



**EFFECTS OF NUTRITION EDUCATION AND EGG-BASED DIET INTERVENTIONS  
ON DIETARY INTAKE, NUTRIENT ADEQUACY AND NUTRITIONAL STATUS  
AMONG PREGNANT WOMEN AND BIRTH OUTCOMES IN THE SIDAMA REGION,  
ETHIOPIA: A CLUSTER RANDOMIZED CONTROL TRIAL**

**A PhD DISSERTATION**

**KALEB MAYISSO RODAMO (MPH)**

**SCHOOL OF NUTRITION, FOOD SCIENCES AND TECHNOLOGY**

**COLLEGE OF AGRICULTURE, HAWASSA UNIVERSITY**

**SEPTEMBER, 2025**

**HAWASSA, ETHIOPIA**

**Effects of Nutrition Education and Egg-based Diet Interventions on Dietary Intake,  
Nutrient Adequacy and Nutritional Status among Pregnant Women and Birth Outcomes  
Sidama Region, Ethiopia: A Cluster Randomized Control Trial**

**A PhD Dissertation**

**Kaleb Mayisso Rodamo (MPH)**

**Major supervisor: Dr. Dessalegn Tamiru (Assoc. Professor)**

**Co-supervisor: Dr. Tafese Bosha (Assoc. Professor)**

**Submitted to School of Graduate Studies in Partial Fulfillment of the Requirements for the  
Degree of Doctor of Philosophy (PhD) in Human Nutrition**

**School of Nutrition, Food Science and Technology College of Agriculture**

**Hawassa University**

**SEPTEMBER, 2025**

**Hawassa, Ethiopia**

**ADVISOR’S APPROVAL SHEET**

SCHOOL OF GRADUATE STUDIES,  
HAWASSA UNIVERSITY ADVISOR’S APPROVAL SHEET

This is to certify that the PhD Dissertation on “**Effects of Nutrition Education and Egg-based Diet Interventions on Dietary Intake, Nutrient Adequacy and Nutritional Status among Pregnant Women and Birth Outcome in Sidama Region, Ethiopia: A cRCT**” submitted in partial fulfillment of the requirement for the Degree of Doctor of Philosophy (PhD) with specialization in Human Nutrition, the Graduate Program of the School of Nutrition, Food Science and Technology has been carried out by “KALEB MAYISSO RODAMO” ID No PhD-005/14 under our supervision. Therefore, we confirm that the PhD candidate has fulfilled the requirements and hence can submit the dissertation to the School of Graduate Studies.

<u>Kaleb Mayisso Rodamo</u>	_____	_____
Name of student	Signature	Date
<u>Dr. Dessalegn Tamiru (Assoc. Prof.)</u>	_____	_____
Name of major supervisor	Signature	Date
<u>Dr. Tafese Bosha (Assoc. Prof.)</u>	_____	_____
Name of co-supervisor	Signature	Date
_____	_____	_____
Head of Department	Signature	Date
_____	_____	_____
Name of SGS Coordinator	Signature	Date

**EXAMINER’S APPROVAL SHEET-I**

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY EXAMINERS’ APPROVAL SHEET-1

We, the undersigned, members of the Board of Examiners of the final open defense by **Kaleb Mayisso Rodamo** have read and evaluated his/her thesis/dissertation entitled “Effects of Nutrition Education and Egg-based Diet Interventions on Dietary Intake, Nutrient Adequacy, and Nutritional Status among Pregnant Women and Birth Outcome in Sidama Region, Ethiopia: A cluster randomized controlled trail”, and examined the candidate. This is, therefore, to certify that the thesis/dissertation has been accepted in partial fulfillment of the requirements for the Doctor of Philosophy degree (PhD).

Name of Major Advisor	-----	Date
	Signature	
Name of Co- Advisor	-----	Date
	Signature	
Name of Internal Examiner	-----	Date
	Signature	
Name of Chairperson	-----	Date
	Signature	
Name of External examiner	-----	Date
	Signature	
SGSApproval	-----	Date
	Signature	

Final approval and acceptance of the thesis/dissertation is contingent upon the submission of the final copy of the dissertation to the School of Graduate Studies (SGS) through the Department/School Graduate Committee (DGC/SGC) of the candidate's department.

Stamp of SGS Date: \_\_\_\_\_

Remark:

- Use this form to submit the dissertation with MINOR CORRECTION suggested by the examining board
- 4 copies

## **Declaration**

I, Kaleb Mayisso Rodamo, hereby declare that this PhD dissertation is my original work and has not been submitted or presented for any degree in any other institute for academic requirement purpose and all materials used in this PhD dissertation are duly acknowledged and cited appropriately.

Name: Kaleb Mayisso Rodamo

Signature: \_\_\_\_\_ Date \_\_\_\_\_

## **Dedication**

I dedicate my dissertation work to my kind, humble, and determined father, “Awuya” Yodo Rodamo Yota, whom I lost during my journey to obtaining this terminal degree. I would have been happier if he could have witnessed his nephew achieving the education he always dreamed of. I also dedicated my dissertation work to my father Mayisso Rodamo Yota and my mother Sharbitu Worana Woma, who with love and effort have accompanied me in this process, without hesitating at any moment of seeing my dreams come true. My parents’ encouragement and belief in me have been a constant source of inspiration, and I am forever grateful for their blessings, guidance and wisdom.

# **General Information on Publication and Participation in Scientific Workshops/Conferences**

## **I. Articles published in internationally reputable journals**

Parts of this PhD dissertation are published on a peer-reviewed and reputable journal and presented at international and national scientific workshop/conference.

1. Mayisso K, Bosha T. and Tamiru D. (2025) Validation of food variety and dietary diversity scores as indicators of micronutrient adequacy among pregnant women in the northern zone of Sidama, Ethiopia. *Front. Public Health* 13:1536419. Available at: <https://doi.org/10.3389/fpubh.2025.1536419>
2. Mayisso, K., Bosha, T. and Tamiru, D. (2025) Effect of nutrition intervention coupled with healthy dietary advice on the nutritional status of pregnant women in the northern zone of the Sidama region, Ethiopia, A multilevel, cRCT'. *Journal of Health, Population and Nutrition*, 44(1), p. 230. Available at: <https://doi.org/10.1186/s41043-025-00968-2>

## **II. Submitted for publication and currently under review:**

1. Effect of nutrition education on improving nutrient adequacy and serum levels of essential micronutrients in pregnant women: submitted to [www.nature.com/scientific-reports](http://www.nature.com/scientific-reports)
2. Suboptimal maternal nutrition during pregnancy is associated with increased risk of low serum folate and preterm birth Sidama Region, Ethiopia. Submitted to <https://www.advances-nutrition.org>
3. Suboptimal consumption of animal-source food during pregnancy is associated with increased risk of low serum ferritin and low birth weight Sidama Region, Ethiopia submitted to <https://www.mdpi.com/>

## **III. Conference Presentations:**

Mayisso, K., Bosha, T. and Tamiru, D. (2025) Effect of nutrition intervention coupled with healthy dietary advice on the nutritional status of pregnant women in the northern zone of the Sidama region, Ethiopia: The Annual Regional Research Conference, Sidama Regional State Health Bureau, Hawassa, Ethiopia. May 2025

## Contents

Acknowledgments.....	ix
Abbreviations and Acronyms .....	x
List of Tables .....	i
List of Figures.....	iii
Abstract.....	iv
CHAPTER I: INTRODUCTION.....	1
1.1. Background.....	1
1.2. Statement of the problem.....	2
1.3. Significance of the study.....	4
1.4. Objectives .....	5
1.4.1. General Goal .....	5
1.4.2. Specific objectives .....	5
1.4.3 Research Hypothesis.....	5
2.1 Overview of undernutrition during pregnancy.....	7
2.2. Dietary diversity during pregnancy.....	8
2.3. Prenatal nutrition education and KAP of dietary intake .....	9
2.4. Dietary diversity and nutrient adequacy .....	10
2.5. Maternal nutrient intake and gestational weight gain .....	12
2.6. Maternal nutrition and newborn’s birth weight .....	13
2.7. Nutrition education intervention and newborn’s birth weight.....	15
2.8. Maternal dietary iron and folate intake and birth outcomes .....	16
2.9. Conceptual framework.....	18
CHAPTER III: METHODS AND MATERIALS .....	19
3.1. Study Area .....	19
3.2. Study Design and Period.....	21
3.3. Source and Study Population.....	21
3.4. Inclusion and Exclusion Criteria.....	21
3.5. Sample Size Determination.....	22
3.6. Sampling Technique .....	23

3.6. Data collection tools and data Collectors.....	25
3.7. Data quality assurance .....	29
3.8. Data management and analysis .....	29
3.9. Ethical Considerations .....	29
RESULTS AND DISCUSSIONS .....	30
CHAPTER V: Effect of Nutrition Education on Improving Micronutrient Adequacy and Serum Levels of Essential Micronutrients among Pregnant Women .....	53
CHAPTER VI: Effect of Egg-Based Diet Intervention Coupled with Healthy Dietary Advice on Nutritional Status among Pregnant Women.....	80
CHAPTER VII: Suboptimal maternal nutrition during pregnancy is associated with increased risk of low serum folate and preterm birth Sidama Region, Ethiopia .....	104
9.1. General Discussion .....	148
9.2. Strength and Limitations of the study .....	161
9.3. Conclusion .....	162
9.4. Recommendations.....	163
References.....	164
Annexes .....	193
Annex I: Policy Brief .....	193
Annex-II: Data Collection Tool English Version .....	196
Annex-III: Translated tool for data collection (Sidamifa Version).....	206
Gafa 7: Anthropometrikete .....	215
Annex IV: Standard operating procedure (SOP) .....	216
Annex V: Curriculum Vitea.....	223

## **Acknowledgments**

I would also like to acknowledge the supervisory team members namely Dr. Dessalegn Tamiru and Dr. Tafese Bosha for their valuable contribution throughout my PhD study. Dear Dr. Dessalegn, I hope that you receive my heartfelt thanks with no reservation as you received my request to advise me for my PhD study with no reservation. Your doors were open widely to let me enter to you as I desired and too your communication channels to receive my concerns. I am very lucky to be supervised by you. I pray to God to bless you with peace and to keep you safe, healthy and productive.

Dear Dr. Tafese, it is not acceptable not to mention that you were my invisible and magical shoulder to lug academic and extra academic challenges I was obliged to face throughout the process of my PhD study. I must also give recognition to the role you played in shaping my communication. I used to enter to your office as your friend, for asking Dr. Dessalegn, to accept my request to advise me for my PhD study with no reservation and sacrifice to support my study. Thank you for your fatherly approach. I pray to God to bless you with peace and to keep you safe, healthy and productive too.

Next to be addressed are my kind wife Bezayehu Agegnehu; lovely sons and daughters Jirame, Atoma, Lali and Arfassa, father and mother in law Mr. Agegnehu Yetera, Karo Bada; and other members of the extended family Mr. Ararso Agegnehu. Thank you for understanding the reasons why I failed to give the time that I am supposed to give you. Thank you for understanding me and not blaming me for not being involved in the happy and sad events of the family physically. Your usual question and concerns “How was the day?; How is the study going?”; “Take care of our kids”; “Take care of my field travel!” and the like were really the positive energy I had for the progress, I demonstrated and I will have to demonstrate more and more achievements in the future. I am proud of having you friends: Evangelist Kebede Shikur, Dr. Tarekegn Yoseph, Dr. Mesay Hailu, Mr. Daniel Kebede, Mr. Belayneh Bekele, Mr. Emala Lamacha, Dr. Selamawit Mengesha, Dr. Keneni Gutema, Mr. Fikadu Tefera, Mr. Zenebe Turche and all those I might have missed to mention.

Finally, I thank the data collectors, and the study participants for their voluntary participation in the study

## Abbreviations and Acronyms

APR	Adjusted Prevalence Ratio
ASF	Animal Source Foods
BMI	Body Mass Index
DBP	Diastolic Blood Pressure
CDC	Centers for Disease Control and Prevention
CMHS	College of Medicine and health Sciences
CSA	Central Statistical Agency
cRCT	Cluster Random Control Trial
CI	Confidence Interval
DD	Dietary Diversity
DDS	Dietary Diversity Score
DHS	Demographic and Health Survey
GDM	Gestational Diebetus Mellitus
DBP	Diastolic Blood Pressure
EAR	Estimated Average Requirements
EDD	Expected Date of Delivery
EPHI	Ethiopia Public Health Institute
ETB	Ethiopian Birr
EFCT	Ethiopian Food Composition Table
FANTA	Food and Nutrition Technical Assistance
FAO	Food and Agriculture Organization
FDRE	Federal Democratic Republic of Ethiopia
FMOH	Federal Ministry of Health
FVS	Food Variety Score
HBM	Health Belief Model
GWG	Gestational Weight Gain
HCG	Human Chorionic Gonadotropin
HEW	Health Extension Workers
HHFS	House Hold Food Security
IDA	Iron Defficiency Anemia
IFAS	Iron and Folic acid supplementation
IFPRI	International Food Policy Research

	Institute
IOM	Institution of Medicine
IRB	Institution Review Board
IUFD	Intra Utrine Fetal Death
IUGR	Intra Uterine Growth Retardation
LMICs	Low and Middle income countries
LMM	Linear Mixed Model
LBW	Low Birth Weight
MAR	Mean Adequacy Ratio
MDD-W	Minimum Dietary Diversity of Women
MUAC	Mid-Upper Arm Circumference
NAR	Nutrient Adequacy Ratio
NFFS	National Food Fortification Strategy
NFNS	National Food and Nutrition Strategy
NEI	Nutrition Education Intervention
NTD	Neural Tube Defect
PCA	Principal Component Analysis
PTB	Preterm Birth
PIH	Pregnancy Induced Hypertension
RBC	Red Blood Cell
RDA	Recommended Daily Allowance
RIN	Recommended Intake of Nutrient
SD	Standard Deviation
SDI	Socio-demographic Index
SGA	Small for Gestational Age
SPSS	Statistical Software for Social Science
SSA	Sub-sahara Africa
USDA	Unites States Development Agency
WBC	White Blood Cell
WDA	Women Developmental Army
WHA	World Health Assembly
WHO	World Health Organization

