BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-043484
Article Type:	Original research
Date Submitted by the Author:	05-Aug-2020

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Keywords:	Nutrition < TROPICAL MEDICINE, Antenatal < GENETICS, Public health < INFECTIOUS DISEASES

What factors determine pre-pregnancy nutritional status? A prospective study in Tigrai regional state, Northern Ethiopia

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Word count: abstract-293, and main text (introduction, methods, results, discussion and conclusion)- 3931

ABSTRACT

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

Design: Population-based prospective study

Setting: Kilite-Awlaelo Health and Demographic Surveillance Site, Eastern Zone of Tigrai 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 baseline. Subsequently, 991 women who became pregnant were included consecutively between February and September 2018. Eligible women were married, aged 18 or older, whose pre-pregnancy weight was measured, and had completed ≤ 20 weeks of gestation at enrolment.

Outcome measures: Outcome measure was pre-pregnancy nutritional status as assessed by body mass index (BMI), and mid-upper arm circumference (MUAC), with undernutrition defined as BMI < 18.5 kg/m^2 and/or MUAC < 21.0 cm. BMI was calculated from weight measured before pregnancy, and MUAC was measured at inclusion. Linear and spline regressions were used to identify factors that determine pre-pregnancy nutritional status.

Results: A total of 991 women were included at an average of 14.8 (±1.9) weeks of gestation. The mean pre-pregnancy BMI and MUAC were 19.7 (±2.0) kg/m^2 and 22.6 (±1.9) cm, respectively. Overall, the prevalence of pre-pregnancy undernutrition was 36.2%. Not being from a model household, lower values of women empowerment score, intimate partner violence, food insecurity, lower dietary diversity, regular fasting, and low agrobiodiversity showed significant associations with lower BMI and MUAC.

Conclusion: The prevalence of pre-pregnancy undernutrition in our study population was very high. 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. In the Ethiopian setting, such changes require the coordinated efforts of concerned governmental bodies and religious leaders.

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

Strengths and limitations of this study

- Measuring weight in a distinct period before starting inclusion of women, and
- Including relatively a large sample of women as well as collecting information on many possible confounders can be considered as strengths.
- As for limitations, MUAC was measured at inclusion unlike to BMI, but as it is insensitive to change overtime it can safely represent the pre-pregnancy status.[17,18]
- Finally, seasonal variation was not considered in dietary diversity measures.

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 for their offspring.[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 low 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% pregnant women were undernourished (MUAC < 21 cm) in Africa;[16] reflective of pre-pregnancy nutritional status for the fact that MUAC is insensitive to change.[17,18] In Ethiopia, the prevalence of undernutrition among 14,505 non-pregnant women of reproductive age involved in the 2011 demographic and health survey was 27%.[14] The problem may be even more profound in Tigrai, 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 Tigrai, the prevalence of undernutrition was about 48%.[19] These studies support the significant importance for public health of pre-pregnancy undernutrition and indicate a 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 determinants of pre-pregnancy nutritional status in low-income countries like Ethiopia in detail. The previous studies also did not control for potential confounders like physical activity, work burden, agrobiodiversity and psychosocial characteristics. Fasting (abstaining from animal-source foods during fasting times for religious reasons) may also influence pre-pregnancy nutritional status but was not assessed. Additionally, the influence of implementation of a health extension package, that is, if the women's respective households received short-term training on a health extension package and implemented the package after the training,[25–27] was not studied well. 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 dwellers or population groups with different socioeconomic and cultural characteristics. For instance, a recent study in Ethiopia included an urban population and assessed the influence of common socioeconomic variables only and therefore does not represent the large majority of the population, living under rural conditions.[22] One previous study in the Kunama population, Tigrai region, was again limited to a subgroup, consisting of a specific small ethnic clan with a different sociocultural context.[19] Knowledge about factors associated with pre-pregnancy nutritional status among women of reproductive age, the target population for interventions to achieve improvement, in countries like Ethiopia is therefore limited. This study was aimed to assess a wide range of determinants of pre-pregnancy nutritional status, a key step towards identifying possible targets for intervention and support to improve maternal and child health outcomes, in both rural and urban areas of Northern Ethiopia.

METHODS

Study design, setting, and population

The present study, a part of an ongoing population-based prospective study, was conducted in Kilite-Awilaelo Health and Demographic Surveillance Site (KA-HDSS) between February and September 2018. The prospective study was designed to assess maternal nutrition, adverse birth outcomes, and child growth. KA-HDSS is located in the Eastern Zone of Tigrai region, Northern Ethiopia. The surveillance site consists of ten rural and three urban kebeles (the smallest administrative units) from 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 at least the population of Tigrai region.

The total population of the KA-HDSS is 113,760. With 24% of the population being reproductive age women, about 4,550 pregnancies are expected per year within the KA-HDSS. Most of the population lives under rural conditions and agriculture is the major source of income. Ethiopia has a three-tier health care system with health posts in the forefront of primary care. Each kebele has one health post staffed by two to three health extension workers. Health posts provide promotional and preventive services under the umbrella of the 'health extension program' mainly at a household level. The program consists of a package 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. Eligible women were married, aged 18 or older, whose pre-pregnancy weight was measured, and who completed ≤ 20 weeks of gestation at enrolment. The sample size was calculated to address the objectives of the prospective study. 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] Including an estimated 10% drop out rate, the total sample size was calculated at 1,100. With this sample size, effect sizes > 0.2 standard deviations could be detected. All eligible pregnant women identified during the study period were included consecutively.

Measurements

Pre-pregnancy weight of women (N=17,500) living in the study area was measured between August and October 2017 using a Seca scale to the nearest 100 g. Subsequently, identification and inclusion of pregnant women took place. At inclusion, data were collected by interviewer-administered questionnaire, anthropometric measurements as per standard techniques and extracting data available in the KA-DHSS database. The questionnaire was adapted from the literature,[7,14,29–33] and pretested on 55 pregnant women selected based on their accessibility in Tahtay-Maichew, Central Zone, Tigrai region. Data were collected by qualified health extension workers and the data collection included:

Socioeconomic variables: Age, residence, religion, education, occupation, family size and wealth index were extracted from the KA-DHSS database. Also, self-reported access to health facility, work burden, physical activity and history of illness were collected. Moreover, implementation of health extension package was assessed by checking if the women's respective households were certified as a model; a household that received short-term training on and implemented the package after the training.[25–27]

Wealth index was assessed by asking 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, wealth index was categorized into quintiles designating poorest to richest economic status.[34]

Physical activity data was obtained using the International Physical Activity Questionnaire (IPAQ)-short form,[33,35] 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 summarized as per algorism described in the scoring protocol.[35]

Reproductive and obstetric conditions: Gravidity, parity, and history of abortion and stillbirth were extracted from the database. Additionally, self-reported intimate partner violence was obtained using the four-item HITS (Hurt, Insult, Threaten and Scream) questions each rated from 1 to 5, and scoring > 10 was used as an indicative of violence.[36] Women were also asked nine questions addressing five domains: earning and control over income (relative income to husband, control over men's income, and control over women's income); decision-making on household purchases; mobility and health care autonomy (decision-making on family visits, and women's own health); attitude towards domestic violence; and ownership of assets (farmland, and house).[14,23,37] Coding each as 0 or 1 and totaling the questions up, 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% were considered as empowered.[38]

Food and diet: Self-reported agrobiodiversity, harvest volume, food insecurity, dietary diversity, fasting, and frequencies of vegetables, fruits, animals-source food, alcohol and coffee intake were obtained. Related to agrobiodiversity, women were queried a list of crops and livestock products their respective households produced in the preceding year with a 'yes' or 'no' options. Then, grouping the products as cereals, roots and tubers; pulses; oil seeds; fruits; vegetables; dairy; egg; and meat and poultry, total score out of eight was attained.[39]

As to dietary diversity, a 24 h data was collected by asking women a list of foods organized in groups with a 'yes' or 'no' response options.[32] Next, foods consumed by the women were categorized into ten: 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. Scoring five or more groups was, then, defined as adequate dietary diversity.[32]

Food insecurity was assessed using the Household Food Insecurity Access Scale.[31] That is, women were asked nine occurrence questions eliciting a 'yes' or 'no' response. Each positive response was followed by a frequency-of-occurrence question asking how often the reported food insecurity associated condition happened in the previous month; (1) rarely, 2) sometimes or 3) often). Then, the sum of the frequency-of-occurrence questions yielded food insecurity score ranging from 0 to 27. Households experienced none of the food insecurity conditions, or just experienced worry, but rarely were classified as food secure.[31]

Psychosocial characteristics: Partner support was measured by the five-item Turner Support Scale each scored from 0 to 3.[40] Also, social support from significant others was assessed using Oslo-3 Social Support Scale with total scores in the range of 3 to 14.[41] Moreover, the ten-item Edinburgh Postnatal Depression Scale and the seven-item anxiety subscale of Hospital Anxiety and Depression Scale with each item in both scales rated from 0 to 3 were used to measure depression and anxiety.[42,43] For stress, the four-item Perceived Stress Scale each scored from 0 to 4 was used.[44]

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 (BMI=18.5 to 24.9) or overweight (BMI $\geq$ 25.0). Likewise, MUAC $<$ 21.0 cm was used to define undernutrition.[45]

Data quality control

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

Statistical analysis

Data were entered to Epi-Data 3.3, verified by re-entering 20% of the filled-in questionnaires selected at random, and analyzed with STATA (Version 11, Stata Corporation, and College Station, Texas, USA). Proportions and means with standard deviations (SD) or medians with interquartile ranges (IQR) were used to summarize the characteristics of the participants.

Non-linear associations between BMI and MUAC, and the independent variables were investigated, and piecewise 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 independent variables. If this test suggested non-linearity, two new continuous variables were created by partitioning each independent variable at the knot value (K) into two using piecewise regression. The first representing the effect of the variable below K and the second the effect at values greater than or equal to K.[46] The knot value for each variable was roughly estimated by viewing the spline regression curves. After that, the knot value resulting in the best fit piecewise model; a model with lowest mean squared of errors, was determined by checking the different values around the value(s) where the knot was estimated to occur. Then, regressing the two new variables and their respective intercepts against the corresponding dependent variable, we tested if the slopes of the two variables were different (test $X< K= X \geq K$). If the test was significant ($p< 0.05$) showing inequality of the slopes, we concluded that the association was non-linear. Finally, comparing piecewise, quadratic and cubic models, one that fits best, as apparent by the lowest root mean squared of errors, was considered in the analysis. In the case of piecewise, 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 determinants of BMI and MUAC. First, separate domain-specific multivariable models were fitted to evaluate the variation explained by each domain of variables. At this stage, variables from the respective domains with a statistically significant association ($P<0.05$, two-sided) in the univariable analysis were included. Lastly, we fitted final multivariable linear regression models including all variables across the domains with a statistically significant association in the univariable analysis to identify the determinants. Residence, occupation, parity and harvest volume were highly correlated with other variables and had 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. Yet, none of the interactions were significant or improved the models and these were therefore not reported. As for model diagnostic tests, multicollinearity was checked using variance inflation factor, and normality of residuals with histograms, and normal probability and quantile-quantile plots. Also, specification error and omitted variable bias were tested using the linktest and ovtest commands.

RESULTS

A total of 991 women were included and their anthropometric measures by BMI categories are summarized in table 1. The mean pre-pregnancy nutritional status of the participating women as assessed by BMI and MUAC were 19.7 (±2.0) kg/m^2 and 22.6 (±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).

Table 1 Anthropometric measures by BMI categories of women (n=991), Tigrai 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	157.0 (±0.1)	135.2 – 175.8	157.8 (±0.1)	132.6 – 181.2	158.8 (±0.1)	152.3 – 168.6	157.5 (±0.1	132.6 – 181.2
Pre-pregnancy weight, kg	43.8 (±4.3)	31.8 – 54.0	51.9 (±5.7)	33.3 – 72.9	64.1 (±5.3)	58.9 – 71.8	49.0 (±6.6)	31.8 – 71.8
Weight at inclusion, kg (n=990)	46.1 (±4.3)	34.2 – 57.1	54.4 (±5.9)	36.6 –75.7	66.6 (±5.5)	60.3 – 73.0	51.4 (± 6.7)	34.2 – 75.7
MUAC at inclusion, cm	20.7 (±0.9)	17.5 – 22.0	23.6 (±1.4)	18.4 – 27.8	28.4 (±1.1)	26.8 – 29.6	22.6 (±1.9)	17.5 – 29.6
Proportion, n (%)	359 (36.2%)		627 (63.3%)		5 (0.5%)		991 (100%)	

Socioeconomic characteristics of the participants are presented in table 2. On average, the women were 29.3 (± 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 univariable analysis, better socioeconomic circumstances, and lower physical activity were associated with higher BMI and MUAC (tables 4 and 5).

Table 2 Socioeconomic characteristics of women and their households (n=991), Tigrai region, Northern Ethiopia, 2018

Characteristics	n (%)/mean (± SD) /median (IQR)
Age at inclusion	29.3 (±6.5)
Residence, rural	647 (65.3%)
Religion	
Orthodox Christian	977 (98.6%)
Others (Muslim and catholic)	14 (1.4%)
Education	
No formal education	362 (36.5%)
Primary education	326 (32.9%)
Secondary education and above	250 (25.2%)
Above secondary education	53 (5.4%)
Occupation	
Farmer	541 (54.6%)
Housewife	337 (34.0%)
Employed	91 (9.2%)
Student, unemployed or others	22 (2.2%)
Education of husband	
No formal education	320 (32.3%)
Primary education	366 (36.9%)
Secondary education	196 (19.8%)
Above secondary education	109 (11.0%)
Occupation of husband	
Farmer	515 (52.0%)
Employed	222 (22.4%)
Daily labourer	161 (16.2%)
Drivers, students, unemployed, or 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 quintiles	
Lowest (Poorest)	198 (20.0%)
Second	199 (20.1%)
Middle	198 (20.0%)
Fourth	196 (19.7%)
Highest (Richest)	200 (20.2%)
Model household, yes	242 (24.4%)
Time to go to the nearest health facility and back home	35 (IQR=25-75) minutes

Access to health service within 1 h, yes	693 (69.8%)
History of pre-pregnancy illness, yes	142 (14.3%)
Access to improved drinking water, yes*	888 (89.6%)
Access to fetching water within 15 minutes, yes	519 (52.4%)
Access to improved sanitation facility, yes**	135 (13.6%)

*Improved drinking water sources refers to piped water on premises, public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs and/or rainwater collection, and ** improved sanitation facility refers to unshared toilet facility; pit latrine with a slab, ventilated improved pit latrine or flush toilet

Table 3 depicts reproductive and obstetric conditions, food and dietary and psychosocial characteristics of the participants. At inclusion, the mean gestational age was 14.8 (±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 75 (7.6%) were empowered. Additionally, the prevalence of intimate partner violence among the 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 (tables 4 and 5).

As shown in table 3, the food and dietary characteristics of most women were poor. Less than 10% women consumed fruits and vegetables three times or more per week. Overall, 518 (52.3%) women had an adequate dietary diversity. With reference to dietary habits, most women (70.0%) fasted during both weekly and longer fasting times like during the Lent time. In addition, 392 (39.6%) women did not have adequate food security. In the univariable analysis, higher dietary diversity and agrobiodiversity showed significant associations with higher BMI and MUAC. Higher coffee intake, fasting, and food insecurity were associated with lower BMI and MUAC (tables 4 and 5).

