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Multivariate analysis of correlates of under five children malnutrition in Tigray region, Ethiopia

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Abstract
Background: Malnutrition is defined as deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients. Malnutrition among children under five years of age is a chronic problem in most regions of Ethiopia, including the Tigray region. The main objective of this study is to assess the prevalence of under-five child malnutritions and the risk factors attributed to nutritional status of children in Tigray region based on Ethiopian Demographic Health Survey, 2016 datasets.
Methods: The information collected from 370 children was considered in the study, and variables like maternal socio and demographic characteristics, child demographic characteristics, health and environmental factors were considered as determinants of nutritional status of a child. The study used descriptive statistics and Multivariate multiple linear regression models to identify significant correlates of perinatal mortality. Factor analysis based on principal component analysis was done to reduce the data and components with Eigen value of more than one were considered for further investigation.
Results: The descriptive statistics in the study reveals that out of a total of 370 children included in the study 25.4% are underweighted, 30.8% are stunted and 17.3% are wasted. Accordingly of total children malnourished 5.9% are severely underweighted while 19.5% are moderately underweighted, about 12.7% are severely stunted and 18.1% moderately stunted and 6.5% are severely wasted and 10.8% are moderate wasted respectively. From Multivariate multiple linear regressions, breast feeding factors, socioeconomic status of households, health status of child, having medical treatments during pregnancy and child vaccination status have significant impacts on nutritional status of the under five children.
Conclusions: The factors duration of breast feeding, number of household members, living children, birth order of a child, current age of child, place of residence, sanitation services like drinking water and availability of toilet, mother educational level and father education level, age of mother, economic level of household, receiving measles, polio and vitamin A in the last six months, and child health status indicators like having diarrhea recently, having fever and cough in the last two months had statistically significant effect on child malnutrition.

Keywords: Wasting, stunting, underweight, factor analysis, multivariate multiple regressions

1. Introduction

The World Health Organization (WHO) defines malnutrition as "deficiencies, excesses or imbalances in a person's intake of energy or nutrients." It generally, refers both to under nutrition and over nutrition, but in this study the term is used to refer solely to a deficiency of nutrition [1]. An anthropometric measurement is used for growth assessment and is a single measurement that best measures the health or nutritional status of a child. It represents measure of child's growth indicators such as weight and height with respect to their age and sex. According to this measure, the nutritional status of children is determined by comparing growth indicator with the distribution of same indicators of healthy, the international reference standard that is most commonly used that is the data on the weights and heights of a statistically valid population (US National Center for Health Statistics (NCHS)) of healthy children in the US [2]. This comparison can be expressed in the form of Z-score (standard deviation score). It is defined as the difference between the value for an individual and the median value of the reference population for the same age, height or weight divided by the standard deviation of the reference population. There are three most commonly used anthropometric indicators for children nutritional status. These are: wasting (weight-for-height), which measures body mass in relation to body height or length and describes current nutritional status. Children whose Z-score is below minus two standard deviations (-2 SD) from the median of the reference population are considered thin (wasted), or acutely undernourished. Children whose weight-for-height Z-score is below minus three standard deviations (-3 SD) from the median of the reference population are considered severely wasted. It is a measure of acute undernutrition that represents the failure to receive adequate nutrition in the period immediately before the survey. Wasting may result from inadequate food intake or from a recent episode of illness that caused weight loss. The second anthropometric indicator stunting (height-for-age) is a measure of linear growth retardation and cumulative growth deficits. Children whose height-for-age Z-score is below minus two standard deviations (-2 SD) from the median of the reference population are considered short for their age (stunted), or chronically undernourished. Children who are below minus three standard deviations (-3 SD) are considered severely stunted. It is sign of chronic undernutrition that reflects failure to receive adequate nutrition over a long period. Another indicator underweight (weight-for-age) is a composite index of height-for-age and weight-for-height that accounts for both acute and chronic undernutrition. Children whose weight-for-age Z-score is below minus two standard deviations (-2 SD) from the median of the reference population are classified as underweight. Children whose weight-for-age Z-score is below minus three standard deviations (-3 SD) from the median are considered severely underweight. Thus, weight-for-age, which includes both acute (wasting) and chronic (stunting) undernutrition, is an indicator of overall undernutrition [3].

Globally, approximately 155 million children under five suffer from stunting and nearly 52 million children under 5 were wasted and 17 million were severely wasted. More than half (56%) of all stunted children under 5 lived in Asia and more than one-third (38%) lived in Africa, more than two-thirds (69%) of all Wasted children under 5 lived in Asia and more than one-quarter (27%) lived in Africa [4].