## List of Tables

<b>Table 1:</b> Summery of methods used to tackle each of specific objectives in dissertation, Northern Zone, Sidama Region, Ethiopia, 2025 .....	22
<b>Table2:</b> Socio-demographic and economic characteristics of pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424) .....	40
<b>Table 3:</b> Comparison in consumption of food variety and dietary diversity against demographic and economic indicators among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424) .....	42
<b>Table 4:</b> Intake of nutrients together with safe level of intake and the nutrient adequacy ratio among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424)....	43
<b>Table 5:</b> Area Under the Curve (AUC) of the Mean Adequacy Ratios (MAR) and dietary diversity score among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424).....	44
<b>Table 6:</b> Pearson’s correlation coefficient (r) between nutrient adequacy ratio (NAR), mean adequacy ratio; dietary diversity score and food variety score among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424) .....	46
<b>Table 7:</b> The linear regression modeling of predictors of dietary diversity, food variety and mean adequacy among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424).....	47
<b>Table 8:</b> Baseline socio-demographic characteristics of pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158).....	64
<b>Table 9:</b> Differences in baseline and end-line measurements of HBM construct among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158) .....	65
<b>Table 10:</b> Baseline and end-line differences in different food groups consumption among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158).....	67
<b>Table 11:</b> Differences in baseline and endline on maternal dietary iron and folate intake knowledge among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158). .....	69
<b>Table 12:</b> Differences in baseline and end line in meal frequency and dietary intake habit among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158).....	71
<b>Table 13.1:</b> Comparison of dietary intake practices, nutrient adequacy, and serum levels of iron and folate among pregnant women participated in the study in baseline and endline in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158) .....	73
<b>Table 13.2:</b> End line multivariable linear mixed model predicting adequacy of folate and iron and serum level of the micronutrients among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, (n=160).....	75
<b>Table 14:</b> Sociodemographic and economic characteristics of pregnant womenin participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158).....	92

<b>Table 15:</b> Comparison of reproductive health characteristics among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158) .....	93
<b>Table 16:</b> Differences between baseline and end-line measurements of nutritional status indicators among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158).....	95
<b>Table 17:</b> Differences between baseline and end-line in nutrient intake among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158). .....	97
<b>Table 18:</b> Differences between baseline and end-line in nutrient adequacy ratios among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158) .....	98
<b>Table19:</b> End-line multivariable LMM analysis for predicting nutritional status and nutrient adequacy among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025 (n=160).....	100
<b>Table 20:</b> Baseline socio-demographic and economic characteristics of cohort of pregnant women in Northern Sidama zone, Ethiopia (n=424) .....	114
<b>Table 21:</b> Base line obstetrics characteristics of cohort of pregnant women in Northern zone of the Sidama region, Ethiopia, 2025 (n=424).....	115
<b>Table 22:</b> Anthropometric characteristics and gestational weight gain of cohort of pregnant women in baseline and follow up in Northern Sidama zone, Ethiopia (n=424) .....	116
<b>Table 23:</b> Intake of dietary folate, mean nutrient adequacy ratio and serum level of folate in cohort of pregnant women in the northern Sidama zone, Ethiopia, 2025 (n=318).....	118
<b>Table 24:</b> Preterm birth and other birth outcomes in cohort of pregnant women in the northern Sidama zone, Ethiopia, 2025, (n=424).....	118
<b>Table 25:</b> predictors of preterm birth in cohort pregnant women in the northern zone of the Sidama region, Ethiopia, 2025, (n=424).....	119
<b>Table 26:</b> Baseline socio-demographic and economic characteristics of cohort of pregnant women in Northern Sidama zone, Ethiopia (n=424) .....	136
<b>Table 27:</b> Base line socio-demographic and obstetric characteristics of cohort of pregnant women by animal source food consumption status in Northern Sidama zone, Ethiopia (n=424).....	137
<b>Table 28:</b> Base line obstetrics characteristics of cohort of pregnant women in Northern zone of the Sidama region, Ethiopia, 2025 (n=424).....	137
<b>Table 29:</b> Anthropometric characteristics and gestational weight gain of cohort of pregnant women by ASF consumption status in baseline and follow up in Northern Sidama zone, Ethiopia (n=424).....	139
<b>Table 30:</b> Intake of dietary iron, nutrient adequacy ratio and serum level of ferritin in cohort of pregnant women by ASF consumption status in baseline and follow up in the northern Sidama zone, Ethiopia, 2025 (n=318).....	140
<b>Table 31:</b> Pregnancy and birth outcomes of pregnant women by animal source food consumption status at end line (term) in Northern Zone, Sidama Region, Ethiopia, 2025 (n=424) .....	141
<b>Table 32:</b> Determinants of low birth weight in cohort of pregnant women in the northern zone of the Sidama region, Ethiopia, 2025, (n=424).....	142

## List of Figures

Figure 1: Conceptual framework on the determinants of undernutrition in pregnant women and newborn (adapted from UNICEF, 2020 with a minor modification).....	18
Figure 2: Map of the Northern Zone of Sidama Regional State, Ethiopia.....	21
Figure 3: Diagrammatic presentation of sampling procedure for cluster randomized controlled trials in Northern Zone, Sidama Region, Ethiopia, 2025 .....	24
Figure 4: Diagrammatic representation of sampling process for two cohort studies in Northern Zone, Sidama Region, Ethiopia, 2025 .....	25
Figure 5: Food groups consumed by study participating pregnant women in Northern Zone, Sidama Region, Ethiopia (n=424).....	41
Figure 6: ROC curve model represents dietary diversity score that indicated MAR of the micronutrients at 3.87 in at the cutoffs of 70% sensitivity and specificity among study participants in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424).....	44
Figure 7: Participant flow chart showing the number of participants progressing through the study milestones in Northern Zone, Sidama Region, Ethiopia, 2025 .....	59
Figure 8: Transparent Reporting of Trials: Participant flow chart showing the number of study participants progressing through the study milestones in Northern Zone, Sidama Region, Ethiopia, 2025 .....	86
Figure 9: The number of study participants placed under different categories of mid-upper arm circumference in Northern Zone, Sidama Region, Ethiopia, 2025 (intervention=160, control=158) .....	94
Figure 10: Study participant flow of the prospective cohort of pregnant mothers in northern zone of Sidama Region, Ethiopia .....	110
Figure 11: Study participant flow of the prospective cohort of pregnant mothers in northern zone of Sidama Region, Ethiopia. ....	131

## **Abstract**

This dissertation comprises of nine concrete chapters and annexes pertinent for the study. The first chapter is all about introduction containing background, problem statement, significance of the study, hypothesis and objectives of the PhD research. The second chapter is review of literatures relevant to the study. The third chapter comprehensively describes materials and methods of the dissertation research work. The chapters from IV to VIII deal with the findings of each of the four specific objectives of the dissertation research, while, chapter IX contains general discussions, conclusions and recommendations.

**Background:** Pregnancy is a unique period in a woman's life, characterized by anatomical, physiological, and biochemical changes that affect nearly all organ systems. During this time, a diverse diet is essential to provide the necessary nutrients to meet the increased nutritional requirements. Pregnant women should consume healthy foods, including chicken eggs, fish, lean meats, fruits, vegetables, legumes, whole grains, and healthy fats those are rich sources of essential nutrients. Among these foods, chicken eggs are particularly valuable. They are a nutritionally complete and naturally nutrient-dense option, supplying easily digestible nutrients, including high-quality protein, vitamin D, vitamin A, vitamin B12, folate, choline, and long-chain omega-3 fatty acids.

Specific nutrients, such as dietary iron and folate, are crucial during pregnancy. They play significant roles in achieving optimal birth outcomes and supporting the rapid growth and development of the fetus. Folate is essential for DNA synthesis and methylation reactions, while iron is vital for the function of red blood cells (RBCs) and white blood cells (WBCs), as well as for tissue oxygenation and blood formation. The requirement for folate during the first 28 days after conception is increased by 0% to 50% and the requirement for iron increases during the second and third trimesters. Globally, 28.8% of pregnant women met the minimum dietary diversity for women (MDD-W) indicating that large number of these women suffer from inadequate intake of micronutrients.

The burden of intake of inadequate micronutrient is obviously higher in developing countries, resulting in adverse pregnancy outcomes. In Ethiopia, diets are typically dominated by starchy cereals, root crops and legumes and often include little to no animal products, as well as fresh fruits and vegetables. Consequently, micronutrient malnutrition becomes highly prevalent in the

country. Prior research studies concluded that inadequate micronutrient intake among pregnant women is attributable to poor dietary practices, poor knowledge, and wrong perceptions. This in turn leads low body mass index (BMI), micronutrient deficiencies, subsequent suboptimal weight gain, and increased risk of poor birth outcomes like preterm birth (PTB) and low birth weight (LBW). Several literatures denote that nutrition education is a well-established intervention to enhance optimal dietary practices and is crucial to designing appropriate diet interventions. However, the effects of integrated nutrition education and egg base diet intervention on improving nutrient adequacy, nutritional status and optimal birth outcomes were not well studied in Ethiopia.

**Objectives:** This study was designed to assess the validation of food variety score (FVS) and dietary diversity score (DDS) as proxy indicators of nutrient adequacy; to evaluate the effect of nutrition education on improving nutrient adequacy and serum levels of ferritin and folate, and to examine the effect of an egg-based diet intervention coupled with healthy dietary advice on nutrient adequacy and nutritional status among pregnant women. The study also intended to determine adequate diet during pregnancy is associated with reduced risk of adverse birth outcomes and low serum ferritin and folate levels.

**Materials and Methods:** This study employed a community-based cross-sectional, cluster randomized controlled trial (cRCT) and prospective cohort studies designs. The study was conducted on randomly selected pregnant women from two districts of Northern Zone, Sidama Region, Ethiopia. The women were selected at first trimester. A multiple-pass 24-hour dietary recall method with standard 10-food groups was used to estimate the DDS and FVS. Nutrient adequacy ratio (NAR) was estimated using the mean adequacy ratio (MAR) of the micronutrients. Receiver operating characteristic (ROC) curve analysis that gives maximum sensitivity and specificity was employed to define the cutoff points of DDS and FVS. Additionally, randomly selected pregnant women were recruited in a ratio of 1:1 of intervention and control group for cRCT.

Nutrition education intervention (NEI) was delivered using health belief model (HBM) theory for the intervention groups, while the standard health care was given for control groups. Between group differences in mean scores on DDS, nutrient intake, nutrient adequacy and serum ferritin and folate levels were tested using an independent samples t-test. A linear mixed model (LMM)

was used to evaluate the effect of interventions on adequacy and serum levels of the ferritin and folate accounting for the clustering effect. In egg-based diet intervention trial, chicken and nutrition messages were provided for intervention group at the health post for 12 weeks in two sessions per week, whereas standard healthcare was given to the control group. Between groups differences in mean scores for nutrient adequacy and nutritional status indicators were tested using Chi-square and independent samples t-test in addition to make analysis using LLM accounting for the clustering effect.

For the prospective cohort study, a total of 438 pregnant women were recruited in the first trimester. The maternal weight and height were measured before 12 weeks' gestation. Pre-pregnancy BMI was calculated in the first trimester, and maternal weight and mid-upper arm circumferences (MUAC) were measured subsequently every trimester until delivery. Serum ferritin and folate levels were measured at first study visit in 12th week of gestation. Pearson's correlation test was employed to determine significant relationships between maternal anthropometric indicators. A poisson regression analysis with a robust variance estimate was used to identify predictors of PTB and LBW.

**Results: Chapter IV** presents results on the validation of FVS and DDS as proxy indicators of nutrient adequacy. It was found that MDD-W showed a positive correlation ( $\rho = 0.159$ , 95% CI: 0.065-0.250) ( $p = 0.001$ ), and had good predictive ability (AUC = 0.839, 95% CI: 0.80 to 0.88) ( $p < 0.001$ ) of MAR of micronutrient. The sensitivity and specificity of the MDD-W in the  $\geq 5$  food group's standard cutoff were 69.9% and 5.3%, respectively. **Chapter V** shows results on effect of nutrition education on nutrient adequacy and serum levels of ferritin and folate during pregnancy. A significant difference was observed in mean serum ferritin and folate levels between the intervention and control groups ( $p < 0.001$ ). NEI was positively associated with adequate intake of folate ( $\beta = 28.52$ , 95% CI: 14.671, 42.367,  $p < 0.001$ ), iron ( $\beta = 9.320$ , 95% CI: 3.119, 15.536,  $P = 0.003$ ), serum levels of ferritin ( $\beta = 12.107$ , 95% CI: 4.406, 19.809,  $p = 0.004$ ), and folate ( $\beta = 2.263$ , 95% CI: 1.852, 2.675,  $p = 0.001$ ).

**Chapter VI** contains results on the effect of an egg-based diet intervention coupled with healthy dietary advice on nutrient adequacy and nutritional status among pregnant women. It was found that nutrition intervention was positively associated with MUAC ( $\beta = 0.54$ , 95% CI: 0.281, 0.782,  $p < 0.001$ ) and MAR ( $\beta = 344.019$ , 95% CI: 275.965, 412.073,  $p < 0.001$ ). The nutrient intakes

varied significantly among the study participating pregnant women. For instance, calcium and vitamin D were very low (1.97-19.9%), vitamin B12 42.1%, protein, folate, and vitamin A were moderate (64-80.6%), while iron intake was high, 95.4%. The MAR of individual nutrients were increased from  $20.00 \pm 0.0$  to  $161.36 \pm 73.58$  after introduction of egg-based diet ( $p < 0.001$ ).

**Chapter VII** presents results on maternal consumption of inadequate diet during pregnancy are associated with an increased risk of low serum levels of essential micronutrients and adverse birth outcomes. The average gestational age at birth was 37.50 weeks and a low birth weight accounted for 37.3%. The prevalence of preterm birth was higher among women who had an inadequate DDS (AOR=0.52, 95% CI: 0.301, 0.890), consumed dietary folate below recommended level (AOR=1.48, 95% CI: 0.741, 2.932), undernourished women (AOR=1.105, 95% CI: 0.98, 1.24), a women with serum folate level  $<2.6-15 \mu\text{g/L}$  (AOR=0.760, 95% CI: 0.552-0.933). The prevalence of low birth weight was higher among women with underweight (AOR=1.126, 95% CI: 1.003, 1.23), short stature (AOR=11.341, 95% CI: 1.097, 11.421), under nutrition (AOR=1.141, 95% CI: 1.025, 1.270), intake of dietary iron below  $<27$ (EAR) (AOR=6.348, 95% CI: 4.144-9.724), serum ferritin of below  $<15 \mu\text{g/L}$  (AOR=1.588, 95% CI: 1.008, 2.502), and inadequate DDS (AOR=2.148, 95% CI: 1.778-2.596).