Furthermore, psychosocial problems were widespread among the women as indicated in table 3. More than one in five women had high symptoms at least in one of the common mental disorders; depression, anxiety and stress. Concerning support from others, 115 (11.6%) reported low support from partner and 378 (38.1%) from significant others. In the unadjusted analysis, significant associations between higher symptoms of common mental disorders, and lower BMI and MUAC were observed. Additionally, higher support from partner and significant other was associated with higher BMI and MUAC (tables 4 and 5).

Table 3 Reproductive and obstetric conditions, food and dietary as well as psychosocial characteristics of women (n=991), Tigrai 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 (IQR=17-20)
Gravidity before the index pregnancy	2 (IQR=1-4)
Parity before the index pregnancy	2 (IQR=1-4)

Age at first birth (n=795)	19.9 (±2.8)
Previous inter-birth spacing in months (n=607)	38 (IQR=30-48)
History of at least one adverse birth outcome*	208 (21.0%)
Women empowerment score	5.6 (±1.5)
Empowered women	75 (7.6%)
Intimate partner violence score	6.9 (±3.0)
Intimate partner violence score > 10	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 (IQR=1-4)
Fruits intake ≥ 3 times per week	57 (5.7%)
Vegetables intake (times per month)	4 (IQR=4-8)
Vegetables intake ≥ 3 times per week	93 (9.4%)
Animal-source food intake (times per month)	4 (IQR=1-8)
Animal-source food intake ≥ 3 times per week	240 (24.3%)
Alcohol intake at least one unit (times per month)	1 (IQR=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 (total score ≥ 5)	518 (52.3%)
Fasting, yes	694 (70.0%)
Agrobiodiversity score	2 (IQR=0-4)
Harvest volume in quintals	2.5 (IQR=0-6)
Food insecurity score	0 (IQR=0-8)
Food insecure	392 (39.6%)
Psychosocial characteristics	
Total depression score	8.0 (±4.7)
High depressive symptoms (total score ≥ 13)	204 (20.6%)
Total anxiety score	4.8 (±3.8)
High anxiety symptoms (total score ≥ 8)	224 (22.6%)
Total perceived stress score	6.4 (±2.7)
High symptoms of perceived stress (total score ≥ 8)	331 (33.4%)
Total partner support score	11.9 (±2.7)
Low partner support (total score < 10)	115 (11.6%)
Total social support score from significant others	9.4 (±2.0)
Low social support from significant others (total score ≤ 8)	378 (38.1%)

*includes abortion, stillbirth, Cesarean section, preterm birth or severe perinatal hemorrhage

Results of univariable and multivariable analysis are shown in tables 4 and 5. In the adjusted model, age < 30 years (coefficient =0.08, 95% CI (0.02, 0.14) and being from a model household (coefficient =0.38, 95% CI (0.12, 0.64) were associated with BMI. Also, women empowerment score ≥ 6 (coefficient =0.26, 95% CI (0.09, 0.43) and intimate partner violence (coefficient =-0.05, 95% CI (-0.09, -0.004) were associated with BMI. From the food and dietary domain, dietary diversity (coefficient =0.11, 95% CI (0.02, 0.20), fasting (coefficient =-0.29, 95% CI (-0.54, -0.04), agrobiodiversity score < 2 (coefficient =-0.49 (-0.96, -0.02) and food insecurity (coefficient =-0.07, 95% CI (-0.09, -0.05) were associated with BMI. In total, the model explained 43.3% of variation (Table 4). In the domain-specific models, the food and dietary domain explained the highest variation (supplementary table).

Table 4 Univariable and multivariable linear regression analysis of determinants of mean pre-pregnancy BMI of women (n=991), Tigrai region, Northern Ethiopia, 2018

Characteristics	Mean BMI difference in kg/m^2 (95% CI)			
	Unadjusted	P-value	Adjusted*	P-value
Age < 30[a]	0.06 (-0.00, 0.12)	.054	0.08 (0.02, 0.14)	**.006**
Age ≥ 30[b]	-0.06 (-0.10, -0.02)	.004	-0.02 (-0.06, -0.03)	.438
Educational status				
No formal education	-0.42 (-0.69, -0.14)	.003	0.55 (-0.10, 1.21)	.099
Primary education	Reference	-	0.36 (-0.27, 0.99)	.262
Secondary education	0.32 (-0.02, 0.66)	.062	0.34 (-0.29, 0.97)	.291
Above secondary	1.07 (0.56, 1.58)	<.001	Reference	-
Occupation of husband				
Farmer	-0.84 (-1.30, -0.38)	<.001	Reference	-
Employed	0.40 (-0.11, 0.92)	.126	0.13 (-0.30, 0.56)	.555
Daily laborer	-0.35 (-0.89, 0.19)	.199	0.20 (-0.14, 0.53)	.248
Others	Reference	-	0.05 (-0.45, 0.55)	.850
Wealth index				
Poorest	-0.65 (-1.03, -0.28)	.001	Reference	
Second poor	-0.27 (-0.65, 0.10)	.157	0.11 (-0.13, 0.35)	.366
Middle	Reference	-	0.11 (-0.14, 0.36)	.399
Second rich	0.42 (0.05, 0.80)	.028	0.02 (-0.38, 0.42)	.924
Richest	0.73 (0.36, 1.10)	<.001	0.12 (-0.35, 0.59)	.609
Physical activity				
Low	1.29 (0.67, 1.91)	<.001	0.35 (-0.05, 0.75)	.089
Moderate	0.46 (-0.17, 1.09)	.153	0.16 (-0.21, 0.53)	.401
High	Reference	-	Reference	-
Model household, yes	1.02 (0.74, -1.29)	<.001	0.38 (0.12, 0.64)	**.004**
Women empowerment score < 6[a]	-0.18 (-0.35, -0.01)	.039	-0.05 (-0.20, 0.10)	.506
Women empowerment score ≥ 6[b]	0.35 (0.17, 0.53)	<.001	0.26 (0.09, 0.43)	**.003**
Intimate partner violence score	-0.16 (-0.20, -0.12)	<.001	-0.05 (-0.09, -0.004)	**.030**
Coffee intake per day < 2 times[a]	0.25 (-0.11, 0.60)	.176	0.11 (-0.40, 0.62)	.673
Coffee intake per day ≥ 2 times[b]	-0.40 (-0.74, -0.07)	.018	-0.35 (-0.85, 0.14)	.157
Dietary diversity score	0.48 (0.40, 0.57)	<.001	0.11 (0.02, 0.20)	**.020**
Fasting, yes	-0.78 (-1.06, -0.51)	<.001	-0.29 (-0.54, -0.04)	**.023**
Agrobiodiversity score < 2 groups[a]	-0.55 (-1.08, -0.01)	.044	-0.49 (-0.96, -0.02)	**.042**
Agrobiodiversity score ≥ 2 groups[b]	0.24 (0.12, 0.36)	<.001	0.02 (-0.08, 0.11)	.720
Food insecurity score	-0.16 (-0.18, -0.14)	<.001	-0.07 (-0.09, -0.05)	**<.001**
Total anxiety score	-0.15 (-0.18, -0.12)	<.001	-0.03 (-0.07, 0.01)	.133
Perceived stress score	0.17 (-0.12, 0.46)	.246	0.15 (-0.26, 0.56)	.464
Total depression score	-0.11 (-0.13, -0.08)	<.001	0.05 (-0.03, 0.13)	.188
Total social support score	0.30 (0.25, 0.36)	<.001	0.07 (-0.08, 0.23)	.350
Partner support score < 9[a]	-0.18 (-0.45, 0.09)	.185	-0.11 (-0.34, 0.12)	.350
Partnersupport score ≥ 9[b]	0.20 (0.14, 0.26)	<.001	0.03 (-0.03, 0.08)	.351

[a&b] represent the two continuous variables below and greater than or equal to the knot value respectively, and * adjusted for husband education, access to health service and improved drinking water, frequencies of fruit, vegetables, animal-source food and alcohol intake per month and squared and cubed perceived stress.

As for MUAC, all the variables that were associated with BMI were associated with MUAC. Of these, being from a model household (coefficient=0.38, 95% CI (0.12, 0.64), women empowerment score ≥ 6 (coefficient=0.26, 95% CI (0.09, 0.43), fasting (coefficient=-0.29, 95% CI (-0.54, -0.04) and agrobiodiversity score < 2 (coefficient=-0.49, 95% CI (-0.96, -0.02) had a larger effect (Table 5). In total, the final model explained 42.2% of variation. Though the domain-specific models may not show the relative influence, the highest variation was explained by the food and dietary domain (supplementary table).

Table 5 Univariable and multivariable linear regression analysis of determinants of mean pre-pregnancy MUAC of women (n=991), Tigrai region, Northern Ethiopia, 2018

Characteristics	Mean MUAC difference in cm (95% CI)			
	Unadjusted	P-value	Adjusted*	P-value
Age < 30[a]	0.06 (-0.00, 0.12)	.064	0.08 (0.02, 0.14)	**.007**
Age ≥ 30[b]	-0.06 (-0.10, -0.02)	.005	-0.02 (-0.06, 0.03)	.461
Educational status				
No formal education	-0.40 (-0.67, -0.13)	.004	0.53 (-0.12, 1.17)	.107
Primary education	Reference		0.34 (-0.27, 0.96)	.272
Secondary education	0.30 (-0.03, 0.64)	.073	0.32 (-0.29, 0.92)	.307
Above secondary	1.05 (0.55, 1.55)	<.001	Reference	
Occupation of husband				
Farmer	-0.84 (-1.31, -0.38)	<.001	Reference	
Employed	0.36 (-0.16, 0.87)	.180	0.11 (-0.33, 0.55)	.626
Daily laborer	-0.36 (-0.90, 0.18)	.191	0.18 (-0.16, 0.51)	.304
Others	Reference		0.07 (-0.44, 0.58)	.800
Wealth index				
Poorest	-0.65 (-0.99, -0.31)	<.001	Reference	
Second poor	-0.28 (-0.63, 0.07)	.111	0.12 (-0.13, 0.36)	.335
Middle	Reference		0.14 (-0.11, 0.39)	.270
Second rich	0.41 (0.03, 0.80)	.035	0.04 (-0.37, 0.45)	.847
Richest	0.68 (0.29, 1.07)	.001	0.11 (-0.35, 0.58)	.633
Physical activity				
Low	1.26 (0.75, 1.78)	<.001	0.35 (-0.04, 0.75)	.078
Moderate	0.45 (-0.07, 0.96)	.091	0.17 (-0.20, 0.54)	.372
High	Reference		Reference	-
Model household, yes	0.99 (0.72, 1.27)	<.001	0.37 (0.11, 0.62)	**.005**
Women empowerment score < 6[a]	-0.16 (-0.33, 0.001)	.052	-0.04 (-0.19, 0.11)	.621
Women empowerment score ≥ 6[b]	0.30 (0.12, 0.48)	.001	0.21 (0.04, 0.38)	**.015**
Intimate partner violence score	-0.16 (-0.20, -0.12)	<.001	-0.05 (-0.09, -0.01)	**.023**
Dietary diversity score	0.46 (0.37, 0.55)	<.001	0.10 (0.03, 0.19)	**.043**
Fasting, yes	-0.77 (-1.04, -0.50)	<.001	-0.30 (-0.55, -0.05)	**.017**
Coffee intake per day < 2 times[a]	0.27 (-0.09, 0.61)	.152	0.13 (-0.39, 0 64)	.633
Coffee intake per day ≥ 2 times[b]	-0.39 (-0.72, -0.06)	.019	-0.33 (-0.83, 0.17)	.196
Agrobiodiversity score < 2 groups[a]	-0.53 (-1.06, -0.01)	.052	-0.49 (-0.97, -0.01)	**.046**
Agrobiodiversity score ≥ 2 groups[b]	0.25 (0.13, 0.37)	<.001	0.03 (-0.06, 0.13)	.500
Food insecurity score	-0.16 (-0.18, -0.14)	<.001	-0.07 (-0.09, -0.04)	**<.001**
Total anxiety score	-0.15 (-0.18, -0.11)	<.001	-0.03 (-0.07, 0.01)	.099
Perceived stress score	0.18 (-0.11, 0.48)	.220	0.12 (-0.29, 0.53)	.579
Total depression score	-0.11 (-0.13, -0.08)	<.001	0.05 (-0.03,0.13)	.228
Total social support score	0.29 (0.24, 0.35)	<.001	0.04 (-0.11, 0.20)	.595
Partner support score < 9[a]	-0.19 (-0.47, 0.09)	.180	-0.13 (-0.37, 0.12)	.317
Partnersupport score ≥ 9[b]	0.30 (0.12, 0.48)	<.001	0.03 (-0.03, 0.08)	.381

[a&b] represent the two continuous variables below and greater than or equal to the knot value respectively, and * adjusted for husband education, access to health service and improved drinking water, frequencies of fruit, vegetables, animal-source food and alcohol intake per month and squared and cubed perceived stress.

DISCUSSION

We performed a population-based study to determine factors associated with pre-pregnancy nutritional status in 991 pregnant women in Northern Ethiopia. Of the women included in the study, a considerable part 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 for regional prevalence (32%).[14] 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 prior to pregnancy is not effectively used in developing countries like Ethiopia and may also offer directions and possibilities for targeted interventions to improve the situation.

Being from a model household; a proxy for implementation of health extension package, was positively associated with pre-pregnancy nutritional status. A model household is a household that received short-term training on health extension package; a package comprising several components including maternal health, family planning, nutrition, and sanitation, and implemented the package after the training. In addition, health extension workers educate women on maternal health including nutrition during their pregnancy individually at their home and in group at a health post. Therefore, it is likely that the observed association between implementation of health extension package, and higher nutritional status is at least in part explained by the effect of the training on dietary practices and the effect of implementing the package on overall health of the women.[47–50] This promising finding suggests that strengthening the health extension program may be a good approach to improving maternal nutritional status.

Moreover, women empowerment score was associated with higher pre-pregnancy nutritional status in the present study and in line with the literature.[23,51,52] This may be partly explained by the effect of women empowerment on access to food, dietary practice and seeking healthcare.[53–59] Related with this finding, intimate partner violence was negatively associated with pre-pregnancy nutritional status as also reported in similar studies.[60–62] As domestic violence is the reflection of low empowerment, this finding further corroborates the importance of considering women empowerment in confronting maternal undernutrition and its consequent effects. In short, finding a means for improving the social, economic, political, and legal strength of the women, to ensure equal-rights to women, and to make them confident enough to claim these rights, such as purchasing resources they want, 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.[19,63,64] As dietary diversity is seen as a proxy of dietary quality, higher dietary diversity can translate to better nutritional status.[65] Likewise, the negative association found between food insecurity and pre-pregnancy nutritional status, which is consistent with the literature,[19,66,67] could be explained by inadequate dietary intakes or quality due to lack of access to food.[68–71] Also, lower agrobiodiversity score was negatively associated with pre-pregnancy nutritional status. Though previous findings are mixed as shown in a recent review,[72] the observed association may suggest that a small change in agrobiodiversity is not enough to have positive impact on maternal diet and nutrition. Moreover, it may be related to the opportunity costs of farm specialization due to the forgone gains from diversification.

Our study also revealed that fasting was negatively associated with pre-pregnancy nutritional status, which aligns with a prior study among lactating women.[73] Almost all the women that involved in our study were Orthodox Christians, and in this religion more than half of the days in a full year are fasting times. During these times, people are expected to abstain from animal-source foods for religious reasons. This could result in poor dietary quality and nutritional status.[74,75] This finding highlights the importance of considering nutrition-sensitive religious practices as part of the efforts targeting to improve maternal nutrition.