Malnutrition is also highly associated with under five mortalities. About 54% of death of children whose age is below five years, is mainly caused by in inadequate nutrition [5]. In Ethiopia malnutrition is one of the most serious healths and welfare problems among infants and young children. According to Ethiopian demographic and health survey (EDHS) 2016 report even though the prevalence of chronic malnutrition has decreased significantly in the past two decades, under five children are still experiencing the highest rates of malnutrition in the country, that is 38 percent of children under age 5 are stunted (short for their age); 10% are wasted (thin for their height); 24% are underweight (thin for their age), and 1% are overweight (heavy for their height) with a greater regional difference ranging from Amhara region (46.3%), Tigray region (39.3%), above the national prevalence to the lowest level in Addis Ababa Ccity (14.6%) and Gambella region (23.5%). Malnutrition among children under five years of age is a chronic problem in the study region Tigray, where 39.3% of the children under age of five were stunted, 23% were underweight, and 11.1% were wasted [6]. This high malnutrition rate in the region possesses a significant obstacle to achieve better child health outcomes. Thus understanding of the factors related to child malnutrition is important to guide the development of focused and evidence based health interventions to decrease the high rate of child mortality due to malnutrition.

Therefore this study aims to investigate the major correlates of children malnutrition in Tigray region and such knowledge will also helpful to the development of effective policy strategies for improving the health policies on child care in the region.

2. Methods

2.1 Source of data and description of the study area

This study was a retrospective study based on 2016 Ethiopian Demographic and Health Survey which is part of the worldwide measure DHS project funded by the United States Agency for International Development (USAID). The primary purpose of this survey is to furnish policy makers and planners with detailed information on fertility, family planning, infant, child, adult and maternal mortality, maternal and child health, nutrition and knowledge of HIV/AIDS and other sexually transmitted infections. Tigray national regional state is located at the northern part of the Ethiopia. It is located between 36 degrees and 40 degrees east longitude. According to the 2007 Census, the state's population size was 3,136,267 of which 1,594,102 were females. The urban residents of the region number 468, 478 and its rural residents 2,667,789 [7].

2.2 Study variables

The dependent or response variable is malnutrition status in children indicated by stunting (z-scores height for age), wasting (z-scores weight for height), and underweight (z-scores weight for age). Thus, there are three dependent variables in the study. From various literatures the independent variables included in this study are given in Table 1 below (Table 1):

2.3 Statistical methods of data analysis

The study used descriptive statistics and the multivariate methods like Principal components analysis, and Factor analysis for data reduction and Multivariate multiple linear regression approaches for data analysis because the response variable is greater than one.

2.3.1 The principal component analysis

Principal components analysis (PCA) is frequently used in public health research. It aims to reduce numerous measures to a small set of the most important summary scores, explaining the variance-covariance structure through a few linear combinations of the original variables.

Let $\boldsymbol{X} = (X_1, X_2, \ldots, X_p)'$ be a p dimensional random variables with mean μ and covariance matrix Σ, we will find a new set of uncorrelated variables $Y_1, Y_2, \ldots, Y_p$ whose variances decrease from the first to the last, that is $var(Y_1) \geq var(Y_2) \geq \ldots \geq var(Y_p)$. The principal components are those uncorrelated linear combinations $Y_1, Y_2, \ldots, Y_p$ whose variances are as large as possible.

The i^th PCA of the observation X is that linear combination:

$Y_i = a_{1i}X_1 + a_{2i}X_2 + \ldots + a_{pi}X_p = a_i'X$, whose sample variance is $Var(Y_i) = a_i'\hat{\Sigma}a_i = a_i'\hat{S}a_i$ subject to $a_i'a_i = 1, i = 1, 2, \ldots, p$.

In our study since the responses are recorded in widely different unit (age in months, weight in kilograms, height in meters, for instance) the linear combinations of the original variables would have little meaning and standardized variates and the correlated matrix should be employed to extract the Principal components.

Let $\boldsymbol{X} = (X_1, X_2, \ldots, X_p)'$ has mean $\boldsymbol{\mu}$ and covariance $\boldsymbol{\Sigma}$, the standardized components are:

$$Z_1 = \frac{X_1 - \mu_1}{\sqrt{\sigma_{11}}},\ Z_2 = \frac{X_2 - \mu_2}{\sqrt{\sigma_{22}}},\ \ldots,\ Z_p = \frac{X_p - \mu_p}{\sqrt{\sigma_{pp}}}$$