**Conclusions:** The study demonstrated that NEI improved daily iron and folate intake as well as serum levels in pregnant women. Additionally, interventions that included egg-based dietary advice positively impacted nutrient adequacy and overall nutritional status. However, despite these benefits, there were still high rates of PTB and LBW. Factors such as low DDS, insufficient folate intake and serum levels, inadequate weight gain (less than 11.5-16 kg), and low MUAC  $< 23$  cm were significant predictors of PTB. Similarly, being underweight, having short stature, malnutrition, experiencing PTB, low total GWG, and low serum ferritin levels were significant predictors of LBW. To address pregnancy-related malnutrition caused by micronutrient deficiencies, it is essential to integrate nutrition behavior change communication with egg-based interventions. Healthcare professionals should actively promote egg consumption during pregnancy through targeted communication efforts directed at families and communities. Enhanced public health initiatives that include nutrition support and anthropometric monitoring during antenatal care are crucial for improving birth outcomes.

**Keywords:** Birth outcomes, Egg-based diet, Nutrient adequacy, Serum levels of micronutrients

# CHAPTER I: INTRODUCTION

## 1.1. Background

Women's nutritional status before and during pregnancy is vital for ensuring healthy outcomes (Black *et al.*, 2018). During pregnancy, there is an increased demand for energy and nutrients to support both the mother and the growing fetus (Darnton-Hill and Mkpuru, 2015). For instance, protein requirements rise by 54% and energy needs increase by 13% in the first trimester (Imdad *et al.*, 2017; Jouanne *et al.*, 2021; Marshall *et al.*, 2022). Meanwhile, the demand for iron, folate, and calcium intensifies during the second and third trimesters. To support overall health for both the mother and the developing baby, it is essential to include whole grains in the diet (Ruel, 2003; Arimond *et al.*, 2011). A healthy diet should consist of chicken, eggs, fish, lean meats, fruits, vegetables, legumes, whole grains, and healthy fats, as these are all important sources of essential nutrients (Jouanne *et al.*, 2021; Marshall *et al.*, 2022).

Chicken eggs are a nutritionally complete and natural source of nutrients. They provide easily digestible components, including high-quality protein, vitamin D, vitamin A, vitamin B12, folate, choline, and long-chain omega-3 fatty acids (Lutter *et al.*, 2018; Caswell *et al.*, 2021; Wallace *et al.*, 2023). Eggs contain between 40–86 micrograms of folate, which constitutes approximately 13–29% of the recommended daily allowance (RDA) during pregnancy (Marta *et al.*, 2021). It is important to adapt diets enriched with eggs, which are difficult to find in many everyday foods, to individual circumstances (Melough *et al.*, 2019; Šarac *et al.*, 2022). Although the benefits of eggs for pregnant women are recognized, their consumption among women in the lowest wealth quintile remains very low. This is primarily due to low socioeconomic status and cultural factors (Lutter *et al.*, 2018).

Programs focused on daily oral IFAS have been developed to promote healthy eating and provide lifesaving nutrition (FDRE, 2020; UNICEF, 2022). However, when supplementation is insufficient, the fortification of staple foods like wheat, maize, and rice becomes necessary (IOM, 1990; Lindsay *et al.*, 2001; Benoist, 2008). HBM-based nutrition education, which emphasizes the importance of perceived susceptibility, perceived severity, perceived benefits, and perceived barriers, has proven to be a more effective strategy for improving dietary behaviors than traditional methods (Chitsaz *et al.*, 2017). Nutrition education is recognized as both a nutrition-sensitive and a nutrition-specific intervention (FAO, 2014). Increasing the

uptake of diversified and nutrient-dense foods, particularly animal source foods (ASF), can be achieved through behavior change communication. This approach may alleviate the burden of micronutrient deficiencies, thereby improving the nutritional status of mothers and the birth outcomes of newborns (WHO., 2012). Serum ferritin concentration is considered a reliable indicator of total body iron stores (Merialdi *et al.*, 2003; Bukowski *et al.*, 2007). Women with serum ferritin levels  $<15 \mu\text{g/L}$ , measured at 16 weeks of gestation, have a significantly higher risk of low birth weight (LBW). A serum ferritin level under  $15 \mu\text{g/L}$  may indicate iron deficiency, leading to iron-deficiency anemia, which affects 29.9 percent of women worldwide (Mei *et al.*, 2023).

BMI and MUAC are among the most widely used and reliable methods for assessing nutritional status in developing countries (Venkataraman *et al.*, 2022). Measuring a woman's height and pre-pregnancy BMI early in her pregnancy can help evaluate how well her body can manage the demands of pregnancy (Kozuki *et al.*, 2015; Bhattacharya *et al.*, 2019). This assessment also helps determine recommended weight gain, identify underweight and overweight individuals, and predict adverse pregnancy outcomes (Rasmussen *et al.*, 2009). The cutoffs for MUAC to define acute malnutrition can vary by country, typically ranging from 21 cm to 23 cm. Values below 23 cm are used to identify pregnant women at risk of malnutrition (Venkataraman *et al.*, 2022).

## **1.2. Statement of the problem**

Approximately 287,000 women died during and after pregnancy and childbirth (WHO, 2023). Undernutrition during pregnancy remains a significant global issue, disproportionately affecting women in LMICs where food insecurity and limited access to high-quality nutrition increase risks for maternal and fetal health (Hendrixson *et al.*, 2025). Nearly 10% of pregnant individuals worldwide are affected by undernutrition, which is defined by anthropometric measurements (WHO, 2018). This condition can have negative effects on both the pregnant individual and their offspring (Hendrixson *et al.*, 2025) and necessitates collaborative interventions from multiple stakeholders (USAID, 2014; Unicef, 2015).

Globally, around 750 million people do not meet their daily energy requirements (IFPRI, 2016), and approximately 2 billion people are also deficient in essential micronutrients (Reinhardt and Fanzo, 2016). Worldwide, only 28.8% of pregnant women meet the MDD-W. In resource-poor

settings, women of reproductive age often suffer from inadequate micronutrient intake due to diets primarily composed of starchy staples, with minimal inclusion of animal products, fresh fruits, and vegetables (Arimond *et al.*, 2011). Folate is one of the crucial micronutrients for fetal growth (Rogers, 2018). Its deficiency is linked to an increased risk of PTB (Marshall *et al.*, 2022). Infants born prematurely are more likely than their full-term counterparts to die during the neonatal phase or infancy. Additionally, they face significant short-term and long-term health challenges, including cerebral palsy, intellectual disabilities, language delays, learning difficulties, and behavioral problems (IOM, 2007).

Multiple micronutrient deficiencies, particularly in iron and folic acid, can lead to adverse pregnancy outcomes (Black *et al.*, 2018). Globally, approximately 41.8% of pregnant women experience iron deficiency anemia (WHO., 2012). In Africa, the prevalence of folate deficiencies ranges from 0.8% to 57.7%, which can result in megaloblastic anemia and NTD (Mgamb *et al.*, 2017; Fatou *et al.*, 2018). In Ethiopia, malnutrition remains a significant public health concern, with 21% of pregnant women classified as underweight and 6% as overweight (Darnton-Hill and Mkpuru, 2015). Micronutrient malnutrition, particularly of iron, iodine, zinc, and vitamin A, is highly prevalent in the country, which ranks 90th out of 116 countries in terms of micronutrient deficiencies. Additionally, folate deficiencies contribute to an incidence of NTDs affecting 65 out of every 10,000 babies (EPHI, 2020).

The overall prevalence of anemia among pregnant women is estimated to be 41%. Among these, 20% are classified as moderately anemic, 18% as mildly anemic, and 3% as severely anemic (Bitew *et al.*, 2020; Woldegebriel *et al.*, 2020). Studies have recommended that pregnant women increase their intake of nutrient-dense food groups and consider multimicronutrient supplementation (Diddana, 2019; Getaneh *et al.*, 2021). However, only a small proportion of respondents met these recommendations—40% were supplied with iron tablets, and just 11% took them for the recommended duration of 90 days (EDHS, 2017). Many women gain less weight during pregnancy than is recommended. According to the World Health Assembly (WHA, 2012); LBW continues to be a significant public health concern. For example, between 7% and 24% of pregnant women gained less weight than the Institute of Medicine (IOM) guidelines suggest. Millions of women are affected by issues such as maternal underweight, short stature, and anemia (UNICEF, 2018). GWG may be influenced by genetic, health, socioeconomic, and cultural factors (WHO, 2023). Poor anthropometric indicators have been

associated with inadequate intake of nutrient-dense ASF, protein, and essential micronutrients (Getaneh *et al.*, 2021).

Existing evidence indicates that 19.8 million newborns worldwide are suffering from LBW (Krasevec *et al.*, 2022). Although there have been significant reductions in the prevalence of LBW in LMICs, the progress has been uneven across different regions and within countries. High prevalence rates persist in sub Saharn Africa countries (SSA) and South Asia. Additionally, short stature, which is an indicator of intergenerational and chronic malnutrition, affects 7% of women aged 20–49 years (Victora *et al.*, 2021). In Ethiopia, 25% of women have a BMI, with 20% of those living in rural areas and 5% in urban areas (EDHS, 2017). The prevalence of low BMI varies by region, ranging from 6% to 29.1%, with a pooled prevalence of 14.1% (Katiso *et al.*, 2020). In the Sidama Region specifically, 16.5% of newborns are born with LBW (Gebremedhin *et al.*, 2012).

### **1.3. Significance of the study**

Given the inconsistent data on low DDS among Ethiopian smallholder farmers, especially pregnant women, few nutrition-sensitive interventions have focused on improving their nutritional status. Evidence shows that nutrition education during pregnancy is a well-established intervention that enhances dietary quality by promoting sustainable healthy eating behaviors, and allowing women to follow cost-effective dietary recommendations. However, socio-economic and cultural barriers often hinder the practical application of this knowledge, and the impact of nutrition education on DD among pregnant women, particularly in the study areas, remains unclear. The routine nutrition education in healthcare settings is often vague and inconsistent, overlook minority populations in rural areas, where knowledge gaps are likely greater and generally narrows in scope and duration. Further population-based interventional studies are recommended, prioritizing nutrition education based on the HBM to develop key messages.

To optimize maternal and fetal health, nutrition interventions like suplemetation of multiple micronutrient and protein-energy nutrients should be integrated with nutrition education. Eggs are a bioavailable source of high-quality protein, omega-3 fatty acids, vitamins, and minerals, making them a nutritious food during pregnancy. However, the impact of egg consumption on overall nutrient adequacy during pregnancy is unclear, and nutrient adequacy from diet alone is often insufficient. Therefore, additional studies are needed to better understand the effects of

egg-based dietary interventions during pregnancy on nutrient adequacy, maternal nutritional status, and birth outcomes. This context-specific data enables researchers, policymakers, and public health experts to address poor dietary practices among pregnant women in the Sidama Region. The intervention can improve community health by promoting sustainable, healthy eating behaviors and micronutrient intake. The findings are applicable to similar settings within Ethiopia and beyond, contributing to the limited literature on optimal pregnancy nutrition.

## **1.4. Objectives**

### **1.4.1. General Goal**

To evaluate the effects of nutrition education and egg-based diet interventions on dietary intake, nutrient adequacy, weight gain among pregnant women and birth outcome in Sidama Region, Ethiopia

### **1.4.2. Specific objectives**

1. To determine validation of food variety and dietary diversity scores as indicators of micronutrient adequacy among pregnant women in Sidama Region, Ethiopia.
2. To examine effect of nutrition education on improving nutrient adequacy and serum levels of essential micronutrients among pregnant women in Sidama Region, Ethiopia.
3. To investigate the effect of egg-based diet intervention coupled with healthy dietary advice on nutritional status among pregnant women in Sidama Region, Ethiopia.
4. To evaluate the association of suboptimal maternal nutrition during pregnancy with increased risk of low serum folate and preterm birth: evidence from a prospective cohort study in Ethiopia.
5. To investigate the association of suboptimal consumption of animal-source food during pregnancy with increased risk of low serum ferritin and low birth weight: evidence from a prospective cohort study in Ethiopia

### **1.4.3 Research Hypothesis**

1. Food variety and dietary diversity scores are valid indicators of micronutrient adequacy among pregnant women in Sidama Region, Ethiopia
2. Nutrition education has a positive effect on micronutrient adequacy and serum levels of folate and ferritin among pregnant women in Sidama Region, Ethiopia

3. Egg based dietary intervention coupled with healthy dietary advice improves nutritional status among pregnant women in Sidama Region, Ethiopia
4. Suboptimal maternal nutrition during pregnancy is associated with increased risk of low serum folate and preterm birth Sidama Region, Ethiopia
5. Suboptimal consumption of animal-source food during pregnancy is associated with increased risk of low serum ferritin and low birth weight Sidama Region, Ethiopia

## CHAPTER II: LITERATURE REVIEW

### 2.1 Overview of undernutrition during pregnancy

Being pregnant is an exciting yet challenging experience. Maternal undernutrition before and during pregnancy refers to an inadequate intake of energy and nutrients, which is essential for ensuring a healthy mother and baby (Hoang, 2019). Severe maternal outcomes are associated with an increased risk of metabolic disorders, such as GDM, as well as complications during labor and delivery (Hoang, 2019). Additionally, both excessive and inadequate weight gain during pregnancy can lead to issues such as small or large gestational age, a higher likelihood of cesarean delivery, and other adverse pregnancy outcomes, including GDM and preeclampsia (Haugen *et al.*, 2014).

Maternal undernutrition is defined as a pregnant woman having BMI of less than 18.5 kg/m<sup>2</sup>, a MUAC of less than 23 cm, and hemoglobin levels below 11.5 mmHg during the first trimester, or below 10.5 mmHg during the second and third trimesters (Victora *et al.*, 2008; Forgie *et al.*, 2020). Globally, one-third of the population is affected by malnutrition (WHO, 2020), with around 13% of women estimated to be undernourished (Ahmed *et al.*, 2013). Maternal malnutrition is particularly common among women in (LMICs), especially in South Asia and Africa, where it affects between one-quarter and one-third of women (Black *et al.*, 2018). Studies in Ethiopia and other LMICs indicate that these countries face a triple burden of malnutrition, which includes micronutrient deficiencies (Tebekaw, 2014; Darnton-Hill and Mkpuru, 2015).

Maternal undernutrition is primarily caused by poor dietary practices (Lindsay *et al.*, 2001; Diddana, 2019), a lack of knowledge, and misconceptions about nutrition (Zerfu and Biadgilign, 2018; Bayked *et al.*, 2024). Additionally, limited consumption of essential food groups such as vegetables, meat, dairy, and fruits contributes to this issue (Torheim *et al.*, 2010; Gernand *et al.*, 2016). Other common causes of malnutrition include low dietary intake, unequal distribution of food among household members, dietary taboos, and infectious diseases (EDHS, 2017). Furthermore, along with physiological changes, improper use of IFAS during pregnancy (Harika *et al.*, 2017; Diddana, 2019; Ayele *et al.*, 2020) results in a high prevalence of iron and folate deficiencies. These deficiencies can lead to poor birth outcomes, such as PTB LBW babies (Bathla and Arora, 2022; Mamme *et al.*, 2023).