The findings of the present study indicated 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 access to food, and the justice sector in tackling domestic violence may be helpful. Additionally, though the Orthodox Church nowadays is showing flexibility on fasting during pregnancy, most pregnant women still adhere to fasting for religious reasons; this would still not address the issue of 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 possibly worsen food insecurity and dietary quality. Thus, involving religious leaders in efforts targeting to improve pre-pregnancy maternal nutrition could be supportive.

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 potentially 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 support by 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.

Ethics approval and consent to participate

Ethical clearance was acquired from the Institutional Research Review Board of College of Health Science, Aksum University [(ref. number: IRB 026/2017 dated 15/08/2017)]. Permission letter was attained from regional health bureau and respective district health offices. Also, verbal consent was obtained from each study participant before data collection.

Consent for publication

Not applicable.

Availability of data and material

Dataset will be used for further work and cannot be publicized at this stage.

Competing interests

None declared.

Funding

Universities of Aksum and Mekelle, Ethiopia supported the study directly and indirectly.

Authors' contributions

KH, HG, MB, EvdB, AM designed the study. KH, HG, and AM were involved in the data collection. KH and HG analyzed the data. KH, HG, MB, and EvdB interpreted the data and prepared the manuscript.

Acknowledgments

Universities of Groningen, Aksum, and Mekelle are acknowledged for their valuable support. Our gratitude goes to the regional health bureau, district health offices, supervisors, data collectors as well as women who participated in this study. We are also thankful to Central Statistics Agency of Ethiopia and district health bureaus including Tahtay-Maichew who allowed us to use their scales for anthropometric measurements. Finally, we appreciate the help of Haileselasie Berhane Alema and Shewit Engdashet Berhe who entered the data.

REFERENCES

1 Black RE, Victora CG, Walker SP, *et al.* Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* 2013;**382**:427–51.
2 Rahman MM, Abe SK, Kanda M, *et al.* Maternal body mass index and risk of birth and maternal health outcomes in low- and middle-income countries: A systematic review and meta-analysis. *Obes Rev* 2015;**16**:758–70.
3 Li N, Liu E, Guo J, *et al.* Maternal prepregnancy body mass index and gestational weight gain on pregnancy outcomes. *PLoS One* 2013;**8**.
4 Yu Z, Han S, Zhu J, *et al.* Pre-Pregnancy Body Mass Index in Relation to Infant Birth Weight and Offspring Overweight/Obesity: A Systematic Review and Meta-Analysis. *PLoS One* 2013;**8**.
5 Pan Y, Zhang S, Wang Q, *et al.* Investigating the association between prepregnancy body mass index and adverse pregnancy outcomes: A large cohort study of 536 098 Chinese pregnant women in rural China. *BMJ Open* 2016;**6**:1–8.
6 Rahman MM, Abe SK, Rahman MS, *et al.* Maternal anemia and risk of adverse birth and health outcomes in low- and middle-income countries: Systematic review and meta-analysis. *Am J Clin Nutr* 2016;**103**:495–504.
7 Assefa N, Berhane Y, Worku A. Wealth status, mid upper arm circumference (MUAC) and Ante Natal Care (ANC) are determinants for low birth weight in Kersa, Ethiopia. *PLoS One* 2012;**7:**6.
8 Negash C, Whiting SJ, Henry CJ, *et al.* Association between maternal and child nutritional status in Hula, rural Southern Ethiopia: A cross sectional study. *PLoS One* 2015;**10**:1–8.
9 Khan MN, Rahman MM, Shariff AA, *et al.* Maternal undernutrition and excessive body weight and risk of birth and health outcomes. *Arch Public Heal* 2017;**75**:1–10.
10 Catalano PM, Farrell K, Thomas A, *et al.* Perinatal risk factors for childhood obesity and metabolic. *Am J Clin Nutr* 2009;**90**:1303–13.
11 Victora CG, Adair L, Fall C, *et al.* Maternal and child undernutrition: consequences for adult health and human capital. *Lancet* 2008;**371**:340–57.
12 Fogelman A. Issues in Brief The Changing Shape of Malnutrition : Obesity in sub-Saharan Africa. 2009.
13 Milton AH, Smith W, Rahman B, *et al.* Prevalence and determinants of malnutrition among reproductive aged women of rural Bangladesh. *Asia-Pacific J Public Heal* 2010;**22**:110–7.
14 CSA and ICF International. Ethiopia Demographic and Health Survey 2011. Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Agency and ICF International. 2012:1–452.
15 Bhutta ZA, Das JK, Rizvi A, *et al.* Evidence-based interventions for improvement of maternal and child nutrition: What can be done and at what cost? *Lancet* 2013;**382**:452–77.
16 Desyibelew HD, Dadi AF. Burden and determinants of malnutrition among pregnant women in Africa : A systematic review and meta-analysis. *PLoS One* 2019;**14**:1–19.
17 WHO. Maternal anthropometry and pregnancy outcomes. *WHO Bull* 1995;**73**:1–98.
18 Krasovec K, Anderson MA, Organization PAH. *Maternal Nutrition and Pregnancy Outcomes: Anthropometric Assessment*. Pan American Health Organization 1995.
19 Abraham S, Miruts G, Shumye A. Magnitude of chronic energy deficiency and its associated factors among women of reproductive age in the Kunama population, Tigray, Ethiopia, in 2014. *BMC Nutr* 2015;**1**:1–9.
20 Haileslassie K, Mulugeta A, Girma M. Feeding practices, nutritional status and associated factors of lactating women in Samre Woreda, South Eastern Zone of Tigray, Ethiopia. *Nutr J* 2013;**12**:1.
21 Headen IE, Davis EM, Mujahid MS, *et al.* Racial-Ethnic Differences in Pregnancy-Related Weight. *Adv Nutr* 2012;**3**:83–94.
22 Tebekaw Y, Teller C, Colón-Ramos U. The burden of underweight and overweight among women in Addis Ababa, Ethiopia. *BMC Public Health* 2014;**14**.
23 Alaofè H, Zhu M, Burney J, *et al.* Association Between Women's Empowerment and Maternal and Child Nutrition in Kalalé District of Northern Benin. *Food Nutr Bull* 2017;**38**:302–18.
24 Pratley P. Associations between quantitative measures of women's empowerment and access to care and health status for mothers and their children: A systematic review of evidence from the developing world. *Soc Sci Med* 2016;**169**:119–31.
25 Assefa Y, Gelaw YA, Hill PS, *et al.* Community health extension program of Ethiopia, 2003-2018: Successes and challenges toward universal coverage for primary healthcare services. *Global Health* 2019;**15**:1–11.
26 Medhanyie A, Spigt M, Kifle Y, *et al.* The role of health extension workers in improving utilization of maternal health services in rural areas in Ethiopia: A cross sectional study. *BMC Health Serv Res* 2012;**12**:1.
27 Yitayal M, Berhane Y, Worku A, *et al.* Health extension program factors, frequency of household visits and being model households, improved utilization of basic health services in Ethiopia. *BMC Health Serv Res* 2014;**14**:156.
28 Kabeer N. Resources, Agency, Achievements: Reflections on the Measurement of Women's Empowerment. *Dev Change* 1999;**30**:435–64.
29 Asefa F, Nemomsa D. Gestational weight gain and its associated factors in Harari Regional State: Institution based cross-sectional study, Eastern Ethiopia. *Reprod Health* 2016;**13**:1–7.
30 Zerfu TA, Umeta M, Baye K. Dietary diversity during pregnancy is associated with reduced risk of maternal anemia, preterm delivery, and low birth weight in a prospective cohort study in rural Ethiopia. *Am J Clin Nutr* 2016;**103**:1482–8.
31 Coates J, Swindale A. Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide Version. *J Chem Inf Model* 2013;**53**:1689–99.
32 FAO & FHI 360. *Minimum Dietary Diversity for Women- A Guide to Measurement*. 2010.
33 The International Physical Activity Questionnaire.Short Last 7 Days Self-Administered Format.2002.http://www.ipaq.ki.se
34 World Food Program. Creation of a Wealth Index. 2017:1–26.
35 International Physical Activity Questionnaire. IPAQ scoring protocol. 2005. http://www.ipaq.ki.se
36 Rabin RF, Jennings JM, Campbell JC, *et al.* Intimate Partner Violence Screening Tools. *Am J Prev Med* 2009;**36**:439-445.e4.
37 Jennings L, Na M, Cherewick M, *et al.* Women's empowerment and male involvement in antenatal care: Analyses of Demographic and Health Surveys (DHS) in selected African countries. *BMC Pregnancy Childbirth* 2014;**14**:1–11.
38 International Labour Office. Women's and Youth Empowerment in Rural Tunisia: An assessment using the Women's Empowerment in Agriculture Index (WEAI). 2018.
39 Gitagia MW, Ramkat RC, Mituki DM, *et al.* Determinants of dietary diversity among women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru, Kenya. *Food Nutr Res* 2019;**63**:1–12.
40 Cheng ER, Rifas-Shiman SL, Perkins ME, *et al.* The Influence of Antenatal Partner Support on Pregnancy Outcomes. *J Women's Heal* 2016;**25**:672–9.
41 Kocalevent RD, Berg L, Beutel ME, *et al.* Social support in the general population: Standardization of the Oslo social support scale (OSSS-3). *BMC Psychol* 2018;**6**:4–11.
42 Cox JL, Holden JM, Sagovsky R. Detection of Postnatal Depression. *Br J Psychiatry* 1987;**150**:782–6.
43 Zigmond AS, Snaith RP. The Hospital Anxiety And Depression Scale.Acta Psychiatr Scand.1983;67:361–70.
44 Karam F, Bérard A, Sheehy O, *et al.* Reliability and validity of the 4-item perceived stress scale among pregnant women: Results

from the OTIS antidepressants study. *Res Nurs Heal* 2012;**35**:363–75.
45 The Sphere. *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response*. 2018.
46 UCLA: Statistical Consulting Group. https://stats.idre.ucla.edu/stata/faq/how-can-i-run-a-piecewise-regression-in-stata/
47 Yitayal M, Berhane Y, Worku A, *et al.* The community-based Health Extension Program significantly improved contraceptive utilization in West Gojjam Zone, Ethiopia. *J Multidiscip Healthc* 2014;**7**:201–8.
48 Medhanyie A, Spigt M, Kifle Y, *et al.* The role of health extension workers in improving utilization of maternal health services in rural areas in Ethiopia: A cross sectional study. *BMC Health Serv Res* 2012;**12**.
49 Tafesse N, Gesessew A, Kidane E. Urban health extension program model housing and household visits improved the utilization of health Services in Urban Ethiopia: A community-based cross-sectional study. *BMC Health Serv Res* 2019;**19**:1–11.
50 Negussie A, Girma G. Is the role of Health Extension Workers in the delivery of maternal and child health care services a significant attribute? the case of Dale district, southern Ethiopia. *BMC Health Serv Res* 2017;**17**:1–8.
51 Tebekaw Y. The Demographic Transition and Development in Africa. *Demogr Transit Dev Africa* 2011;:105–24.
52 Malapit HJL, Kadiyala S, Quisumbing AR, *et al.* Women's Empowerment Mitigates the Negative Effects of Low Production Diversity on Maternal and Child Nutrition in Nepal. *J Dev Stud* 2015;**51**:1097–123.
53 Amugsi DA, Lartey A, Kimani E, *et al.* Women's participation in household decision-making and higher dietary diversity: findings from nationally representative data from Ghana. *J Health Popul Nutr* 2016;**35**:16.
54 Ghose B, Feng D, Tang S, *et al.* Women's decision-making autonomy and utilisation of maternal healthcare services: Results from the Bangladesh Demographic and Health Survey. *BMJ Open* 2017;**7**:1–8.
55 Ousman SK, Mdala I, Thorsen VC, *et al.* Social Determinants of Antenatal Care Service Use in Ethiopia: Changes Over a 15-Year Span. *Front Public Heal* 2019;**7**:1–10.
56 Ahmed S, Creanga AA, Gillespie DG, *et al.* Economic status, education and empowerment: Implications for maternal health service utilization in developing countries. *PLoS One* 2010;**5**.
57 Pandey S, Lama G, Lee H. Effect of women's empowerment on their utilization of health services: A case of Nepal. *Int Soc Work* 2012;**55**:554–73.
58 Sado L, Spaho A, Hotchkiss DR. The influence of women's empowerment on maternal health care utilization: Evidence from Albania. *Soc Sci Med* 2014;**114**:169–77.
59 Adhikari R. Effect of Women's autonomy on maternal health service utilization in Nepal: A cross sectional study. *BMC Womens Health* 2016;**16**:1–7.
60 Rahman M, Nakamura K, Seino K, *et al.* Intimate partner violence and chronic undernutrition among married Bangladeshi women of reproductive age: Are the poor uniquely disadvantaged? *Eur J Clin Nutr* 2013;**67**:301–7.
61 Rahman M, Nakamura K, Seino K, *et al.* Intimate partner violence and use of reproductive health services among married women: Evidence from a national Bangladeshi sample. *BMC Public Health* 2012;**12**:1.
62 Ackerson LK, Subramanian S V. Domestic violence and chronic malnutrition among women and children in India. *Am J Epidemiol* 2008;**167**:1188–96.
63 Ersino G, Zello GA, Henry CJ, *et al.* Gender and household structure factors associated with maternal and child undernutrition in rural communities in Ethiopia. *PLoS One* 2018;**13**:1–20.
64 Amugsi DA, Dimbuene ZT, Bakibinga P, *et al.* Dietary diversity, socioeconomic status and maternal body mass index (BMI): quantile regression analysis of nationally representative data from Ghana, Namibia and Sao Tome and Principe. *BMJ Open* 2016;**6**:e012615.
65 Arimond M, Wiesmann D, Becquey E, *et al.* Simple Food Group Diversity Indicators Predict Micronutrient Adequacy of Women ' s Diets in. *J Nutr* 2010;**140**:2059–69.
66 McDonald CM, McLean J, Kroeun H, *et al.* Household food insecurity and dietary diversity as correlates of maternal and child undernutrition in rural Cambodia. *Eur J Clin Nutr* 2015;**69**:242–6.
67 Di Cesare M, Bhatti Z, Soofi SB, *et al.* Geographical and socioeconomic inequalities in women and children's nutritional status in Pakistan in 2011: An analysis of data from a nationally representative survey. *Lancet Glob Heal* 2015;**3**:e229–39.
68 Nguyen PH, Avula R, Ruel MT, *et al.* Maternal and Child Dietary Diversity Are Associated in Bangladesh, Vietnam, and Ethiopia. *J Nutr* 2013;**143**:1176–83.
69 Adubra L, Savy M, Fortin S, *et al.* The Minimum Dietary Diversity for Women of Reproductive Age (MDD-W) Indicator Is Related to Household Food Insecurity and Farm Production Diversity: Evidence from Rural Mali. *Curr Dev Nutr* 2019;**3**:1–9.
70 Na M, Mehra S, Christian P, *et al.* Maternal Dietary Diversity Decreases with Household Food Insecurity in Rural Bangladesh: A Longitudinal Analysis. *J Nutr* 2016;**146**:2109–16.
71 Kang Y, Hurley KM, Ruel-Bergeron J, *et al.* Household food insecurity is associated with low dietary diversity among pregnant and lactating women in rural Malawi. *Public Health Nutr* 2019;**22**:697–705.
72 Sibhatu KT, Qaim M. Review: The association between production diversity, diets, and nutrition in smallholder farm households. *Food Policy* 2018;**77**:1–18.
73 Desalegn BB, Lambert C, Riedel S, *et al.* Ethiopian orthodox fasting and lactating mothers: Longitudinal study on dietary pattern and nutritional status in rural tigray, Ethiopia. *Int J Environ Res Public Health* 2018;**15**:1–20.
74 D'Haene E, Desiere S, D'Haese M, *et al.* Evidence from the Ethiopian Milk Market. *Foods* 2019;**8**:1–21.
75 Bezabih AM, Wereta MH, Kahsay ZH, *et al.* Demand and Supply Side Barriers that Limit the Uptake of Nutrition Services among Pregnant Women from Rural Ethiopia: An Exploratory Qualitative Study. *Nutrients* 2018;**10**.

