternal BMI can also be used as an indicator of food security in the household. This assumption is based on the fact that mothers in some societies play a major role in ensuring household food security as well as parental care[17].

However, how far the above assumptions hold true and their implications in nutritional screening programs have been systematically investigated by some studies. Other studies have also tried to find simple associations between maternal and child nutrition. In the subsequent sections, we will first discuss the nutritional status of children, then maternal nutrition, dual burden households and finally correlations of their nutritional statuses.

2.1. Child Undernutrition

Assessment of growth has been the single most important measurement that best defines nutritional status of children under five years of age[18, 19]. Circumstances such as inadequacy of food intake, severe and repeated infections or a combination of both often operate as a vicious cycle. Disturbance in nutrition as a result of these conditions affect the growth of a child and are closely linked to the general standard of living and the population's ability to meet its basic needs for nutritious food, safe water, good housing, acceptable levels of environmental sanitation, and ready and easy access to health care[19].

However, there are doubts whether estimates of undernutrition based on nutritional anthropometric survey data in children alone (without any information about the adults in the community) necessarily reflect the overall nutritional status and the adequacy of food availability within the entire community[20].

In Sub-Saharan Africa, high levels of undernutrition are mostly associated with the age of the child. The decreasing trend in nutritional status from birth is surprisingly fast as newborns in many African households live in a poor health environment and most of the times they are sub-optimally fed, that is to say, lack of exclusive breastfeeding and inappropriate or untimely complementary feeding. When these children reach the age of 12 to 15 months almost half of them are underweight (weight-for-age Z-score less than −2) with very slight improvement afterward[21].

Place of residence (urban or rural) is another determinant of child undernutrition. Undernutrition among preschoolers is more common in rural than urban areas [1, 21-24]. The rural-urban disparity is largely contributed by social-economic characteristics such as maternal education and wealth index[22].

Another obvious determinant of undernutrition which is more or less related to economy is household wealth. Poorest households have the highest levels of undernutrition than the richest quintile household [21, 22, 25]. For instance, lancet series on maternal and child undernutrition has shown stunting prevalence among under-five children was higher by 2. 47 times among the poorest quintile of households than in the richest quintile [13].

Gender inequality in child nutrition is also another factor but is much smaller than economic inequality[1]. Stunting prevalence tends to be higher among boys than girls [1, 21, 26]. There are, however, speculations on why there these differences in anthropometry with girls having advantage overs boys[27].

2.2. Maternal Undernutrition

Adult malnutrition is commonly measured by BMI and stature. BMI is simple and the most suitable indicator by which weight-for-height can be associated with health outcome and proposed by WHO in 1995 to monitor both undernutrition and overweight[28].

BMI is considered to be the most suitable, objective anthropometric indicator of nutritional status of the adult. It was chosen because this anthropometric indicator, derived from measures of weight and height of individuals of both sexes, is consistently and highly correlated with body weight (or energy stores within the body) and is relatively independent of the height of the adult. While a BMI <18.5kg/m^2 is considered as the cutoff for the diagnosis of chronic undernutrition in adults, a series of cut- offs are provided to delineate the degrees of severity of undernutrition [29]. Though the use of a single BMI cutoff is much more controversial as a healthy BMI is likely to vary with age, sex, pregnancy/lactation, ethnicity, climate and other factors[30].

Maternal nutritional status is important for her overall health and healthy pregnancy outcome[31]. However, maternal undernutrition is still evident and pose a serious problem in most African countries where the prevalence of low BMI (<18.5 kg/m^2) is still higher than 10%[1]. Maternal undernutrition (BMI and short stature) is believed to increase the risk for intrauterine growth retardation and low birth weight leading to undernutrition in infancy and childhood. This may turn into a vicious cycle that may carry on malnutrition from one generation to the next[13, 32, 33]. Maternal stature is a complex indicator that reflects both genetic and environmental effects on the growing period of childhood[1]. Association between maternal stature and child stunting is evident in many studies [34-37]. For instance, a study involving 109 Demographic Health Surveys has shown the risk for a child being stunted was 0.194 for the tallest mothers and 0.682 for the shortest[34].

Low maternal BMI (<18.5 kg/m^2) is also known to be associated with intra uterine growth retardation[18, 31]. Fetal growth restriction may, in turn, contribute to stunting and wasting in children. About 20% of childhood stunting could have its origins in the fetal period by being born small for gestational age (SGA)[1].

2.3. Double burden household: Maternal obesity and overweight and child undernutrition

The fact that many children and women in Ethiopia are affected by undernutrition we can assume the nutritional status of women and their children are homogenous. However, studies have shown rising trend in double burden households. That is to say, households that have both underweight or stunted and overweight/obese persons. Countries that their economies are in the middle range of gross national product (GNP) have the highest prevalence[38, 39]. In Sub-Sahara Africa, however, double burden households was shown to exist [24, 39, 40]. Studies involving 26[24] and 23 [40] African Demographic Health Surveys have shown less than 10% of households with stunted child-overweight mother pairs. Jehn and Brewis [39] found the prevalence of households that included an overweight mother with a child with undernutrition was less than 0.3% for Ethiopia in 2000, which the lowest prevalence of all sub-Saharan countries.

Though the above prevalence was in 2000, the prevalence of double burden nutrition in Ethiopia is still less than 3% according to a recent study [41]. The same study showed underweight children with an overweight mother were more likely to live in urban areas. Therefore, we can assume the trend in Ethiopia is relatively similar which in turn we can also assume homogeneity of nutritional status of mothers and their children.

2.4. Correlations in nutritional status of mothers and their offspring

In sub-Saharan Africa, countries that have a high prevalence of child undernutrition also have a high prevalence of adult underweight [24]. According to a recent study that analyzed 26 DHS data sets from sub-Saharan Africa, the prevalence mother-child pair undernutrition was greater than 5% for 8 countries and for some countries the prevalence was almost 10%. The prevalence for underweight mother/underweight child pairs as indicated by the same study was 4.85% (95% CI 4.67-5.04%), 4.74% (95% CI 4.56-4.92%) for underweight mother with stunted child, and 1.50% (95% CI 1.41-1.59%) for underweight mother with wasted child[24].

Several studies have tried to examine the association between maternal and child nutritional status. Some did simple associations and few went further to see if either of the maternal or child anthropometric indices could be used to predict the nutritional status of the child or the mother. All studies reviewed were observational in nature and had adequate sample sizes with few exceptions. We will start the review with the ones that are relatively related to the current study and emphasize on them a little bit more and consequently, we will see the rest.

As mentioned above only two studies were found to be relatively related to the current study. According to one of these studies, childhood nutrition indices appear to be more highly correlated with maternal weight and BMI than with maternal height when a sample of children is considered as a whole. For the full sample of children, all correlations between the mothers and children were positive lying in the range of 0.040-0.309. All of the correlations were significant except for WHZ for the age group 0-11 months which was not significantly correlated to any of maternal nutritional indices[16]. The second study also showed that HAZ among children aged 0-2 years was significantly correlated with maternal height ($r=0.22$, $p<0.05$) and weight($r=0.22$, $p<0.05$). WAZ among the same group was also significantly correlated with maternal BMI($r=0.25$, $p<0.05$) and weight($r=0.30$, $p<0.05$). Among children aged 2-5 years, only WHZ was significantly correlated with maternal weight ($r=0.27$, $p<0.05$)[15]. A secondary analysis using data set from Ethiopia, India and Zimbabwe also showed the relationship between the average WHZ of each community's children and the average maternal BMI for the same region ($p<0.05$). The correlation between the Z-score for weight-for-height in children of all ages and their mother's BMIs lies between 0.06 and 0.32 [28].

When it comes to screening for child malnutrition based on anthropometric indicators of the mother was inefficient for both of studies [15, 16]. All indicators showed low sensitivity (<20% for all anthropometric indicators), although the specificity is higher (>89.7%). On the other hand, the positive predictive value of the screening test was somewhat low (<20%) for any anthropometric indicator considered, while the negative predictive values are high (>89%) for all the indicators [16]. The result of the sensitivity, specificity, and predictive values were relatively similar even after screening was performed in the reverse direction [15, 16].

The above studies were cross-sectional in nature. Though their samples were large enough to evaluate anthropometric indices as screening tool they didn't found strong statistical significance associations. The reasons why they missed the strong associations could be the homogenous nature of their study participants.