Poor nutrition during pregnancy, combined with infections, is a common cause of maternal and infant mortality and morbidity, LBW, and intrauterine growth retardation (IUGR) (Daba *et al.*, 2013). This can lead to PTB and reproductive losses, including stillbirths (Zahangir *et al.*, 2017). Major nutritional issues affecting pregnant women include protein and energy malnutrition, as well as deficiencies in micronutrients such as iron, folate, calcium, and vitamins (Lee *et al.*, 2013; Black *et al.*, 2018). Globally, 38% of pregnant women experience anemia, which contributes to 20% of maternal mortality (NNPI, 2016). Pregnancy increases the risk of iron deficiency anemia (IDA) due to higher maternal iron requirements (Copelton, 2007). Low consumption of dietary micronutrients is linked to excessive intake of cereals (Beal *et al.*, 2017), resulting in only 25.4% of pregnant mothers consuming adequate DD. National nutrition surveys in Ethiopia have consistently reported inadequate folate intake, which has been recognized as a public health issue (Kebede, 2016).

Furthermore, it has been reported that pregnant women often do not consume enough eggs, dark green vegetables, whole grains, and fruits, leading to a low intake of dietary iron (Tsegaye and Kassa, 2018). Women in LMICs frequently enter pregnancy already malnourished, and the increased nutritional demands during gestation can worsen micronutrient deficiencies, posing health risks to the fetus. Pregnant women need adequate iron intake to reduce the risk of LBW, especially when maternal iron requirements exceed the average absorbable iron intake. Consequently, the developing fetus may cause the mother to develop IDA (Adikari *et al.*, 2016). The estimated prevalence of prenatal IDA is approximately 15-20% (Gernand *et al.*, 2016), while the prevalence of folate deficiencies is reported to be 46% (Harika *et al.*, 2017). Insufficient intake of these micronutrients represents a significant public health issue and is one of the independent predictors of low DD in Ethiopia (Fite *et al.*, 2023).

## **2.2. Dietary diversity during pregnancy**

Nutritional needs during pregnancy increase to support the heightened demands for fetal growth and development (FAO, 2016; Tran *et al.*, 2019). However, in many resource-limited environments, women's diets tend to be monotonous, primarily consisting of starchy staple foods that often lack sufficient micronutrients (Arimond *et al.*, 2011; Chakona and Shackleton, 2017). Studies have reported that in Ethiopia, the pooled prevalence of low, medium, and high DDS among pregnant women was 37.1%, 41.55%, and 39.3%, respectively. Furthermore, around

56.6% of pregnant women were found to have inadequate DD, while two-thirds (65.7%) had poor DD. Starchy staple foods were the most commonly consumed, while very few women included meats and dairy products in their diets (Bitew *et al.*, 2021).

Inadequate dietary practices during pregnancy have led to a high prevalence of undernutrition. Factors significantly associated with inadequate DD include household monthly income, type of housing, access to nutrition information, and the household's food insecurity status (Seid and Cherie, 2022). Additionally, poor dietary practices are often linked to insufficient knowledge and misconceptions about dietary behavior (Daba *et al.*, 2013; Diddana *et al.*, 2018). In various regions of Ethiopia, between 51.6% and 73% of pregnant women are reported to have inadequate DD (Jemal and Awol, 2019; Kebede *et al.*, 2022; Wondmeneh, 2022). Specifically, in the Sidama Region, both energy and nutrient intake have been found to be lower than the RDA. Contributing factors to poor and inadequate DD include having fewer than one ANC visit, illiteracy, lack of knowledge, and lower monthly income (Kuche *et al.*, 2015).

### **2.3. Prenatal nutrition education and KAP of dietary intake**

Women's knowledge and practices regarding antenatal nutrition are crucial for ensuring their proper nutritional intake (Teweldemedhin *et al.*, 2021). This knowledge is also vital for developing effective strategies that improve diet quality and promote healthy dietary behaviors, leading to positive pregnancy outcomes (Wang *et al.*, 2017; Mahmoud and Ghaly, 2019). Factors such as household food security, nutrition, and health practices significantly influence DD in Ethiopia (Gebremichael *et al.*, 2023). Additionally, due to limitations in time, space, and counseling skills, pregnant women often do not receive sufficient nutrition education (Nankumbi *et al.*, 2018).

NEI focuses not only on imparting knowledge but also on engaging individuals and groups in the community in a systematic way (Sahu *et al.*, 2022). It promotes an interactive exchange of information between educators and the community, empowering people to make informed decisions by utilizing both scientific and local knowledge. This approach fosters improved behaviors and has the potential to enhance knowledge and dietary practices among pregnant women (Nankumbi *et al.*, 2018; Suryani *et al.*, 2022). Average knowledge scores significantly improved during the pre-intervention phase, immediately after the intervention, and six weeks post-intervention (Teweldemedhin *et al.*, 2021). The mean score for dietary practices among

pregnant women was recorded at 78% before the intervention and increased to 82% six weeks after the nutritional education intervention (Gebremedhin *et al.*, 2015).

According to dietary guidelines, a higher proportion of antenatal mothers exceeded the recommended weight gain immediately following the NEI (MOH, 2021). Pregnant women demonstrated satisfactory knowledge about the adequacy of nutrients during pregnancy; however, there were notable gaps in applying that knowledge to their dietary practices. Approximately two-thirds of them reported insufficient intake of most recommended nutrients (Mahmoud and Ghaly, 2019). In many SSA, ANC services do not provide adequate nutrition awareness to enhance proper dietary intake practices (Alehegn *et al.*, 2021; Katenga *et al.*, 2021; Kushi *et al.*, 2023). Additionally, there are gaps in dietary intake that hinder optimal nutrition and better dietary practices in Ethiopia (FMOH, 2022).

#### **2.4. Dietary diversity and nutrient adequacy**

Micronutrients have become increasingly important for public health. DD is a qualitative measure of food consumption that reflects a household's access to a variety of foods. It serves as a proxy indicator for the nutrient adequacy of an individual's diet (Daba *et al.*, 2013; Kennedy, *et al.*, 2013). Despite substantial investments in nutrition interventions and IFAS programs (WHO., 2011; FDRE, 2016; Yismaw *et al.*, 2022), only 5% of pregnant women in Ethiopia engaged in these interventions for at least 90 days (EDHS, 2017). The underutilization of supplements can be attributed to inadequate provider compliance in offering counseling and a shortage of available tablets (Shiferaw *et al.*, 2021). Consequently, more than half of pregnant women in the country are found to be micronutrient deficient (Fite *et al.*, 2023).

Micronutrient deficiencies can have significant impacts on the health of women and the development of their infants, particularly during the critical first 1,000 days of life (Wang *et al.*, 2017). Studies show that only one-third of pregnant women include all five food groups, including meat, poultry, fish, eggs; dairy and beans; grains; fruits; and vegetables in their diets. Additionally, only 55% consumed protein from more than three different sources, while 63% and 24% consumed fewer than half of the recommended servings of vegetables and fruits, respectively (Woldeamanuel *et al.*, 2019). Research has indicated that eggs can play an important role in a healthy diet for pregnant women. Eating two eggs per day can provide 10% to 30% of the daily vitamin requirements (Sophie *et al.*, 2019). However, nearly half of pregnant women

did not achieve adequate DD (Ansari, 2020). In South Africa, all pregnant women living in urban areas consumed starchy staples but did not meet the MDD-W (Chakona and Shackleton, 2017).

The intake of eggs can help meet the increased nutritional demands during pregnancy (Lutter et al., 2018; Caswell *et al.*, 2021). Eggs are an affordable and excellent food choice, providing a highly nutrient-dense option. They are rich in various nutrients, including high-quality protein, vitamin B12, folate, carotenoids, choline, and iron (Gray, 2019). It is recommended that pregnant women consume 2-3 eggs per week (Sophie et al., 2019). Consuming 50 grams of egg daily leads to significantly lower fat intake while providing higher nutrient density, making it a safe and healthy food option. Contrary to some beliefs, eggs do not increase plasma cholesterol to harmful levels (Lisa, 2010; Ruxton, 2013). During the second and third trimesters, an intake of 630–680 µg of dietary folate equivalents per day is required to achieve a serum folate level of at least 10 nmol/L or an RBC folate level of at least 340 nmol (Sebastian *et al.*, 2022). The consumption of eggs can fulfill 10-20 times the daily folate requirement and double the vitamin B12 requirements.

A total of 120 mg of stored iron is necessary to achieve adequate serum ferritin levels at conception, while during a singleton pregnancy, a total of 835 mg of iron is required (EFSA, 2019). Consuming eggs contributes significantly to nutritional needs, providing essential nutrients such as protein, iron, and choline (Soma-Pillay *et al.*, 2016). One serving of eggs offers 90% of the additional protein needed during pregnancy (Lutter et al., 2018; Sophie et al., 2019), as each egg contains approximately 75 calories, 7 grams of high-quality protein, 5 grams of fat, and 1.6 grams of saturated fat (Lutter et al., 2018). Eggs are also a complete source of protein, supplying all nine essential amino acids in a highly bioavailable form (Sophie et al., 2019). Consuming two eggs per day during the third trimester fulfills 54% of the RDA for protein (Lutter et al., 2018).

Additionally, eggs are rich in bioactive compounds, such as lutein and zeaxanthin, which can help protect against diseases (Wallace *et al.*, 2023). However, egg consumption is closely linked to socioeconomic status in a dose-response manner: women in the lowest wealth quintile tend to consume the fewest eggs, while those in the highest quintile consume the most. Cultural factors likely also influence egg consumption during pregnancy (Lutter et al., 2018). As a result, women of reproductive age in LMICs do not consume eggs widely (Schiavone and Barroeta, 2011; Bell

*et al.*, 2014)

## **2.5. Maternal nutrient intake and gestational weight gain**

A healthy dietary pattern during pregnancy is crucial for promoting fetal growth and development (Ramakrishnan *et al.*, 2012; Li *et al.*, 2021). As pregnancy progresses, a woman's daily nutritional needs increase significantly. This is particularly evident in the third trimester, where appropriate weight gain, along with the intake of energy, protein, and omega-3 fatty acids, is essential (Diemert *et al.*, 2016; Lutter *et al.*, 2018). Fostering a diverse diet can help support adequate GWG and meet the necessary micronutrient requirements. However, barriers such as insufficient resources and limited access to a varied diet have hindered the fulfillment of these nutritional needs (Kumera *et al.*, 2018).

The WHO (WHO, 2017) recommends the following weight gain during pregnancy based on a woman's pre-pregnancy weight: 10–16 kg for women of normal weight, 13–18 kg for underweight women, 7–11 kg for overweight women, and 5–9 kg for those who are obese. Key indicators of appropriate weight gain during pregnancy include fetal growth and the development of maternal nutritional stores (Sharma and Sunita, 2014). This underscores the importance of maternal diet quality, which is a modifiable factor that can help prevent insufficient or excessive GWG (Kelishadi *et al.*, 2015). The barriers and facilitators of dietary diversity among pregnant women differ across countries and regions (Bezabih *et al.*, 2018; Derso *et al.*, 2021; Workneh *et al.*, 2021; Jateno *et al.*, 2023). Factors such as maternal illiteracy (Zerfu *et al.*, 2016; Jemal and Awol, 2019) and lower levels of maternal knowledge (Enyew *et al.*, 2023) are linked to lower dietary diversity scores and inadequate intake of essential micronutrients.

Maternal height and total GWG have a strong association with fetal growth and birth weight (Sharma and Sunita, 2014; Woldeamanuel *et al.*, 2019). BMI and GWG are important indicators of maternal nutritional status and are critical determinants of birth weight (Sommer *et al.*, 2015). Inadequate weight gain during pregnancy is a predominant contributor to IUGR and LBW (Sharma and Sunita, 2014; Wang *et al.*, 2018; Jouanne *et al.*, 2021). The mean birth weight increases with higher GWG, rising from approximately 3,100 grams with a 7-kilogram weight gain to about 3,600 grams with a 13.6-kilogram weight gain. Lower weight gain during pregnancy may result from a smaller increase in cell mass and extracellular fluid, leading to greater loss of body fat due to inadequate intake of protein and calories (Sharma and Sunita,

2014).

Research indicates that increased GWG is linked to lower risks of macrosomia and cesarean deliveries, but it is also associated with PTB, LBW, and SGA infants (Asefa *et al.*, 2020; Champion and Harper, 2020). A study conducted in the SSS revealed that 42.0% of pregnant women had insufficient GWG, while 22.0% had adequate GWG, and 36.0% experienced excessive GWG (Yang *et al.*, 2022). In contrast, research from developed nations showed that 21%, 18%, and 31% of pregnant women fell below the IOM GWG guidelines. Insufficient GWG was found to increase the risk of SGA and PTB (Goldstein *et al.*, 2017). Studies in Ethiopia have reported that more than two-thirds (67.2%) of pregnant women gained inadequate weight (Asefa *et al.*, 2020), while another study indicated that 64.0% experienced similar issues (Misgina *et al.*, 2021). Factors contributing to lower GWG included a lower pre-pregnancy BMI, unemployment, lower DD, and reduced hemoglobin levels (Asefa *et al.*, 2020; Misgina *et al.*, 2021).

Effective lifestyle interventions could potentially reduce the risks associated with inadequate GWG by 72% to 82%. Additionally, multi-component interventions for overweight or obese women could result in a reduction of GWG by 0.91 to 0.63 kg and a decrease in macrosomia cases by 85%. Notably, dietary interventions have been shown to have a greater impact on reducing the risks of GWG compared to other types of interventions (Farpour-Lambert *et al.*, 2018). Furthermore, studies indicate that the rate of weight gain is typically lower in the first half of pregnancy compared to the second half (Santos *et al.*, 2018). In Ethiopia, the percentage of women with adequate and inadequate GWG ranged from 3% to 62% and exceeded 50%, respectively. Factors positively associated with adequate GWG included having at least four ANC visits and a diet rich in fruits, vegetables, and meat (Asefa and Nemomsa, 2016).