2.3.2. Factor analysis model

This analysis describes the covariance relationships among many variables (items) in terms of a few underlying and unobservable random quantities. The observable random vector X' = ($X_1, X_2, \ldots, X_p$) with P components has mean μ and covariance matrix Σ. The factor model postulates that **X** is linearly dependent upon a few *m* unobservable random variables $f_1, f_2, \ldots, f_m$ called common factors, ($m < p$) and p additional source of variation $\varepsilon_1, \varepsilon_2, \varepsilon_3, \ldots, \varepsilon_p$ called errors (specific factors).
The factor analysis model is given by:

$$\mathbf{X} = \boldsymbol{\mu} + \mathbf{LF} + \boldsymbol{\varepsilon},$$

Where

$$L_{pxm} = \begin{pmatrix} l_{11} & l_{12} & \cdots & l_{1m} \\ l_{21} & l_{22} & \cdots & l_{2m} \\ \vdots & \cdots & \ddots & \vdots \\ l_{p1} & l_{p2} & \cdots & l_{pm} \end{pmatrix}, \quad F = \begin{pmatrix} f_1 \\ f_2 \\ \vdots \\ f_m \end{pmatrix}, \quad \varepsilon = \begin{pmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_p \end{pmatrix}, \quad \mu = \begin{pmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_p \end{pmatrix}$$

L_{pxm} is a matrix of unknown constants called factor loadings.

The coefficient l_{ij} is the loading of the i^{th} variable on the j^{th} factor.

$i = 1, 2, \ldots, p, j = 1, 2, \ldots, m, m < p$

i^{th} specific factor ε_i is associated with i^{th} response X_i only.

Assumptions

- Measurement error has constant variance and is, on average, 0.

$E(\varepsilon) = \mathbf{0} = (0, 0, \ldots, 0)'$

$Cov(\boldsymbol{\varepsilon}) = E\left(\varepsilon\varepsilon'\right) = \boldsymbol{\Psi}, \Psi$ is a diagonal matrix

- No association between the factor and measurement error

$Cov(\varepsilon, F) = E(\varepsilon F') = \mathbf{0} = (0, 0, \ldots 0)'$

- No association between errors:

$Cov(e_j, e_k) = 0$

- $Cov(X_i, X_k) = L_i' L_k$
- $E(F) = \mathbf{0} = (0, 0, \ldots 0)'$
- $cov(F) = E(FF') = \boldsymbol{I}_m$
- $Cov(X_i, F_k) = l_{ik}$, i = 1, 2, …, p, and k = 1, 2, …, m.

The portion of variance of X_i due to the m common factors $F_1, F_2, \ldots, F_m$ given by $l_{i1}^2 + l_{i2}^2 + \cdots + l_{im}^2 = \sum_{i=1}^{m} l_{ij}^2 = h_i^2$ is called the i^{th} communality.
The specific factor ε_i is given by Ψ_i is called the uniqueness of the specific variance $\sigma_{ii} = h_i^2 + \Psi_i$, i = 1, 2, …, p.
$Thus\ var(X_i) = communality + specificvariance$

The factor model assumes that $p + \frac{p(p-1)}{2} = \frac{p(p+1)}{2}$ variables and covariance for X can be reproduced from *pm* factor loadings l_{ij} and *p* specific variablesΨ_i.
The factor model provides a simple explanation of the covariation in X with parameters $(p + pm)$ which are fewer than $p(p+1)/2$ parameters in Σ.
Factor rotations are an orthogonal transformation of the factor loadings, as well as the implied orthogonal transformations of the factors. If $\hat{L}$ is the pxm matrix of estimated factor loadings obtained, then $\hat{\mathbf{L}}^* = \hat{\mathbf{L}}\mathbf{T},$ where $TT' = T'T = I$, was a matrix of 'rotated' loadings, ***I*** is the identity matrix. $\hat{\mathbf{L}}\hat{\mathbf{L}}' + \hat{\boldsymbol{\Psi}} = \hat{\mathbf{L}}\mathbf{TT}'\hat{\mathbf{L}}' + \hat{\boldsymbol{\Psi}} = \hat{\mathbf{L}}^* \hat{\mathbf{L}}'^* + \hat{\boldsymbol{\Psi}}.$
This shows that the specific variances $\hat{\Psi}_i$ and the communalities h_i^2 remain unchanged.

For the given original data x_{ij} (i= 1,2,3,...n and j = 1,2,3,..., p) the factor score of the i^{th} individual child on the k^{th} principal component retained can be calculated as:

$$\hat{f}_{ik} = \hat{l}_1 x_{1i} + \hat{l}_2 x_{2i} + \ldots + \hat{l}_p x_{pi},$$

Where

$\hat{f}_{ik}$ =factor score of the i^{th} subject or sampling unit for the k^{th} factor retained,

$\hat{l}_j$ = the principal component (factor) loading of variable j.

2.3.3 Multivariate Multiple Linear Regression Model

The multivariate extension of multiple linear regressions used to model the relationship between m responses variables denoted by

$Y_1, Y_2, \ldots, Y_m$ and a set of k predictor variables $x_1, x_2, \ldots, x_k$.

