Undernutrition in early life: using windows of opportunity to break the vicious cycle

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CHAPTER 02

What factors are associated with pre-pregnancy nutritional status? Baseline analysis of the KITE cohort: a prospective study in northern Ethiopia

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Abstract

Objective: To assess a broad range of factors associated with pre-pregnancy nutritional status, a key step towards improving maternal and child health outcomes, in Ethiopia.

Design: A baseline data analysis of a population-based prospective study.

Setting: Kilite-Awlaelo Health and Demographic Surveillance Site, eastern zone of Tigray regional state, northern Ethiopia.

Participants: We used weight measurements of all 17,500 women of reproductive age living in the surveillance site between August and October 2017 as a baseline. Subsequently, 991 women who became pregnant were included consecutively at an average of 14.8 (standard deviation [SD])=1.9) weeks of gestation between February and September 2018. Eligible women were married, aged 18 or older, with a pre-pregnancy weight measurement performed, and a gestational age ≤20 weeks at inclusion.

Outcome measures: The outcome was pre-pregnancy nutritional status measured by body mass index (BMI) and mid-upper arm circumference (MUAC). Undernutrition was defined as BMI <18.5 kg/m^2 and/or MUAC <21.0 cm. BMI was calculated using weight measured before pregnancy, and MUAC was measured at inclusion. Linear and spline regressions were used to identify factors associated with pre-pregnancy nutritional status as a continuous and Poisson regression with pre-pregnancy undernutrition as a dichotomous variable.

Results: The mean pre-pregnancy BMI and MUAC were 19.7 (SD=2.0) kg/m^2 and 22.6 (SD=1.9) cm, respectively. Overall, the prevalence of pre-pregnancy undernutrition was 36.2% based on BMI and/or MUAC. Lower age, not being from a model household, lower values of women empowerment score, food insecurity, lower dietary diversity, regular fasting, and low agrobiodiversity showed significant associations with lower BMI and/or MUAC.

Conclusion: The prevalence of pre-pregnancy undernutrition in our study population was very high. The pre-pregnancy nutritional status could be improved by advancing community awareness on dietary practice and gender equality, empowering females, raising agricultural productivity, and strengthening health extension. Such changes require the coordinated efforts of concerned governmental bodies and religious leaders in the Ethiopian setting.

Keywords: pre-pregnancy nutrition, body mass index, and mid-upper arm circumference

Introduction

Undernutrition continues to be a public health problem in developing countries.[1] For women, undernutrition not only directly affects their current health, but it can also lead to additional health problems when they get pregnant. Maternal undernutrition is related to pregnancy complications like anemia and hypertension, and also to adverse birth outcomes such as low birth weight and preterm birth.[2–7] These adverse outcomes, in turn, are related to short and long-term adverse health outcomes of the mothers and their offspring.[1,8–11] Clearly, pre-pregnancy undernutrition, defined as body mass index (BMI) <18.5 kg/m^2 and/or mid-upper arm circumference (MUAC) <21 cm, contributes to the vicious cycle of transgenerational malnutrition and its subsequent effects.[1,11]

Pre-pregnancy undernutrition is widespread in developing countries.[12–15] According to a recent review, nearly 32% of pregnant women were undernourished (MUAC <21 cm) in Africa.[16] Since MUAC is relatively insensitive to short-term change, this could also reflect pre-pregnancy nutritional status.[17,18] In Ethiopia, the prevalence of undernutrition among non-pregnant women of reproductive age was 22% in 2016.[14] The problem may be even more profound in Tigray, a region in northern Ethiopia repeatedly hit by drought and war.[14,19] According to a study among non-pregnant women of reproductive age in the Kunama population, a minority group in Tigray, the prevalence of undernutrition was about 48%.[19] These studies support the significant importance for public health of pre-pregnancy undernutrition and indicate substantial regional variation in developing countries like Ethiopia.

Factors that may influence pre-pregnancy nutritional status include socioeconomic,[13,19–22] reproductive and obstetric conditions, food and dietary habits,[19,23,24] and psychosocial characteristics. Few studies have investigated the factors associated with pre-pregnancy nutritional status in low-income countries like Ethiopia in detail.[19,22] The previous studies also did not control potential confounders like implementing a health extension package, fasting, agrobiodiversity, and psychosocial characteristics.[25–27] Likewise, the role of women's empowerment, the process by which women who have been denied the ability to make strategic life choices acquire such an ability, expressed by their economic, socio-familial, and legal empowerment, did not get attention yet.[28]

Furthermore, other studies focused on specific population subgroups only, such as urban residents who may not represent the large majority of the population living in rural conditions [19] or population groups with different socioeconomic and cultural characteristics.[22] Knowledge about factors associated with pre-pregnancy nutritional status among women of reproductive age, the target population for interventions to achieve improvement, is therefore limited in countries like Ethiopia. The present study aimed to assess a wide range of factors associated with pre-pregnancy nutritional status, a key step towards identifying possible targets for intervention and support to improve maternal and child health outcomes in rural and urban areas of northern Ethiopia.

Methods

Study design, setting, and population

The present study, a baseline analysis of an ongoing population-based prospective study, the KITE cohort, was conducted in Kilite-Awilaelo Health and Demographic Surveillance Site (KA-HDSS) between February and September 2018. The KITE cohort was designed to assess maternal nutrition prior to and during pregnancy, adverse birth outcomes, and child growth. KA-HDSS is located in the eastern zone of the Tigray region of northern Ethiopia. The surveillance site consists of ten rural and three urban kebeles (the smallest administrative units) spread across three districts: Kilte-Awilaelo, Wukro, and Atsbi-Wonberta. Climatic conditions, rural-urban composition, altitude, and disease burden were considered in selecting the kebeles to represent the population of the Tigray region.