Some of other studies also found a significant association between maternal nutritional status and child undernutrition [4, 8-10, 42]. A study done in Nigeria found undernourished mothers have about 11 and 12 times risk of having children with underweight and wasting respectively (OR 11.2, 95% CI = 1.4-86.5, p = 0.005) and (OR 12.3, 95% CI = 1.6-95.7, p = 0.003) respectively [4]. Another study that was done in India also found an increase in 1 unit of maternal BMI was associated with a lower relative risk (RR) for childhood undernutrition. Underweight RR: 0.957 (95% CI: 0.947– 0.967); stunting RR: 0.985 (95% CI: 0.977– 0.993); wasting RR: 0.941 95% CI: 0.926–0.958) [8]. Likewise, studies that were done in Brazil and Kenya showed significant positive association (P < 0.05) between maternal weight, height, BMI and children's HAZ, WAZ, WHZ, and MUAC-for-age *z*-score [9, 10]. Last but not least, study done by Gewa and his colleagues found that short maternal stature (<150 cm) was associated with 1.93 (95% CI 1.22, 3.04) odds of stunting while maternal underweight, compared with normal weight, was associated with 1.55 (95% CI 1.09, 2.22) odds of stunting, 1.82 (95% CI 1.26, 2.62) odds of underweight and 2.05 (95% CI 1.31, 3.21) odds of wasting among the younger group of children[42].

The above studies didn't further analyze the data to see if either of the maternal or child anthropometric indices could be used to predict the nutritional status of the child or the mother. All of them had adequate sample sizes with an exception of a study by Senbanjo et al., and C.A. Gewa et al., [4, 10]. We believe findings of the rest of studies [8, 9, 42] are reliable since they have used DHS data sets. DHS data are considered to be of high quality, the standardized procedures used by DHS increases the quality of the data and also allows for comparability across countries. DHS also provides a sample that is nationally representative, allowing inference to the entire country and in particular the mother-child pairs available (under-five).

We have seen that several studies have found an association between maternal nutritional status and childhood undernutrition. Two studies went further to see if nutritional status of family members could be used to predict the nutritional status of other members. The two studies due to the nature of their study populations which was too homogenous in terms of socioeconomic, environmental and behavior , screening for child malnutrition based on anthropometric indicators of the mother was inefficient.

3. Objectives

General objective

- The general objective of this study is to examine whether maternal undernutrition indicators can be used as a proxy indicator of their offspring's undernutrition.

Specific objectives

The study has the following specific objectives:

- To determine whether maternal BMI (<18.5kg/m^2) could be used as a proxy indicator for undernutrition (stunting, underweight and wasting) among children under the age of five.
- To determine whether maternal height (<145cm) could be used as a proxy indicator for undernutrition (stunting, underweight and wasting) among children under the age of five.

4. Methods and data

4.1. Study setting

Ethiopia is a country with 94 million people, second largest among African countries and among the least urbanized countries in the world. The majority of the population resides in the highland areas[14]. The source of livelihood of the settled rural population is farming while the lowland areas are mostly inhabited by nomads, who depend mainly on livestock production and move from place to place in search of pasture and water.

There are 11 administrative regions in Ethiopia (9 regional states and two administrative cities); Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations Nationalities and Peoples (SNNP), Gambella, Harari, Addis Ababa, and Dire Dawa. Regions are divided into zones, and zones, into administrative units called *weredas*. Each *wereda* is further subdivided into the lowest administrative unit, called *kebele*. More than 80 percent of the country's total population lives in the regional states of Amhara, Oromiya, and SNNP.

The 2011 EDHS is the third Demographic and Health Survey conducted in Ethiopia. It is intended to measure levels, patterns, and trends in demographic and health indicators. EDHS provides data on fertility, family planning, maternal and child health, childhood mortality, nutrition, malaria, HIV knowledge and behavior, and HIV prevalence[14].

4.2. Data source

Secondary analysis was performed using data from the 2011 Ethiopian Demographic Health Survey (EDHS), which is a nationally representative cross-sectional household survey of women of reproductive age and children less than five years old in Ethiopia. The data have been weighted to cater for the different sample proportions [14]. The survey was conducted from September 2010 to January 2011 and included three structured questionnaires: the Household Questionnaire, the Woman's Questionnaire, and the Man's Questionnaire.

4.3. EDHS Sample Design and Procedure

A representative probability sample of 18,720 households was selected using a multistage stratified two- stage cluster sampling design in which samples of households within clusters (enumeration areas) are selected. This sample was constructed to allow for separate estimates of health indicators for each of the 11 geographic/administrative regions (nine regional states and two city administrations), as well as for urban and rural areas separately. A total of 624 clusters, 187 urban and 437 rural were selected from the sampling frame (The 2007 Population and Housing Census) in the first stage. In the second stage, a fixed number of 30 households were selected for each enumeration area. Of all the selected 18,720 households, 5,610 are in urban areas and 13,110 are in rural areas[14].

4.4. Sample size and Study population

The EDHS sample design considers different parameters for the indicators to estimate the final sample size. In view of that, we have used children's recode file with 7764 women and 11,654 children. But our study focused only on children whose mothers are not pregnant and living with their biological mothers. Therefore, the following inclusion and exclusion criteria were used as depicted in the figure below.

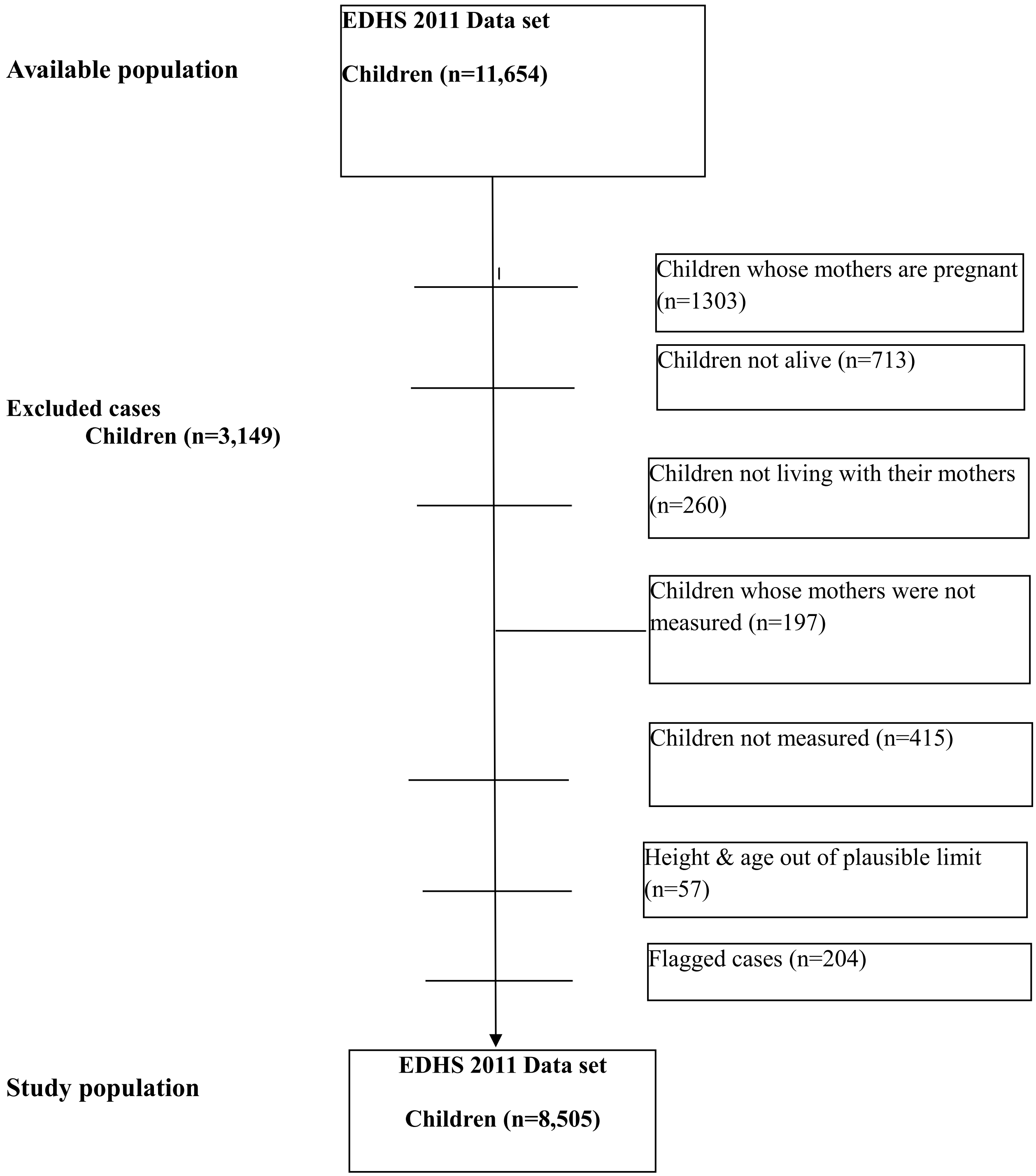

Figure 1: Study population diagram

4.5. Study variables

4.5.1. Outcome variables

Child undernutrition was defined along three anthropometric indices: underweight, stunting and wasting. Weight measurements were obtained using lightweight, SECA mother-infant scales with a digital screen, designed and manufactured under the guidance of UNICEF. Height measurements were carried out using a measuring board manufactured by Shorr Productions. Children younger than 24 months were measured for height while lying down, and older children, while standing [14].