Suppose that the number of response variables is m, so we have n observations for each Y_i, i = 1,2,…,m. The general formula for the multivariate regression model is given by:

$Y_i = \beta_{0i} + \beta_{1i}X_1 + \beta_{2i}X_2 + \cdots + \beta_{ki}X_k + \varepsilon_i$ For all i= 1,2,3,...,m.

Thus

$$\begin{aligned}
Y_1 &= \beta_{01} + \beta_{11}X1 + \cdots + \beta_{k1}X_k + \varepsilon_1 \\
Y_2 &= \beta_{02} + \beta_{12}X_1 + \cdots + \beta_{k2}X_k + \varepsilon_2 \\
&\vdots \\
Y_m &= \beta_{0m} + \beta_{1m}X1 + \cdots + \beta_{Km}X_K + \varepsilon_m
\end{aligned}$$

$\varepsilon = (\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_m)'$ has expectation 0 and variance matrix Σ. The errors associated with different responses on the same sample unit may have different variances and may be correlated.

We can now formulate the multivariate multiple regression model:

$$\begin{pmatrix} Y_{11} & Y_{12} & \cdots & Y_{1m} \\ Y_{21} & Y_{22} & \cdots & Y_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ Y_{n1} & z_{n2} & \cdots & Y_{nm} \end{pmatrix} = \begin{pmatrix} 1 & X_{11} & X_{12} & \cdots & X_{1k} \\ 1 & X_{21} & X_{22} & \cdots & X_{2k} \\ 1 & X_{31} & X_{32} & \cdots & X_{3k} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & X_{n1} & X_{n2} & \cdots & X_{nk} \end{pmatrix} \begin{pmatrix} \beta_{10} & \beta_{11} & \cdots & \beta_{1k} \\ \beta_{21} & \beta_{22} & \cdots & \beta_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ \beta_{n0} & \beta_{n1} & \cdots & \beta_{nk} \end{pmatrix} + \begin{pmatrix} \varepsilon_{11} & \varepsilon_{12} & \cdots & \varepsilon_{1m} \\ \varepsilon_{21} & \varepsilon_{22} & \cdots & \varepsilon_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \varepsilon_{n1} & \varepsilon_{n2} & \cdots & \varepsilon_{nm} \end{pmatrix}$$

$$\mathbf{Y}_{(nxm)} = \mathbf{X}_{(nx(k+1))} \boldsymbol{\beta}_{((k+1)xm)} + \boldsymbol{\varepsilon}_{(nxm)}$$

With $E(\boldsymbol{\varepsilon}) = \mathbf{0}$ $\text{var}(\boldsymbol{\varepsilon}) = \boldsymbol{\Sigma}$ and $\text{cov}(\varepsilon_i, \varepsilon_k) = \sigma_{ik} xI$ for i, k = 1,2,...,m. Thus the error terms associated with different responses may be correlated.

The m measurements on the j^{th} sample unit have covariance matrix Σ but the n sample units are assumed to respond independently.

2.3.3.1 Parameter Estimation in Multivariate Multiple Linear Regression

We estimate the regression coefficients associated with the i^{th} response using only the measurements taken from the n sample units for the i^{th} variable. The least squares estimator for β minimizes the sums of squares elements on the diagonal of the residual sum of squares and cross products matrix.

$$\left(Y - X\hat{\beta}\right)' \left(Y - X\hat{\beta}\right) =$$

$$[\left(Y_{(1)} - X\hat{\beta}_{(1)}\right)' (Y_{(1)} - X\hat{\beta}_{(1)}) \ldots \left(Y_{(1)} - X\hat{\beta}_{(1)}\right)' (Y_{(m)} - X\hat{\beta}_{(m)})$$

$$(Y_{(2)} - X\hat{\beta}_{(2)})'(Y_{(1)} - X\hat{\beta}_{(1)}) \dots \left(Y_{(2)} - X\hat{\beta}_{(2)}\right)' (Y_{(m)} - X\hat{\beta}_{(m)})$$
$$\vdots$$
$$(Y_{(1)} - X\hat{\beta}_{(1)})'(Y_{(1)} - X\hat{\beta}_{(1)}) \dots \left(Y_{(m)} - X\hat{\beta}_{(m)}\right)' (Y_{(1)} - X\hat{\beta}_{(m)})]$$

By solving the normal equations

$\mathbf{X'X\hat{\beta}} = \mathbf{X'Y}$ we get the solution in the form $\hat{\boldsymbol{\beta}} = (\mathbf{XX})^{-1}\mathbf{X'Y}$

Using least squares and with X of full column rank for univariate estimate:

$$\hat{\beta}_{(i)} = X'X^{-1}X'Y_{(i)}$$

2.3.3.2 Checking the Goodness of Fit of the Model

In this study we used MANOVA for assessing the multivariate multiple regression models goodness of fit. To test the coefficient of the independent variables we use, the following hypothesis:

H_0: $\beta_1 = \beta_2 =, \dots, = \beta_k = 0$ versus H_1: At least one of the parameter is different from zero.