The total population of the KA-HDSS is 113,760. With 24% of the population being women of reproductive age, about 4,550 pregnancies are expected per year within the KA-HDSS. Most of the population lives in rural settings, and agriculture is the primary source of income. Ethiopia has a three-tier health care system with health posts at the forefront of primary care. Each kebele has one health post staffed by two to three Health Extension Workers (HEWs). Health posts provide promotional and preventive services under the umbrella of the ‘health extension package’ mainly at a household level. The health extension package consists of 16 components including maternal health, family planning, nutrition, and sanitation.[25]

Pregnant women living in the study area, whose expected date of delivery lay before the end of January 2019, were the study population. Married women, aged 18 or older, whose pre-pregnancy weight was measured, and who completed ≤20 weeks of gestation were eligible to be included in the study. The sample size was calculated to address the objectives of the KITE cohort. The critical assumption included a 5% alpha level (two-sided) and 80% power to find a difference of 24.6% low birth weight among women with MUAC ≥23.0 cm versus 32.6% among women with MUAC <23.0 cm.[7] Taking an estimated 10% drop out rate into account, the total sample size was calculated at 1,100. With this sample size, effect sizes >0.2 standard deviations (SD) for continuous outcomes could also be detected.

Different methods were applied to identify pregnant women, including a community-based survey by Health Extension Workers through the “Women Development Army” (WDA), a network of health information workers reaching individual households around the health posts. The records of the nearby antenatal clinics and the KA-HDSS database were also used. Ethiopia is implementing a Productive Safety Net Program that aimed to improve food security through the participation of households in community asset building projects and earn a wage either in cash or in-kind. Also, households are expected to participate in soil and water conservation activities at least 20 days per year for free. In both cases, pregnant women are exempted upon reporting their pregnancy status to the HEWs, allowing us to identify them for participation.

Furthermore, a campaign offering trachoma treatment was taking place during the data collection period. As the treatment is contraindicated in the first trimester of pregnancy, women had to report their pregnancy status to HEWs. The opportunity was, therefore, used to identify pregnant women. All eligible pregnant women identified during the study period through any of the methods mentioned above were visited at their homes, invited for the study, and included consecutively.

Measurements

The pre-pregnancy weight of women of reproductive age (n=17,500) living in the study area was measured between August and October 2017 using a Seca scale to the nearest 100 g at a community level in collaboration with the district health and KA-DHSS offices. Subsequently, the identification and inclusion of pregnant women took place. At inclusion, data were collected by interviewer-administered questionnaire, anthropometric measurements as per standard techniques [29] and extracting data available in the KA-DHSS database. The questionnaire was adapted from the literature [7,14,30–34] and pretested on 55 pregnant women selected based on their accessibility in Tahtay-Maichew, central zone, Tigray region. Data including the pre-pregnancy weight were collected by qualified HEWs, and the data collection included:

Socioeconomic variables: Age in complete years, residence (urban or rural), religion (Orthodox, Catholic, Muslim or others), educational status (no formal education, primary education or secondary education and above), occupation (farmer, housewife, employed, or others), husband educational status (no formal education, primary education or secondary education and above), husband occupation (farmer, employed, daily laborer or others), family size (the number of people living in the same household), and wealth index were extracted from the KA-DHSS database. The surveillance site updates the database every six months except for wealth index. The update for wealth index is taken place every five years. Accordingly, data on wealth index was updated in 2015. Therefore, adjustment was made at inclusion when there was a change since the last update.

Wealth index was assessed by asking about housing characteristics, access to improved drinking water and sanitation facilities, and ownership of household assets, land, and livestock. First, the dichotomized socioeconomic proxy indicator variables were standardized using principal component analysis, and factor coefficient scores were created. Then, the indicator values were multiplied by the factor scores and summed to produce a standardized wealth index value. Finally, using the factor scores with the largest proportion of the variance, the wealth index was categorized into quintiles designating the lowest to the highest economic status.[35] Access to improved drinking water sources refers to access to piped water on-premises, public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs and/or rainwater collection. Similarly, access to an improved sanitation facility was defined as access to an unshared toilet facility, pit latrine with a slab, ventilated improved pit latrine, or flush toilet.[36]

Furthermore, time needed to fetch improved drinking water was collected at inclusion by asking ,'What is the time needed to fetch improved drinking water from the nearest source in minutes?'. Then, it was dichotomised at a cut-off point of 30 with the time needed not exceeding 30 min showing better service.[36] Likewise, access to health service was measured at inclusion by asking the time needed to go to the nearest health facility and back home, with ≤1 hour indicating better access. Also, implementation of the health extension package was assessed by checking if the women's households were certified as model households or not at inclusion. A model household was defined as a household that received short-term training on the health extension package as described above and subsequently implemented the package.[25–27] Moreover, history of pre-pregnancy illnesses was recorded at inclusion.

To assess work burden, women were asked to rate their work as easy, moderate or difficult at inclusion. Moreover, physical activity data were obtained at inclusion using the International Physical Activity Questionnaire short form,[34,37] by asking women about the kinds of physical activities—vigorous, moderate and walking—they did in the preceding week. Also, they were probed for how many days and how long per day they did each activity. Then, the data were summarised as low, moderate or high physical activity using the algorithm described in the scoring protocol.[37]

Reproductive and obstetric conditions: Gestational age at inclusion was estimated from self-reported last menstrual period, fundal palpation and/or ultrasound. The latter two were extracted from antenatal records. Gravidity, that is, the number of previous pregnancies, parity, history of abortion, and stillbirth were extracted from the KA-DHSS database. Also, age at first marriage, age at first birth, previous inter-birth spacing in months, history of preterm birth, delivery by Caesarean section and severe perinatal haemorrhage were collected by interview at inclusion. Based on this information, a history of adverse pregnancy outcomes was defined as having experienced one or more of the following: abortion, stillbirth, preterm birth, severe perinatal haemorrhage or delivery by Caesarean section. Furthermore, self-reported information on intimate partner violence was obtained using the four-item Hurt, Insult, Threaten and Scream Questionnaire at inclusion. Each question was rated from 1 to 5, and a total score of >10 was used as a cut-off for the presence of violence.[38]