The WHO 2006 growth standards were used to transform children's weight and length/height measurements into sex- and age-specific Z-scores: height-for-age Z-score (HAZ), weight-for-age Z-score (WAZ) and weight-for-height Z-score (WHZ) [43]. Stunting was defined as HAZ below -2SD, underweight was defined as WAZ below -2SD while wasting was defined as WHZ below -2SD from the respective WHO 2006 growth standards reference median.

4.5.2. Exposure variables

The nutritional status of women was assessed by use of two anthropometric indices; height and body mass index (BMI). To derive those indices, EDHS measured the height and weight of women age 15-49 years. BMI is used to measure thinness or obesity. BMI is defined as weight in kilograms divided by height in meters squared (kg/m^2). A BMI below $18.5 kg/m^2$ indicates thinness or acute undernutrition. A BMI below $17 kg/m^2$ indicates severe undernutrition. A BMI of $25.0 kg/m^2$ or above indicates overweight or obesity.

4.5.3. Covariates

We included in the study a number of theoretically important covariates that have been considered before in studies on childhood undernutrition [18]. Child's sex and age, maternal age, maternal education, place of residence (urban and rural). We also included a number of additional covariates: currently breastfeeding, maternal smoking status, maternal parity, and household wealth index.

4.6. Data analysis

DHS has developed the concept of recode files in order to facilitate data analysis. Recode files have standard data definitions across countries and across DHS phases. There are seven common types of recode data files associated with the core questionnaires. The datasets are available in the standard recode file formats in SPSS, SAS, Stata and CSPro; only completed questionnaires are included in these files. Among the types of the recode data files, children's recode file is one of them. This is a dataset that has one record for every child of interviewed women, born in the five years preceding the survey. Therefore, we used the children's recode data file in the form of Stata for analysis.

The available sample in the child recode file was 11, 654 children under age five and 7764 mothers. Of the 11,654 children, we excluded from the analysis children from pregnant mothers (1303); children not alive at the time of interview (n=713); children not living with their mothers (n= 260); children not measured (n=612); and values that are flagged and out the plausible limit (n=261). The final data set comprised 8505 children aged 0-59 months (Figure 1). We have not used child-mother pairs instead we have used all children and repeated their mothers. For example, if the mother had three children she was repeated three times. It's not a good idea to match mother with the younger child by doing this we will introduce bias because the youngest child born in the last five years tend to be healthier than other children[44]. It would have been better to select the matched child at random but that means it's impossible to match our results exactly. Statistical analysis was performed using the STATA software package, version 14.0 (Stata Corp., College Station, TX, USA). Its survey commands (*svy*)account for the complex sample survey data composition: strata, clusters, and weights.

We estimated weighted prevalence of stunting, underweight and wasting by maternal, child and household variables. Overall differences across the categories were tested with design-based Pearson chi-squared test. We also carried out correlation analysis to investigate possible associations between nutritional indices of the mother and the children and statistical significance was considered at the significance level of 5%. STATA does not give confidence intervals for correlations, so new command (*corrci*) was used to estimate confidence intervals. We then calculated sensitivity, specificity, predictive values and Area Under Roc Curve of the nutrition indices of the mother and the children using *diagt* command. Nutritional status of the mother (BMI and Height) was used to predict the nutrition status of the children. The area under the ROC curve (AUC) determines the overall level of accuracy, with a value of 0.50 indicating purely random performance and 1.00 indicating the maximal value possible. According to an arbitrary guideline based on a suggestion by Swets, one could distinguish between non-informative (AUC=0.5), less accurate ($0.5<AUC\leq0.7$), moderately accurate ($0.7<AUC\leq0.9$), highly accurate ($0.9<AUC<1$) and perfect tests (AUC=1)[45].

Roc regression analysis

Receiver operating characteristic (ROC) analysis provides a quantitative measure of the accuracy of diagnostic tests to discriminate between two states of health condition. ROC regression is more than determining the basic accuracy of a test, rather it determines factors that affect its accuracy. In doing so, it is possible to identify populations and settings where a test is more or less accurate, which can be useful in determining how best to use a test. This is accomplished using regression analysis of test accuracy or Roc regression analysis[46]. Therefore, we used *rocreg* command to fit a parametric probit model fit using maximum likelyhood. We fitted the model for status variable wasting and classifier maternal underweight (BMI $<18.5kg/m^2$) with the following covariate; child sex, currently breastfeeding, maternal age, maternal education, smoking status, maternal parity, place of residence and household wealth index. To determine specifically where the test (maternal BMI <18.5 kg/m^2) performed the best we used *rocreg postestimation* to calculate Receiver Operating Curve summary statistics for covariate-specific ROC curves.

4.7. Ethical consideration

Ethical clearance for the survey was provided by the EHNRI Review Board, the National Research Ethics Review Committee (NRERC) at the Ministry of Science and Technology, the Institutional Review Board of ICF International, and the CDC. Online application to analyze the secondary data was requested from DHS Program, USAID and we have been authorized to download data from the Demographic and Health Surveys (DHS) online archive. The proposal was reviewed and approved by the IRB of the School of Public Health at Addis Ababa University.

4.8. Dissemination of results

The result of the study will be presented to School of Public Health, College Health sciences, Addis Ababa University as part of Masters of Public Health in Nutrition thesis. Efforts will be made to present the results to scientific conferences and peer-reviewed journal publications.

5. Result

5.1 Background characteristics

The background characteristics of children are presented in Table 1. Fifty-one percent of children were male and the rest were females. Twenty-three percent of children were aged 0-11 months and 21% were aged 36-47 months. Of all children, 42.9% were stunted, 28.2% were underweight, and 10% exhibited wasting. The mean age of stunted, underweight and wasted children was 33.9, 32.5 and 22.5 months respectively. Mean maternal BMI of stunted children was 20.01 (95% CI: 19.86–20.16), whereas that for children who were not stunted was 20.46 (95% CI: 20.31– 20.62). Similarly, children who experienced underweight or wasting had mothers who had consistently lower BMI than those who did not ($p < 0.001$). Lower prevalence of child undernutrition was observed as the maternal BMI increases. The same is true for maternal height; children who experienced undernutrition had shorter mothers except for wasting ($p < 0.05$). We also examined the distribution of covariates across categories of child undernutrition. Children currently breastfeeding had a higher prevalence of wasting (11.2%) than those who were not ($p < 0.001$). On the other hand, no relationship was found between breastfeeding with stunting and underweight. Higher prevalence of undernutrition was also observed among children of male sex and older ages and among children whose mothers have lower levels of education and among children from rural area and poorest households ($p < 0.05$). We have found no relationship between maternal parity with underweight and wasting. Likewise, no relationship was found between maternal age, marital status and smoking status with the three forms of child undernutrition.