Figure 1 Pre-pregnancy nutritional status as assessed by BMI and MUAC of women, Tigrai region, Northern Ethiopia, 2018

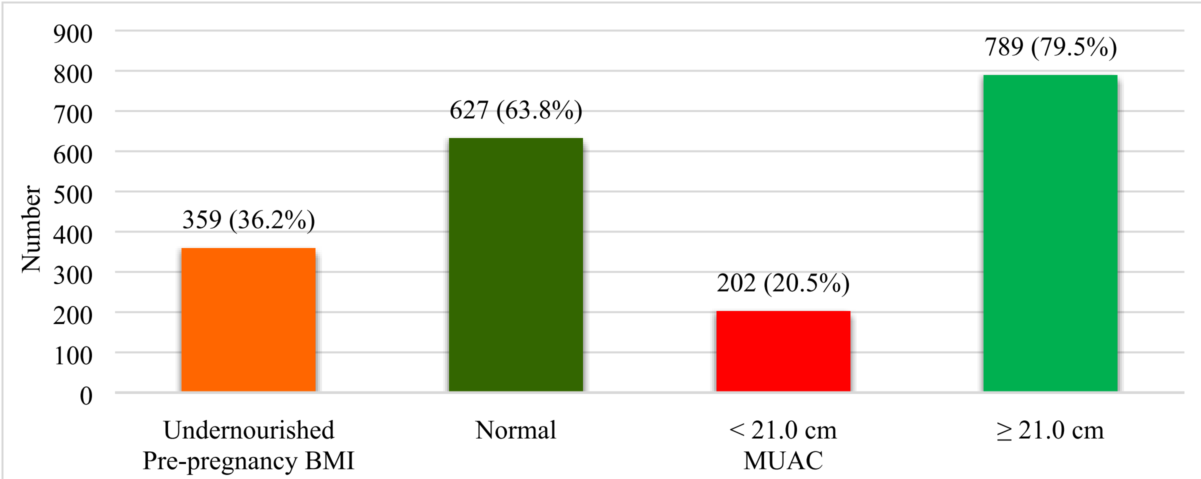

Figure 1 Pre-pregnancy nutritional status as assessed by BMI and MUAC of women, Tigrai region, Northern Ethiopia, 2018

Supplementary table 1. Domain-specific multivariable linear regression analysis of determinants of BMI and MUAC among women, Tigrai region, Northern Ethiopia, 2018

Domain specific models	**Mean BMI difference in kg/m^2**		**Mean MUAC difference in cm**	
Socioeconomic model*	**Coefficient (95% C.I)**	**P-value**	**Coefficent (95% C.I)**	**P-value**
Age < 30[a]	0.07 (0.004, 0.12)	.035	0.06 (0.03, 0.12)	.039
Age ≥30[b]	-0.02 (-0.06, 0.03)	.448	-0.02 (-0.06, 0.03)	.471
Educational status				
No formal education	-0.48 (-1.16, 0.21)	.176	-0.48 (-1.17, 0.20)	.167
Primary education	-0.38 (-1.03, 0.26)	.242	-0.40 (-1.03,0.24)	.220
Secondary education	-0.30 (-0.83, 0.43)	.539	-0.22 (-0.84, -0.41)	.493
Above secondary	Reference	-	Reference	-
Occupation of husband				
Farmer	Reference	-	Reference	-
Employed	0.31 (-0.26, 0.88)	.286	0.26 (-0.31, 0.82)	.376
Daily laborer	-0.13 (-0.61, 0.36)	.607	-0.15 (-0.63, 0.33)	.548
Others	0.11 (-0.55, 0.77)	.738	0.11 (-0.55, 0.77)	.752
Wealth index				
Poorest	-0.17 (-0.68, 0.33)	.500	-014 (-0.63, 036)	.590
Second poor	0.19 (-0.34, 0.73)	.479	0.22 (-0.31, 0.75)	.415
Middle	0.17 (-0.33, 0.67)	.512	0.21 (-0.29, 0.71)	.405
Second rich	-0.09 (-0.51, 0.34)	.691	-0.04 (-0.46, 0.38)	.835
Richest	Reference	-	Reference -	-
Physical activity				
Low	0.94 (0.36, 1.52)	.002	0.92 (0.36, 1.48)	.001
Moderate	0.53 (-0.02, 1.08)	.061	0.52(-0.02, 1.05)	.059
High	Reference	-	Reference	-
Model household, no	-0.61 (-0.91, -0.32)	<.001	-0.60 (-0.89, -0.32)	<.001
Adjusted R^2	13.3%		13.0%	
Reproductive & obstetric model**				
Women empowerment score < 6[a]	-0.18 (-0.34, -0.11)	.037	-0.17 (-0.33, -0.01)	.044
Women empowerment score ≥ 6[b]	0.38 (0.20, 0.56)	<.001	0.32 (-0.14, 0.50)	.001
Intimate partner violence score	-0.09 (-0.13, -0.05)	<.001	-0.09 (-0.13, -0.05)	.000
Adjusted R^2	20.0%		19.1%	
Food and dietary model***				
Dietary diversity score	0.29 (0.20, 0.38)	<.001	0.27 (0.18, 0.37)	.000
Fasting, yes	-0.34 (-0.61, -0.07)	.012	-0.34 (-0.61, -0.08)	.011
Coffee intake per day < 2 times[a]	0.23 (-0.10, 0.56)	.173	0.23 (-0.10, 0.55)	.176
Coffee intake per day ≥ 2 times[b]	-0.45 (-0.73, -0.17)	.002	-0.44 (-0.72, -0.16)	.002
Agrobiodiversity score < 2 groups[a]	-0.26 (-0.76, -0.24)	.305	-0.26 (-0.76. 0.24)	.313
Agrobiodiversity score ≥ 2 groups[b]	0.15 (-0.05, 0.26)	.003	0.17 (0.07, 0.27)	.001
Food insecurity score	-0.12 (-0.14, -0.10)	<.001	-0.12 (-0.14, -0.09)	.000
Adjusted R^2	27.4%		26.3%	
Psycho-social model****				
Total anxiety score	-0.05 (-0.09, -0.01)	.016	-0.05 (-0.09, -0.01)	.011
Perceived stress score	-0.06 (-0.52, 0.41)	.812	-0.09 (-0.55, 0.38)	.719
Total depression score	0.06 (-0.04, 0.15)	.240	0.05 (-0.04, 0.14)	.276
Total social support score	0.05 (-0.12, 0.22)	.585	0.02 (-0.15, 0.19)	.835
Partner support score < 9[a]	-0.20 (-0.46, 0.06)	.136	-0.21 (-0.47, 0.06)	.129
Partnersupport score ≥ 9[b]	0.06 (0.04, 0.12)	.036	0.02 (-0.15, 0.19)	.045
Adjusted R^2	22.9%		22.5%	

[a&b] represent the two continuous variables below and greater than or equal to the knot value respectively, * adjusted for husband education and access to health service and source of drinking water,** adjusted for parity and age at marriage,*** adjusted for fruit, vegetables, animal-source food and alcohol intake, and**** adjusted for squared and cubed perceived stress score, and an interaction of social support and stress and also depression and stress.

BMJ Open

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Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-043484.R1
Article Type:	Original research
Date Submitted by the Author:	10-Dec-2020
Complete List of Authors:	Misgina, Kebede; University of Groningen, Epidemiology; Aksum University, Public Health Boezen, H. Marike; University of Groningen, University Medical Center Groningen, Department of Epidemiology van der Beek, Eline M.; Danone Nutricia Research; University Medical Centre Groningen, Department of Pediatrics Mulugeta , Afework ; Mekelle University, School of Public Health Groen, Henk; Rijksuniversiteit Groningen, Epidemiology
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Obstetrics and gynaecology
Keywords:	PREVENTIVE MEDICINE, NUTRITION & DIETETICS, EPIDEMIOLOGY

What factors are associated with pre-pregnancy nutritional status? Baseline analysis of 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 Tigrai 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 (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: Outcome measure was pre-pregnancy nutritional status as assessed 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.

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. Not being from a model household, lower values of women empowerment score, intimate partner violence, food insecurity, lower dietary diversity, regular fasting, and low agrobiodiversity showed significant associations with lower BMI and 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. In the Ethiopian setting, such changes require the coordinated efforts of concerned governmental bodies and religious leaders.

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

Strengths and limitations of this study

- Measuring weight in a distinct period before starting the inclusion of women, and
- Including relatively a large sample of women as well as collecting information on many possible confounders can be considered as strengths.
- As for limitations, MUAC was measured at inclusion unlike BMI, but as it is insensitive to change over time it can safely represent the pre-pregnancy status.
- Finally, seasonal variation was not considered in dietary diversity measures.

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 low 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 Tigrai, 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 Tigrai, 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] as well as psychosocial characteristics. Few studies have investigated the factors associated with pre-pregnancy nutritional status in low-income countries like Ethiopia in detail.[19,25] The previous studies also did not control for potential confounders like physical activity, work burden, implementation of a health extension package, fasting, agrobiodiversity, and psychosocial characteristics.[26–28] 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.[29]

Furthermore, other studies focused on specific population subgroups only, such as urban residents who may not represent the large majority of the population that is living in rural conditions,[22] or population groups with different socioeconomic and cultural characteristics.[19] Knowledge about factors associated with pre-pregnancy nutritional status among women of reproductive age, the target population for interventions to achieve improvement, in countries like Ethiopia is therefore limited. The present study was 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 both 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, was conducted in Kilite-Awilaelo Health and Demographic Surveillance Site (KA-HDSS) between February and September 2018. The prospective study 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 Tigrai 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 Tigrai 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 major 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.[26]

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 prospective study. 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. All eligible pregnant women identified during the study period were included consecutively. 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. In addition, the records of the nearby antenatal clinics as well as the KA-HDSS database were used.

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, 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, Tigrai region. Data including the pre-pregnancy weight were collected by qualified Health Extension Workers and the data collection included:

Socioeconomic variables: Age, residence, religion, education, occupation, family size (the number of persons living in the same household), and wealth index were extracted from the KA-DHSS database. Also, self-reported access to a health facility, perceived work burden (rated as easy, moderate or difficult), physical activity, and history of pre-pregnancy illness was recorded. Access to health facility was measured by asking the time to go to the nearest health facility and back home. Moreover, implementation of the health extension package was assessed by checking if the women's households were certified as a model household or not. 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.[26–28]

Wealth index was assessed by asking 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 poorest to the richest economic status.[35] Pertaining access to improved drinking water sources, it refers 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 improved sanitation facility is defined as access to unshared toilet facility; pit latrine with a slab, ventilated improved pit latrine or flush toilet.[36]

Physical activity data were obtained using the International Physical Activity Questionnaire (IPAQ)-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 summarized using the algorithm described in the scoring protocol.[37]

Reproductive and obstetric conditions: Gravidity; the number of previous pregnancies, parity, and history of abortion as well as stillbirth were extracted from the KA-DHSS database. Also, age at first marriage, age at first birth, previous inter-birth interval in months, and history of preterm birth, delivery by Caesarean section and severe perinatal hemorrhage were collected by interview at inclusion. Based on this information, a history of adverse pregnancy outcome was defined as having experienced one or more of the following: abortion, stillbirth, preterm birth, severe perinatal hemorrhage or delivery by Caesarean section. Furthermore, self-reported information on intimate partner violence was obtained using the four-item HITS (Hurt, Insult, Threaten and Scream) questionnaire. Each question was rated from 1 to 5 and a total score > 10 was used as a cut-off for presence of violence.[38]

To assess women empowerment, participants were asked nine questions addressing five domains: 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 health care autonomy (decision-making on family visits, and women's health); 4. attitude towards domestic violence; 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. Fasting is abstaining from animal-source foods such as meat, dairy products, egg and fish for religious reasons. Christians fast almost every Wednesday and Friday weekly throughout the year, in addition to longer fasting periods of several days, including the 40 days Christmas fast, the 55 days of the Lenten fast, at least 14 days of an Apostles' fast and 14 days Dormition fast. Data on fasting was collected by asking women if they fast the weekly fast and adhere to the long fast times. Finally, women were categorized 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 zero to eight was calculated based on the answers for each of the categories.[41]

Dietary diversity was assessed by asking women about consumption of a list of foods over a 24-hour period with 'yes' or 'no' as the answer options.[33] The list was organized in ten 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 five or more groups was defined as adequate dietary diversity.[33]

Food insecurity was assessed using the Household Food Insecurity Access Scale.[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, with each item scored from 0 to 3. A sum score < 10 was defined as low.[42] Also, social support from significant others was assessed using the Oslo-3 Social Support Scale with total scores in the range of 3 to 14, and scores ≤ 8 being considered as low.[43] Moreover, the ten-item Edinburgh Postnatal Depression Scale and the seven-item anxiety subscale of Hospital Anxiety and Depression Scale with each item in both scales 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 of ≥ 8 showing high symptoms of stress.[46]

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 3.3, 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). Proportions, means with standard deviations (SD), or medians with interquartile ranges (IQR) were used to summarize the characteristics of the participants.

Non-linear associations between 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 and 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 $X \geq K$, robust), we tested if the slopes of the two variables were different (test $X < K = X \geq K$). 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 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. 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 normality of residuals was checked with histograms, normal probability and quantile-quantile plots. Also, specification error and omitted variable bias were tested using the linktest and ovtest commands.

Patient and public involvement

There was no patient or public involvement.

RESULTS

A total of 991 women were included and their anthropometric measures by BMI categories are summarized in table 1. The mean pre-pregnancy nutritional status of the participating women as assessed 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) (see figure 1).

Table 1. Anthropometric measures by BMI categories of women (n=991) from the Tigrai 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.

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, and lower physical activity were associated with higher BMI and MUAC (tables 4 and 5).

Table 2 Socioeconomic characteristics of women and their households (n=991), Tigrai 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%)
Education	
No formal education	362 (36.5%)
Primary education	326 (32.9%)
Secondary education	250 (25.2%)
Above secondary education	53 (5.4%)
Occupation	
Farmer	541 (54.6%)
Housewife	337 (34.0%)
Employed	91 (9.2%)
Others*	22 (2.2%)
Education of husband	
No formal education	320 (32.3%)
Primary education	366 (36.9%)
Secondary education	196 (19.8%)
Above secondary education	109 (11.0%)
Occupation of husband	
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 quintiles	
Lowest (Poorest)	198 (20.0%)
Second	199 (20.1%)
Middle	198 (20.0%)
Fourth	196 (19.7%)
Highest (Richest)	200 (20.2%)
Model household	242 (24.4%)
Time to go to the nearest health facility and back home in minutes	35 (25-75)
Access to health service within 1 h	693 (69.8%)
History of pre-pregnancy illness	142 (14.3%)

Access to improved drinking water	888 (89.6%)
Time to fetching water within 15 minutes	519 (52.4%)
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 of the participants. 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 75 (7.6%) 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 (tables 4 and 5).