To assess women empowerment, participants were asked nine questions addressing five domains at inclusion: (1) earning and control over income (relative income to husband, control over men's income and control over women's income); (2) decision-making on household purchases; (3) mobility and healthcare autonomy (decision-making on family visits and women's health); (4) attitude towards domestic violence and (5) ownership of assets (farmland and house).[14,23,39] By coding each positive response as 1 and adding the responses, a women empowerment score ranging from 0 to 9 was obtained. Also, assigning each domain an equal weight (1) to be shared by the indicators within the respective domains, women who scored ≥80% or at least 4 out of 5 were considered as empowered.[40]

Food and diet: Self-reported agrobiodiversity, harvest volume, food insecurity, dietary diversity, number of meals per day, fasting and frequencies of vegetables, fruits, animals-source food, alcohol and coffee intake were obtained at inclusion. Fasting is abstaining from animal-source foods such as meat, dairy products and egg for religious reasons. Christians fast almost every Wednesday and Friday weekly throughout the year, in addition to the long fast times. The longer fasting periods include the 40-day Christmas fast, the 55-day Lenten fast, the 14-day Apostles fast and the 14-day Dormition fast. Data on fasting were collected by asking women if they fast weekly and adhere to the long fast times. Finally, women were categorised as fasting if they fasted both the weekly and the long fasting times.

To assess agrobiodiversity, women were queried using a list of crops and livestock products and were asked to indicate whether their households produced any of these in the preceding year by 'yes' or 'no' options. Products from the list were grouped into eight categories: cereals, roots and tubers; pulses; oilseeds; fruits; vegetables; dairy; egg; and meat and poultry. A total agrobiodiversity score from 0 to 8 was calculated based on each category's answers.[41] Also, the amount of produces of each crop in quintals was asked, and total harvest volume was calculated by adding all.

Dietary diversity was assessed by asking women about consuming a list of foods over a 24-hour period with 'yes' or 'no' as the answer options.[33] The list was organised into 10 groups: grains, white roots and tubers; pulses; nuts and seeds; dairy; meat, fish and poultry; egg; dark green leafy vegetables; other vitamin A-rich fruit and vegetables; other fruit; and other vegetables. Consumption of foods from 5 or more groups was defined as adequate dietary diversity.[33]

Household Food Insecurity Access Scale was used to collect data concerning food security status.[32] First, women were asked nine occurrence questions eliciting a 'yes' or 'no' response. Next, each positive response was followed by a frequency-of-occurrence question asking how often the reported food insecurity condition happened in the previous month. Response options were (1) rarely, (2) sometimes or (3) often. The sum of the frequency-of-occurrence questions across all nine questions yielded a food insecurity score ranging from 0 to 27. A household was classified as food secure if the response to all occurrence questions was 'no' or if the only 'yes' response concerned the question, 'did you worry that your household would not have enough food' and the frequency of occurrence was 'rarely'. All other households were classified as food insecure.[32]

Psychosocial characteristics: Partner support was measured by the five-item Turner Support Scale at inclusion, with each item scored from 0 to 3. A sum score <10 was defined as low.[42] Also, social support from other social sources was assessed using the Oslo-3 Social Support Scale at inclusion, with total scores ranging from 3 to 14 and ≤ 8 being considered low.[43] Totaling the two measures of support at inclusion, a total social support score was created, and low total social support was defined as low support from partner and other social sources.

Moreover, anxiety, depression, and stress were collected at inclusion. The ten-item Edinburgh Postnatal Depression Scale and the seven-item anxiety subscale of the Hospital Anxiety and Depression Scale with each item rated from 0 to 3 were used to measure depression and anxiety. Cut-off points of ≥ 13 and ≥ 8 were applied to indicate high symptoms of depression and anxiety, respectively.[44,45] For stress, the Perceived Stress Scale was used, with a score for each of the four items ranging from 0 to 4 and a cut-off point of ≥ 8 showing high symptoms of stress.[46] Summing depression, anxiety, and stress scores, a total distress score was obtained. Also, the presence of high symptoms in one, two, or three domains of distress, i.e., anxiety, depression, or stress, was considered to indicate the level of distress.

Anthropometrics: Height and MUAC to the nearest 0.1 cm were measured at inclusion using a height-measuring board and MUAC-measuring tape. Also, weight was measured as described earlier. All were measured twice and averaged. Based on pre-pregnancy BMI in kg/m^2 calculated from pre-pregnancy weight and height at inclusion, women were classified as undernourished (BMI <18.5), normal weight (BMI=18.5 to 24.9), or overweight (BMI ≥25.0). Likewise, MUAC <21.0 cm was used to define undernutrition.[47]

Data quality control

Data collection was supervised by health extension supervisors (BSc). Data collectors and supervisors were trained on the protocol for one day. Besides regular supervision, 10% of the completed questionnaires were selected at random to be checked by asking the women again. Also, some of the data were cross-checked with antenatal records.

Statistical analysis

Data were entered into Epi-Data 3.1, verified by re-entering a random selection of 20% of the completed questionnaires, and analyzed with STATA (Version 11, Stata Corporation, and College Station, Texas, USA). Proportion, mean with standard deviation (SD), or median with interquartile range (IQR) were used to summarize the characteristics of the participants.