Table 1: Frequency and Weighted Prevalence of Stunting, Underweight and Wasting of Children age less than 5 Years According to Maternal Anthropometry and Other Maternal, Child, and Household Characteristics. EDHS 2011

	< -2 SD[1]						
Variable	**HAZ[3]**	***p*[2]**	**WAZ[4]**	***p*[2]**	**WHZ[5]**	***p*[2]**	**Total**
Total n (weighted %)	3478(42.9)		2472(28.2)		1007(10.01)		8505(100)
Child's sex n (weighted %)		0.03		0.001		0.001	
M	1824(44.7)		1337(30.4)		575(11.5)		4312(51)
F	1654(41.1)		1135(25.9)		432(8.5)		4193(49)
Child's age in month n (weighted %)		<0.001		<0.001		<0.001	
0-11	267(15.6)		319(15.3)		331(14.7)		1943(22.9)
12-23	699(44.8)		500(29.6)		255(13.5)		1612(18.6)
24-35	817(55.8)		542(33.9)		145(8.8)		1515(17.5)
36-47	931(55.3)		584(32.9)		134(6.1)		1766(21.2)
48-59	764(48.2)		527(31.6)		142(6.6)		1669(19.8)
Currently breastfeeding		0.18		0.44		<0.001	
No	865(45.3)		559(27.0)		174(5.1)		1944(19.2)
Yes	2613(42.4)		1913(28.4)		833(11.2)		6561(80.8)
Maternal BMI n (weighted %)		<0.001		<0.001		<0.001	
<17 kg/m^2	317(42.5)		302(41)		158(16.9)		760(5.9)
17.0-18.4kg/m^2	738(47.9)		614(37.6)		260(13.4)		1622(16.8)
18.5-24.9kg/m^2	2314(43.0)		1505(25.9)		563(8.9)		5646(73.3)
≥25kg/m^2	109(22.3)		51(11.7)		26(7.2)		477(4.1)
Maternal height n (weighted %)		<0.001		0.01		0.93	
<145cm	108(61.3)		77(39.4)		22(10.3)		177(2.2)
≥145cm	3370(42.5)		2395(27.9)		985(10.0)		8328(97.8)
Maternal age n (weighted %)		0.18		0.14		0.54	
15-19	108(36.8)		84(25.4)		49(12.9)		357(3.9)
20-24	639(40.7)		436(26.1)		199(10.5)		1675(20.0)
25-29	1069(43.0)		757(28.8)		300(10.2)		2638(31.4)
30-34	738(44.9)		542(30.2)		214(9.0)		1726(19.6)
35-39	575(42.4)		399(25.8)		148(9.3)		1348(15.6)
40-44	274(48.3)		207(33.7)		81(11.3)		571(7.1)
45-49	75(42)		47(25.1)		16(7.0)		190(2.4)
Maternal education in years n(weighted %)		<0.001		<0.001		0.002	
No education	2635(45.2)		1946(30.8)		778(11.0)		5975(70.4)
1-5	608(42.2)		398(26.5)		151(8.0)		1548(19.7)
6-10	208(31.8)		119(15.2)		68(7.2)		758(8.0)
>10	27(14.8)		9(3.8)		10(4.3)		224(1.9)
Maternal parity n (weighted %)[6]		0.01		0.22		0.28	
1	1354(44.0)		921(28.6)		366(9.6)		3242(37.5)
2	1703(44.0)		1241(29.0)		516(10.6)		4101(49.9)
≥3	421(35.7)		310(23.8)		125(9.0)		1154(13.6)
Maternal marital status n (weighted %)		0.37		0.15		0.07	
Never in union	19(49.3)		10(22.3)		6(9.6)		51(0.6)
Married	3044(42.7)		2195(28.6)		901(10.4)		7448(87.6)
Living with partner	146(40.2)		93(23.8)		35(5.8)		424(5.0)
Widowed	77(45.4)		44(18.5)		15(4.0)		165(1.9)
Divorced	142(49.8)		100(30.8)		35(10.1)		286(3.4)
Separated	50(46.3)		30(28.5)		15(7.5)		131(1.5)

Maternal smoking status n (weighted %)		0.06		0.46		0.85	
No	3452(42.9)		2453(28.3)		1001(10.0)		8447(99.7)
Yes	26(64.7)		19(36.5)		9(11.3)		58(0.3)
Place of residence n (weighted %)		<0.001		0.0002		<0.001	
Urban	371(31.4)		221(16.9)		115(5.5)		1401(13)
Rural	3107(44.6)		2251(29.9)		892(10.7)		7104(87)
Household wealth index n (weighted %)		<0.001		<0.001		<0.001	
Poorest	1145(47.3)		925(35.3)		415(13.4)		2572(22.4)
Poor	738(46.0)		531(32.1)		191(12.8)		1569(21.9)
Middle	611(44.8)		356(25.6)		160(9.1)		1424(20.8)
Richer	583(43.4)		356(25.7)		135(7.8)		1410(19.9)
Richest	401(28.3)		223(14.4)		106(5.2)		1530(15.0)
Maternal BMI, mean(SE)[7], kg/m^2	20.01(0.08)	<0.001[8]	19.7(0.10)	<0.001[8]	19.7(0.22)	<0.001[8]	20.3(0.06)
Maternal height, mean(SE), cm	155.4(0.17)	<0.001	155.6(0.20)	<0.001	156.2(0.34)	0.74	156.6(0.14)
Child age, mean(SE), months	33.9(0.37)	<0.001	32.5(0.45)	<0.001	22.9(0.82)	<0.001	28.9(0.26)

[1] SD: Standard Deviation
[2]Design-based Pearson chi-squared test
[3]HAZ: height-for-age z-score
[4]WAZ: weight-for-age z-score
[5]WHZ: weight-for-height z-score
[6]Total number of birth in the last five years
[7]Mean and Standard Error accounting for complex design

[8]t-test (mean comparison test)

5.2. Correlations in nutritional status of mothers and their children

The result on the correlation between maternal and children nutritional indicators is presented in table 2. Maternal and child nutritional status were positively correlated at statistically significant levels. However, the strength of association was low in many cases and varied considerably across child age groups. For the whole sample, only WAZ appear to be more strongly correlated with maternal weight (r = 0.212, p <0.05) and BMI (r = 0.281, p <0.05) than HAZ and WHZ. In addition, HAZ is more strongly correlated with maternal height (r = 0.192, p <0.05) than WAZ and WHZ. The age-disaggregated data revealed considerable variability in the strength of the correlations. The correlations between maternal and child nutrition levels were higher among 12-23 months old than the rest of the age groups. In the remaining age groups, the correlation patterns across age groups vary, depending on the index. Overall, WAZ was consistently positively correlated with maternal nutritional indices.

Table 2: Correlation coefficients (95% CI) between Maternal and Child Anthropometry Indices. EDHS, 2011

	Maternal Anthropometry (Pearson correlation coefficients)		
Child anthropometry	**BMI**	**Weight**	**Height**
0-59 months (n=8505)			
[1]HAZ	0.109(0.088, 0.130)*	0.203(0.183, 0.224)*	0.192(0.171, 0.212)*
[2]WAZ	0.212(0.192, 0.232)*	0.281(0.261, 0.301)*	0.141(0.120, 0.161)*
[3]WHZ	0.191(0.170, 0.211)*	0.178(0.157, 0.198)*	-0.026(-0.047, -0.005)
0-11 months (n=1943)			
HAZ	0.099(0.055, 0.143)*	0.229(0.186, 0.270)*	0.261(0.219, 0.302)*
WAZ	0.201(0.158, 0.244)*	0.281(0.240, 0.322)*	0.193(0.150, 0.236)*
WHZ	0.163(0.119, 0.206)*	0.123(0.079, 0.167)*	-0.037(-0.081, 0.008)
12-23 months (n=1612)			
HAZ	0.126(0.078, 0.174)*	0.232(0.185, 0.277)*	0.214(0.167, 0.260)*
WAZ	0.250(0.204, 0.295)*	0.331(0.287, 0.374)*	0.151(0.103, 0.199)*
WHZ	0.204(0.156, 0.250)*	0.254(0.208, 0.300)*	0.015(-0.034, 0.064)
24-35 months (n=1515)			
HAZ	0.137(0.088, 0.187)*	0.205(0.156, 0.253)*	0.153(0.103, 0.053)
WAZ	0.201(0.152, 0.203)*	0.251(0.203, 0.298)*	0.103(0.053, 0.153)*
WHZ	0.155(0.105, 0.203)*	0.156(0.106, 0.205)*	-0.010(-0.061, 0.040)
36-47 months (n=1766)			
HAZ	0.092(0.046, 0.138)*	0.195(0.150, 0.240)*	0.191(0.146, 0.236)*
WAZ	0.179(0.134, 0.224)*	0.271(0.227, 0.314)*	0.127(0.081, 0.173)*
WHZ	0.166(0.120, 0.211)*	0.182(0.137, 0.227)*	-0.036(-0.082, 0.011)
48-59 months (n=1669)			
HAZ	0.099(0.051, 0.146)*	0.200(0.153, 0.246)*	0.228(0.182, 0.273)*
WAZ	0.250(0.204, 0.294)*	0.294(0.250, 0.338)*	0.142(0.095, 0.189)*
WHZ	0.258(0.212, 0.302)*	0.197(0.151, 0.243)*	-0.072(-0.119, -0.024)

[1]HAZ: height-for-age z-score
[2]WAZ: weight-for-age z-score
[3]WHZ: weight-for-height z-score
**P* <0.05

5.3. Screening for child undernutrition based on maternal BMI

The result on the use of maternal nutritional status as a screening tool for child undernutrition is presented in table 3 & 4. For the whole sample of children, the sensitivity of maternal underweight (defined by BMI < 18.5kg/m^2) as a predictor of child nutritional status (<-2 z-scores) is low, failing to reach 50% for any of the child nutrition indices. WHZ performed better than the other indicators for the full sample of children. Conversely, specificity was generally quite high (>73). The positive predictive value of the screening was also low (<44%), irrespective of the anthropometric indicator considered while the negative predictive values are fairly high

(>74%) with an exception of HAZ. With the age-disaggregated data, sensitivity tends to improve as the age of child increases for all child anthropometric indices with WHZ reaching 50.2%. However, this incremental pattern does not appear to go beyond the age of 23 months. The patterns vary across the rest of age groups depending on the index. Overall, maternal BMI(<18.5 kg/m^2) was less accurate but relatively better predictor of wasting than underweight and stunting AUC = 0.577(0.561, 0.593).