## **2.6. Maternal nutrition and newborn's birth weight**

Maternal intake of a high-quality diet during pregnancy is associated with higher infant birth weight (Olmedo-Requena *et al.*, 2019). This diet has also been linked to a reduction in macrosomia and a decreased likelihood of SGA of new bornes (Emond *et al.*, 2018). It is recommended that pregnant individuals consume a variety of protein-rich foods, including both ASF and plant-based options, as well as healthy fats and essential micronutrients, to support healthy weight gain (WHO, 2017). A balanced diet should include dairy products, meat (25–35 g), fish (120 g, 25–30 g per serving), eggs (6 g), and a slice of cheese (15 g), legumes, nuts,

seeds, beans, ample vegetables, fruits, and whole grains. These dietary components significantly influence newborn birth weight (Gyimah *et al.*, 2021; Mursil *et al.*, 2024)

During the first half of pregnancy, it is recommended to consume 0.8 to 1.0 grams of protein per kilogram of body weight and 10 to 15% of daily energy intake. In the second half of pregnancy, the protein intake should increase to 1.1 grams per kilogram per day. Following these guidelines can help achieve optimal weight gain and ensure normal birth weight (Sharma and Sunita, 2014). Eggs are a significant source of essential nutrients, including vitamin A, and they play a crucial role in supporting a healthy immune system. They also provide vital micronutrients like iron, which contribute to positive pregnancy outcomes (Ruxton, 2010; Sophie *et al.*, 2019). Furthermore, eggs are highly digestible and have a well-balanced and diverse nutrient profile. Therefore, it is recommended to include eggs in the diet during each trimester of pregnancy (Sophie *et al.*, 2019).

Research indicates that MDD-W during pregnancy is linked to lower risks of LBW and PTB (Kelishadi *et al.*, 2015). Insufficient DD during pregnancy, particularly in the first trimester, is significantly associated with suboptimal GWG, which can result in PTB and LBW (Rahman *et al.*, 2020). This inadequacy may also lead to a higher rate of fetal morbidity and mortality (Jemal and Awol, 2019). Poor dietary quality during pregnancy can adversely affect fetal growth and infant birth weight (Emond *et al.*, 2018), increasing the risk of LBW (defined as less than 3,000 grams) and IUGR (Parets *et al.*, 2014). IDA, which stems from inadequate intake of iron-rich foods such as meat and eggs, is associated with several complications, including PTB and LBW (Kelishadi *et al.*, 2015). Additionally, low maternal protein intake, excessive nutrient loss, placental dysfunction, and maternal infections can lead to embryonic loss, IUGR, and LBW (Herring *et al.*, 2018; Handiso *et al.*, 2020).

In Ethiopia, studies have shown that approximately 2%, 24%, and 5% of newborns are delivered with LBW, with mean birth weights of 3.22 kg, 2.94 kg, and 3.14 kg, respectively (Ahmed *et al.*, 2018; Woldeamanuel *et al.*, 2019). The national pooled prevalence of LBW is reported to be 14.1%, with significant variations across different regions. The Tigray region has the highest prevalence of LBW at 15.4%, while the lowest prevalence is found in Addis Ababa City at 8.7% (Gebregzabiherher *et al.*, 2017; Tadesse *et al.*, 2023). Factors such as maternal parity, low MUAC, and a lower wealth index have been positively associated with LBW. The study reported

that about 11.0% of babies were born with LBW (Goshu *et al.*, 2018).

## **2.7. Nutrition education intervention and newborn's birth weight**

The ANC period provides regular opportunities for contact with health professionals, making it an ideal time to introduce the NEI. This initiative can enhance the health outcomes of pregnant women and their babies by encouraging them to adopt healthier dietary practices. Nutrition messages delivered by trained health professionals can significantly increase pregnant women's knowledge and promote positive changes in their diets (Teweldemedhin *et al.*, 2021). However, uneducated rural pregnant women in LMICs are less likely to follow an optimal diet during pregnancy that aligns with WHO recommendations (Workie and Ramana, 2013; Zerfu *et al.*, 2016; Adubra *et al.*, 2019).

The NEI encompasses various educational strategies implemented at different levels (Girard and Olude, 2012). Its goals include achieving lasting improvements in eating behaviors, enhancing the intake of the RDA of energy and protein, preventing excessive weight gain, and reducing the risk of adverse birth outcomes (FAO, 2020). Studies have shown that NEI improved GWG by an average of 0.45 kg, decreased the risk of anemia by 30%, increased average birth weight by 105 grams, and lowered the risk of PTB by 19% (Girard and Olude, 2012). To enhance maternal nutrition education, it is essential to improve nutrition care and support (Nankumbi *et al.*, 2018). Messages should be tailored to align with the cultural norms, aspirations, and needs of the target audience to effectively promote changes in attitudes and behaviors. The most effective approach to educate people combines interpersonal communication at the community level with support from mass media. It is crucial that individuals are given the opportunity to actively participate in finding solutions to their nutritional issues; otherwise, they risk being marginalized (Nayak *et al.*, 2001).

The integration of NEI in culturally tailored and responsive manners is crucial for enhancing dietary practices (Ahsan, 2022). Such initiatives significantly boost maternal nutrition knowledge and positively impact fetal growth (Nankumbi *et al.*, 2018; Ibikunle *et al.*, 2021). Effective prenatal nutrition accounts for factors such as a woman's food accessibility, socioeconomic conditions, and cultural dietary preferences (EDHS, 2017; Miele *et al.*, 2021). By optimizing nutrient intake, we can address women's BMI, which in turn can alleviate common clinical pregnancy symptoms (Jouanne *et al.*, 2021). Implementing a NEI aimed at increasing energy and

protein consumption within the general obstetric population not only reduces the risks of PTB and LBW but also fosters healthier outcomes. Adhering to recommended dietary practices can enhance newborn head circumference and birth weight, setting a solid foundation for their future health (Fallah *et al.*, 2013; Ota *et al.*, 2015; Omer *et al.*, 2020).

## **2.8. Maternal dietary iron and folate intake and birth outcomes**

Expectant women often feel excited during the third trimester as they anticipate the birth of healthy children and hope to maintain good health themselves to care for their newborns. However, this expectation is not always met due to various factors. Poor maternal nutritional status can lead to unfavorable outcomes for both mothers and children, as highlighted by Thomas *et al.*, (Thomas *et al.*, 2008). During pregnancy, numerous physiological changes occur, making appropriate and balanced nutrition essential. These nutritional aspects are fundamental to a healthy lifestyle that optimizes both maternal and child health (Alwan and Hamamy, 2015). Previously, prenatal nutrition epidemiology primarily focused on the effects of malnutrition and nutritional deficiencies. In contrast, current literature is increasingly emphasizing the overall quality of the maternal diet (Martin *et al.*, 2016).

Optimal nutritional status for expectant mothers is crucial for achieving healthy growth and development of the fetus (Martin *et al.*, 2016). Pregnant women require adequate intake of both macronutrients and micronutrients; however, the demand for micronutrients is relatively higher during pregnancy (Procter and Campbell, 2014). Nutrient deficiencies can lead to significant consequences for both the mother and the developing fetus, as supported by the physiological roles of women (Koletzko *et al.*, 2013). For example, a diet that includes eggs can help reduce the risks associated with pregnancy, such as stillbirths, SGA infants, and LBW (Lassi and Padhani, 2020). Therefore, by incorporating an egg-based diet into their daily meals, pregnant women can meet their nutritional requirements. Eggs are rich in high-quality protein and essential nutrients, which can contribute to a lower incidence of LBW (Lutter *et al.*, 2018).

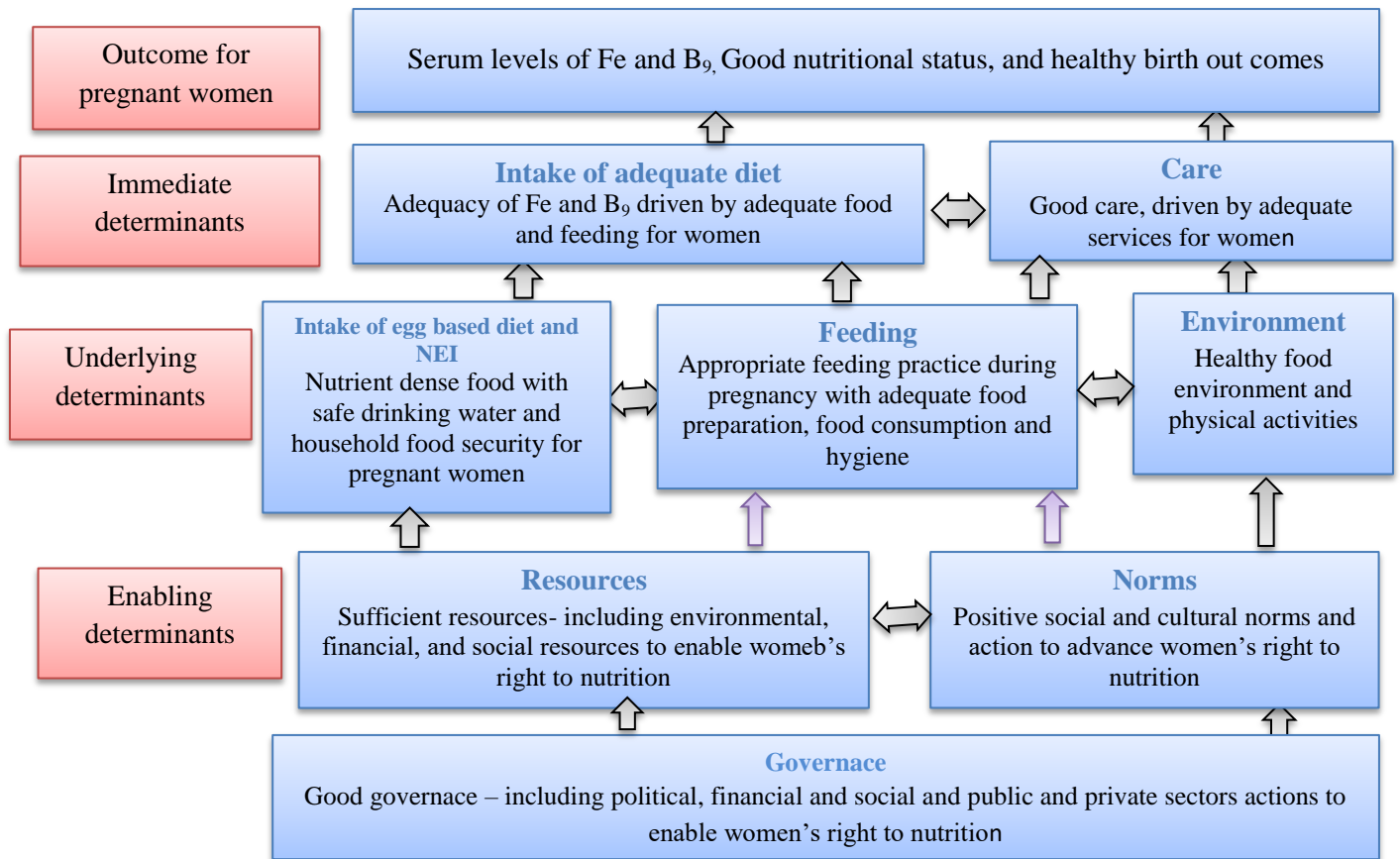
Two essential micronutrients during pregnancy are iron and folate (Milman, 2012). Iron is crucial because it is a vital component of hemoglobin, which is necessary for blood formation and oxygen delivery. Maternal anemia during pregnancy is linked to an increased risk of LBW and PTB, and it can affect postnatal infant growth (Milman, 2012). This highlights the importance of maintaining adequate iron levels during gestation. Typically, humans are born

with approximately 270 mg of iron in their bodies; however, the iron requirement during pregnancy is significantly higher (Procter and Campbell, 2014). On average, the total iron requirement during pregnancy (excluding losses during delivery) is about 835 mg for a singleton pregnancy. The RDA for iron during pregnancy is 27 mg per day (EFSA, 2015). The WHO recommends optimal iron intake from both dietary sources and supplements, advising a daily oral iron intake of 30 to 60 mg (WHO., 2012).

Dietary folate plays a crucial role during pregnancy, contributing to positive birth outcomes. A deficiency in folate has been linked to LBW, PTB, and fetal malformations, among other issues (Li *et al.*, 2009). NTDs are one type of fetal malformation that can arise from a lack of maternal folate. Maternal folate is essential before conception and during the first month of fetal development, as this is when the neural tube closes (Imbard *et al.*, 2013). To address the risk of NTDs due to folate deficiency, the WHO and the Centers for Disease Control and Prevention (CDC) recommend fortifying foods with 1.4 mg/kg of folic acid (Bailey *et al.*, 2015). In addition to consuming fortified foods, folate can also be obtained from various dietary sources. To prevent NTDs, it is advised that women take a daily supplement of 400 µg of folic acid for three months before conception and throughout the first trimester. For those with a history of NTDs, an intake of 5 mg per day is recommended (WHO, 2015).

## 2.9. Conceptual framework

The conceptual framework presents a combination of factors and interventions that directly and indirectly determine the nutritional status of pregnant women and the birth outcome (Ruel et al., 2013).



**Figure 1: Conceptual framework on the determinants of nutritional status in pregnant women (adapted from UNICEF, 2020 with a minor modification).**

## CHAPTER III: METHODS AND MATERIALS

### 3.1. Study Area

The study was conducted in Northern Zone of the Sidama Regional State, Ethiopia. The zone is composed of eight rural districts and two town administrations. From these, Shebedino and Boricha Districts were randomly selected for this study. Below are details on the backgrounds of the Shebedino and Boricha districts.

**Shebedino** is located 30 km to southeast to Hawassa, the capital of the Sidama regional state and 302 km south of Addis Ababa, the capital of Ethiopia. It is bordered on the south by Dale, on the west by Boricha, on the north by Hawela, and on the east by Gorche. The district has 23 kebeles (lower administrative units). Agriculture is prominent in the districts, serving as the main means of sustenance for 85% of the local community (Zekaria, 2007). The elevation of the district varies from about 1760 to 3000m above sea level. There are two agro climatic zones in the district, Woyna Dega (84.4%) and Dega (15.6%). Annual range of temperature varies from 16 ° c to 25 ° c. Annual range of rainfall also varies from 800mm to 1600 mm (Alemu, 2018).