Non-linear associations between pre-pregnancy BMI and MUAC as continuous dependent variables, and the independent variables were investigated, and linear spline regression was applied if indicated (Stata adjust_rcspline package). Non-linearity was initially tested with ANOVA comparing mean BMI and mean MUAC by categories of each independent variable. If this test suggested non-linearity as apparent by statistically significant deviation from linearity ($p<0.05$), two new continuous variables were created by partitioning each independent variable at the knot value (K) into two using linear spline regression. The coefficient for the first variable represented the effect of the variable below K. The coefficient for the second variable reflected the effect at values greater than or equal to K.[48] The knot value for each variable was roughly estimated by viewing the linear spline regression curves. Subsequently, the knot value resulting in the best fitting linear spline model, i.e., a model with the lowest mean squared sum of errors, was determined by testing different values. Then, after regressing the two new variables and their respective intercepts against the corresponding dependent variable (reg BMI int_1 X<K int_2 X≥K, robust), we tested if the slopes of the two variables were different (test X<K=X≥K). If the test showed that the slopes were significantly different ($p<0.05$), we concluded that the association was non-linear. Finally, after comparing linear spline, quadratic and cubic models, the model that had the best fit, as apparent by the lowest root mean squared sum of errors, was considered in the final analysis. In case of linear spline model had the best fit, the two new variables with their intercepts were included in the analysis.

Following the linearity test, linear regression with robust standard errors was used to identify factors associated with pre-pregnancy BMI and MUAC. In the final adjusted linear regression models, variables with a statistically significant association ($p<0.05$, two-sided) in the unadjusted analysis were included. β-coefficients with their corresponding 95% confidence intervals were computed. Residence, occupation, parity, and harvest volume were highly correlated with other variables and had a lower correlation with BMI and /or MUAC than their correlates. Thus, they were not included in the final models. Possible interaction between variables was assessed and included when important based on the likelihood ratio test. However, none of the interactions were significant or improved the models, so these were not reported. As for model diagnostic tests, multicollinearity was checked using the variance inflation factor, and the normality of residuals was checked with histograms, normal probability plots, and quantile-quantile plots. Also, specification error and omitted variable bias were tested using the linktest and ovtest commands.

Additionally, Poisson regression with robust variance was used to identify factors associated with pre-pregnancy undernutrition, defined as BMI <18.5 kg/m^2 and <21.0 cm as measured by MUAC. Independent variables significantly associated with pre-pregnancy undernutrition in the unadjusted analysis examined by the chi-square test were included in the final model. Incidence rate ratios with 95% confidence interval were computed.[49] All continuous variables were modeled as categorical variables to enhance data convergence and interpretation. Model selection was made based on Akaike and Bayesian Information Criteria (AIC and BIC).

Results

A total of 991 eligible women were identified and included in the study. Table 1 summarizes the anthropometric measures of the participating women by pre-pregnancy BMI categories. The mean pre-pregnancy nutritional status of the women as measured by BMI and MUAC was 19.7 (SD=2.0) kg/m^2 and 22.6 (SD=1.9) cm, respectively. Overall, 36.2% (95% CI: 33.3-39.3) were undernourished (BMI <18.5 kg/m^2) before pregnancy. According to MUAC, the prevalence of undernutrition (MUAC <21 cm) was 20.5% (95% CI: 18.0-23.0) (Figure 1).

The socioeconomic characteristics of the participants are presented in Table 2. On average, the women were 29.3 (SD=6.5) years old at inclusion. Most women lived in rural areas (65.3%), received primary education or below (69.4%), and were farmers (54.6%). As for their respective household characteristics, 242 (24.4%) were model households. Also, the majority (89.6%) had access to an improved drinking water source, whereas only 135 (13.6%) had access to an improved sanitation facility. In the unadjusted analysis, better socioeconomic circumstances were associated with higher BMI and MUAC.

Table 1. Anthropometric measures by pre-pregnancy BMI categories of women (n=991) from the Tigray region, northern Ethiopia, 2018.

Anthropometric measures	Undernourished (BMI < 18.5 kg/m²)		Normal (BMI=18.5 - 24.5 kg/m²)		Overweight (BMI ≥ 25.0 kg/m²)		Total	
	mean (SD)	Range	mean (SD)	Range	mean (SD)	Range	mean (SD)	Range
Height, cm	157.01 (0.1)	135.2 – 175.8	157.80 (0.1)	132.6 – 181.2	158.82 (0.1)	152.3 – 168.6	157.52 (0.1)	132.6 – 181.2
Pre-pregnancy weight, kg	43.84 (4.3)	31.8 – 54.0	51.87 (5.7)	33.3 – 72.9	64.10 (5.3)	58.9 – 71.8	49.02 (6.6)	31.8 – 71.8
Weight at inclusion, kg*	46.09 (4.3)	34.2 – 57.1	54.43 (5.9)	36.6 – 75.7	66.58 (5.5)	60.3 – 73.0	51.44 (6.7)	34.2 – 75.7
MUAC at inclusion, cm	20.67 (0.9)	17.5 – 22.0	23.61 (1.4)	18.4 – 27.8	28.44 (1.1)	26.8 – 29.6	22.57 (1.9)	17.5 – 29.6
Proportion, n (%)	359 (36.2%)		627 (63.3%)		5 (0.5%)		991 (100%)	

*one woman had inconsistent data and was excluded.