Table 3: Result of screening for child undernutrition based on maternal nutritional status (BMI≤18.5kg/m^2). EDHS, 2011

	95% Confidence Interval				
Anthropometric indices	**Sensitivity**	**Specificity**	**PPV[1]**	**NPV[2]**	**[3]AUC**
0-59 months (n=8505)					
[4]HAZ(< -2)	30.3(28.8, 31.9)	73.6(72.4, 74.9)	44.3(42.3, 46.3)	60.4(59.2, 61.7)	0.52(0.51, 0.529)
[5]WAZ(< -2)	37.1(35.1, 39)	75.7(74.6, 76.8)	38.5(36.5, 40.4)	74.6(73.5, 75.7)	0.564(0.553, 0.575)
[6]WHZ(< -2)	41.5(38.4, 44.6)	73.8(72.8, 74.8)	17.5(16, 19.1)	90.4(89.6, 91.1)	0.577(0.561, 0.593)
0-11 months (n=1943)					
HAZ(< -2)	29.2(23.8, 35.1)	76.3(74.2, 78.3)	16.4(13.2, 20.1)	87.1(85.3, 88.8)	0.528(0.498, 0.557)
WAZ(< -2)	31(26, 36.4)	76.8(74.7, 78.9)	20.8(17.3, 24.8)	85(83.1, 86.8)	0.539(0.512, 0.567)
WHZ(< -2)	32(27, 37.3)	77.1(75, 79.1)	22.3(18.6, 26.3)	84.7(82.7, 86.5)	0.546(0.518, 0.573)
12-23 months (n=1612)					
HAZ(< -2)	34.5(31, 38.1)	70(66.9, 72.9)	46.8(42.4, 51.2)	58.2(55.3, 61.2)	0.522(0.499, 0.545)
WAZ(< -2)	43.6(39.2, 48.1)	73.3(70.6, 75.9)	42.3(38, 46.7)	74.3(71.6, 76.9)	0.584(0.559, 0.61)
WHZ(< -2)	50.2(43.9, 56.5)	71.5(69, 73.9)	24.9(21.2, 28.8)	88.4(86.4, 90.3)	0.608(0.575, 0.641)
24-35 months (n=1515)					
HAZ(< -2)	29.9(26.7, 33.1)	73.8(70.4, 77)	57.1(52.3,61.9)	47.3(44.3, 50.4)	0.518(0.496, 0.541)
WAZ(< -2)	37.1(33, 41.3)	76.8(74, 79.4)	47.1(42.3, 51.9)	68.7(65.8, 71.4)	0.569(0.545, 0.594)
WHZ(< -2)	37.9(30, 46.4)	72.8(70.4, 75.2)	12.9(9.85, 16.4)	91.7(89.9, 93.3)	0.554(0.513, 0.595)
36-47 months (n=1766)					
HAZ(< -2)	28.6(25.7, 31.6)	72.6(69.4, 75.6)	53.7(49.2, 58.2)	47.7(44.9, 50.5)	0.506(0.485, 0.527)
WAZ(< -2)	34.1(30.2, 38.1)	75(72.4, 77.4)	40.2(35.9, 44.9)	69.7(67.1, 72.2)	0.545(0.552, 0.568)
WHZ(< -2)	44.8(36.2, 53.6)	73.3(71.1, 75.5)	12.1(9.38, 15.3)	94.2(92.7, 95.4)	0.591(0.547, 0.634)
48-59 months (n=1669)					
HAZ(< -2)	29.6(26.4, 33)	73(70, 75.9)	48.1(43.5, 52.7)	55.1(52.3, 58)	0.513(0.491, 0.535)
WAZ(< -2)	37.8(33.6, 42.1)	76.3(73.7, 78.7)	42.3(37.8, 47)	72.6(70, 75.2)	0.57(0.546, 0.594)
WHZ(< -2)	48.6(40.1, 57.1)	73.7(71.5, 75.9)	14.7(11.6, 18.2)	93.9(92.4, 95.2)	0.612(0.569, 0.654)

[1]PPV: Positive predictive value
[2]NNP: Negative predictive value
[3]AUC: Area Under Roc Curve
[4]HAZ: height-for-age z-score
[5]WAZ: weight-for-age z-score
[6]WHZ: weight-for-height z-score

5.4. Screening for child undernutrition based on maternal Height

As indicated in Table 4, the use of maternal height (defined by height < 145cm) as a screening tool for child malnutrition had even lower sensitivity (<4% for all anthropometric indicators) than for screening performed using maternal underweight, though the specificity was higher (>98%). Disaggregating the data by age of the child did not alter the overall conclusions.

Table 4: Result of screening for child undernutrition based on maternal nutritional status (Height <145cm). EDHS, 2011

	95% Confidence Interval				
Anthropometric indices	**Sensitivity**	**Specificity**	**[1]PPV**	**[2]NPV**	**[3]AUC**
0-59 months (n=8505)					
[4]HAZ(< -2)	3.11(2.55, 3.74)	98.6(98.3, 98.9)	61(53.4, 68.2)	59.5(58.5, 60.6)	0.509(0.505, 0.512)
[5]WAZ(< -2)	3.11(2.47, 3.88)	98.3(98, 98.6)	43.5(36.1, 51.1)	71.2(70.3, 72.2)	0.507(0.504, 0.511)
[6]WHZ(< -2)	2.18(1.37, 3.29)	97.9(97.6, 98.2)	12.4(7.96, 18.2)	88.2(87.5, 88.9)	0.501(0.496, 0.505)
0-11 months (n=1943)					
HAZ(< -2)	6.37(3.75, 10)	98.5(97.8, 99)	40.5(25.6, 56.7)	86.8(85.2, 88.3)	0.524(0.509, 0.539)
WAZ(< -2)	5.96(3.96, 9.15)	98.6(97.9, 99.1)	45.2(29.8, 62.3)	84.2(82.5, 85.8)	0.523(0.509, 0.536)
WHZ(< -2)	2.11(0.85, 4.31)	97.8(97, 98.5)	16.7(6.79, 31.4)	83(81.2, 84.6)	0.5(0.491, 0.508)
12-23 months (n=1612)					
HAZ(< -2)	3.43(2.21, 5.07)	98.4(97.3, 99.1)	61.5(44.6, 76.6)	57.1(54.6, 59.6)	0.509(0.501, 0.517)
WAZ(< -2)	3.6(2.15(5.63)	98.1(97.1, 98.8)	46.2(30.1, 62.8)	69.4(67, 71.6)	0.509(0.499, 0.518)
WHZ(< -2)	3.53(1.63, 6.59)	97.8(96.9, 98.5)	23.1(11.1, 39.3)	84.4(82.5, 86.1)	0.507(0.495, 0.519)
24-35 months (n=1515)					
HAZ(< -2)	1.96(1.12, 3.16)	99.3(98.3, 99.8)	76.2(52.8, 91.8)	46.4(43.8, 49)	0.506(0.501, 0.512)
WAZ(< -2)	1.85(0.89, 3.37)	99.9(98, 99.4)	47.6(25.7, 70.2)	64.4(61.9, 66.8)	0.504(0.497, 0.51)
WHZ(< -2)	0.69(0.18, 3.78)	98.5(97.8, 99.1)	4.76(0.12, 23.8)	90.4(88.8, 91.8)	0.496(0.489, 0.504)
36-47 months (n=1766)					
HAZ(< -2)	2.9(1.92, 4.19)	98.3(97.2, 99.1)	65.9(49.4, 79.9)	47.6(45.2, 50)	0.506(0.499, 0.513)
WAZ(< -2)	2.23(1.19, 3.78)	97.6(96.6, 98.4)	31.7(18.1, 48.1)	66.9(64.6, 69.1)	0.499(0.492, 0.507)
WHZ(< -2)	2.24(0.46, 6.4)	97.7(96.8, 98.3)	7.32(1.54, 19.9)	92.4(91.1, 93.6)	0.5(0.486, 0.513)
48-59 months (n=1669)					
HAZ(< -2)	3.14(2.02, 4.64)	98.9(98, 99.5)	70.6(52.5, 84.9)	54.7(52.3, 57.2)	0.51(0.503, 0.517)
WAZ(< -2)	3.23(1.89, 5.11)	98.5(97.6, 99.1)	50(32.4, 67.6)	68.8(66.5, 71)	0.509(0.5, 0.57)
WHZ(< -2)	1.41(0.17, 5)	97.9(97.1, 98.6)	5.88(0.72, 19.7)	91.4(90, 92.7)	0.497(0.486, 0.507)