Consider the p by p positive definite matrix of (corrected) total sums of squares and cross products (SS and CP) defined as:

$$\text{TSS and CP} = \mathbf{T} = \mathbf{Y'Y} - \frac{1}{n}\mathbf{Y'ii'Y} = \mathbf{Y'}\left\{\mathbf{I} - \frac{1}{n}\mathbf{ii'}\right\}\mathbf{Y}$$

Where $\mathbf{i} = (1, 1, 1, \dots, 1)'$ denotes an $(nx1)$ vector of each element unity.

Consequently, the diagonal elements of $\mathbf{T}$ are the (corrected) total sums of squares for the respective dependent variables. Assuming that$Rank(\mathbf{X}) = (k + 1)$, this matrix can be partitioned as the sum of the two$p$ by p positive definite matrices.

$$\boldsymbol{T} = \boldsymbol{R} + \boldsymbol{E}$$

Where

$$R = \mathrm{Y}\{\mathrm{X}(\mathrm{X'X})^{-1}\mathrm{X'} - \frac{1}{n}\mathrm{ii'}\ \mathrm{Y}\} = \mathrm{Y'X}\hat{\beta} - \frac{1}{n}\mathrm{Y'ii'Y}$$
$$\mathrm{E} = \mathrm{Y}\{\mathrm{I} - \mathrm{X}(\mathrm{X'X})^{-1}\mathrm{X'}\}\mathrm{Y} = \mathrm{Y'Y} - \mathrm{Y'}\,\mathrm{X}(\mathrm{X'X})^{-1}\mathrm{X'Y}$$
$$= \mathrm{Y'Y} - \mathrm{Y'X}\hat{\beta} = \left(Y - \hat{Y}\right)'\left(Y - \hat{Y}\right),$$

And $\widehat{\boldsymbol{Y}} = \mathbf{X}\widehat{\boldsymbol{\beta}}$ is the matrix of the predicted values of matrix $\mathbf{Y}$. The matrix $\boldsymbol{R}$ represents the matrix of model or regression sums of squares and cross products, while the matrix $\boldsymbol{E}$ represents that corresponding to error. Note that the diagonal elements of these matrices respectively represent the usual regression and error sums of squares for the corresponding dependent variables in the univariate linear regression setup.

An unbiased estimator of $\mathbf{\Sigma}$ is given by$\widehat{\Sigma} = \frac{W}{n-k-1}$

If H_0 is not true Wilk's lambda (Λ^*) $= \frac{|\boldsymbol{E}|}{|\boldsymbol{E}+\boldsymbol{R}|}$ is small**.**

The most popular MANOVA tests for multivariate measures for assessing the multivariate multiple regression models are: Wilks' lambda, Pillai's trace, Lawley-Hotelling trace, and Roy‟s largest root [8], and we fail to reject H_0 for small values of all the above four tests.

The null hypothesis for an individual test may be stated mathematically as:

$H_0 : \beta_{(s,i)} = 0$ vs $H_0 : \beta_{(s,i)} \neq 0$ for all s = 1,2,3,..., k and i= 1,2,3,...,m.

A test statistic is: $t = \dfrac{\hat{\beta}_{(s,i)}}{SE(\hat{\beta}_{(s,i)})} \sim t(n-k-1)$

If $t > t(n-k-1)$ or p-value less than the level of significance, we reject the null hypothesis. On the other hand, the confidence ellipsoid for β can be easily contracted with the one at a time t value $t(n-k-1)$ at the given significance level. Here if the confidence interval includes $\beta_i = 0$, the variable X_i might be dropped out from the regression model [9].

2.3.3.3 Model Diagnostics

The most commonly used methods of checking normality of an individual variable are the Quantile-Quantile plot (Q-Q plot), P-P plot and Normal density curve of the histogram. The P-P plotted as expected cumulated probability against observed cumulated probability of standardized residuals line should be at 45 degrees. The variable is normality distributed if this plot illustrates a linear relationship [10].

3. Results

3.1 Descriptive statistics

Table 2 presents the descriptive statistics of the major covariates considered in this study with stunting (H/A z-scores) underweight (W/A z-score) and wasting (W/H z-score) respectively. Out of a total of 370 children included in the study 25.4% are underweighted, 30.8% are stunted and 17.3% are wasted. Accordingly**,** of total children underweighted 5.9% are severely underweighted while 19.5% are moderately underweighted. Concerning the anthropometric height for age z-score (stunting) 30.8% are malnourished from which about 12.7% are severely stunted and 18.1% of the children in the study are moderately malnourished (stunted). Wasting (Z score weight for height) is indicator child malnutrition; regarding this 17.3% are malnourished (6.5% severe and 10.8% moderate) malnutrition respectively.