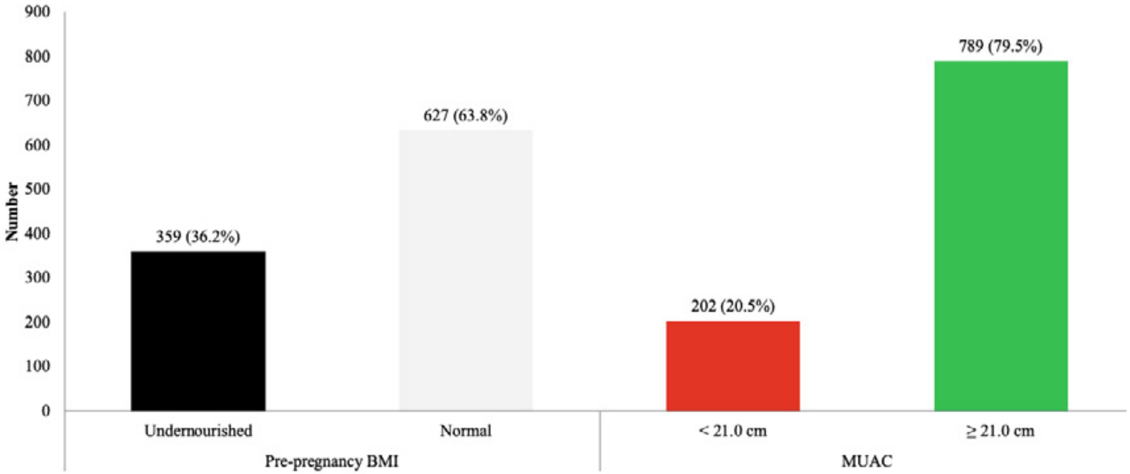

Figure 1. Pre-pregnancy nutritional status as measured by BMI and MUAC of women, northern Ethiopia, 2018.

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Table 2. Socioeconomic characteristics of women and their households (n=991), Tigray region, northern Ethiopia, 2018

Characteristics	n (%)/mean (SD) / median (IQR)
Age at inclusion in years	29.3 (6.5)
Residence, rural	647 (65.3%)
Religion	
Orthodox Christian	977 (98.6%)
Others (Muslim and Catholic)	14 (1.4%)
Educational status	
No formal education	362 (36.5%)
Primary education	326 (32.9%)
Secondary education and above	303 (30.6%)
Occupation	
Farmer	541 (54.6%)
Housewife	337 (34.0%)
Employed	91 (9.2%)
Others*	22 (2.2%)
Husband educational status	
No formal education	320 (32.3%)
Primary education	366 (36.9%)
Secondary education and above	305 (30.8%)
Husband occupation	
Farmer	515 (52.0%)
Employed	222 (22.4%)
Daily labourer	161 (16.2%)
Others**	93 (9.4%)
Family size	4.5 (2.0)
Perceived work burden	
Easy	404 (40.8%)
Moderate	442 (44.6%)
Difficult	145 (14.6%)
Physical activity	
Low	527 (53.2%)
Moderate	425 (42.9%)
High	39 (3.9%)
Wealth index	
Lowest	198 (20.0%)
Low	198 (20.0%)
Middle	200 (20.2%)
High	200 (20.2%)
Highest	195 (19.6%)
Model household	242 (24.4%)
Access to health service within 1 hour	693 (69.8%)
History of pre-pregnancy illness	142 (14.3%)
Access to improved drinking water source	888 (89.6%)
Time to fetch improved drinking water within 30 minutes	788 (79.5%)
Access to improved sanitation facility	135 (13.6%)

*Student, unemployed or others, and **Drivers, students, unemployed, or others

Table 3 depicts the reproductive and obstetric conditions, food, and dietary and psychosocial characteristics. At inclusion, the mean gestational age was 14.8 (SD=1.9) weeks. The median parity of the women was two, and 208 (21.0%) had a history of an adverse birth outcome. As for women empowerment, only 114 (11.5%) were empowered. Additionally, the prevalence of intimate partner violence among women was 16.2%. In the unadjusted analysis, higher women empowerment was associated with higher BMI and MUAC, whereas higher intimate partner violence was associated with lower BMI and MUAC.

As shown in Table 3, most women's food and dietary characteristics were poor. In total, 518 (52.3%) women had adequate dietary diversity. With reference to dietary habits, most women (70.0%) fasted. Additionally, 392 (39.6%) women did not have adequate food security. In the unadjusted analysis, higher dietary diversity and agrobiodiversity showed significant associations with higher BMI and MUAC. Fasting and food insecurity were associated with lower BMI and MUAC.

Furthermore, psychosocial problems were widespread among the women, as indicated in Table 3. More than one in five (21.9%) women had high symptoms of distress in one of the three domains of distress. Concerning social support, 75 (7.6%) women reported low social support. In the unadjusted analysis, a higher total distress score was associated with lower BMI and MUAC. Whereas, higher total social support score was associated with higher BMI and MUAC.

Results of the unadjusted and adjusted linear regression analyses are shown in Table 4. In the adjusted model, age <30 years (coefficient=0.08, 95% CI (0.03, 0.14), being from a model household (coefficient=0.40, 95% CI (0.15, 0.66), and women empowerment score ≥6 (coefficient=0.35, 95% CI (0.18, 0.53) were positively associated with BMI. From the food and dietary domain, higher dietary diversity (coefficient=0.13, 95% CI (0.05, 0.22) was associated with higher BMI. Additionally, fasting (coefficient=-0.26, 95% CI (-0.50, -0.02), food insecurity (coefficient=-0.07, 95% CI (-0.10, -0.05) and agrobiodiversity score <2 (coefficient=-0.56 (-0.74, -0.38) were negatively associated with BMI. In total, the model explained 39.5% of the variation.

All variables that were associated with pre-pregnancy BMI were also associated with MUAC. Of these variables that had a larger effect, being from a model household (coefficient=0.38, 95% CI (0.13, 0.63) and women empowerment score ≥6 (coefficient=0.30, 95% CI (0.13, 0.48) were positively associated with MUAC. However, fasting (coefficient=-0.27, 95% CI (-0.51, -0.03) and agrobiodiversity score <2 (coefficient=-0.61, 95% CI (-1.07, -0.15) were negatively associated with MUAC. The model explained 38.5% of the variation in MUAC.