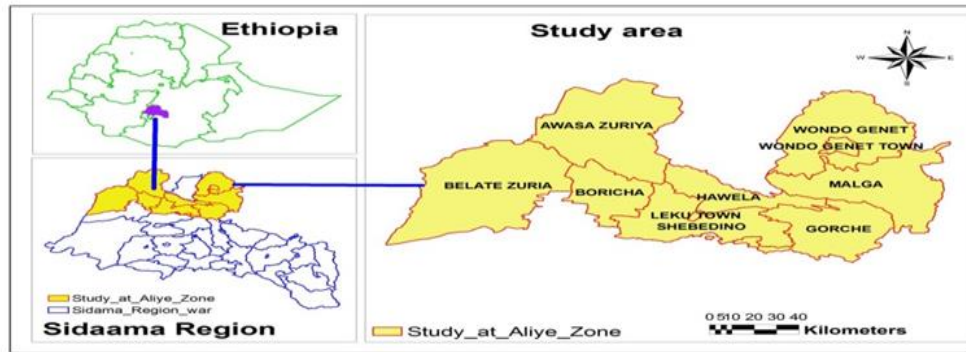
Based on the 2007 population and housing census of Ethiopia (CSA, 2007) the total population of the district is about 209,063, where 105,577 are males and 103486 are females. Women of reproductive age and an expected pregnancy rate in the year 2024 were 48084 and 6,272. With an estimated 500 people per square km, the district is among the most densely populated districts in the Sidama regional state. The average household size is about 5 people and extends to 7 to 10 persons in the poorest households. The majority of the population belongs to Sidama ethnic group (93%) and “Sidamifa” is the official language of the district. The district has an area of 411.7 square kilometers, where 0.2% of it is covered with forest, 72.3% under cultivation, 19.6% grazing land, and 3.4% potential land for future development. The major livelihood sources in the district are crop production, livestock rearing, petty trade, unskilled labor, and semiskilled labor like carpentry. The major crops grown are inset, coffee, and chat; maize, barley, wheat, and bean coffee are cash crops. Seasonal food insecurity and malnutrition characterized the district (Niguse and Mebratu, 2023).

**Boricha** is the other selected district. The district is located at 337 kilometers away from Addis Ababa, the capital of Ethiopia. It is bordered on the south by Derara, on the west by Balela, on the north by Hawassa zuriya, and on the east by Shebedino. The district has 14 kebeles and

covers about 588 square km. Agriculture is prominent in the districts, which consists of the main means of sustenance farm for 95% of the local community, and comprises mostly small, rain-fed farms and grain, maize, enset (*Enset ventricosum*), potatoes, haricot beans, sweet potatoes, and teff-producing kebeles (Zekaria, 2007). Some farmers grow cash crops like coffee, chat, spices, and eucalyptus. Livestock provide transport, milk, meat, and eggs, which are important income sources, though yield is typically low.

Based on the 2007 population and housing census of Ethiopia (CSA, 2007), the district has an estimated total population of 135, 273, where 68,313 are males and 66960 are females. Women of reproductive age and an expected pregnancy rate in the year 2024 were 31,112, and 4,058, respectively (15). The geographical location of the district extends from 6°46'N to 7°01'N and 38°04'E to 38°24'E (Tamene *et al.*, 2020). The elevation of the district varies from about 1200–1800 mm above sea level. Most of its 135,273 people, 14% of whom are children aged 6–59 months, belong to the Sidama ethnic group and speak Sidamifa. Most (95%) of the population live in rural areas, and are subsistence farmers. A few (4.5%) are merchants. The average family has five members, and the population density is 409 persons per square kilometer (Tesfaye, 2011). The district is drought prone and characterized by seasonal food insecurity and malnutrition.

High population growth, absence of adequate surface water for irrigation, inaccessibility of underground water, decreasing soil fertility, low rainfalls, land degradation, and deforestation are important contributors to food insecurity in the area (Tesfaye, 2011). The rainy seasons in Sidama are biannual, and the Belg rains which last from March to May contribute to most of the crop production. The Keremt rains usually last from June to September and are smaller (Diriba, 2013). Thus, following the agricultural cycle, the season of plenty usually occurs after the Belg harvest (mid-June to August) and Keremt harvest.



**Figure 2:** Map of the Northern Zone of Sidama Regional State, Ethiopia

### 3.2. Study Design and Period

This research employed three different study designs: (i) a community-based cross-sectional study design to tackle the 1<sup>st</sup> specific objective which aimed to determine the validation of FVS and DDS as indicator of nutrient adequacy among pregnant women in Northern Zone, Sidama Region, Ethiopia; (ii) cRCT to address the 2<sup>nd</sup> and 3<sup>rd</sup> specific objectives dealing with evaluating the effect of nutrition education and egg-based diet coupled with health dietary counseling on nutritional status of pregnant women, (iii) prospective cohort study to conquer the 4<sup>th</sup> and 5<sup>th</sup> specific objectives which determine the association between maternal anthropometric status, and folate and feretin levels during pregnancy with the risk of PTB and LBW. The study was conducted from March 2024 to December 2024.

### 3.3. Source and Study Population

The source population for this study was all reproductive age pregnant women living in Northern Zone of Sidama Region, Ethiopia. And, the study population was a randomly selected pregnant woman from the source population in the study area.

### 3.4. Inclusion and Exclusion Criteria

All reproductive age pregnant women living in Northern Zone of Sidama Region, Ethiopia were eligible for this study. However, pregnant women who were not permanent residents (living only for <6 months) in study area; the ones with a multiple gestation and who have a history of chronic medical illness such as diabetes mellitus, hypertension and any other pregnancy complications which could hinder anthropometric measurements were not included in the study.

Moreover, pregnant women with a known abstinence of any food or meal, and the ones severely sick during the data collection were excluded from the study.

### 3.5. Sample Size Determination

Sample size was calculated for each of the specific objective. Accordingly, the sample size for the first specific objective was calculated using a single population proportion formula (Chadha, 2006), while two population proportion formula for the second and third ones. Proportion for pregnant women who received HBM based nutrition education from the cross-sectional data analysis was considered in the calculation (Faul *et al.*, 2009). The, sample sizes for the objectives 4 and 5 were calculated using paired sample for the exposed and unexposed groups with a time-to-event endpoint (Shieh *et al.*, 2024).

**Table 1:** Summary of methods used to tackle each of specific objectives in dissertation, Northern Zone, Sidama Region, Ethiopia, 2025

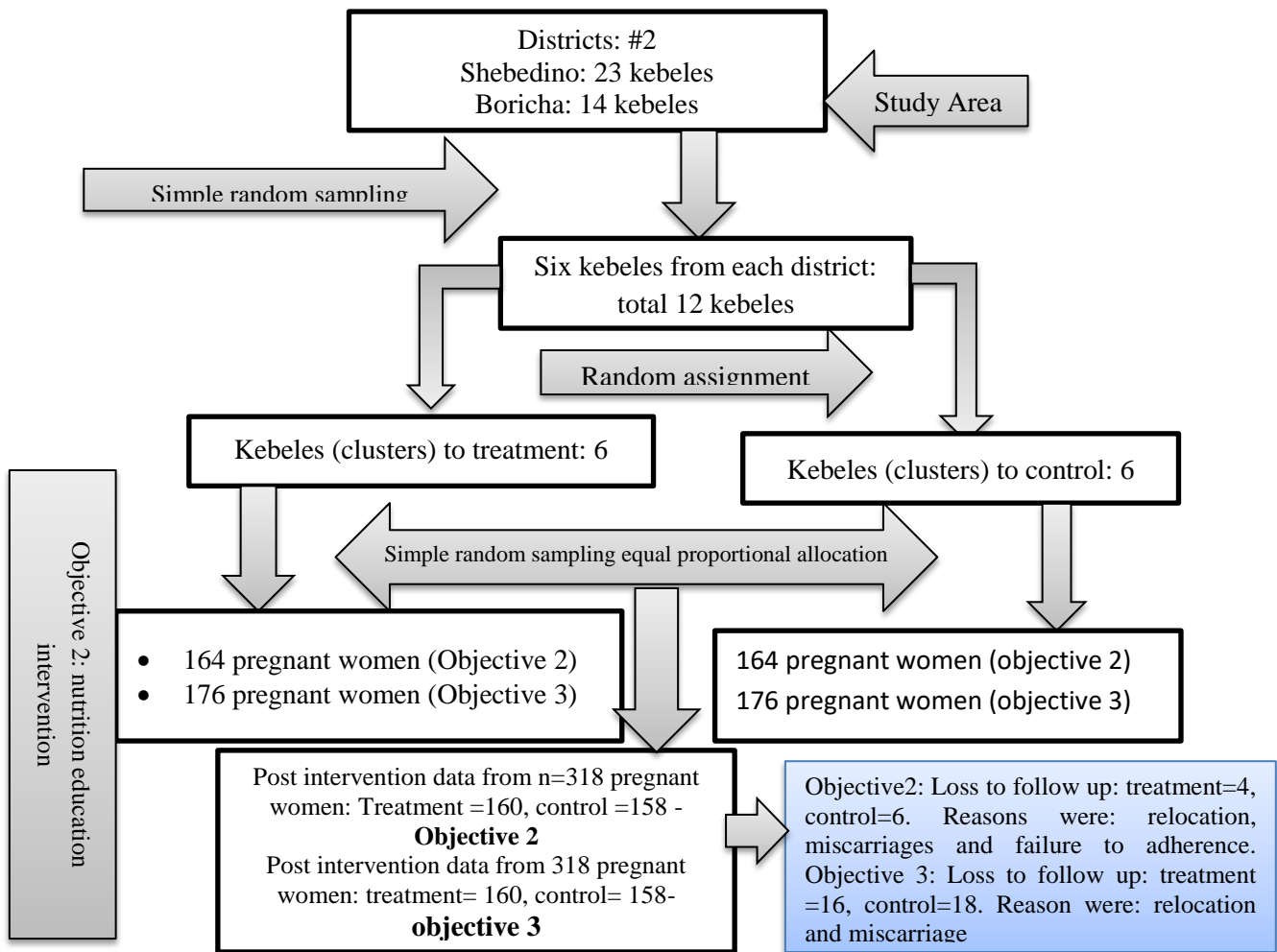
Specific objectives	Variables	Statistical assumption for sample size calculation	Sample size	Study design
1 <sup>st</sup>	FVS, DDS and MAR	Single population formula (Chadha, 2006). Proportion of women obtained MDDS-W (14.7%) (Demilew et al., 2020)	424	Cross sectional
2 <sup>nd</sup>	Intake of dietary iron and folate, NAR of iron and folate, serum ferritin and serum folate	Two population proportion formula (Faul <i>et al.</i> , 2009). Proportions of pregnant women consumed dietary iron and folate, NAR, serum ferritin and folate levels	328	cRCT
3 <sup>rd</sup>	Anthropometrics (MUAC) and MAR of the nutrients	Two population proportion formula (Faul <i>et al.</i> , 2009). Proportions of pregnant women with improved anthropometric indicators, and MAR of nutrients	352	cRCT
4 <sup>th</sup>	DDS, serum folate, PTB	Paired sample for exposed and unexposed groups	438	Cohort
5 <sup>th</sup>	ASF, GWG, Serum ferritin, LBW	Paired sample for the exposed and unexposed groups	440	Cohort

*LBW= Low birth weight, PTB= Preterm birth, GWG= Gestational weight gain, DD= Dietary diversity; NAR= Nutrient adequacy ratio, MAR= Mean adequacy ratio; MDDS-W= Minimum dietary diversity score for women; MUAC= mid-upper arm circumference; DBP=Diastolic blood pressure, cRCT: Cluster randomized controlled trial*

### **3.6. Sampling Technique**

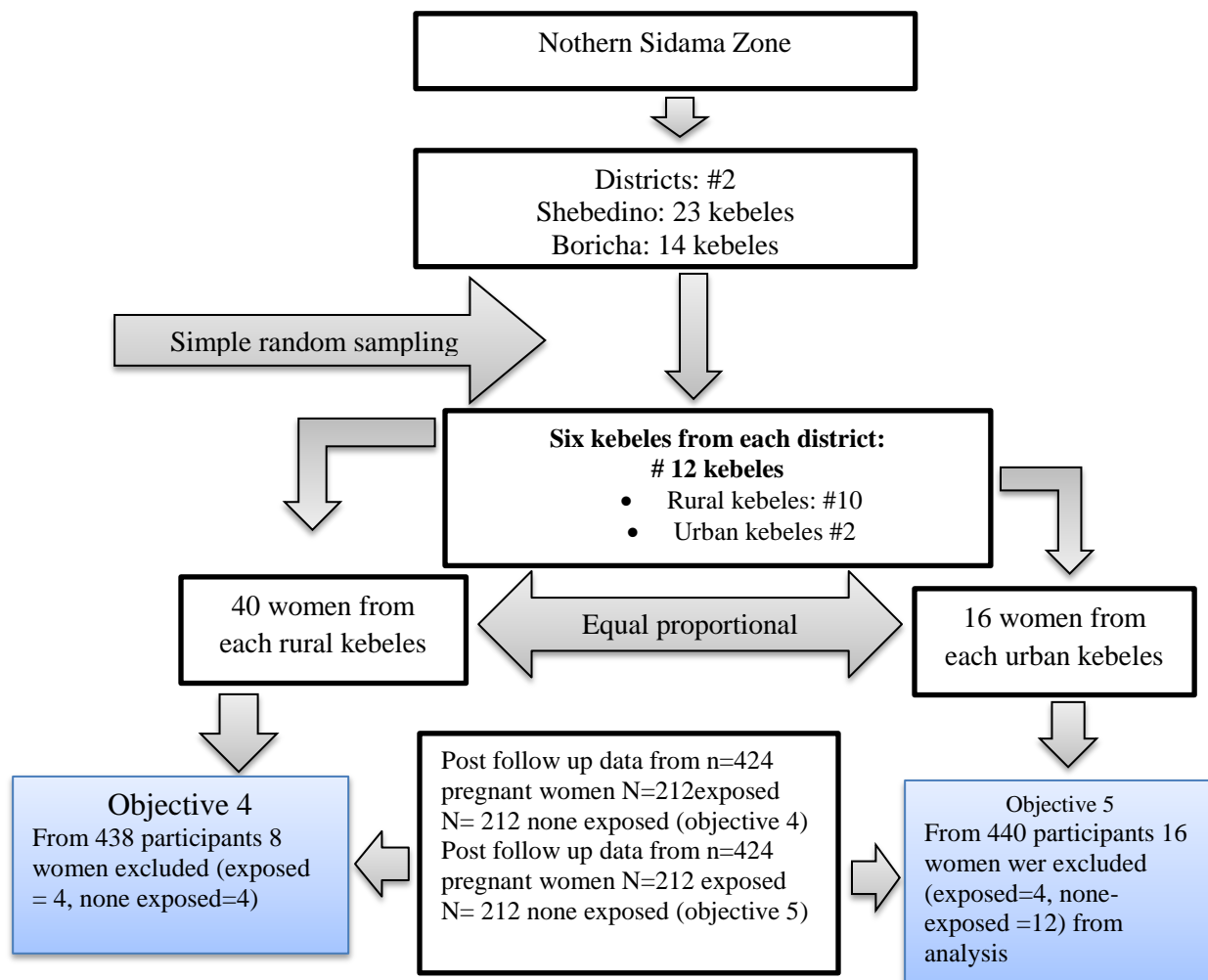
This study employed a multi-stage sampling technique. Firstly, a simple random sampling technique was employed to select the districts. Then, six clusters (Kebeles, the lowest administrative unit) were also randomly selected from each district with equal proportional allocation. Finally, pregnant women in the first trimester (12 weeks) of gestation were recruited randomly. Participants of the cross-sectional assessments were selected with the application of a systematic random sampling technique. List for all of the pregnant women in the selected kebeles was collected from respective kebele administrative unit, and list for pregnant women in first trimester (12 weeks of gestation), eligible for the study was developed for each of the selected clusters through house-to-house census, with the help of health extension workers and volunteer in the respective kebele. List of all pregnant women and list eligible were used as sampling frames. Equal proportion allocation was used to pick required number of pregnant women in the first trimester gestation from each of the kebele.