[1]PPV: Positive predictive value
[2]NNP: Negative predictive value
[3]AUC: Area Under Roc Curve
[4]HAZ: height-for-age z-score
[5]WAZ: weight-for-age z-score
[6]WHZ: weight-for-height z-score

5.5. ROC Regression

As indicated in table 3, maternal BMI(<18.5 kg/m^2) is less accurate but relatively better predictor of wasting than underweight and stunting AUC = 0.577(0.561, 0.593). Thus, factors potentially influencing maternal BMI (<18.5 kg/m^2) capacity to distinguish between wasted children and non-wasted include the age and sex of the child, maternal age, breastfeeding status, maternal education, maternal parity, place of residence and household weatlth index. In the roc regression analysis, maternal BMI(<18.5 kg/m^2) became a more accurate predictor of wasting among children whose mother are older (β= -0.014, *p* =0.002) and higher parity (β= -0.035, *p* = <0.001), and among children who are not currently breastifeeding(β= -0.042, *p* = 0.006) and from richer households (β= -0.037, *p* = <0.001). The test also a more accurate predicator among male and younger children, and among children whose mothers are better educated and from urban areas, though the results were inconclusive (table 5).

Table 5: Result of ROC regression analysis for the predictors of wasted children. EDHS, 2011.

Maternal underweight (BMI<18.5)	Coefficient (β)	Robust SE[1]	[2]t	p-value	95% CI[3]
Child's sex	0.005	0.010	0.46	0.642	(-0.015, 0.025)
Child's age	0.004	0.003	1.26	0.210	(-0.002, 0.009)
Maternal age	-0.014	0.005	-3.09	0.002 *	(-0.023, -0.005)
Currently breastfeeding	-0.042	0.015	-2.78	0.006*	(-0.071, -0.012)
Maternal education	-0.005	0.009	-0.59	0.559	(-0.023, 0.012)
Parity	-0.035	0.009	-3.65	<0.001*	(-0.053, -0.016)
Place of residence	0.010	0.024	0.43	0.671	(-0.036, 0.057)
Wealth index	-0.037	0.007	-5.58	<0.001*	(-0.050, -0.024)
Constant	0.482	0.066	7.27	<0.001*	(0.352, 0.613)

[1] Standard error adjusted for complex design
[2]t-statistics
[3] Confidence interval
*$p < 0.05$

5.6. Rocreg Postestimation.

As indicated in table 5, the coefficient estimates for maternal age, currently breastfeeding children, maternal parity and household weath index were negative and statistically significant.

We did *rocreg postestimation* to evaluate where exactly the test performed best. Therefore, as indicated in table 6 maternal underweight (BMI<18.5kg/m^2) is more informative in predicting wasting among children whose mothers gave birth to four children AUC = 0.70113 (0.604, 0.798) and among children from richest households AUC = 0.740(0.630, 0.850).

Table 6: Result of Roc Regression Postestimation: Covariate-specific Area Under Roc Curves (AUC) for maternal BMI(<18.5kg/m^2) as a predictor of wasting in children. EDHS, 2011

Covariates	AUC[1]	SE[2]	95% CI[3]
Maternal age			
15-19	0.490	0.031	(0.430, 0.551)
20-24	0.516	0.021	(0.475, 0.557)
25-29	0.542	0.013	(0.516, 0.568)
30-34	0.567	0.013	(0.541, 0.593)
35-39	0.592	0.021	(0.551, 0.633)
40-44	0.617	0.030	(0.558, 0.676)
45-49	0.641	0.040	(0.564, 0.719)
Currently breastfeeding			
Yes	0.561	0.015	(0.532, 0.590)
No	0.601	0.047	(0.510, 0.694)
Parity			
1	0.502	0.021	(0.461, 0.544)
2	0.571	0.014	(0.545, 0.598)
3	0.638	0.031	(0.577, 0.70)
4	0.701	0.049	(0.604, 0.798)
Household wealth index			
Poorest	0.462	0.047	(0.369, 0.554)
Poorer	0.536	0.028	(0.480, 0.591)
Middle	0.608	0.024	(0.560, 0.656)
Richer	0.677	0.038	(0.601, 0.752)
Richest	0.740	0.056	(0.630, 0.850)

[1] Standard error adjusted for complex design [2] Area Under Roc Curve [3] Confidence interval

6. Discussion

Using a large and representative nationwide sample of children and mothers from Ethiopia, we observed a significant but weak correlation between maternal and their offspring's nutritional status. Although maternal BMI (<18.5 kg/m^2) became a more accurate predictor of wasting among children whose mother are older and of higher parity, and among children who are not currently breastfeeding and from richer households.

One of the main findings of our study is the variability of the strength of correlation when the data was disaggregated according to the age of the child. The correlation between maternal and child nutrition status was lower for under 12 months and 24-35 months children than the older children for most of the indicators. This may be part as a result of increased measurement error among these age groups. However, since WAZ has no height measurement and tends to be less affected by field measurements than HAZ and WHZ, this suggest that the data have been affected by age variation among the under five children.This may also possibly attributable to the nutritional and protective benefits of breastfeeding. It is likely that breastfeeding protects younger children from the adverse consequences of socioeconomic and environmental factors. This is to say that it's only after complimatary feeding does the deleterious effects of these factors begin to be reflected in anthropometric indicators.

Additionally, this study has shown that HAZ is more strongly correlated with maternal height than WAZ and WHZ. This result is expected since measures of cumulative exposure to socioeconomic and environmental risk factors should be more highly correlated than measures that respond to more immediate environmental change. The attained height of the adult is a consequence of genetic and environmental effect on the growing period of childhood[1]. For instance, the stunted mother may provide an inadequate supply of nutrients for the fetus, which restricts fetal growth and promotes low birth weight and stunting in the offspring[13, 32, 33].

The low sensitivity of the maternal undernutrition as screening test suggests that factors associated with undernutrition tend not to be fully shared by mothers and their off springs. On the other hand, the high specificity suggests that factors which mitigate nutritional risk tend to be fully shared by mothers and their children. In other words, when mothers are well nourished their children tend also to be well nourished. Likewise, the low PPV and the high NPV suggest that knowledge about mother undernutrition only slightly improves the likelihood of correctly classifying the child as being malnourished. Our result is analogous with studies done by Mock et al [16] and Lindtjorn and Alemu [15].

These findings are unanticipated, in view of the intergeneration continuity of undernutrition [33, 34]. Shared genetic, household socioeconomic and cultural resources including food availability are important influences on the inter-generational continuities of undernutrition [8]. Though, the following factors may explain the lack of stronger correlation between mothers and their children.

The causes of undernutrition are multidimensional and they include both food and non-food related factors that often interact to form a complex web. Social, political, economic and environmental factors by large cause climate change resulting in variation in food supply. Association between these variables and undernutrition indicators does not necessarily mean causality. They simply show that many factors such as mentioned above influence the rate of undernutrition[19].

The relationship between maternal and child could be also mediated by the dual burden of malnutrition. Even in food secure households some members may be undernourished while others may be overweight, suggesting that with the process of nutritional transition with economic development, it's possible to see double burden households [38, 39]. This is even evident in our data; 22.3% of stunted, 11.7% of underweight and 7.2% of wasted children are from households with overweight mothers. In addition, using a single BMI cutoff still remain controversial. A healthy BMI is likely to vary with age, sex, pregnancy and lactation, ethnicity and other factors[30]. Therefore, using a BMI <18.5 kg/m^2 as the cutoff for everyone and everywhere is likely to be too crude.