Results of Poisson regression analysis are shown in Table 5. Not being from a model household (IRR=1.61, 95% CI (1.26, 2.06), not being empowered woman (IRR=2.68, 95% CI (1.58, 4.52), food insecurity (IRR=1.65, 95% CI (1.38, 1.97), and inadequate dietary diversity (IRR=1.66, 95% CI (1.38, 2.00) were associated with higher incidence rate ratio of pre-pregnancy undernutrition defined as BMI <18.5 kg/m^2. All these variables were also associated with pre-pregnancy undernutrition, defined as MUAC <21.0 cm.

Table 3. Reproductive and obstetric conditions, food and dietary as well as psychosocial characteristics of women (n=991), Tigray region, northern Ethiopia, 2018

Reproductive and obstetric conditions	**n (%)/mean (SD) / Median (IQR)**
Gestational age at inclusion in weeks	14.8 (1.9)
≤16 weeks of gestation at inclusion	874 (88.2%)
Age at first marriage	18 (17-20)
Gravidity before the index pregnancy	2 (1-4)
Parity before the index pregnancy	2 (1-4)
Age at first birth (n=795)	19.9 (2.8)
Previous inter-birth spacing in months (n=607)	38 (30-48)
History of at least one adverse birth outcome	208 (21.0%)
Women empowerment score	5.6 (1.5)
Empowered women	114 (11.5%)
Intimate partner violence score	6.9 (3.0)
Experienced intimate partner violence	161 (16.2%)
Food and dietary characteristics	
Meal frequency (times per day)	3.3 (0.6)
Meal frequency ≥3 times per day	661 (72.1%)
Fruits intake (times per month)	2 (1-4)
Fruits intake ≥3 times per week	57 (5.7%)
Vegetables intake (times per month)	4 (4-8)
Vegetables intake ≥3 times per week	93 (9.4%)
Animal-source food intake (times per month)	4 (1-8)
Animal-source food intake ≥3 times per week	240 (24.3%)
Alcohol intake at least one unit (times per month)	1 (0-3)
Alcohol intake at least one unit ≥1 time per week	233 (23.5%)
Coffee intake (times per day)	1.4 (1.0)
Coffee intake ≥1 time per day	782 (78.9%)
Dietary diversity score	4.6 (1.4)
Adequate dietary diversity	518 (52.3%)
Fasting	694 (70.0%)
Agrobiodiversity score	2 (0-4)
Harvest volume in quintals	2.5 (0-6)
Food insecurity score	0 (0-8)
Food insecure	392 (39.6%)
Psychosocial characteristics	
Total social support score	21.3 (3.8)
Low total social support score	75 (7.6%)
Total distress score	19.1 (9.7)
Level of distress	
Not distressed at all	550 (55.5%)
Distressed in one domain	217 (21.9%)
Distressed in two domains	130 (13.1%)
Distressed in three domains	94 (9.5%)

Table 4. Unadjusted and adjusted linear regression analysis of factors associated with mean pre-pregnancy BMI and MUAC of women (n=991), Tigray region, northern Ethiopia, 2018

Characteristics	Mean BMI difference in kg/m² (95% CI)				Mean MUAC difference in cm (95% CI)			
	Unadjusted	p-value	Adjusted*	p-value	Unadjusted	p-value	Adjusted*	p-value
Age <30[a]	0.06 (-0.001, 0.12)	.054	0.08 (0.03, 0.14)	**.004**	0.06 (-0.003, 0.12)	.064	0.08 (0.02, 0.14)	**.005**
Age ≥30[b]	-0.06 (-0.10, -0.02)	.004	-0.01 (-0.04, 0.02)	.463	-0.06 (-0.10, -0.02)	.005	-0.01 (-0.04, 0.02)	.476
Educational status								
No formal education	-0.87 (-1.18, -0.56)	.000	0.21 (-0.11, 0.54)	.805	-0.83 (-1.14, -0.53)	.000	0.22 (-0.10, 0.55)	.177
Primary education	-0.45 (-0.76, -0.14)	.004	0.11 (-0.18, 0.40)	.444	-0.43 (-0.74, -0.13)	.006	0.12 (-0.17, 0.40)	.415
Secondary education and above	Reference	-	Reference	-	Reference	-	Reference	-
Wealth index								
Lowest	-0.54 (-0.93, -0.14)	.008	0.11 (-0.22, 0.43)	.514	-0.52 (-0.91, -0.13)	.009	0.10 (-0.22, 0.42)	.531
Low	-0.33 (-0.73, 0.07)	.101	0.21 (-0.11, 0.53)	.198	-0.31 (-0.70, 0.08)	.124	0.22 (-0.10, 0.53)	.180
Middle	-0.38 (-0.78, 0.01)	.056	0.04 (-0.27, 0.35)	.817	-0.36 (-0.74, 0.03)	.070	0.05 (-0.27, 0.36)	.766
High	-0.49 (-0.90, -0.08)	.020	0.004 (-0.33, 0.34)	.982	-0.51 (-0.91, -0.10)	.015	-0.04 (-0.37, 0.30)	.832
Highest	Reference	-	Reference	-	Reference	-	Reference	-
Being from a model household	1.02 (0.74, 1.29)	.000	0.40 (0.15, 0.66)	**.002**	0.99 (0.72, 1.27)	.000	0.38 (0.13, 0.63)	**.003**
Women empowerment score <6[a]	-0.18 (-0.35, -0.01)	.039	-0.05 (-0.20, 0.10)	.537	-0.16 (-0.33, 0.001)	.052	-0.04 (-0.19, 0.11)	.957
Women empowerment score ≥6[b]	0.35 (0.17, 0.53)	.000	0.35 (0.18, 0.53)	**.000**	0.30 (0.12, 0.48)	.001	0.30 (0.13, 0.48)	**.001**
Intimate partner violence score	-0.17 (-0.20, -0.13)	.000	-0.03 (-0.07, 0.01)	.092	-0.16 (-0.20, -0.12)	.000	-0.03 (-0.07, -0.004)	.080
Dietary diversity score	0.48 (0.40, 0.57)	.000	0.13 (0.05, 0.22)	**.002**	0.46 (0.38, 0.55)	.000	0.12 (0.04, 0.21)	**.004**
Fasting	-0.78 (-1.06, -0.51)	.000	-0.26 (-0.50, -0.02)	**.036**	-0.77 (-1.04, -0.50)	.000	-0.27 (-0.51, -0.03)	**.028**
Agrobiodiversity score <2 groups[a]	-0.55 (-1.08, -0.01)	.044	-0.62 (-1.07, -0.16)	**.008**	-0.53 (-1.06, -0.01)	.052	-0.61 (-1.07, -0.15)	**.010**
Agrobiodiversity score ≥2 groups[b]	0.24 (0.12, 0.36)	.000	-0.02 (-1.07, -0.16)	.648	0.25 (0.13, 0.37)	.000	-0.002 (-0.10, 0.09)	.969
Food insecurity score	-0.16 (-0.19, -0.14)	.000	-0.07 (-0.10, -0.05)	**.001**	-0.16 (-0.18, -0.14)	.000	-0.07 (-0.09, -0.05)	**.000**