The result shows the proportion of stunting, underweight and wasting differs by type of place of residence. Accordingly, higher numbers of stunted children are in the rural area, that is among 30.8% of total children stunted in the region 27.9% (11.4% severe and 16.5% moderate malnutrition) are residing in rural areas and relatively small numbers of stunted children only 2.9% reside in urban counters. Regarding underweight 23.5% of rural children in the sample are underweight (5.1% severe and 18.4% moderately malnourished respectively). In terms of wasting again the highest proportion is observed for rural residents, where this figure is 15%.

Concerning family demographic and socioeconomic status child malnutrition differs by maternal education level, household economic level and partners/husband education. Children born to mothers with no education have the highest proportion of malnutrition; 29.5% stunted (8.4% severe malnutrition and 11.1% moderately stunted), 16.8% underweight (2.7% severe and 14.1% moderately underweight) and 11.1% wasted (4.3% severe and 6.8% moderately) malnourished. This figure also consistent as partners' education is concerned, i.e. 15.9% (7.3% severe and 8.6% moderate) of stunted children are from a mother whose partner is illiterate. Compared to those with secondary and above education level children to mothers whose partner is illiterate or has primary education has high proportion of malnutrition. 12% of children from uneducated partners are underweight, and 6.5% are wasted, while 11.4% from partners with primary education are underweight and 8.9% are wasted respectively.

Another factor that shows high variation in under five child malnutrition statuses is household wealth index. Tables 2 reveal that the poor families account for the higher proportion of children malnutrition in terms of stunting 19.4% (8.6% severely stunted and 10.8% had moderately stunted), underweight 18.2% (4.1% severely and 14.1% moderately had underweight) and 11.9% wasted (5.1% severe and 6.8% moderately wasted) respectively.

Majority of the respondents have no access to sanitation services like pure water and toilet facility services. About more than half, 54% of the respondents do not have access to toilet facility and among this 10.5% has malnutrition problem in terms of wasting, 14.6% are underweight and 18.7% are stunted. Thus, those mothers without toilet facility services have the highest percentage of child malnutrition than any of those with facility. Concerning access to pure water more than two third about 70% of the respondents uses protected well or surface water. Mothers who use protected well or surface water for drinking sources have relatively high under five child malnutrition problems. Among those who use surface water 7.9% wasted, 8.4% underweight and 8.9% stunted respectively.

As family size, i.e. number of household members and child birth order concerned, the highest proportion of child malnutrition is observed for family with 5 - 8 household members, in which 19.2 % are thin for age (4.6% are severely underweight, 14.6% moderately underweight), 23.5% have short height for age (10.5% severely stunted, 13% moderately stunted) and 11.7% thin for height (3.2% severely wasted, and 8.4% moderately wasted) respectively. For birth order number children with birth order number 3-4 accounts for the highest proportion of malnutrition, of those children with birth order number 3-4, 7.8%, were underweight, 9.7% were stunted and 5.9% were wasted, respectively.

With regard to child sex, 14.6 % of male children are underweight (3% severe and 11.6 % moderately underweight), while 10.8% of females were underweight (3% severe and 7.8% moderately underweight) 15.7% of male children's were stunted (7.3% severe and 8.4% moderate stunted) and 15.1% of females are stunted (5.4% severe and 9.7% moderately stunted). Concerning wasting as anthropometric indicator of child malnutrition the proportion of malnutrition is almost equal i.e. 8.7% of male children were malnourished while 8.6% of females was malnourished. Over all male children has the highest percentage of malnutrition in terms of underweight, stunting and wasting. (Table 2)

3.2 Factor Analysis

The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy in Table 3 tests whether the partial correlations among variables are small. Bartlett's test of sphericity tests whether the correlation matrix is an identity matrix, which would indicate that the factor model is inappropriate. The KMO measure of sampling adequacy tests were 0.714, greater than 0.5 indicating that the sampling was adequate for factor analysis and there were significant relationships among the perceived factors of nutritional measures. The data were also checked for Bartlett's test of Sphericity to see that the correlation matrix is an identity matrix; the test shows that the factor model is appropriate ($p\text{-value} < 0.0001$). Table (3)