Another main finding is maternal BMI (<18.5kg/m^2) may be a better measure of wasting among children whose mothers gave birth to four children and among children from richest households. A possible explanation is that high parity depletes mothers of nutrients because of physiological stresses of multiple pregnancies and lactations [47]. To put it differently, overlapping of closely spaced pregnancies with the lactation period could lead to loss of maternal body weight. Therefore, the association between maternal and child undernutrition is likely to be stronger.

On the other hand, underweight (BMI<18.5 kg/m^2) was also more informative in predicting wasting among children from richest households. This suggests that factors associated with undernutrition tend to be more shared by children and their mothers as household socioeconomic status increases. One possible interpretation of this finding is that among poor households where resources including food are most limited, there is an attempt to protect the most vulnerable members of the household, the young children, from food and related stresses that contribute to undernutrition. As these constraints are relaxed, the association between child and maternal nutrition become stronger, generally from the lowest level of economic well-being to the highest level. It is also possible that exposure to media and other sources of information are encouraging women in the upper end of the wealth distribution to limit their body mass.

The estimation of three forms of undernutrition (stunting, underweight and wasting) was comparable to that of EDHS report but we could not exactly replicate the figures except for wasting. We believe the main source of our discrepancy from the report is that we used the child recode file (KR file), whereas the DHS report uses the household recode file (PR file) for stunting, underweight, and wasting. Height and weight of all children under five and all women 15-49 are measured in the household interview. If the mother is alive and in the same household as the child, then the child will also be in the KR file. Otherwise, the child will not be in the KR file. In other words, the children who are in the PR file but not in the KR file are more likely to be stunted.

Age and gender are factors that influence children susceptibility to malnutrition. For that reason, our results show that the male children are underprivileged across all three forms of undernutrition. There studies that documented higher prevalence of undernutrition among male children compared to female children [1, 21, 26, 27]. These studies corroborate our findings and there could be a biological explanation. For instance, Wamani and his colleagues found from epidemiological and cohort studies that neonatal and preterm babies mortality and morbidity to be consistently higher in males and females in early life though the underlying mechanism is poorly understood. However, the reported male predominance suggests that boys are generally vulnerable[27]. The child's age is also an important factor for malnutrition. We found undernutrition to be more prevalent in older than in younger children. Children among 24–35 months have the highest levels of undernutrition, and the youngest age group (0–11 months) has the lowest levels except for wasting. The higher proportion of undernutrition among older children could be due to inappropriate child feeding practices [21].

Non-breast-milk diet diversity is associated with child nutritional status [48]. Accordingly, our data showed that currently breastfeeding children have a higher prevalence of wasting. This could be as a result of longer breastfeeding and the untimely introduction of or poor quality of complimentary food leading to undernutrition[21]. Results on maternal education and place of residence and child nutrition are similar with those of other studies [1, 21-23, 42]. Education and place residence are socio-economic indicators and are expected to reflect both current and ongoing access to resources. In our result undernutrition is common among children from rural areas and whose mothers have lower levels of education.

Additionally, our data has shown that child undernutrition is more common among children in the poorest wealth quintiles than in the richest quintiles. Our result is consistent with findings of studies that found that children in the poorest households are more at risk of being malnourished compared to their counterparts in the richest households[1, 21, 25]. This could be explained by the fact the rich are able to afford better living conditions that may improve child nutrition.

The following limitations need to be considered while interpreting the above findings. First, though the DHS data is of high quality, recall bias in reporting offspring birth histories remains a potential concern[49]. Moreover, a quality analysis of height data in 81 DHS surveys also showed clustering on whole and half centimeters, with some additional heaping at multiples of 5 and 10 cm[50]. Second, we have used all children and repeated their mothers and we did not match randomly a mother with her child. This is likely to bias our standard errors because we are not getting a full amount of new information by adding new children to the same mother. The good news is that we used the DHS clustering method (*svyset*) which accounted for this. The basic intuition is that, without DHS survey design, we would want to "cluster" on the household (all those with the same mom). But, since DHS requires us to cluster at the PSU level, and all children in a household are in the same PSU, we are already taking the within-household serial correlation in maternal BMI into account. Lastly, this study is limited by its cross-sectional nature and hence, causal inferences cannot be made.

Despite these limitations, our study has some persuasive strength. First, EDHS data are considered to be of high quality and reliable source of maternal and child health data. Second, the standardized procedures used by these surveys increases the quality of the data and also allows for comparability across countries. Third, it provides a nationally representative sample, allowing for drawing conclusions about the entire country. Moreover, we believe we used the appropriate statistical methods to investigate these relationships and controlling for important covariates.

7. Conclusion and recommendations

Our study provides evidence that maternal undernutrition indicators are less informative in predicting their offspring's undernutrition, although maternal BMI (<18.5 kg/m^2) may be a better measure of wasting among children whose mothers gave birth to four children and among children from richest households. In other words, maternal BMI is less useful measure of wasting among all children less than five years of age but given specific population of under five children such as those whose mothers gave birth to four children and those from richest households maternal undernutrition (BMI <18.5kg/m^2) may be a better measure of wasting. However, efforts to evaluate its practical usefulness constitute an important research agenda.

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Annex

1. DHS Download Account Application

From: archive@dhsprogram.com.
To: alinuriana@yahoo.com

**See Attached. **

You have been authorized to download data from the Demographic and Health Surveys (DHS) Program. This authorization is for unrestricted countries requested on your application.

The data should only be used for the purpose of the registered research or study. To use the same or different data for another purpose, a new research project request should be submitted. This can be done from the "Create A New Project" link in your user account.

All DHS data should be treated as confidential, and no effort should be made to identify any household or individual respondent interviewed in the survey.

The data sets must not be passed on to other researchers without the written consent of DHS. Users are required to submit a copy of any reports/publications resulting from using the DHS data files. These reports should be sent to:archive@dhsprogram.com.

To begin downloading datasets, please login at:
http://www.dhsprogram.com/data/dataset_admin/login_main.cfm

once you are logged in, you may also edit your contact information, change your email/password, request additional countries or Edit/Modify an existing Description of Project.

If you are a first time user of DHS Data, please view the following videos on downloading and opening DHS data:
http://www.dhsprogram.com/data/Using-DataSets-for-Analysis.cfm#CP_JUMP_14039

Additional resources to help you analyze DHS data efficiently include:
http://dhsprogram.com/data/Using-Datasets-for-Analysis.cfm, a video on Introduction to DHS Sampling Procedures - found at:http://youtu.be/DD5npelwh80 and a video on Introduction to Principles of DHS Sampling Weights - found at:http://youtu.be/SJRVxvdIc8s

The files you will download are in zipped format and must be unzipped before analysis.

Following are some guidelines:

After unzipping, print the file with the .DOC extension (found in the Individual/Male Recode Zips). This file contains useful information on country specific variables and differences in the Standard Recode definition.

Please download the DHS Recode Manual:http://dhsprogram.com/publications/publication-dhsg4-dhs-questionnaires-and-manuals.cfm

The DHS Recode Manual contains the documentation and map for use with the data. The Documentation file contains a general description of the recode file, including the rationale for recoding; coding standards; description of variables etc. The Map file contains a listing of the standard dictionary with basic information relating to each variable.

It is essential that you consult the questionnaire for a country, when using the data files. Questionnaires are in the appendices of each survey's final report:http://dhsprogram.com/publications/publications-by-type.cfm

We also recommend that you make use of the Data Tools and Manuals:http://www.dhsprogram.com/accesssurveys/technical_assistance.cfm

DHS statistics can also be obtained using the STATcompiler tool: http://www.statcompiler.com

This tool allows users to select countries and indicators to create customized tables. It accesses nearly all of the indicators that are published in the final reports. Authorization is not needed to use the STATcompiler.

For problems with your user account, please email

For data questions, we recommend that users register to participate in the DHS Program User

Forum at:http://userforum.dhsprogram.com

The User Forum is an online community of DHS data users and contains discussions about many DHS analysis and dataset topics. Please search the contents of the forum, and if you do not see your question addressed, consider posting a new question for users to discuss.

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PROFESSIONAL EXPERIENCE

Jigjiga University, Ethiopia (9/2013– Present)

- **Lecturer,** Jigjiga, Ethiopia
  - Prepare and Deliver lectures, tutorials and practical classes
  - Assess students assignments and grade students performance
  - Discuss with students their progress
  - Conduct research and community services individually or in group
  - Attend meetings and conferences related to research

Ethiopian Somali Regional State Health Bureau (9/2011-5/2013)

- **Health Promotion and Disease Prevention Coordinator, Woreda Health Office,** Jigjiga, Ethiopia
  - Responsible for the technical quality implementation of health promotion and disease prevention activities of the woreda.
  - Facilitate high quality micro planning and capacity building for EPI.
  - Support high quality supplementary immunization and outbreak response activities.
  - Assists in surveillance, contributing to early life-saving response to vaccine preventable disease outbreaks.