*Additionally adjusted for total distress score, total social support score, access to health service within one hour, and time to fetch improved drinking water within 30 minutes. [a&b] represent the two continuous variables below and greater than or equal to the knot value respectively. BMI; body mass index, MUAC; mid-upper arm circumference, and CI; confidence interval.

Table 5. Unadjusted and adjusted Poisson regression analysis of factors associated with pre-pregnancy undernutrition as assessed by BMI and MUAC (n=991), Tigray region, northern Ethiopia, 2018

Characteristics	Undernutrition (pre-pregnancy BMI <18.5 kg/m^2)				Undernutrition (MUAC <21.0 cm)			
	Unadjusted IRR	**p-value**	**Adjusted IRR***	**p-value**	**Unadjusted IRR**	**p-value**	**Adjusted IRR***	**p-value**
Educational status								
No formal education	1.51 (1.22, 1.86)	.000	0.94 (0.78, 1.13)	.499	1.66 (1.22, 2.25)	.001	0.89 (0.66, 1.18)	.410
Primary education	1.15 (0.91, 1.45)	.241	0.94 (0.77, 1.15)	.457	0.99 (0.69, 1.40)	.934	0.75 (0.54, 1.04)	.089
Secondary education and above	Reference	-	Reference	-	Reference	-	Reference	-
Not being from a model household	2.04 (1.57, 2.66)	.000	1.61 (1.26, 2.06)	**.000**	2.40 (1.61, 3.58)	.000	1.74 (1.19, 2.53)	**.004**
History of pre-pregnancy illness	1.37 (1.13, 1.67)	.002	1.16 (0.96, 1.40)	.126	1.48 (1.10, 1.99)	.010	1.11 (0.81, 1.50)	.520
Not being empowered woman	4.11 (2.33, 7.26)	.000	2.68 (1.58, 4.52)	**.000**	4.25 (1.93, 9.35)	.000	2.44 (1.22, 4.89)	**.012**
Experiencing intimate partner violence	1.88 (1.60, 2.21)	.000	1.10 (0.92, 1.30)	.302	2.23 (1.74, 2.86)	.000	1.06 (0.80, 1.39)	.691
Food insecure	2.60 (2.19, 3.09)	.000	1.65 (1.38, 1.97)	**.000**	3.45 (2.63, 4.52)	.000	1.89 (1.41, 2.51)	**.000**
Fasting	1.40 (1.14, 1.72)	.001	1.11 (0.93, 1.323)	.254	1.54 (1.13, 2.09)	.006	1.16 (0.87, 1.53)	.314
Inadequate dietary diversity	2.51 (2.08, 3.03)	.000	1.66 (1.38, 2.00)	**.000**	3.16 (2.36, 4.22)	.000	1.80 (1.35, 2.42)	**.000**

*Additionally adjusted for level of distress, total social support, access to health service within one hour, and time to fetch improved drinking water within 30 minutes. BMI; body mass index, MUAC; mid-upper arm circumference, and IRR; incidence rate ratio.

Discussion

We performed a population-based study to determine factors associated with pre-pregnancy nutritional status in 991 pregnant women in northern Ethiopia. A considerable part of the women included in the study did not have optimal nutritional status. Overall, nearly one-third were undernourished before pregnancy. These numbers are higher than the national prevalence (22%) but comparable to data reported as the regional prevalence in Tigray (32%),[14] and for Africa as a whole (32%).[16] In the present study, we were able to identify a wide range of factors that contribute to the persistence of highly prevalent pre-pregnancy undernutrition. Our findings signal that the identified opportunity to curb the trans-generational cycle of malnutrition before pregnancy is not effectively used in developing countries like Ethiopia. Our results may also offer directions and possibilities for targeted interventions to improve the situation.

Age until 29 years was positively associated with pre-pregnancy nutritional status and negatively but insignificantly after 29. This finding implies an association between lower age and lower pre-pregnancy nutritional status. Lower schooling, socioeconomic status and dietary practice could partly explain the relation between lower age and lower nutritional status. Similar finding has been reported by studies in Ethiopia.[50,51]

Being from a model household, a proxy for implementing the so-called health extension package, was positively associated with pre-pregnancy nutritional status. A model household received short-term training on the health extension package, comprising several components including maternal health, family planning, nutrition and sanitation. After the training, implementation of the package was required to be labeled as a model household. In addition, health extension workers educate women, individually at their home and in a group at a health post, on maternal health including nutrition during their pregnancy. Therefore, it is likely that the observed association between implementation of the health extension package and better nutritional status is at least in part explained by the effect of the training on dietary practices and the impact of implementing the package on the overall health of the women.[52–55] This promising finding suggests that strengthening the health extension program may be a good approach to improving maternal nutritional status.