As shown in table 3, the food and dietary characteristics of most women were poor. Less than 10% of women consumed fruits and vegetables three times or more per week. Overall, 518 women (52.3%) had adequate dietary diversity. With reference to dietary habits, most women fasted (70.0%). In addition, 392 women (39.6%) did not have adequate food security. In the univariable analysis, higher dietary diversity and agrobiodiversity showed significant associations with higher BMI and MUAC. Higher coffee intake, fasting, and food insecurity were associated with lower BMI and MUAC (tables 4 and 5).

As shown in table 3, the food and dietary characteristics of most women were poor. Less than 10% of women consumed fruits and vegetables three times or more per week. Overall, 518 (52.3%) women had adequate dietary diversity. With reference to dietary habits, most women (70.0%) fasted. In addition, 392 (39.6%) women did not have adequate food security. In the univariable analysis, higher dietary diversity and agrobiodiversity showed significant associations with higher BMI and MUAC. Higher coffee intake, fasting, and food insecurity were associated with lower BMI and MUAC (tables 4 and 5).

Furthermore, psychosocial problems were widespread among the women as indicated in table 3. More than one in five women had high symptoms at least in one of the measured mental disorders depression, anxiety, or stress. Concerning support from others, 115 (11.6%) reported low support from partners and 378 (38.1%) from significant others. In the unadjusted analysis, significant associations between higher symptoms of mental disorders, and lower BMI and MUAC were observed. Additionally, higher support from partner and significant others was associated with higher BMI and MUAC (tables 4 and 5).

Table 3 Reproductive and obstetric conditions, food and dietary as well as psychosocial characteristics of women (n=991), Tigrai 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	75 (7.6%)
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 depression score	8.0 (4.7)
High depressive symptoms	204 (20.6%)
Total anxiety score	4.8 (3.8)
High anxiety symptoms	224 (22.6%)
Total perceived stress score	6.4 (2.7)
High symptoms of perceived stress	331 (33.4%)
Total partner support score	11.9 (2.7)
Low partner support	115 (11.6%)
Total social support score from significant others	9.4 (2.0)
Low social support from significant others	378 (38.1%)

Results of the unadjusted and adjusted analyses are shown in tables 4 and 5. In the adjusted model, age < 30 years (coefficient=0.08, 95% CI (0.02, 0.14) and being from a model household (coefficient=0.38, 95% CI (0.12, 0.64) were positively associated with BMI. Also, women empowerment score ≥ 6 (coefficient=0.26, 95% CI (0.09, 0.43) was positively associated with BMI whereas intimate partner violence (coefficient=-0.05, 95% CI (-0.09, -0.004) was negatively associated with BMI. From the food and dietary domain, dietary diversity (coefficient=0.11, 95% CI (0.02, 0.20) was positively associated with BMI whereas fasting (coefficient=-0.29, 95% CI (-0.54, -0.04), agrobiodiversity score < 2 (coefficient=-

0.49 (-0.96, -0.02) and food insecurity (coefficient=-0.07, 95% CI (-0.09, -0.05) were negatively associated with BMI. In total, the model explained 43.3% of the variation (table 4).

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

Characteristics	**Mean BMI difference in kg/m^2 (95% CI)**			
	Unadjusted	**P-value**	**Adjusted***	**P-value**
Age < 30[a]	0.06 (-0.00, 0.12)	.054	0.08 (0.02, 0.14)	**.006**
Age ≥ 30[b]	-0.06 (-0.10, -0.02)	.004	-0.02 (-0.06, -0.03)	.438
Educational status				
No formal education	-1.29 (-1.69, -0.88)	<.001	0.55 (-0.10, 1.21)	.099
Primary education	-0.77 (-1.18,-0.36)	<.001	0.36 (-0.27, 0.99)	.262
Secondary education	-0.60 (-1.06,-0.15)	.009	0.34 (-0.29, 0.97)	.291
Above secondary	Reference	-	Reference	-
Occupation of husband				
Farmer	-0.84 (-1.30, -0.38)	<.001	Reference	-
Employed	0.40 (-0.11, 0.92)	.126	0.13 (-0.30, 0.56)	.555
Daily laborer	-0.35 (-0.89, 0.19)	.199	0.20 (-0.14, 0.53)	.248
Others	Reference	-	0.05 (-0.45, 0.55)	.850
Wealth index				
Poorest	Reference	-	Reference	-
Second poor	0.38 (0.06, 0.71)	.022	0.11 (-0.13, 0.35)	.366
Middle	0.65 (0.31, 1.00)	<.001	0.11 (-0.14, 0.36)	.399
Second rich	1.08 (0.71, 1.44)	<.001	0.02 (-0.38, 0.42)	.924
Richest	1.38 (1.00, 1.77)	<.001	0.12 (-0.35, 0.59)	.609
Physical activity				
Low	1.29 (0.67, 1.91)	<.001	0.35 (-0.05, 0.75)	.089
Moderate	0.46 (-0.17, 1.09)	.153	0.16 (-0.21, 0.53)	.401
High	Reference	-	Reference	-
Model household	1.02 (0.74, -1.29)	<.001	0.38 (0.12, 0.64)	**.004**
Women empowerment score < 6[a]	-0.18 (-0.35, -0.01)	.039	-0.05 (-0.20, 0.10)	.506
Women empowerment score ≥ 6[b]	0.35 (0.17, 0.53)	<.001	0.26 (0.09, 0.43)	**.003**
Intimate partner violence score	-0.16 (-0.20, -0.12)	<.001	-0.05 (-0.09, -0.004)	**.030**
Coffee intake per day < 2 times[a]	0.25 (-0.11, 0.60)	.176	0.11 (-0.40, 0.62)	.673
Coffee intake per day ≥ 2 times[b]	-0.40 (-0.74, -0.07)	.018	-0.35 (-0.85, 0.14)	.157
Dietary diversity score	0.48 (0.40, 0.57)	<.001	0.11 (0.02, 0.20)	**.020**
Fasting	-0.78 (-1.06, -0.51)	<.001	-0.29 (-0.54, -0.04)	**.023**
Agrobiodiversity score < 2 groups[a]	-0.55 (-1.08, -0.01)	.044	-0.49 (-0.96, -0.02)	**.042**
Agrobiodiversity score ≥ 2 groups[b]	0.24 (0.12, 0.36)	<.001	0.02 (-0.08, 0.11)	.720
Food insecurity score	-0.16 (-0.18, -0.14)	<.001	-0.07 (-0.09, -0.05)	**<.001**
Total anxiety score	-0.15 (-0.18, -0.12)	<.001	-0.03 (-0.07, 0.01)	.133
Perceived stress score	0.17 (-0.12, 0.46)	.246	0.15 (-0.26, 0.56)	.464
Total depression score	-0.11 (-0.13, -0.08)	<.001	0.05 (-0.03, 0.13)	.188
Total social support score	0.30 (0.25, 0.36)	<.001	0.07 (-0.08, 0.23)	.350
Partner support score < 9[a]	-0.18 (-0.45, 0.09)	.185	-0.11 (-0.34, 0.12)	.350
Partnersupport score ≥ 9[b]	0.20 (0.14, 0.26)	<.001	0.03 (-0.03, 0.08)	.351

[a&b] represent the two continuous variables below and greater than or equal to the knot value respectively, and *was additionally adjusted for husband education, access to health service and improved drinking water, frequencies of fruit, vegetables, animal-source food and alcohol intake per month and squared and cubed perceived stress.

All variables that were associated with BMI were also associated with MUAC. Of these variables that had a larger effect, being from a model household (coefficient=0.37, 95% CI (0.11, 0.62) and women empowerment score ≥ 6 (coefficient=0.21, 95% CI (0.04, 0.38) were positively associated with MUAC whereas fasting (coefficient=-0.30, 95% CI (-0.55, -0.05) and agrobiodiversity score < 2 (coefficient=-0.49, 95% CI (-0.97, -0.01) were negatively associated with MUAC (table 5). In total, the final model explained 42.2% of the variation.

Table 5 Unadjusted and adjusted linear regression analysis of factors associated with mean pre-pregnancy MUAC of women (n=991), Tigrai region, Northern Ethiopia, 2018

Characteristics	Mean MUAC difference in cm (95% CI)			
	Unadjusted	**P-value**	**Adjusted***	**P-value**
Age < 30[a]	0.06 (-0.00, 0.12)	.064	0.08 (0.02, 0.14)	**.007**
Age ≥ 30[b]	-0.06 (-0.10, -0.02)	.005	-0.02 (-0.06, 0.03)	.461
Educational status				
No formal education	-1.24 (-1.63, -0.85)	<.001	0.53 (-0.12, 1.17)	.107
Primary education	-0.74 (-1.14,-0.35)	<.001	0.34 (-0.27, 0.96)	.272
Secondary education	-0.59 (-1.03,-0.15)	.009	0.32 (-0.29, 0.92)	.307
Above secondary	Reference	-	Reference	-
Occupation of husband				
Farmer	-0.84 (-1.31, -0.38)	<.001	Reference	
Employed	0.36 (-0.16, 0.87)	.180	0.11 (-0.33, 0.55)	.626
Daily laborer	-0.36 (-0.90, 0.18)	.191	0.18 (-0.16, 0.51)	.304
Others	Reference	-	0.07 (-0.44, 0.58)	.800
Wealth index				
Poorest	Reference	-	Reference	-
Second poor	0.37 (0.05, 0.70)	.026	0.12 (-0.13, 0.36)	.335
Middle	0.65 (0.31, 0.99)	<.001	0.14 (-0.11, 0.39)	.270
Second rich	1.07 (0.70, 1.43)	<.001	0.04 (-0.37, 0.45)	.847
Richest	1.33 (0.96, 1.71)	<.001	0.11 (-0.35, 0.58)	.633
Physical activity				
Low	1.26 (0.75, 1.78)	<.001	0.35 (-0.04, 0.75)	.078
Moderate	0.45 (-0.07, 0.96)	.091	0.17 (-0.20, 0.54)	.372
High	Reference	-	Reference	**-**
Model household	0.99 (0.72, 1.27)	<.001	0.37 (0.11, 0.62)	**.005**
Women empowerment score < 6[a]	-0.16 (-0.33, 0.001)	.052	-0.04 (-0.19, 0.11)	.621
Women empowerment score ≥ 6[b]	0.30 (0.12, 0.48)	.001	0.21 (0.04, 0.38)	**.015**
Intimate partner violence score	-0.16 (-0.20, -0.12)	<.001	-0.05 (-0.09, -0.01)	**.023**
Dietary diversity score	0.46 (0.37, 0.55)	<.001	0.10 (0.03, 0.19)	**.043**
Fasting	-0.77 (-1.04, -0.50)	<.001	-0.30 (-0.55, -0.05)	**.017**
Coffee intake per day < 2 times[a]	0.27 (-0.09, 0.61)	.152	0.13 (-0.39, 0 64)	.633
Coffee intake per day ≥ 2 times[b]	-0.39 (-0.72, -0.06)	.019	-0.33 (-0.83, 0.17)	.196
Agrobiodiversity score < 2 groups[a]	-0.53 (-1.06, -0.01)	.052	-0.49 (-0.97, -0.01)	**.046**
Agrobiodiversity score ≥ 2 groups[b]	0.25 (0.13, 0.37)	<.001	0.03 (-0.06, 0.13)	.500
Food insecurity score	-0.16 (-0.18, -0.14)	<.001	-0.07 (-0.09, -0.04)	**<.001**
Total anxiety score	-0.15 (-0.18, -0.11)	<.001	-0.03 (-0.07, 0.01)	.099
Perceived stress score	0.18 (-0.11, 0.48)	.220	0.12 (-0.29, 0.53)	.579
Total depression score	-0.11 (-0.13, -0.08)	<.001	0.05 (-0.03, 0.13)	.228
Total social support score	0.29 (0.24, 0.35)	<.001	0.04 (-0.11, 0.20)	.595
Partner support score < 9[a]	-0.19 (-0.47, 0.09)	.180	-0.13 (-0.37, 0.12)	.317
Partnersupport score ≥ 9[b]	0.30 (0.12, 0.48)	<.001	0.03 (-0.03, 0.08)	.381

[a&b]represent the two continuous variables below and greater than or equal to the knot value respectively, and *was additionally adjusted for husband education, access to health service and improved drinking water, frequencies of fruit, vegetables, animal-source food and alcohol intake per month and squared and cubed perceived stress.

DISCUSSION

We performed a population-based study to determine factors associated with pre-pregnancy nutritional status in 991 pregnant women in Northern Ethiopia. Of the women included in the study, a considerable part 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 (32%),[14] as well as for Africa as a large.[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 prior to 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.

Being from a model household, a proxy for implementation of 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. Implementation of the package after the training was required to be labeled as 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 effect of implementing the package on the overall health of the women.[49–52] This promising finding suggests that strengthening the health extension program may be a good approach to improving maternal nutritional status.

Being from a model household; a proxy for implementation of the health extension package was positively associated with pre-pregnancy nutritional status. A model household is a household that received short-term training on health extension package; a package comprising several components including maternal health, family planning, nutrition, and sanitation, and implemented the package after the training. In addition, health extension workers educate women on maternal health including nutrition during their pregnancy individually at their home and in a group at a health post. Therefore, it is likely that the observed association between implementation of health extension package, and higher nutritional status is at least in part explained by the effect of the training on dietary practices and the effect of implementing the package on the overall health of the women.[49–52] This promising finding suggests that strengthening the health extension program may be a good approach to improving maternal nutritional status.

Moreover, higher women empowerment score was associated with higher pre-pregnancy nutritional status in the present study, which is in line with the literature.[23,53,54] This may be partly explained by the effect of women empowerment on access to food, dietary practice and seeking healthcare.[55–61] Related with this finding, intimate partner violence was negatively associated with pre-pregnancy nutritional status as is also observed in previous similar studies.[62–64] As domestic violence is the reflection of low empowerment, this finding further corroborates the importance of considering women empowerment in confronting maternal undernutrition and its consequent effects. In short, finding a means for improving the social, economic, political, and legal strength of the women, ensuring equal rights for women, and making them confident enough to claim these rights, such as purchasing resources they want, 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, which is consistent with the literature,[19,68,69] could be explained by inadequate dietary intakes 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 small change in agrobiodiversity is not enough to have a positive impact on 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.[75] 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 almost every Wednesday and Friday weekly fast throughout the year, and the long fasting periods including the 40 days Christmas fast, the 55 days of the Lenten fast, at least 14 days Apostles' fast and 14 days Dormition fast. During these times, people are expected to abstain from animal-source foods for religious reasons. This could result in poor dietary quality and nutritional status.[76,77] This finding highlights the importance of considering nutrition-sensitive religious practices as part of the efforts to improve maternal nutrition.

The findings of the present study 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 is showing flexibility on fasting during pregnancy, most pregnant women still adhere to fasting for religious reasons. Maintaining this practice will counteract other measures to solve the issue of 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 in efforts targeted to improve pre-pregnancy maternal nutrition could be supportive.