Ethiopian Somali Regional State Health Bureau (9/2007-6/2011)

- **Mobile Health and Nutrition Team Leader, Garbo Woreda, Nogob Zone.**
  - Delivered basic health care services (UNICEF funded) in the conflict affected women and children which include:
    - Treatment of SAM cases,
    - Provision of free of charge health consultations,
    - Referral of cases for specialized care and
    - Provision of clean delivery kits

EDUCATION & TRAINING

- **Addis Ababa University**, Addis Ababa, Ethiopia (6/2016)
  - MPH (Nutrition)

- **Jigjiga University**, Jigjiga, Ethiopia, (6/2013)
  - Degree in Public Health

- **Jigjiga Health Science College**, Jigjiga, Ethiopia (9/2011)
  - Diploma in Nursing

- **Johns Hopkins Bloomberg School Of Public Health** Global Health eLearning Center.
  - M&E Frameworks for HIV/AIDS Programs, 10/2015
  - Gender M &E Fundamentals, 10/2015
  - DHS: Data use, 8/2015
  - HIV Stigma & Discrimination, 8/2014
  - Emergency Obstetric & Newborn Care, 9/2012
  - Nutrition (An introduction), 11/2011
  - Commercial Private Health Sector Basics, 9/2011
  - Mother to Child Transmission of HIV, 1/2009
  - Tuberculosis Basics, 1/2009
  - Population, Health and Environment Basics, 7/2009

- **Ethiopian Public Health Association**
  - Leadership and Communication for Public Health Professionals, 6/2014

- **Wageningen University through edX**
  - Nutrition and Health Part 1: Macronutrients and Overnutrition, 10/2015
  - Nutrition and Health Part 2: Micronutrients and Malnutrition, 12/2015

RESEARCH EXPERIENCE

- Iron Folic Acid Supplementation for Adolescent Girls: Assessment of Need and Modalities of Implementation in Amhara, Oromia and SNNPR, Ethiopia (Supervisor)

PROFESSIONAL ASSOCIATIONS MEMBERSHIP

- Ethiopian Public Health Association (EPHA)

AWARDS & HONORS

- Gold medalist at Jigjiga University
- Gold medalist at Jigjiga Health Science College

SKILLS

Languages: Somali (Excellent), English (Excellent), Amharic (V. Good), Swahili (V. Good)

Computer: Microsoft Office applications, STATA, ENA for SMART, SPSS, Epi Info, Windows XP, Windows Vista, Windows 8 and Windows 10.

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I. Academic Qualification

1. Masters of Public Health in Epidemiology (MPH):

Period of study: September 2012- July 2014
Program: Masters of Public Health, Epidemiology Specialty Track
Institution: Addis Ababa University, School of Public Health, Addis Ababa, Ethiopia

2. Degree of Doctor of Medicine (MD):

Period of study: January 2006-September 2011

Program: Medicine
Institution: Addis Ababa University, School of Medicine, Addis Ababa, Ethiopia

3. Ethiopian Higher Education Entrance Certificate:
Period of study: September 2003-July 2005
Program: Preparatory Program
Institution: Medhaniyalem , Addis Ababa, Ethiopia

4. Ethiopian General Secondary Education Certificate:
Period of study: September 2001-July 2003 G.C
Program: High School
Institution: Dilachin, Addis Ababa, Ethiopia

II. Work Experience

1. **Assistant Professor of Public Health**
   Duration of employment: Since July, 2014
   Institution: Addis Ababa University, School of Public Health, Addis Ababa, Ethiopia
2. **Lecturer**
   Duration of employment: September, 2011 – June, 2014
   Institution: Addis Ababa University, School of Public Health, Addis Ababa, Ethiopia
3. **Co-PI** of Addis Ababa Mortality Surveillance Program: June, 2014 -July,2015
4. **PI** of Addis Ababa Mortality Surveillance Program-Since July,2015
5. **Clinical Intern**
   Duration of Employment: July, 2010 – July, 2011
   Institution: Tikur Anbessa Specialized Teaching Hospital

Research experience

- Assessment of the relationship between malnutrition and malaria among under-five children in Adami Tulu district: A case-control study *(Under Review, BMC-Public Health Journal)*
- Assessment of the magnitude and factors associated with exclusive breast feeding among employed and unemployed mothers: a comparative cross sectional study
- Immunization in completion rate and associated factors among children aged 12-23 months in Yirgalem town, SNNPR.
- Prevalence and factors associated with work related injuries in Iron and Steel industries Addis Ababa, Ethiopia.
- Prevalence and Risk factors of Diabetes mellitus and impaired glucose level among federal police officers in Addis Ababa, Ethiopia.

- Substance use and other predictors of academic outcomes among undergraduate medical students of Addis Ababa University (on going)

Teaching

- Lecture masters of public health students of Addis Ababa University, on public health nutrition
- Lecture undergraduate medical students of Addis Ababa University and Myung Sung Medical College (MMC), on public health nutrition

Committee Membership and related activities

- Member of the managing committee of the Butajira Demographic and Health Survey (One of the oldest demographic surveillance sits in Africa)
- Member of Research Ethics Committee (REC) for the department of Reproductive Health and Health Service management
- I was a member and secretary of School of Public Health's Golden Jubilee Core Committee.

Merits received

- AMREF young African research scholarship award winner
- PI in a research award by Addis Ababa University-Medical Education Partnership Initiative (MEPI)
- Ethiopian General Secondary Education Certificate with **4.00 GPA** (9As)
- Ethiopian Higher Education Entrance Certificate with **Distinction**
- Masters in Public Health with very great distinction with **CGPA-3.97 (the top Grade of the year)**
- MPH Research-**Excellent grade**

Professional Associations Memberships

- Ethiopian Medical Association (EMA)
- Ethiopian Public Health Association (EPHA)
- Ethiopian Society of General Medical Practitioners (ESGMP)

Consultancy services

- Maternal and Neonatal Health in Ethiopia Initiative (MaNHEP) a project on Amhara and Oromia regions of Ethiopia; end line survey

Trainings taken and Conferences attended

- Oral presenter on AMREF health Africa international conference at Nairobi, Kenya
- Oral presenter at EPHA 51st conference
- PMTCT training from AAU & John Hopkins University/TSEHAI project, March, 2011.
- ART & HIV care training from AAU School of Medicine & WHO, August 2011.
- Training on "Understanding and Using the Demographic and Health Surveys", Measure DHS, August, 2012
- Ethiopian Public Health Association 25th Annual Conference, Feb 20 -22, 2014, African Union, Addis Ababa, Ethiopia
- MDR/XDR TB management training from Ethiopian Society of General Medical Practitioners and USAID, September 2010.
- Emergency Medicine training for interns from AAU, September, 2010.
- BPR & Government policy training from Ministry of Health, September, 2011.
- TOT on Application of Behavior Change Communication Strategies for HIV/AIDS, by AAU-MARCH Project, Johns Hopkins University Bloomberg School of Public Health & the US CDC.
- Research Ethics, Addis Ababa University, College of Health Sciences IRB in collaboration with MEPI
- Reproductive Health Commodity Security, Addis Ababa University School of Public Health in collaboration with UNFPA

Skills, interests and hobbies

- Know how on statistical software packages (SPSS, EPI INFO, WHO-Anthro, ENA-SMART, OPEN EPI, open code, STATA)
- Trainer on life skills
- Team leadership
- Good communication skills
- IT know how
- Public speech

Future Plans and Interests

- To upgrade my level of education to the next higher level
- To be a distinguished health researcher and academician
- Giving voluntary health services
- To be an expert on my area of study

References:

1. Dr. Wakgari Deressa, Dean of the School of Public Health at Addis Ababa University. (*deressaw@gmail.com*)
2. Dr. Ahmed Reja, Chief Executive Director, College of Health Sciences, Addis Ababa University
   (ahmedreja@yahoo.com)

ASSURANCE OF PRINCIPAL INVESTIGATOR

The undersigned agrees to accept responsibility for the scientific ethical and technical Conduct of the research project and for provision of required progress reports as Per terms and conditions of the Research Publications Office in effect at the time of Grant is forwarded as the result of this application.

Name of the student: ____

Date.____________________ Signature _________________

Approval of the primary Advisor

Name of the primary advisor:_______________________________

Date._____________________ Signature __________________