Moreover, a higher women empowerment score was associated with higher pre-pregnancy nutritional status in the present study, which is in line with the literature.[23,56,57] This may be partly explained by the effect of women empowerment on access to food, dietary practice, and seeking healthcare.[58–64] Therefore, the observed association reflects the importance of considering women empowerment in confronting maternal undernutrition and its consequent effects. In short, finding a means for improving the women's social, economic, political, and legal strength, ensuring equal rights for women, and making them confident enough to claim these rights, such as purchasing resources they want and using health care they need, may be helpful.

In congruence with the literature, we observed a positive association between dietary diversity and pre-pregnancy nutritional status.[19,65,66] As dietary diversity is seen as a proxy of dietary quality, higher dietary diversity can translate to better nutritional status.[67] Likewise, the negative association found between food insecurity and pre-pregnancy nutritional status, consistent with the literature,[19,68,69] could be explained by inadequate dietary intake or quality due to lack of access to food.[70–73] Also, a lower agrobiodiversity score was negatively associated with pre-pregnancy nutritional status. Though previous findings are mixed, as shown in a recent review,[74] the observed association may suggest that a slight change in agrobiodiversity is not enough to positively impact maternal diet and nutrition. Moreover, it may be related to the opportunity costs of farm specialization due to the foregone gains from diversification.

Our study also revealed that fasting was negatively associated with pre-pregnancy nutritional status, which corresponds with a previous study among lactating women.[50] Almost all the women involved in our study were Orthodox Christians, and in this religion, more than half of the days in a full year are fasting times. This includes regular fasting days almost every Wednesday and Friday throughout the year. The long fasting periods include the 40-day Christmas fast, the 55-day of Lenten fast, at least 14 days for the Apostles fast, and 14-day Dormition fast. People are expected to abstain from animal-source foods for religious reasons during these times. This could result in poor dietary quality and poor nutritional status.[75,76] This finding highlights the importance of considering nutrition-sensitive religious practices as part of the efforts to improve maternal nutrition.

The present study's findings indicate that coordinated and considerable efforts of different bodies and functions might be needed to address pre-pregnancy undernutrition. For instance, involving the agricultural sector in mounting better access to food and involving the justice sector in tackling domestic violence may be helpful. Also, though the Orthodox Church nowadays shows flexibility on fasting during pregnancy, most pregnant women still adhere to fasting for religious reasons. Maintaining this practice will counteract other measures to solve pre-pregnancy undernutrition. Moreover, physical work like farming activities is not allowed on almost half of the days in a year, i.e., all saints' days and the weekends, which may worsen food insecurity and dietary quality. Thus, involving religious leaders to improve pre-pregnancy maternal nutrition could be supportive.

Strengths and limitations

Our study has some strengths and limitations. Using weight measured during a distinct period before starting recruitment of pregnant women, including a relatively large sample of women, and collecting information on many possible confounders can be considered strengths. As for limitations, MUAC was measured at inclusion, unlike BMI, but as MUAC is relatively insensitive to change over time it can safely represent the pre-pregnancy status.[17,18] Additionally, seasonal variation was not addressed in the dietary diversity measurements. However, agrobiodiversity and food insecurity have been assessed, and adjusting for these variables may account for the bias that can be introduced due to the seasonal variation. Therefore, we do not believe that these limitations have seriously affected the generalizability of our findings. Finally, our study might not have been free of type one error due to the multiple hypothesis testing.

Conclusions

Pre-pregnancy undernutrition was prevalent in the women living in the study area. The findings of the present study suggest that considerable improvements could be made by advancing community awareness related to dietary practice and habits, also in the area of gender equality. Empowering females, raising agricultural productivity and broader implementation of the health extension package are all factors that may improve maternal nutritional status. In the Ethiopian setting, this would require the coordinated efforts of concerned bodies, including religious leaders.

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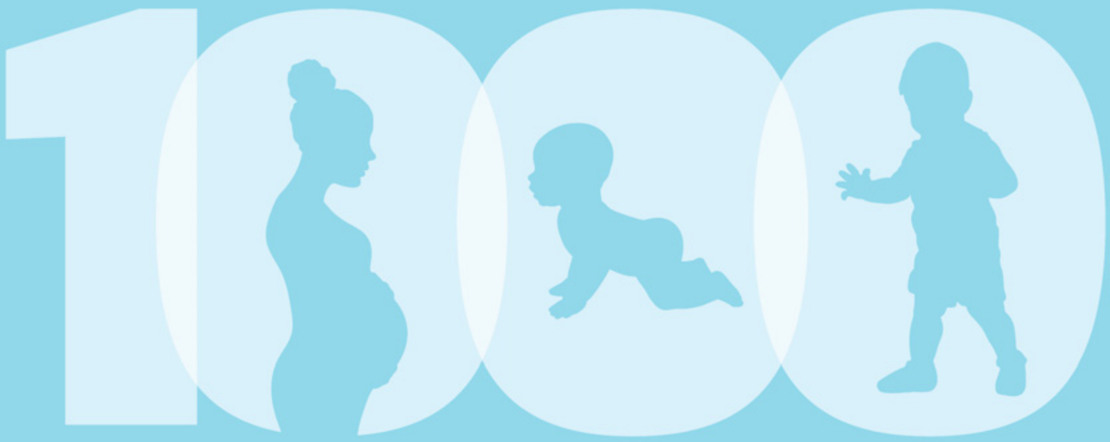
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