The findings of the present study indicated 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 access to food, and the justice sector in tackling domestic violence may be helpful. Additionally, though the Orthodox Church nowadays is showing flexibility on fasting during pregnancy, most pregnant women still adhere to fasting for religious reasons; this would still not address the issue of 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 in efforts targeting 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 as well as collecting information on many possible confounders can be considered as strengths. As for limitations, MUAC was measured at inclusion unlike BMI, but as it is relatively insensitive to change over time it can safely represent the pre-pregnancy status.[17,18] Additionally, our study might have not been free of type one error due to the multiple hypothesis testing, although most of our findings are biologically plausible and several of the p-values are sufficiently strong to substantially diminish the risk of a chance finding. Finally, seasonal variation was not considered in dietary diversity measures.

However, we do not believe that the limitations have affected the generalizability of our findings.

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 potentially 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 wider 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.

Ethics approval and consent to participate

Ethical clearance was acquired from the Institutional Research Review Board of College of Health Science, Aksum University [(ref. number: IRB 026/2017 dated 15/08/2017)]. Permission letter was attained from regional health bureau and respective district health offices. Also, verbal consent was obtained from each study participant before data collection.

Consent for publication

Not applicable.

Availability of data and material

Dataset will be used for further work and cannot be publicized at this stage.

Competing interests

None declared.

Funding

No specific grant for this research from any funding agency.

Authors' contributions

KH, HG, MB, EvdB, AM designed the study. KH, HG, and AM were involved in the data collection. KH and HG analyzed the data. KH, HG, MB, and EvdB interpreted the data and prepared the manuscript.

Acknowledgments

Universities of Groningen, Aksum, and Mekelle are acknowledged for their valuable support. Our gratitude goes to the regional health bureau, district health offices, supervisors, data collectors as well as women who participated in this study. We are also thankful to Central Statistics Agency of Ethiopia and district health bureaus including Tahtay-Maichew who allowed us to use their scales for anthropometric measurements. Finally, we appreciate the help of Haileselasie Berhane Alema and Shewit Engdashet Berhe who entered the data.

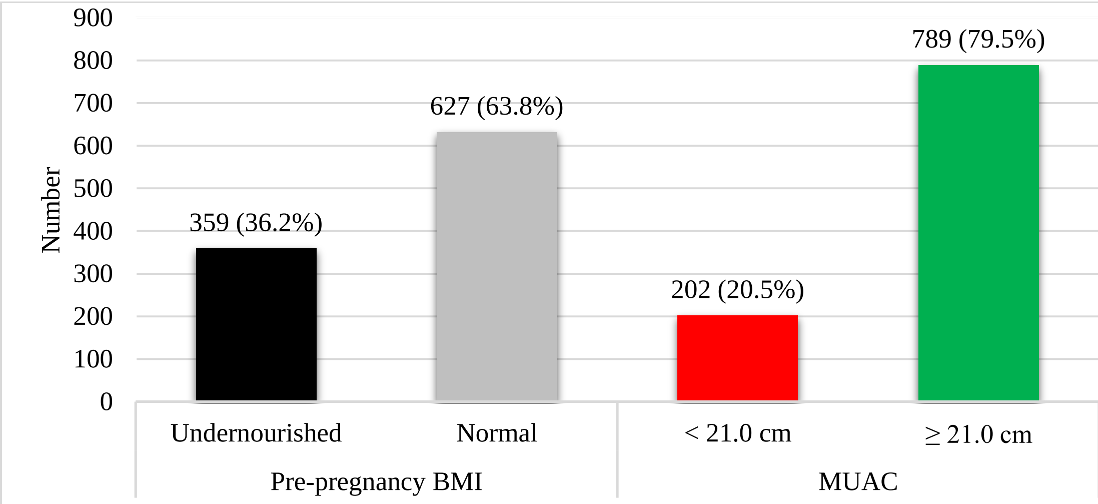
REFERENCES

1 Black RE, Victora CG, Walker SP, *et al.* Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* 2013;**382**:427–51.
2 Rahman MM, Abe SK, Kanda M, *et al.* Maternal body mass index and risk of birth and maternal health outcomes in low- and middle-income countries: A systematic review and meta-analysis. *Obes Rev* 2015;**16**:758–70.
3 Li N, Liu E, Guo J, *et al.* Maternal prepregnancy body mass index and gestational weight gain on pregnancy outcomes. *PLoS One* 2013;**8**.
4 Yu Z, Han S, Zhu J, *et al.* Pre-Pregnancy Body Mass Index in Relation to Infant Birth Weight and Offspring Overweight/Obesity: A Systematic Review and Meta-Analysis. *PLoS One* 2013;**8**.
5 Pan Y, Zhang S, Wang Q, *et al.* Investigating the association between prepregnancy body mass index and adverse pregnancy outcomes: A large cohort study of 536 098 Chinese pregnant women in rural China. *BMJ Open* 2016;**6**:1–8.
6 Rahman MM, Abe SK, Rahman MS, *et al.* Maternal anemia and risk of adverse birth and health outcomes in low- and middle-income countries: Systematic review and meta-analysis. *Am J Clin Nutr* 2016;**103**:495–504.
7 Assefa N, Berhane Y, Worku A. Wealth status, mid upper arm circumference (MUAC) and Ante Natal Care (ANC) are determinants for low birth weight in Kersa, Ethiopia. *PLoS One* 2012;**7**.
8 Negash C, Whiting SJ, Henry CJ, *et al.* Association between maternal and child nutritional status in Hula, rural Southern Ethiopia: A cross sectional study. *PLoS One* 2015;**10**:1–8.
9 Khan MN, Rahman MM, Shariff AA, *et al.* Maternal undernutrition and excessive body weight and risk of birth and health outcomes. *Arch Public Heal* 2017;**75**:1–10.
10 Catalano PM, Farrell K, Thomas A, *et al.* Perinatal risk factors for childhood obesity and metabolic. *Am J Clin Nutr* 2009;**90**:1303–13.
11 Victora CG, Adair L, Fall C, *et al.* Maternal and child undernutrition: consequences for adult health and human capital. *Lancet* 2008;**371**:340–57.
12 Fogelman A. Issues in Brief The Changing Shape of Malnutrition : Obesity in sub-Saharan Africa. 2009.
13 Milton AH, Smith W, Rahman B, *et al.* Prevalence and determinants of malnutrition among reproductive aged women of rural Bangladesh. *Asia-Pacific J Public Heal* 2010;**22**:110–7.
14 CSA and ICF International. Ethiopia Demographic and Health Survey 2016. Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Agency and ICF International. 2016; 1–452.
15 Bhutta ZA, Das JK, Rizvi A, *et al.* Evidence-based interventions for improvement of maternal and child nutrition: What can be done and at what cost? *Lancet* 2013;**382**:452–77.
16 Demelash H, Id D, Dadi AF. Burden and determinants of malnutrition among pregnant women in Africa : A systematic review and meta-analysis. 2019;:1–19.
17 WHO. Maternal anthropometry and pregnancy outcomes. *WHO Bull* 1995;**73**:1–98.
18 Krasovec K, Anderson MA, Organization PAH. *Maternal Nutrition and Pregnancy Outcomes: Anthropometric Assessment*. Pan American Health Organization 1995.
19 Abraham S, Miruts G, Shumye A. Magnitude of chronic energy deficiency and its associated factors among women of reproductive age in the Kunama population, Tigray, Ethiopia, in 2014. *BMC Nutr* 2015;**1**:1–9.
20 Haileslassie K, Mulugeta A, Girma M. Feeding practices, nutritional status and associated factors of lactating women in Samre Woreda, South Eastern Zone of Tigray, Ethiopia. *Nutr J* 2013;**12**:1.
21 Headen IE, Davis EM, Mujahid MS, *et al.* Racial-Ethnic Differences in Pregnancy-Related Weight. *Adv Nutr* 2012;**3**:83–94.
22 Tebekaw Y, Teller C, Colón-Ramos U. The burden of underweight and overweight among women in Addis Ababa,

Ethiopia. *BMC Public Health* 2014;**14**.
23 Alaofè H, Zhu M, Burney J, *et al.* Association Between Women's Empowerment and Maternal and Child Nutrition in Kalalé District of Northern Benin. *Food Nutr Bull* 2017;**38**:302–18.
24 Pratley P. Associations between quantitative measures of women's empowerment and access to care and health status for mothers and their children: A systematic review of evidence from the developing world. *Soc Sci Med* 2016;**169**:119–31.
25 Y. T, C. T, U. C-R. The burden of underweight and overweight among women in Addis Ababa, Ethiopia. *BMC Public Health* 2014;**14**:1126.
26 Assefa Y, Gelaw YA, Hill PS, *et al.* Community health extension program of Ethiopia, 2003-2018: Successes and challenges toward universal coverage for primary healthcare services. *Global Health* 2019;**15**:1–11.=
27 Medhanyie A, Spigt M, Kifle Y, *et al.* The role of health extension workers in improving utilization of maternal health services in rural areas in Ethiopia: A cross sectional study. *BMC Health Serv Res* 2012;**12**:1.
28 Yitayal M, Berhane Y, Worku A, *et al.* Health extension program factors, frequency of household visits and being model households, improved utilization of basic health services in Ethiopia. *BMC Health Serv Res* 2014;**14**:156.
29 Kabeer N. Resources, Agency, Achievements: Reflections on the Measurement of Women's Empowerment. *Dev Change* 1999;**30**:435–64.
30 Asefa F, Nemomsa D. Gestational weight gain and its associated factors in Harari Regional State: Institution based cross-sectional study, Eastern Ethiopia. *Reprod Health* 2016;**13**:1–7.
31 Zerfu TA, Umeta M, Baye K. Dietary diversity during pregnancy is associated with reduced risk of maternal anemia, preterm delivery, and low birth weight in a prospective cohort study in rural Ethiopia. *Am J Clin Nutr* 2016;**103**:1482–8.
32 Coates J, Swindale A. Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide Version. *J Chem Inf Model* 2013;**53**:1689–99.
33 FAO & FHI 360. *Minimum Dietary Diversity for Women- A Guide to Measurement*. 2016.
34 The International Physical Activity Questionnaire.Short Last 7 Days Self-Administered Format.2002.http://www.ipaq.ki.se.
35 World Food Program. Creation of a Wealth Index. 2017;:1–26.
36 WHO/UNICEF. Progress on Sanitation and DrWorld Health Organization Unicef Joint Monitoring Programme for Water Supply and Sanitationinking Water: Update 2010. *WHO Libr* 2010;:1–55.
37 International Physical Activity Questionnaire. IPAQ scoring protocol. 2005. http://www.ipaq.ki.se.
38 Rabin RF, Jennings JM, Campbell JC, *et al.* Intimate Partner Violence Screening Tools. *Am J Prev Med* 2009;**36**:439-445.e4.
39 Jennings L, Na M, Cherewick M, *et al.* Women's empowerment and male involvement in antenatal care: Analyses of Demographic and Health Surveys (DHS) in selected African countries. *BMC Pregnancy Childbirth* 2014;**14**:1–11.
40 Malapit HJL, Quisumbing AR. What dimensions of women's empowerment in agriculture matter for nutrition in Ghana? *Food Policy* 2015;**52**:54–63.
41 Gitagia MW, Ramkat RC, Mituki DM, *et al.* Determinants of dietary diversity among women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru, Kenya. *Food Nutr Res* 2019;**63**:1–12.
42 Cheng ER, Rifas-Shiman SL, Perkins ME, *et al.* The Influence of Antenatal Partner Support on Pregnancy Outcomes. *J Women's Heal* 2016;**25**:672–9.
43 Kocalevent RD, Berg L, Beutel ME, *et al.* Social support in the general population: Standardization of the Oslo social support scale (OSSS-3). *BMC Psychol* 2018;**6**:4–11.
44 Cox JL, Holden JM, Sagovsky R. Detection of Postnatal Depression. *Br J Psychiatry* 1987;**150**:782–6.
45 Zigmond AS, Snaith RP. The Hospital Anxiety And Depression Scale.Acta Psychiatr Scand.1983;67:361–70.
46 Karam F, Bérard A, Sheehy O, *et al.* Reliability and validity of the 4-item perceived stress scale among pregnant women: Results from the OTIS antidepressants study. *Res Nurs Heal* 2012;**35**:363–75.
47 The Sphere. *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response*. 2018.
48 UCLA Statistical Consulting Group. Stata FAQ How can I run a piecewise regression in Stata? 2011;:1–7.
49 Yitayal M, Berhane Y, Worku A, *et al.* The community-based Health Extension Program significantly improved contraceptive utilization in West Gojjam Zone, Ethiopia. *J Multidiscip Healthc* 2014;**7**:201–8.
50 Medhanyie A, Spigt M, Kifle Y, *et al.* The role of health extension workers in improving utilization of maternal health services in rural areas in Ethiopia: A cross sectional study. *BMC Health Serv Res* 2012;**12**.
51 Tafesse N, Gesessew A, Kidane E. Urban health extension program model housing and household visits improved the utilization of health Services in Urban Ethiopia: A community-based cross-sectional study. *BMC Health Serv Res* 2019;**19**:1–11.
52 Negussie A, Girma G. Is the role of Health Extension Workers in the delivery of maternal and child health care services a significant attribute? the case of Dale district, southern Ethiopia. *BMC Health Serv Res* 2017;**17**:1–8.
53 Tebekaw Y. The Demographic Transition and Development in Africa. *Demogr Transit Dev Africa* 2011;:105–24.
54 Malapit HJL, Kadiyala S, Quisumbing AR, *et al.* Women's Empowerment Mitigates the Negative Effects of Low Production Diversity on Maternal and Child Nutrition in Nepal. *J Dev Stud* 2015;**51**:1097–123.
55 Amugsi DA, Lartey A, Kimani E, *et al.* Women's participation in household decision-making and higher dietary diversity: findings from nationally representative data from Ghana. *J Health Popul Nutr* 2016;**35**:16.
56 Ghose B, Feng D, Tang S, *et al.* Women's decision-making autonomy and utilisation of maternal healthcare services: Results from the Bangladesh Demographic and Health Survey. *BMJ Open* 2017;**7**:1–8.
57 Ousman SK, Mdala I, Thorsen VC, *et al.* Social Determinants of Antenatal Care Service Use in Ethiopia: Changes Over a 15-Year Span. *Front Public Heal* 2019;**7**:1–10.
58 Ahmed S, Creanga AA, Gillespie DG, *et al.* Economic status, education and empowerment: Implications for