The criteria that the required amount of explained variation accounted for being large, logical interpretability of factors and Scree plot tests were considered with Kaiser Criteria. Depending on the correlation matrix and communalities, of all 370 observed items, using

principal component extraction and Varimax rotation, the study found eight underlying common factors for factor analysis that constituted or explained 68.787% of the total variability in the corresponding original observed variables. Table (4).
The output matrixes contained the loading of each variable onto each factor. The results of factor analysis (with factor loadings greater than 0.4 in an absolute) are presented in Table 5. The scree plot in Figure 1 also reveals the first eight components have Eigen values above 1, explaining at least as much of the variation as the original variables. (Figure 1)
Principal Component Factor Analysis was done considering the socioeconomic characteristics of households, demographic characteristics of a child, health status of child, and environmental variables. The component loadings represent the correlation between the components and original variables. In this study we concentrate on loadings above 0.4 or below -0.4 and components/factors are named based on the highest loadings. (Table 5)

3.3 Results of Multivariate Multiple Linear Regression Analysis
The PCFA technique was used in the data reduction, and the multivariate multiple linear regression analyses was applied to the reduced data to identify the determinant factors of child malnutrition. The explanatory variables were the common factors obtained from the PCFA.

3.3.1 Assessing Multivariate Multiple Models Goodness of Fit
Table 6 presents model summary of Multivariate Multiple Linear Regression Model. The F-value column reveals that the three models are good fit (P-value ≤ 0.001). Also table 1 and 2 on Appendix A shows the various summary of the model and MANOVA measures for assessing the multivariate multiple regression models for each covariates. (Table 6)
The fitted model was checked for possible presence of outliers and influential values and also for normality of the residuals. The histogram plot and p-p lot, figures shows that the normal p-p plot of standardized residuals lies along the 45^0 line an indication of normality of the residuals. Thus, from the goodness of fit test and diagnostic test results presented in Figure 2, we can conclude that our model is adequate. (Figure 2)
The results in Table 7 show the multivariate multiple linear regression analysis and determinant factors for nutritional status of under five children based on the three anthropometric indicators: The factors breast feeding, household socio economic status and child health status was found to be jointly statistically significant for Z score weight for height (wasting). Z score weight for age was significantly associated with factors breast feeding, family size, household socio economic status, and vaccination status of a child. The factors breast feeding, family size medical treatments taken during pregnancy and vaccination status of a child has a significant influence on Z score height for age (stunting). However, the factors like size of child at birth and sex of a child were insignificantly related to nutritional status measures. (Table 7)
The result of the multivariate multiple linear regression analysis indicated that the factors breast feeding which encompassed duration of breast feeding, currently breast feeding and months of breast feeding, socioeconomic status of households composed of place of residence, education level of mothers and partner, source of drinking water, and availability of toilet facility and economic level of households, health status of child encompassing had diarrhea recently, had cough in last two weeks, and had fever in the last two weeks, having medical treatments during pregnancy like given or bought iron tablets/syrup, antenatal visits, and tetanus injections before birth, and child vaccination which encompassed of vitamin A last six months, measles and polio have significant impacts on nutritional status of the under five children.

4. Discussion
Breast feeding that encompassed duration of breast feeding, currently breast feeding and months of breast feeding had a significant negative impact on child malnutrition in terms of wasting (low weight-for-height), underweight (low Weight-for-age) and stunting (low height-for-age). This may be due to the longer time that a mother feed breast to her child at least for six months the more the child is health and gets balanced nutrients. The factor household size characteristic that deals with number off household members, number of living children, and birth order of a child also had significant negative impact on child malnutrition in terms of low Weight-for-age. This may because of large household size is widely regarded as a risk factor for malnutrition in, particularly for infants and young children due to food insecurity.
Household economic status which encompasses parents economic level, residence, and sanitary services like availability of clean drinking water and toilet farcicality, mother educational level and father education level another factor that had a significant impact on malnutrition in terms of Z score weight for age (low Weight-for-age) and Z score weight for height (low weight-for-height). Theoretically the risk of malnutrition/health problem is, on average, significantly higher for children whose mothers have no education in terms of long and short-run measures (i.e. underweight). This may indicate that education improves the ability of mothers to implement simple health knowledge and facilitates their capacity to manipulate their environment including health care facilities, interact more effectively with health professionals, comply with treatment recommendations, and keep their environment clean. Furthermore, educated women have greater control over health choices for their children. Better off households has better access to food and higher cash incomes than poor households, allowing them a quality diet, better access to medical care and more money to spend on essential non-food items such as schooling, clothing and hygiene products [11, 12].
The findings of this study also show that child health status incorporating recently had diarrhea, cough or fever in the last two weeks has inversely related to child malnutrition. From various literatures and theories children who have diarrhea or fever and cough are significantly vulnerable to malnutrition and health problem [13, 14]. This is due to the fact that diarrhea accelerates the onset of malnutrition

by reducing food intake and increasing catabolic reactions in the organism. Diarrhea also affects both dietary intakes and utilization, which may have a negative effect on improved children nutritional status.