The cRCT was conducted by identifying eligible women from the same clusters where the cross-sectional assessments were done. New list of pregnant women who were in the early second trimester (13-16 weeks) and consented to participate in the intervention of nutrition education was developed through a second round house-to-house census. On the other hand, list of pregnant women in the early third trimester who consented to participate in egg-based local diet intervention was prepared. Participants for the cRCT were selected using simple random sampling technique from the same sampling frame with equal proportion allocation (Figure 3).



**Figure 3:** Diagrammatic presentation of sampling procedure for cluster randomized controlled trials in Northern Zone, Sidama Region, Ethiopia, 2025

The prospective cohort study was conducted by identifying eligible pregnant women from the same clusters used in cross-sectional study. A new list of pregnant women who have consented to participate in the follow up study was developed through a second round house-to-house census. Participants for the prospective cohort studies were selected using a simple random sampling technique from the same sampling frame developed above (Figure 4).



**Figure 4:** Diagrammatic representation of sampling process for two cohort studies in Northern Zone, Sidama Region, Ethiopia, 2025

### 3.6. Data collection tools and data Collectors

The data collection tool consists of sections for three types of nutritional status assessments (dietary, clinical, and biochemical) for pregnant women to gather data during baseline, follow-up, and end-line studies. The baseline survey consists of sociodemographic and socioeconomic data, fertility and obstetric data, DD data, assessment of knowledge, attitude, and practice of dietary iron and folate intake, nutrient adequacy of the diets, investigation of serum folate and ferritin status, household food security, and household wealth index. A semi-structured questionnaire was developed considering standard recommendations for household food security status (FANTA, 2007) and DD of pregnant women (FAO, 2021) assessment. A multiple-pass

qualitative 24-hour dietary recall method was adapted to assess the dietary intake of pregnant women, helping overcome the major limitations of recording a single day's dietary intake.

The follow-up study focused on dietary intake of pregnant women during the second and third trimesters, and included a monthly survey of GWG and BP assessment throughout pregnancy, as well as trimester-based anthropometric measurement. The end-line studies focused on post-intervention study focused on change in dietary iron and folate intake knowledge, attitude, and practice; assessment of change in anthropometric measurements; assessment of change in nutrient adequacy of the diets, change in serum levels of ferritin and folate; and assessment of GWG and pregnancy and birth outcomes (gestational age at birth and birth weight of the newborns).

The data collection tool was translated into a local language, Sidamiffa. The weight and height of pregnant women were measured using SECA digital weighing scales and measuring instruments (GmbH & Co. KG, a German company). MUAC was measured using MUAC tape produced by the World Food Program (WFP) (fully white colored) for mothers. All anthropometric measurements (weight and height) for women were taken by the principal investigator. Standard anthropometric measurement procedures were used as recommended in a document developed by Food and Nutrition Technical Assistance (FANTA). Selection of measurement point/area and standardization and calibration of instruments used for measurements were considered accordingly (Bruce, 2017).

The intervention group in NEI received audio-assisted and banners with picture-based key messages which were developed by national food and nutrition strategy (NFNS), FMOH, Ethiopia (FDRE, 2021). The nutrition education materials focused on DD and enriching pregnant women's diet, increasing knowledge on iron and folate-rich food sources, use of IFAS, meal frequency and portion size with increasing gestational age; taking day rest; reducing heavy workloads; enhancers and inhibitors of iron absorption; factors leading to iron and folate deficiencies and standardizing knowledge regarding intake of fruit and vegetables. For each of the session, banners with pictures and key messages were prepared and posted during delivery of the respective session. The materials were originally prepared in English, and then translated to the local language Sidamiffa. In addition, the women in the group received an additional five HBM-based nutrition educations including educating pregnant women to eat one additional meal

in addition to their pregnancy meal, supplement pregnant women with iron/folate tablets, and give them deworming tablets after the third month of pregnancy.

The nutrition education was delivered at the community health post into two sessions per month for three months. Women's knowledge and practice of daily intake of iron and folate in the diet and HBM constructs were measured according to knowledge, attitude and practice (KAP) model questionnaires of FAO (FAO, 2014). Data on the level of adherence to IFAS was collected using questionnaires adapted from the previous report (Fiedler, 2014). Data on nutritional knowledge was collected by using 15 nutrition knowledge questions. Participants were given score =1, if they correctly answer knowledge question, and score = 0, if they did not correctly answer the question. Dietary intake practices data were collected using 17 dietary habit questions. Participants were given score=1, if they correctly answer question, favorable or healthy for dietary practice, and score =0, if they did not correctly answer the question, not favorable or healthy for dietary practice. HBM constructs were measured using five-point likert scale (strongly agree= 5; through strongly disagree =1). Then, the value of each likert scale scored by participants for each question was summed and the average was calculated.

A 5 mL venous blood samples were collected aseptically from the ante cubital vein and placed into anticoagulant-free test tubes. The blood samples for serum folate and ferritin investigation was collected in July 2024 and end-line samples were collected in September 2024 for the second specific objective. Additionally, blood samples for serum folate and ferritin analysis was collected in early pregnancy for the fourth specific objective, and in second trimester for the fifth one. Before blood sample collection, the women were informed about the required blood sample and each woman was relaxed for safe and precise prick at the cubital vein to prevent minimum risk. Trained laboratory technologists collected blood sample for baseline and end-line surveys.

The blood samples were centrifuged, and the serum was separated before being frozen at  $-80^{\circ}\text{C}$  and transported to Internatil Clinical Laboratory (ILC) in Addis Ababa for analysis. The serum level of the micronutrients were analysed using the Electrochemiluminescence method on a fully automated Cobas e411-Cobas 4000 analyser series; Germany and Japan immunoassay analyser using commercial kits supplied by Roche (Germany) to analyze serum level of ferritin. A fully automated liquid chromatography-tandem mass spectrometry (LC-MS/MS) method was used to analyses serum level of folate using commercial kits supplied by Roche Company, Germany.

The cut-off point for serum ferritin and serum folate were indicated based on international standard of the nutrients for pregnant women based on metabolic indicators with the reference of WOH cut-offs of (14.7–184.3 mg/L) for serum level of ferritin (WHO., 2012) and 10nmol/L (4ng/mL) for serum folate (Rogers, 2018).

Staff from the health offices of the two districts collected the data. The data collectors were fluent in the local language Sidamiffa. Completeness, quality and consistency of data were checked by the investigator at spot during the data collection at the field. The research team provided five days (40 hours) intensive training to the recruited nutrition educators on the purpose of the study, purpose of the nutrition education, basics of low health literacy approach, nutrition education skills and knowledge, skills and attitude pertinent to the specific sessions to be covered by the nutrition education sessions to the mothers. During the training, teach back sessions were also conducted by the nutrition educators. This gave them to rehearse session specific knowledge and practice skills acquired before they are placed to the real community settings to deliver the nutrition education. This also provided them an opportunity to practice strategies though which they are expected to apply low health literacy approach.

Nutrition education sessions were delivered following a low health literacy approach (Murimi, 2013) in consideration of recommended strategies to improve it (Kountz, 2009). Key messages were repeatedly conveyed verbally and with posted material to mothers. Mothers were also given colored pictures of varieties of food to post in their house. A total of eight sessions were delivered: (1) Meal frequency and portion size with increasing gestational age (2) Nutrition during pregnancy, (3) DD, (4) standardizing knowledge regarding intake of fruit and vegetables (5) Knowledge on iron and folate-rich food sources, and use of IFAS, (6). Taking day rest and reducing heavy workloads; (7) Review of sessions, and (8) demonstrations on feeding. Each of the sessions on average took one hour. All the sessions were provided at kebele health post.

Participants in the nutrition intervention group were provided an egg-based diet coupled with key nutrition messages in the third trimester (between 25 and 36 weeks of gestation). The intervention was continued at the health facility for 12 weeks, with two sessions per week. The key nutrition messages were adopted from those recommended by the MOH, Ethiopia (FDRE, 2013). Following recruitment at the health post in each cluster, we provided the intervention group with two boiled eggs and two loaves of bread after orientation with nutrition messages.

Community HEW holding diplomas prepared and facilitated the feeding ceremony at the health post.

### **3.7. Data quality assurance**

Data collectors attended training for three days for the cross-section study and two days for the cRCT on basics of research in community, data collection techniques, research ethics and purposes of the respective study. Pre-testes of the data collection tool was conducted on 5% of the sample size in area different from the study districts for the sake of testing and making necessary correction on the tool and familiarizing data collectors with the actual data collection scenario.

### **3.8. Data management and analysis**

Nutritional status indicators were generated using WHO Anthropometric monitoring software during pregnancy. BMI of the pregnant women were computed using excel worksheet. Other quantitative data were analyzed using Statistical Software Package for Social Sciences (SPSS). Both descriptive (frequency, mean/median scores, proportions/percentages) and inferential statistics (Chi-square tests, t-tests, logistic regressions, multilevel generalized mixed model and Poisson regression) were used to generate descriptive quantitative results, and other nutritional outcome variables and compare statistical significance of pre- and post-intervention differences on nutritional status of mothers. Multicollinearity was detected using the Variance Inflation Factor (VIF), correlation matrices, and tolerance. Model fitness was checked through measures like R-squared, adjusted R-squared, and residual analysis. Statistical significance was detailed with p-value less than 0.05.

### **3.9. Ethical Considerations**

Ethical clearance was obtained from Institutional Review Board (IRB), College of Medicine and Health Sciences (CMHS), Hawassa University (Ref. No: IRB098/2016) on 12/03/2024. Besides, the study protocol was registered at <https://clinicaltrials.gov/> with a registration number NCT06521151 on July 22, 2024. Finally, informed written consent was taken from the study participating pregnant women. Those women identified as moderately undernourished were provided with nutrition counseling. Severely undernourished ones were referred to the community-based management of acute malnutrition program.

## RESULTS AND DISCUSSIONS

CHAPTER IV: Validation of Food Variety and Dietary Diversity Scores as Indicators of Micronutrient Adequacy among Pregnant Women

### Published Article



TYPE Original Research  
PUBLISHED 11 June 2025  
DOI 10.3389/fpubh.2025.1536419

Frontiers in Public Health 13:1536419. Doi: <https://doi.org/10.3389/fpubh.2025.1536419>

## Abstract

**Background:** A diet that includes a variety of foods provides all the essential nutrients needed to meet nutritional requirements. The link between dietary diversity and the adequate intake of micronutrients has not been established across different cultural contexts. Additionally, none of the studies successfully established a link between dietary diversity scores and nutrient adequacy in Ethiopia. Thus, we aimed to validate the food variety score and dietary diversity scores as proxy indicators of nutrient adequacy among pregnant women in Ethiopia.

**Methods:** A multi-stage systematic random sampling method was used to identify study participants from March 1 to March 30, 2024. The multiple-pass 24-hour dietary recall method, which includes standard nine food groups, was employed to estimate the dietary diversity score of pregnant women. The nutrient adequacy ratio was derived from the mean adequacy ratio of various micronutrients. To establish cutoffs for dietary diversity scores and food variety scores, ROC curve analysis was utilized, maximizing both sensitivity and specificity.

**Results:** MDD-W showed a positive correlation ( $\rho = 0.159$ , 95% CI: 0.065-0.250) ( $p = 0.001$ ) and demonstrated strong predictive ability (AUC = 0.839, 95% CI: 0.80 to 0.88) ( $p = 0.001$ ) for the mean adequacy ratio in assessing micronutrient adequacy. The sensitivity and specificity of the MDD-W at the  $\geq 5$  food group standard cutoff were found to be 69.9% and 5.3%, respectively. However, the food variety indicator across nine food groups showed a negative correlation ( $\rho = -0.402$ , 95% CI: -0.137 to 0.053) ( $P > 0.05$ ) and was a poor predictor (AUC = 0.709, 95% CI: 3.49 to 4.03) of the mean adequacy ratio. The optimal cutoff points for the dietary diversity score and the food variety score to predict micronutrient adequacy were found to be 3.42 and 4.67, respectively.

**Conclusions:** MDD-W had a positive correlation and good predictive ability in determining micronutrient intake adequacy. The sensitivity and specificity of the MDD-W in the  $\geq 5$  food group's standard cutoff were 69.9 and 5.3%, respectively. However, the findings differed from those of other studies, and discrepancies with FAO recommendations concerning the levels and cutoffs of MDD-W in assessing micronutrient adequacy were observed, necessitating further investigation.

**Keywords:** Dietary diversity score, Nutrient adequacy, pregnant women, Ethiopia

## **Introduction**

Pregnancy is a unique period in a woman's life, which results in anatomical, physiological, and biochemical alterations that occur in almost all her organ systems (Kazma *et al.*, 2020). More energy and nutrients are required during pregnancy to meet the growing demands of the mother and the growing fetus (Darnton-Hill and Mkpuru, 2015). Additionally, incorporating whole grains and healthy fats can further support overall health, ensuring the mother and the developing baby receives essential nutrients for optimal growth and development. It is crucial to consult with healthcare providers to tailor dietary choices to individual needs throughout the pregnancy (Arimond *et al.*, 2011; Roos *et al.*, 2015)

Only 28.8% of pregnant women met the MDD-W worldwide (Cunningham *et al.*, 2014). In resource-poor settings, women of reproductive age are suffering from inadequate intake of micronutrients as a result of diets that are dominated by starchy staples and often include little or no animal products and fresh fruits and vegetables (Arimond *et al.*, 2011). Poor maternal micronutrient intake is associated with IDA, hypertension, PTB, LBW, birth defects like NTD, intracranial hemorrhage, spontaneous abortion, stillbirth, IUGR, reduced immune competence, visual impairment, complications of labor, and even death in the mother (Darnton-Hill and Mkpuru, 2015; Jans *et al.*, 2015).