maternal health service utilization in developing countries. *PLoS One* 2010;**5**.
59 Pandey S, Lama G, Lee H. Effect of women's empowerment on their utilization of health services: A case of Nepal. *Int Soc Work* 2012;**55**:554–73.
60 Sado L, Spaho A, Hotchkiss DR. The influence of women's empowerment on maternal health care utilization: Evidence from Albania. *Soc Sci Med* 2014;**114**:169–77.
61 Adhikari R. Effect of Women's autonomy on maternal health service utilization in Nepal: A cross sectional study. *BMC Womens Health* 2016;**16**:1–7.
62 Rahman M, Nakamura K, Seino K, *et al.* Intimate partner violence and chronic undernutrition among married Bangladeshi women of reproductive age: Are the poor uniquely disadvantaged? *Eur J Clin Nutr* 2013;**67**:301–7.
63 Rahman M, Nakamura K, Seino K, *et al.* Intimate partner violence and use of reproductive health services among married women: Evidence from a national Bangladeshi sample. *BMC Public Health* 2012;**12**:1.
64 Ackerson LK, Subramanian S V. Domestic violence and chronic malnutrition among women and children in India. *Am J Epidemiol* 2008;**167**:1188–96.
65 Ersino G, Zello GA, Henry CJ, *et al.* Gender and household structure factors associated with maternal and child undernutrition in rural communities in Ethiopia. *PLoS One* 2018;**13**:1–20.
66 Amugsi DA, Dimbuene ZT, Bakibinga P, *et al.* Dietary diversity, socioeconomic status and maternal body mass index (BMI): quantile regression analysis of nationally representative data from Ghana, Namibia and Sao Tome and Principe. *BMJ Open* 2016;**6**:e012615.
67 Arimond M, Wiesmann D, Becquey E, *et al.* Simple Food Group Diversity Indicators Predict Micronutrient Adequacy of Women's Diets in. *J Nutr* 2010;**140**:2059–69.
68 McDonald CM, McLean J, Kroeun H, *et al.* Household food insecurity and dietary diversity as correlates of maternal and child undernutrition in rural Cambodia. *Eur J Clin Nutr* 2015;**69**:242–6.
69 Di Cesare M, Bhatti Z, Soofi SB, *et al.* Geographical and socioeconomic inequalities in women and children's nutritional status in Pakistan in 2011: An analysis of data from a nationally representative survey. *Lancet Glob Heal* 2015;**3**:e229–39.
70 Nguyen PH, Avula R, Ruel MT, *et al.* Maternal and Child Dietary Diversity Are Associated in Bangladesh, Vietnam, and Ethiopia. *J Nutr* 2013;**143**:1176–83.
71 Adubra L, Savy M, Fortin S, *et al.* The Minimum Dietary Diversity for Women of Reproductive Age (MDD-W) Indicator Is Related to Household Food Insecurity and Farm Production Diversity: Evidence from Rural Mali. *Curr Dev Nutr* 2019;**3**:1–9.
72 Na M, Mehra S, Christian P, *et al.* Maternal Dietary Diversity Decreases with Household Food Insecurity in Rural Bangladesh: A Longitudinal Analysis. *J Nutr* 2016;**146**:2109–16.
73 Kang Y, Hurley KM, Ruel-Bergeron J, *et al.* Household food insecurity is associated with low dietary diversity among pregnant and lactating women in rural Malawi. *Public Health Nutr* 2019;**22**:697–705.
74 Sibhatu KT, Qaim M. Review: The association between production diversity, diets, and nutrition in smallholder farm households. *Food Policy* 2018;**77**:1–18.
75 Desalegn BB, Lambert C, Riedel S, *et al.* Ethiopian orthodox fasting and lactating mothers: Longitudinal study on dietary pattern and nutritional status in rural tigray, Ethiopia. *Int J Environ Res Public Health* 2018;**15**:1–20.
76 D'Haene E, Desiere S, D'Haese M, *et al.* Evidence from the Ethiopian Milk Market. *Foods* 2019;**8**:1–21.
77 Bezabih AM, Wereta MH, Kahsay ZH, *et al.* Demand and Supply Side Barriers that Limit the Uptake of Nutrition Services among Pregnant Women from Rural Ethiopia: An Exploratory Qualitative Study. *Nutrients* 2018;**10**.

Figure 1: Pre-pregnancy nutritional status as assessed by BMI and MUAC of women, Tigrai region, Northern Ethiopia, 2018.


900
800
700
600
500
400
300
200
100
0
Number
359 (36.2%)
627 (63.8%)
202 (20.5%)
789 (79.5%)
Undernourished
Normal
< 21.0 cm
≥ 21.0 cm
Pre-pregnancy BMI
MUAC

STROBE statement-checklist of items that should be included in reports of cross-sectional studies

	Item no	Recommendation	Page and line number
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Pages 1 lines 1-2 and page 2 line 4
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2 lines 7-23
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Pages 3 and 4
Objectives	3	State specific objectives, including any pre-specified hypotheses	Page 4 lines 13-16
Methods			
Study design	4	Present key elements of study design early in the paper	Page 4 lines 19-22 and page 5 lines 4-13
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 4 lines 19-32
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	Page 5 lines 4-7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Pages 5,6,7 and 8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Pages 5,6,7 and 8
Bias	9	Describe any efforts to address potential sources of bias	Page 8 lines 25-28
Study size	10	Explain how the study size was arrived at	Page 5 lines 7-13
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Pages 5,6,7,8 and 9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Pages 9
		(*b*) Describe any methods used to examine subgroups and interactions	Page 9
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 5 lines 20-23 (partly)
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Pages 12, 13 and 14
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	Pages 10 and 11
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Pages 14, 15 and 16
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA

Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses	Page 9
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 16 lines 10 – 13, and Page 17 lines 1 – 7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 19 lines 23-31
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Pages 17,18 and 19
Generalizability	21	Discuss the generalizability (external validity) of the study results	Page 20 lines 1-2
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 20 line 23

*Give information separately for exposed and unexposed groups.

BMJ Open

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

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2020-043484.R2
Article Type:	Original research
Date Submitted by the Author:	02-Jun-2021
Complete List of Authors:	Misgina, Kebede; University of Groningen, Epidemiology; Aksum University, Public Health Boezen, H. Marike; University of Groningen, Epidemiology van der Beek, Eline M.; University of Groningen, Paediatrics Mulugeta , Afework ; Mekelle University, School of Public Health Groen, Henk; University of Groningen, Epidemiology
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Obstetrics and gynaecology
Keywords:	PREVENTIVE MEDICINE, NUTRITION & DIETETICS, EPIDEMIOLOGY

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 Tigrai 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 (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 measure was pre-pregnancy nutritional status assessed 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

Strengths and limitations of this study

- Measuring weight in a distinct period before starting the inclusion of women, and
- 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 insensitive to change over time, it can safely represent the pre-pregnancy status.
- Finally, seasonal variation was not considered in dietary diversity measurements.

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 low 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 Tigrai, 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 Tigrai, 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.[19,25] The previous studies also did not control potential confounders like implementing a health extension package, fasting, agrobiodiversity, and psychosocial characteristics.[26–28] 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.[29]

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 [22] or population groups with different socioeconomic and cultural characteristics.[19] 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 Tigrai 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 Tigrai 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.[26]

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. In addition, we identified pregnant women through two ongoing projects in Ethiopia. The first project concerns a Productive Safety Net Programme that is being implemented, aiming 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 [30] and extracting data available in the KA-DHSS database. The questionnaire was adapted from the literature [7,14,31–35] and pretested on 55 pregnant women selected based on their accessibility in Tahtay-Maichew, central zone, Tigrai 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, i.e., 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 last update for wealth index was done in 2015 in most of kebeles and in 2017 in two kebeles that were included into the surveillance site recently. 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.[36] 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 is defined as access to an unshared toilet facility, pit latrine with a slab, ventilated improved pit latrine, or flush toilet.[37]

Furthermore, time to fetch 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 dichotomized at a cut-off point of 30 with the time needed not exceeding 30 minutes showing better service.[37] 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.[26–28] Furthermore, history of pre-pregnancy illnesses were 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 (IPAQ)-short form,[35,38] 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 summarized as low, moderate, or high physical activity using the algorithm described in the scoring protocol.[38]

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, i.e., the number of previous pregnancies, parity, and history of abortion, as well as stillbirth, were extracted from the KA-DHSS database. Also, age at first marriage, age at first birth, previous inter-birth spacing in months, and history of preterm birth, delivery by Caesarean section, and severe perinatal hemorrhage 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 hemorrhage, or delivery by Caesarean section. Furthermore, self-reported information on intimate partner violence was obtained using the four-item HITS (Hurt, Insult, Threaten and Scream) questionnaire at inclusion. Each question was rated from 1 to 5, and a total score > 10 was used as a cut-off for the presence of violence.[39]

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 health care autonomy (decision-making on family visits, and women's health); 4. attitude towards domestic violence; 5. ownership of assets (farmland and house).[14,23,40] 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.[41]

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 of Lenten fast, the 14-day Apostles fast, and the14-day Dormition fast. Data on fasting was collected by asking women if they fast the weekly fast and adhere to the long fast times. Finally, women were categorized 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 zero to eight was calculated based on each category's answers.[42] 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 hours period with 'yes' or 'no' as the answer options.[34] The list was organized into ten groups: grains, white roots, and tubers; pulses; nuts and seeds; dairy; meat, fish and poultry; egg; dark green leafy vegetables; other vitamins A-rich fruit and vegetables; other fruit; and other vegetables. Consumption of foods from five or more groups was defined as adequate dietary diversity.[34]

Household Food Insecurity Access Scale was used to collect data concerning food security status.[33] 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.[33]

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.[43] 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.[44] Totaling the two measures of support, 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.[45,46] 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 of ≥ 8 showing high symptoms of stress.[47] 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.[48]

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 3.3, 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.[49] 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 $X \geq K$, robust), we tested if the slopes of the two variables were different (test $X < K = X \geq K$). 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, relevant variables as per the literature 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. 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 MUAC < 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 [50]. 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.

Patient and public involvement

There was no patient or public involvement.

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 assessed 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) (see figure 1).

Table 1. Anthropometric measures by pre-pregnancy BMI categories of women (n=991) from the Tigrai 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.

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 2 Socioeconomic characteristics of women and their households (n=991), Tigrai 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 needed to fetch water not exceed 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 as well as 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. However, 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.

Table 3 Reproductive and obstetric conditions, food and dietary as well as psychosocial characteristics of women (n=991), Tigrai 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%)

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.

Table 4. Unadjusted and adjusted linear regression analysis of factors associated with mean pre-pregnancy BMI and MUAC of women (n=991), Tigrai 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 1 hour, and time needed to fetch water not exceed 30 minutes. [a&b] represent the two continuous variables below and greater than or equal to the knot value respectively.

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 5. Unadjusted and adjusted Poisson regression analysis of factors associated with pre-pregnancy undernutrition as assessed by BMI and MUAC (n=991), Tigrai 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 1 hour, and time needed to fetch water not exceed 30 minutes. IRR refers to 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 [51,52].

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.[53–56] 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.[23,57,58] This may be partly explained by the effect of women empowerment on access to food, dietary practice, and seeking healthcare.[59–65] 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.[19,66,67] As dietary diversity is seen as a proxy of dietary quality, higher dietary diversity can translate to better nutritional status.[68] Likewise, the negative association found between food insecurity score and pre-pregnancy nutritional status, consistent with the literature,[19,69,70], could be explained by inadequate dietary intake or quality due to lack of access to food.[71–74] Also, a lower agrobiodiversity score was negatively associated with pre-pregnancy nutritional status. Though previous findings are mixed, as shown in a recent review,[75] 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.[51] 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, the 14-day Apostles fast, and the14-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.[76,77] 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. However, 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.

Ethics approval and consent to participate

Ethical clearance was acquired from the Institutional Research Review Board of College of Health Science, Aksum University [(ref. number: IRB 026/2017 dated 15/08/2017)]. Permission letter was attained from the regional health bureau and respective district health offices. Also, verbal consent was obtained from each study participant before data collection.

Consent for publication

Not applicable.

Availability of data and material

Dataset will be used for further work and cannot be publicized at this stage.

Competing interests

None declared.

Funding

No specific grant for this research from any funding agency.

Authors' contributions

KHM, HG, HMB, EvdB, and AM designed the study. KHM, HG, and AM were involved in the data collection. KHM and HG analyzed the data. KHM, HG, HMB, and EvdB interpreted the data and prepared the manuscript.

Acknowledgments

The universities of Groningen, Aksum, and Mekelle are acknowledged for their valuable support. Our gratitude goes to the regional health bureau, district health offices, supervisors, data collectors as well as women who participated in this study. We are also thankful to the Central Statistics Agency of Ethiopia and district health bureaus, including Tahtay-Maichew, who allowed us to use their scales for anthropometric measurements. Finally, we appreciate the help of Haileselasie Berhane Alema and Shewit Engdashet Berhe, who entered the data.

REFERENCES

1 Black RE, Victora CG, Walker SP, *et al.* Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* 2013;**382**:427–51.
2 Rahman MM, Abe SK, Kanda M, *et al.* Maternal body mass index and risk of birth and maternal health outcomes in low- and middle-income countries: A systematic review and meta-analysis. *Obes Rev* 2015;**16**:758–70.
3 Li N, Liu E, Guo J, *et al.* Maternal prepregnancy body mass index and gestational weight gain on pregnancy outcomes. *PLoS One* 2013;**8**.
4 Yu Z, Han S, Zhu J, *et al.* Pre-Pregnancy Body Mass Index in Relation to Infant Birth Weight and Offspring Overweight/Obesity: A Systematic Review and Meta-Analysis. *PLoS One* 2013;**8**.
5 Pan Y, Zhang S, Wang Q, *et al.* Investigating the association between prepregnancy body mass index and adverse pregnancy outcomes: A large cohort study of 536 098 Chinese pregnant women in rural China. *BMJ Open* 2016;**6**:1–8.
6 Rahman MM, Abe SK, Rahman MS, *et al.* Maternal anemia and risk of adverse birth and health outcomes in low-