Maternal health care and medical treatments during pregnancy which encompasses during pregnancy given iron tablets/syrup, number of antenatal visits, and number of tetanus injections is also an important factor that affects the nutrition/health status of children in terms of long short height and for age (i.e. stunting). This is because of access to medical treatments during pregnancy helpful to the mother to protect her child from different infections. Moreover, access to improved quality to medical treatment not only reduces child exposure to diseases but also saves women the life from different pregnancy complicated problem.

5. Conclusions

This study was intended to identify some factors contributing to malnutrition among under five children. Accordingly, factor analysis and multivariate multiple linear regression techniques on the three anthropometric measures were employed. The factor analyses conducted in this study indicated that only eight factors (instead of 25 original observed variables or items) were sufficient to explain 68.787%, of the total variation in PCFA of observed items related to children nutritional status.

The study revealed that the factors duration of breast feeding, number of household members, living children, birth order of a child, current age of child in months, place of residence, sanitation services like drinking water and availability of toilet, mother educational level and father education level, age of mother, economic level of household, receiving measles, polio and vitamin A in the last six months, and child health status indicators like having diarrhea recently, having fever and cough in the last two months had statistically significant on child malnutrition. However, sex of a child and size of a child at birth were found to be insignificant factors of child malnutrition in Tigray region.

Based on the findings of the study, we recommend the administrative there should be aware the community about exclusive breast feeding for 6 months and special attention needs to be paid to reduce child malnutrition. It is recommended that during pregnancy maternal food supplementation along with iron tablets/syrup are the most intervention to prevent the problem.

6. Appendix

List of Acronyms

ANOVA	Analysis of Variance
CIA	Central Intelligence Agency
CSA	Central Statistics Agency
EDHS	Ethiopia Demographic and Health Survey
FA	Factor Analysis
HIV	Human Immune Virus
MANOVA	Multivariate Analysis of Variance
NCHS	National Center for Health Statistics
OLS	Ordinary Least Square
PCA	Principal Component Analysis
PCFA	Principal Component Factor Analysis
SD	Standard deviation
SSCP	Sum of squares and Cross product
WHO	World Health Organization
WFP	World Food Program
UNICEF	United Nations International Children Emergency Fund
US	United States
USAID	United States Agency for International Development

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

TT involved from the inception to design, acquisition of data, analysis and interpretation, drafting the manuscript, BT involved in the inception to design, analysis and interpretation and revise critically the manuscript and edit the manuscript for the final submission. Both authors read and approved the final manuscript.

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7. Reference

1. WHO, 2010 World Health Organization. Indicators for Assessing Infant and Young Child Feeding Practices Part 3: Country Profiles; World Health Organization: Geneva, Switzerland, 2010.
2. Park K. Park's Textbook of Preventive and social medicine Nutrition and Health 21st Ed. India, 2011.
3. Cogill B. Anthropometric Indicators Measurement Guide: Food and Nutrition Technical Assistance Project. European Journal of Clinical Nutrition. 2001; 58:532-540.
4. UNICEF- WHO- World Bank Group - Joint Child Malnutrition Estimates 2017 edition
5. WHO. Better care for newborns crucial for Millennium Development Goal on child deaths'' World Health Organization, Geneva, 2010.
6. Ethiopia Central Statistical Agency (CSA): Ethiopia Demographic and Health Survey 2016. Central Statistical Agency, Addis Ababa & ICF International, Calverton, MD.
7. Ethiopia Central Statistical Agency (CSA). Population and Housing Census, Ethiopia, 2007.
8. Johnson RA, Wichern Dean W Applied Multivariate Statistical Analysis (Third Edition) Prentice-Hall, Inc., Upper Saddle River, NJ, 2007.
9. Johnson A. Applied Multivariate Statistical Analysis (6th ed.), Pearson Prentice Hall, Trademark of Pearson Education, Upper Saddle River, New Jersey 07458, 2007.
10. Burdenski T, Texas A, University M. Evaluating Univariate, Bivariate, and Multivariate Normality Using Graphical and Statistical Procedures, Multiple Linear Regression View Points, 2000.
11. Gezae B, Nigatu R. Nutritional status of children under five years of age, Ethiopia, 2014.
12. Dereje D, Ayele T. Nutritional Status of Under- five Children in Hawassa Zuria District, Southern Ethiopia, 2015.
13. Sommerfelt Elizabeth A, Kathryn S. Children's nutritional status. DHS Comparative Studies No. 12.Calverton, Maryland, USA: Macro International Inc, 1994.
14. World Health Organization. Use and Interpretation and Anthropometric Indicators of Nutritional Status, 1986.