and middle-income countries: Systematic review and meta-analysis. *Am J Clin Nutr* 2016;**103**:495–504.
7 Assefa N, Berhane Y, Worku A. Wealth status, mid upper arm circumference (MUAC) and Ante Natal Care (ANC) are determinants for low birth weight in Kersa, Ethiopia. *PLoS One* 2012;**7**.
8 Negash C, Whiting SJ, Henry CJ, *et al.* Association between maternal and child nutritional status in Hula, rural Southern Ethiopia: A cross sectional study. *PLoS One* 2015;**10**:1–8.
9 Khan MN, Rahman MM, Shariff AA, *et al.* Maternal undernutrition and excessive body weight and risk of birth and health outcomes. *Arch Public Heal* 2017;**75**:1–10.
10 Catalano PM, Farrell K, Thomas A, *et al.* Perinatal risk factors for childhood obesity and metabolic. *Am J Clin Nutr* 2009;**90**:1303–13.
11 Victora CG, Adair L, Fall C, *et al.* Maternal and child undernutrition: consequences for adult health and human capital. *Lancet* 2008;**371**:340–57.
12 Fogelman A. Issues in Brief The Changing Shape of Malnutrition : Obesity in sub-Saharan Africa. 2009.
13 Milton AH, Smith W, Rahman B, *et al.* Prevalence and determinants of malnutrition among reproductive aged women of rural Bangladesh. *Asia-Pacific J Public Heal* 2010;**22**:110–7.
14 CSA and ICF International. Ethiopia Demographic and Health Survey 2016. Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Agency and ICF International. 2016; 1–452.
15 Bhutta ZA, Das JK, Rizvi A, *et al.* Evidence-based interventions for improvement of maternal and child nutrition: What can be done and at what cost? *Lancet* 2013;**382**:452–77.
16 Demelash H, Id D, Dadi AF. Burden and determinants of malnutrition among pregnant women in Africa : A systematic review and meta-analysis. 2019;:1–19.
17 WHO. Maternal anthropometry and pregnancy outcomes. *WHO Bull* 1995;**73**:1–98.
18 Krasovec K, Anderson MA, Organization PAH. *Maternal Nutrition and Pregnancy Outcomes: Anthropometric Assessment*. Pan American Health Organization 1995.
19 Abraham S, Miruts G, Shumye A. Magnitude of chronic energy deficiency and its associated factors among women of reproductive age in the Kunama population, Tigray, Ethiopia, in 2014. *BMC Nutr* 2015;**1**:1–9.
20 Haileslassie K, Mulugeta A, Girma M. Feeding practices, nutritional status and associated factors of lactating women in Samre Woreda, South Eastern Zone of Tigray, Ethiopia. *Nutr J* 2013;**12**:1.
21 Headen IE, Davis EM, Mujahid MS, *et al.* Racial-Ethnic Differences in Pregnancy-Related Weight. *Adv Nutr* 2012;**3**:83–94.
22 Tebekaw Y, Teller C, Colón-Ramos U. The burden of underweight and overweight among women in Addis Ababa, Ethiopia. *BMC Public Health* 2014;**14**.
23 Alaofè H, Zhu M, Burney J, *et al.* Association Between Women's Empowerment and Maternal and Child Nutrition in Kalalé District of Northern Benin. *Food Nutr Bull* 2017;**38**:302–18.
24 Pratley P. Associations between quantitative measures of women's empowerment and access to care and health status for mothers and their children: A systematic review of evidence from the developing world. *Soc Sci Med* 2016;**169**:119–31.
25 Tebekaw Y, Teller C, & Colón-Ramos U. The burden of underweight and overweight among women in Addis Ababa, Ethiopia. *BMC Public Health* 2014;**14**:1126.
26 Assefa Y, Gelaw YA, Hill PS, *et al.* Community health extension program of Ethiopia, 2003-2018: Successes and challenges toward universal coverage for primary healthcare services. *Global Health* 2019;**15**:1–11. doi:10.1186/s12992-019-0470-1
27 Medhanyie A, Spigt M, Kifle Y, *et al.* The role of health extension workers in improving utilization of maternal health services in rural areas in Ethiopia: A cross sectional study. *BMC Health Serv Res* 2012;**12**:1.
28 Yitayal M, Berhane Y, Worku A, *et al.* Health extension program factors, frequency of household visits and being model households, improved utilization of basic health services in Ethiopia. *BMC Health Serv Res* 2014;**14**:156.
29 Kabeer N. Resources, Agency, Achievements: Reflections on the Measurement of Women's Empowerment. *Dev Change* 1999;**30**:435–64.
30 WHO Expert Committee. Physical Status: The use and Interpretation of Anthropometry. *WHO Technical Report Series 854. 19985;WHO, Geneva.*
31 Asefa F, Nemomsa D. Gestational weight gain and its associated factors in Harari Regional State: Institution based cross-sectional study, Eastern Ethiopia. *Reprod Health* 2016;**13**:1–7.
32 Zerfu TA, Umeta M, Baye K. Dietary diversity during pregnancy is associated with reduced risk of maternal anemia, preterm delivery, and low birth weight in a prospective cohort study in rural Ethiopia. *Am J Clin Nutr* 2016;**103**:1482–8.
33 Coates J, Swindale A. Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide Version. *J Chem Inf Model* 2013;**53**:1689–99.
34 FAO & FHI 360. *Minimum Dietary Diversity for Women- A Guide to Measurement*. 2016.
35 The International Physical Activity Questionnaire. Short Last 7 Days Self-Administered Format.2002.http://www.ipaq.ki.se.
36 World Food Program. Creation of a Wealth Index. 2017;:1–26.
37 WHO/UNICEF. Progress on Sanitation and DrWorld Health Organization Unicef Joint Monitoring Programme for Water Supply and Sanitationinking Water: Update 2010. *WHO Libr* 2010;:1–55.
38 International Physical Activity Questionnaire. IPAQ scoring protocol. 2005;:15.
39 Rabin RF, Jennings JM, Campbell JC, *et al.* Intimate Partner Violence Screening Tools. *Am J Prev Med* 2009;**36**:439-445.e4.
40 Jennings L, Na M, Cherewick M, *et al.* Women's empowerment and male involvement in antenatal care: Analyses of Demographic and Health Surveys (DHS) in selected African countries. *BMC Pregnancy Childbirth* 2014;**14**:1–11.
41 Malapit HJL, Quisumbing AR. What dimensions of women's empowerment in agriculture matter for nutrition in

Ghana? *Food Policy* 2015;**52**:54–63.

42 Gitagia MW, Ramkat RC, Mituki DM, *et al.* Determinants of dietary diversity among women of reproductive age in two different agro-ecological zones of Rongai Sub-County, Nakuru, Kenya. *Food Nutr Res* 2019;**63**:1–12.

43 Cheng ER, Rifas-Shiman SL, Perkins ME, *et al.* The Influence of Antenatal Partner Support on Pregnancy Outcomes. *J Women's Heal* 2016;**25**:672–9.

44 Kocalevent RD, Berg L, Beutel ME, *et al.* Social support in the general population: Standardization of the Oslo social support scale (OSSS-3). *BMC Psychol* 2018;**6**:4–11.

45 Cox JL, Holden JM, Sagovsky R. Detection of Postnatal Depression. *Br J Psychiatry* 1987;**150**:782–6.

46 Zigmond AS, Snaith RP. The Hospital Anxiety And Depression Scale. *Acta Psychiatr Scand.*1983;**67**:361–70.

47 Karam F, Bérard A, Sheehy O, *et al.* Reliability and validity of the 4-item perceived stress scale among pregnant women: Results from the OTIS antidepressants study. *Res Nurs Heal* 2012;**35**:363–75.

48 The Sphere. *The Sphere Handbook: Humanitarian Charter and Minimum Standards in Humanitarian Response*. 2018.

49 UCLA Statistical Consulting Group. Stata FAQ How can I run a piecewise regression in Stata? 2011;:1–7.

50 Barros A., Hirakata V. Alternatives for logistic regression in cross-sectional studies: an empirical comparison of models that directly estimate the prevalence ratio. *BMC Med Res Methodol* 2003;**3:**21.

51 Desalegn BB, Lambert C, Riedel S, *et al.* Ethiopian orthodox fasting and lactating mothers: Longitudinal study on dietary pattern and nutritional status in rural tigray, Ethiopia. *Int J Environ Res Public Health* 2018;**15**:1–20.

52 Workicho A, Belachew T, Argaw A, *et al.* Maternal nutritional status mediates the association between maternal age and birth outcomes. Matern. Child Nutr. 2020;**16**.

53 Yitayal M, Berhane Y, Worku A, *et al.* The community-based Health Extension Program significantly improved contraceptive utilization in West Gojjam Zone, Ethiopia. *J Multidiscip Healthc* 2014;**7**:201–8.

54 Medhanyie A, Spigt M, Kifle Y, *et al.* The role of health extension workers in improving utilization of maternal health services in rural areas in Ethiopia: A cross sectional study. *BMC Health Serv Res* 2012;**12**.

55 Tafesse N, Gesessew A, Kidane E. Urban health extension program model housing and household visits improved the utilization of health Services in Urban Ethiopia: A community-based cross-sectional study. *BMC Health Serv Res* 2019;**19**:1–11.

56 Negussie A, Girma G. Is the role of Health Extension Workers in the delivery of maternal and child health care services a significant attribute? the case of Dale district, southern Ethiopia. *BMC Health Serv Res* 2017;**17**:1–8.

57 Tebekaw Y. The Demographic Transition and Development in Africa. *Demogr Transit Dev Africa* 2011;:105–24.

58 Malapit HJL, Kadiyala S, Quisumbing AR, *et al.* Women's Empowerment Mitigates the Negative Effects of Low Production Diversity on Maternal and Child Nutrition in Nepal. *J Dev Stud* 2015;**51**:1097–123.

59 Amugsi DA, Lartey A, Kimani E, *et al.* Women's participation in household decision-making and higher dietary diversity: findings from nationally representative data from Ghana. *J Health Popul Nutr* 2016;**35**:16. doi:10.1186/s41043-016-0053-1

60 Ghose B, Feng D, Tang S, *et al.* Women's decision-making autonomy and utilisation of maternal healthcare services: Results from the Bangladesh Demographic and Health Survey. *BMJ Open* 2017;**7**:1–8.

61 Ousman SK, Mdala I, Thorsen VC, *et al.* Social Determinants of Antenatal Care Service Use in Ethiopia: Changes Over a 15-Year Span. *Front Public Heal* 2019;**7**:1–10.

62 Ahmed S, Creanga AA, Gillespie DG, *et al.* Economic status, education and empowerment: Implications for maternal health service utilization in developing countries. *PLoS One* 2010;**5**.

63 Pandey S, Lama G, Lee H. Effect of women's empowerment on their utilization of health services: A case of Nepal. *Int Soc Work* 2012;**55**:554–73.

64 Sado L, Spaho A, Hotchkiss DR. The influence of women's empowerment on maternal health care utilization: Evidence from Albania. *Soc Sci Med* 2014;**114**:169–77.

65 Adhikari R. Effect of Women's autonomy on maternal health service utilization in Nepal: A cross sectional study. *BMC Womens Health* 2016;**16**:1–7.

66 Ersino G, Zello GA, Henry CJ, *et al.* Gender and household structure factors associated with maternal and child undernutrition in rural communities in Ethiopia. *PLoS One* 2018;**13**:1–20.

67 Amugsi DA, Dimbuene ZT, Bakibinga P, *et al.* Dietary diversity, socioeconomic status and maternal body mass index (BMI): quantile regression analysis of nationally representative data from Ghana, Namibia and Sao Tome and Principe. *BMJ Open* 2016;**6**:e012615.

68 Arimond M, Wiesmann D, Becquey E, *et al.* Simple Food Group Diversity Indicators Predict Micronutrient Adequacy of Women ' s Diets in. *J Nutr* 2010;**140**:2059–69.

69 McDonald CM, McLean J, Kroeun H, *et al.* Household food insecurity and dietary diversity as correlates of maternal and child undernutrition in rural Cambodia. *Eur J Clin Nutr* 2015;**69**:242–6.

70 Di Cesare M, Bhatti Z, Soofi SB, *et al.* Geographical and socioeconomic inequalities in women and children's nutritional status in Pakistan in 2011: An analysis of data from a nationally representative survey. *Lancet Glob Heal* 2015;**3**:e229–39.

71 Nguyen PH, Avula R, Ruel MT, *et al.* Maternal and Child Dietary Diversity Are Associated in Bangladesh, Vietnam, and Ethiopia. *J Nutr* 2013;**143**:1176–83.

72 Adubra L, Savy M, Fortin S, *et al.* The Minimum Dietary Diversity for Women of Reproductive Age (MDD-W) Indicator Is Related to Household Food Insecurity and Farm Production Diversity: Evidence from Rural Mali. *Curr Dev Nutr* 2019;**3**:1–9.

73 Na M, Mehra S, Christian P, *et al.* Maternal Dietary Diversity Decreases with Household Food Insecurity in Rural Bangladesh: A Longitudinal Analysis. *J Nutr* 2016;**146**:2109–16.

74 Kang Y, Hurley KM, Ruel-Bergeron J, *et al.* Household food insecurity is associated with low dietary diversity among pregnant and lactating women in rural Malawi. *Public Health Nutr* 2019;**22**:697–705.

75 Sibhatu KT, Qaim M. Review: The association between production diversity, diets, and nutrition in smallholder

farm households. *Food Policy* 2018;**77**:1–18.
76 D'Haene E, Desiere S, D'Haese M, *et al.* Evidence from the Ethiopian Milk Market. *Foods* 2019;**8**:1–21.
77 Bezabih AM, Wereta MH, Kahsay ZH, *et al.* Demand and Supply Side Barriers that Limit the Uptake of Nutrition Services among Pregnant Women from Rural Ethiopia: An Exploratory Qualitative Study. *Nutrients* 2018;**10**.

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

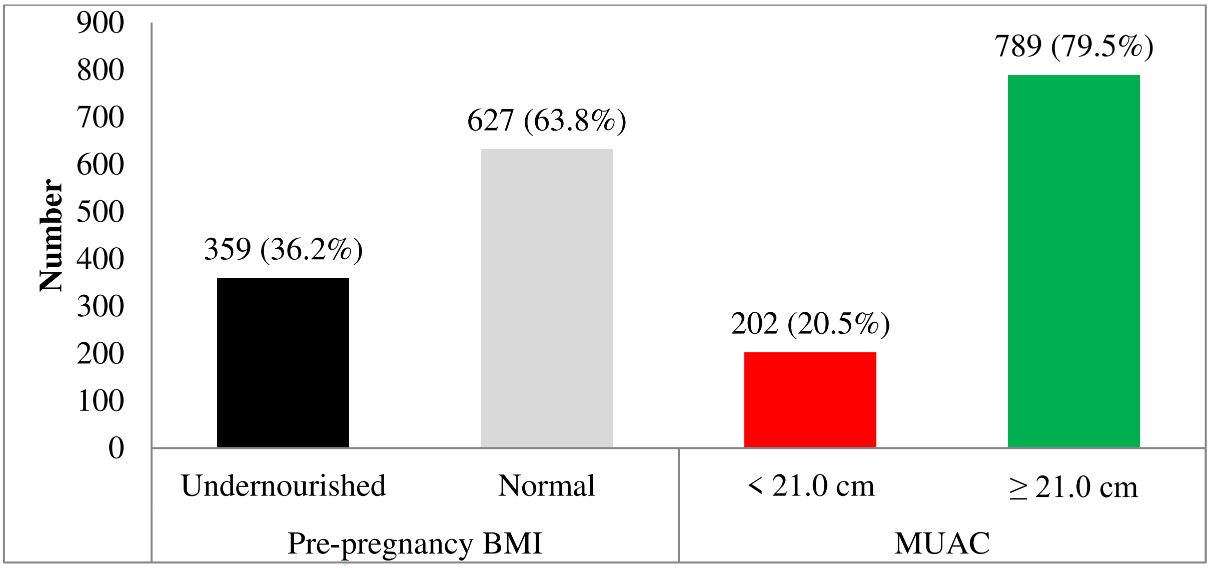

Figure 1. Pre-pregnancy nutritional status as assessed by BMI and MUAC of women, northern Ethiopia, 2018.

STROBE statement-checklist of items that should be included in reports of cross-sectional studies

	Item no	Recommendation	Page and line number
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Pages 1 lines 1-2 and page 2 line 4
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2 lines 7-24
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Pages 3 and 4
Objectives	3	State specific objectives, including any pre-specified hypotheses	Page 4 lines 15-18
Methods			
Study design	4	Present key elements of study design early in the paper	Page 4 lines 21-25 and page 5 lines 9-14
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 4 lines 21-32 and page 5 lines 1-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	Page 5 lines 6-9 and 29-31
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Pages 6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Pages 6-9
Bias	9	Describe any efforts to address potential sources of bias	Page 9 lines 28-31
Study size	10	Explain how the study size was arrived at	Page 5 lines 9-14
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Pages 6-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Pages 10
		(*b*) Describe any methods used to examine subgroups and interactions	Page 10
		(*c*) Explain how missing data were addressed	NA
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	NA
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Page 6 lines 1-4 (partly) and page 11 line 14
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	Pages 13 and 14
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	Pages 11 and 12
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Pages 10, 11, 15 and 17
		(*b*) Report category boundaries when continuous variables were categorized	Page 11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA

Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 19 lines 3 – 12, and Page 17 lines 1 – 7
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 21 lines 11-18
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Pages 19,20 and 21
Generalizability	21	Discuss the generalizability (external validity) of the study results	Page 21 lines 16-18
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Page 22 line 10

*Give information separately for exposed and unexposed groups.