Micronutrient malnutrition, notably iron, iodine, zinc, and vitamin A, becomes highly prevalent in Ethiopia, ranking 90th out of 116 countries in Africa (EPHI, 2013). Validation of the DDS as a key indicator of nutrient adequacy becomes an important dimension, which is the simplest and non-invasive tool to improve the quality of the diet. In addition, only 9% of the households met the DDS across all regions in (Jateno *et al.*, 2023; Mesfin *et al.*, 2023). Therefore, we need to validate DDS as a key indicator of nutrient adequacy.

Moreover, empirical evidence suggests that eating the right balance of nutrients and various foods during pregnancy is important to prevent nutritional deficiencies (Darnton-Hill and Mkpuru, 2015; Jans *et al.*, 2015). However, while there is a clear link between increasing the diversity of the diet and improving nutrient adequacy, the nature of their association has not yet been sufficiently validated across different cultural settings and documented in developing countries (Arimond *et al.*, 2011). On the other hand, due to differences in socioeconomic conditions and living styles in different developing countries, research validating DDS as a key

indicator of nutrient adequacy cannot bring about uniform results. Thus, policy actions that help achieve nutrition and DD in one context may not yield the same result elsewhere (Arimond *et al.*, 2011).

Despite the fact that there are several studies assessed the prevalence and the determinants of DD in Ethiopia, a country characterized by significant variations in dietary consumption practices, none of the studies successfully established a link between DDS and nutrient adequacy (Aliwo *et al.*, 2019; Demilew *et al.*, 2020; Tilahun and Kebede, 2021; Jateno *et al.*, 2023; Mesfin *et al.*, 2023). Therefore, there is a need to get a nuanced understanding of FVS and DDS as key indicators of nutrient adequacy using a simpler and less expensive tool for data collection and analysis than time-consuming and expensive biochemical tests (Martin-prevel *et al.*, 2017). The findings of this context-specific research would have significant implications for designing and implementing country-specific nutrition programs. Therefore, this study aimed to validate FVS and DDS as key indicators of nutrient adequacy in the northern zone of the Sidama region, Ethiopia.

## **Materials and methods**

### **Study setting and design**

A community-based cross-sectional study was conducted from March 1 to 30, 2024, during the dry season following the autumn harvest. The study was conducted in the Boricha and Shebedino districts in the northern zone of the Sidama region. The districts are approximately 300 and 337 kilometers away from Addis Ababa, the capital of Ethiopia, respectively. The districts have 23 and 14 kebeles (lower administrative units) and were chosen at random. The multistage sampling method was applied to select 12 kebeles from the districts. Agriculture is prominent in the districts, serving as the main means of sustenance for 85% of the local community, mainly consisting of grain, maize, and haricot bean-producing kebeles (Tamene *et al.*, 2020). The Shebedino district is located 1760 to 3000m above sea level, had an estimated total population of 209,063, 48,084 women of reproductive age, and an expected pregnancy rate of 6,272. The other selected district was Boricha, with an estimated total population of 135,273; the number of women of reproductive age was 31,112, and the expected pregnancy rate was 4,058 (Zekaria, 2007). The geographical location of the district extends from 6°46'N to 7°01'N and 38°04'E to 38°24'E (Tamene *et al.*, 2020).

**Eligibility criteria:**

Pregnant women in their first trimester who were willing to participate in the study and had lived in the study area for at least six months were eligible to take part. However, women who were ill, particularly those suffering from anemia during the data collection period, were excluded from the study.

**Sample size determination and sampling technique**

The sample size was calculated using Open Epi version 3.01. The single population proportion formula  $(N) = \{(z\alpha/2)^2 p (1-q)\} / (d)^2$  was used to compute sample size, where “p” is an attribute that was presented in an estimated proportion (14.7%) of those who practiced diverse diets taken from the previous study (Demilew *et al.*, 2020), 95% confidence interval with 5% margin of error;  $Z\alpha/2=1.96$ , 14% probability for non-response rate, and a design effect of 1.9. Hence, the total sample size of 424 pregnant women who were in the first trimester was determined for the study.

Twelve kebeles were randomly selected from 37 kebeles in the districts. A systematic random sampling was employed to select the study participants from the chosen Kebeles. The pregnancy test of the eligible women was conducted by human chorionic gonadotropin (HCG) test, and the gestational age of the pregnancy was confirmed by the principal investigator using menstrual history and clinical examination. The sampling frame was prepared using a list of the selected households containing women with confirmed pregnancies. The sample size was proportionally allocated to each kebele based on the total population of each kebele. If multiple eligible women were present in a selected household, one was chosen using a lottery method. If a woman was absent from the home for three consecutive visits during the data collection period, she was classified as a non-respondent.

**Variables of the study****Outcome variables**

The study consists of primary and secondary outcomes. The primary outcome was nutrient adequacy, whereas DDS and FVS were secondary outcome variables.

**Independent variables**

The independent variables were categorized into individual-level and household-level variables. Individual-level variables were residence, religion, ethnicity, age, school attendance, educational

status, occupation, and marital status, which were sociodemographic factors. Pregnancy-related variables were gestational age, parity, and inter-pregnancy interval. Variables related to dietary practices were meal frequency, DDS, and FVS. Household-level variables were family size, residence, mass media usage, ownership of agricultural land and livestock, household wealth index, and household food security (HHFS).

### **Data collection and measurements**

Data were collected by using a structured and pretested interviewer-administered questionnaire developed based on a review of relevant literature (Acham *et al.*, 2012; Demilew *et al.*, 2020; Gudeta *et al.*, 2022). The questionnaire covered socio-demographic and economic characteristics, dietary practice, household family size, food security, sanitation and hygiene, and anthropometric measurement. A set of local household utensils was calibrated, and graduated food models were used before data collection. To maintain originality and consistency, language experts translated the English version of the questionnaire into "Sidamifa" and then back to English.

The data collection process included four data collectors and two supervisors, who received four days training on the Kobo Toolbox system and 24 hour recall interview skills. A pilot test for interactive 24-hour recall was conducted on 5% of pregnant women in another kebele of the study. The purpose of the interactive 24-hour recall and the details about the data collection arrangements, the details of the 24-hour recall interviews, and the procedures used to estimate portion size during training were explained during training. The data collectors conducted face-to-face interviews and recorded the data using the Kobo Toolbox application installed on Android devices. Rigorous supervision included daily examinations and prompt error correction. The collected data were submitted to a central server.

### **Assessment of household food security**

To estimate overall perceived household food insecurity, we used the Food Insecurity Access Scale (FIAS) questionnaire, comprising nine questions that reflect three different domains of food insecurity, including anxiety and uncertainty about food supply, insufficient food quality, and insufficient food intake. We categorized the households into 4 levels of food insecurity grades as recommended by the United States Agency for International Development (USAID) FANTA III Project: food secure, mildly food insecure, moderately food insecure, and severely

food insecure (Castell *et al.*, 2015).

### **Assessment of household wealth index**

The wealth index was calculated using PCA as a combined indicator of life standards based on 17 questions related to ownership of prudently selected household assets (television, mobile phone, radio, and kerosene lamp); housing quality (type and size of house, number of persons per room, type of floor, type of wall, and type of roof material); home facilities (electricity, source of drinking water, cooking fuel, and toilet facility); and means of transport. For each household, the coordinate on the first axis of the correspondence analysis was interpreted as an index of the economic level, and the wealth index was categorized into terciles in subsequent analyses. If the variables were available, it was categorized as "1" and otherwise as "0."

### **Assessment of dietary intake**

A multiple-pass qualitative 24-hour dietary recall method was adapted to assess the dietary intake of pregnant women, helping overcome the major limitations of recording a single day's dietary intake using a multiple-pass quantitative 24-hour diet recall. The method does not represent a person's usual intake due to the day-to-day variation of dietary intake (Foster and Bradley, 2018). Four passes were made to collect detailed information on food items and quantities. In the first pass, the respondents recalled all the foods and drinks consumed in the previous 24 hours. The second pass involved a detailed description of food preparation, including cooking methods and the time and place of consumption. In the third pass, portion sizes and amounts of each food and drink consumed were probed using standardized measurement methods. Finally, the entire list of data was reviewed to ensure completeness and accuracy and to identify errors. Respondents reported their food consumption from 25 predefined food groups within 24 hours, both at home and outside.

Each food or drink recorded in the household measurement and different calibrated utensils and portion sizes from the 24-hour recall was manually converted into weights (in grams). Nutritional values per 100 grams were determined using the Ethiopian Food Composition Table (EFCT) (Agren *et al.*, 1969). For food items not covered by the EFCT, relevant African countries' food composition data were utilized, and nutrient values from the USDA table of Nutrient Retention Factors Release (USDA., 2007; Lukmanji *et al.*, 2008) were used. The tables were used to calculate the nutrient intake data, which was already processed for cooked foods or

ingredients.

### **Assessment of food variety score and dietary diversity score**

We classified food variety into a predefined list of 25 food groups and further aggregated them into nine food groups. Additionally, we assessed DDS using a 24-hour recall questionnaire provided by the FAO. We calculated FVS and DDS by summing up the number and kind of food consumed from the nine groups (FAO, 2011): (1) Starchy staple; (2) Pulses and legumes; (3) Nuts and seeds food groups; (4) Dairy food group; (5) Fleshy food group; (6) Eggs; (7) Dark green vegetables; (8) Other fruits and vegetables; (9) Other vitamin A vegetables and fruits. Other remaining items, such as tea, sugar, and sweets, were not used in DDS and FVS calculations. The MDD-W was calculated and categorized as per the FAO's recommendation: "inadequate" for those who consumed < 5 food items and "adequate" for those who consumed > 5 (FAO, 2021). The food groups were categorized as a dichotomous variable, equaling 1 if the women consumed at least 5 food groups during the past 24 hours and 0 otherwise. Women who achieved an FVS and DDS were expected to have a greater likelihood of meeting their nutrient needs than those who consumed foods from fewer food groups (Acham *et al.*, 2012).

### **Assessment of nutrient adequacy of the diet**

To summarize nutrient adequacy, micronutrients that are important for public health, such as vitamin A, thiamin, riboflavin, niacin, vitamin B-6, folate, vitamin B-12, vitamin C, calcium, iron, and zinc—as well as those that may affect pregnancy outcomes were included. The distribution of estimated usual nutrient intake to the requirement distribution was established by WHO/FAO (FAO and WHO., 2002; USDA., 2007). The estimated average requirement (EAR) of nutrient intakes was calculated based on the recommendations of the IOM (FAO, 2021). Usual dietary intake distributions were computed before calculating the NAR for each nutrient. The MAR for a group of food items consumed is equivalent to the prevalence of adequacy for a particular nutrient (IOM., 2000).

The nutrient adequacy of the micronutrients was determined by calculating the NAR, % of each of the 11 micronutrients for each nutrient. We calculated the intake of each nutrient divided by the recommended intake for that nutrient using WHO/FAO recommended intakes, which are set at two standard deviations above the average requirements (FAO and WHO., 2002), which are set at two standard deviations above the average requirements. The calculation was carried out

taking into account nutrient requirement distributions and inter- and intra-individual variation in intakes. In the case of iron and zinc, the category for moderate bioavailability was used. As a summary indicator of an overall measure of the nutrient adequacy, the MAR was calculated for the overall diet, where MAR is the sum of each NAR (truncated at 100%) divided by the number of micronutrients (Torheim *et al.*, 2004), as  $MAR = \frac{\sum NAR}{Number\ of\ nutrient}$ .

MAR is equivalent to a population-level estimate of nutrient adequacy. For both NAR and MAR, a value of 100% is ideal since it means that the intake is the same as the requirement. That would mean that the intake of all 11 nutrients, namely vitamin A, vitamin B1, vitamin B2, vitamin B3, vitamin B6, vitamin B9, vitamin B12, vitamin C, calcium, iron, and zinc, is equal to or greater than the RDA, and the requirements for all the nutrients are met. Since no participant had a MAR score of 1 in this study, overall micronutrient intake inadequacy was operationalized to be <0.75 (Hatløy *et al.*, 1998; Acham *et al.*, 2012).

### **Data management and analyses**

Data were collected using the Kobo Toolbox system, a free, open-source tool for mobile data collection. Statistical analysis was performed in statistical software for data science STATA (Ho *et al.*, 2021). Before doing the main analysis, all necessary variable recoding, computations, and categorizations were done. Data were described using frequency distributions, measures of central tendency, and dispersion. For all statistical tests, values of  $p < 0.05$  were considered significant. A linear regression model was performed to test statistically significant associations between individual- and household-level determinants and the dietary quality indexes (FVS and DDS). All covariates showing linear association with the indexes with  $p$ -values less than 0.25 in a univariate model were included in the final model with a  $p$ -value  $< 0.05$  using adjusted odds ratios (AORs) with 95% CI after controlling for confounding factors. Variables contributing to the variation in the final model were declared as associated factors when the AORs did not contain 1. Potential modifier effects were investigated by including in the models statistical interaction terms to assess the relation between the main explanatory variables and outcome variables.

A multinomial logit model was previously computed by treating MDD-W as categorical, non-ordered values (Kennedy, *et al.*, 2013). In this study, we opted for an ordered logit model to estimate the determinants of MDD-W, as the dependent variable has an ordered nature—

specifically, adequate versus inadequate DD in relation to age differences and socio-economic variability between urban and rural residents. Pearson's correlation tests were conducted to identify significant relationships between MDD-W and the Minimum Acceptable Diet, as well as nutrient adequacy for individual nutrients. Additionally, a household wealth index was constructed using PCA as a composite indicator of living standards. Factor analysis was employed to analyze the indicators of the food insecurity scale.

ROC curve analysis was computed to provide a graphical representation of the range of possible cutoff points with their associated sensitivity vs. 1-specificity (i.e., false positive rate) and to assess the accuracy of DDS and FVS to classify pregnant women with a low or high MAR. Sensitivity indicates the proportion of pregnant women with higher MAR values, while specificity indicates the proportion of pregnant women with a lower MAR (Safari *et al.*, 2016). The area under the curve (AUC) was calculated using a ROC curve based on the nutrient adequacy as either yes ( $MAR \geq 0.387$ ) or no ( $MAR < 0.387$ ). Additionally, further analyses were conducted to assess the performance of the MDD-W at different MAR thresholds, which were set between 0.50 and 0.85. The AUC values were then interpreted according to predefined criteria, which categorized them as fail (0.5–0.6), poor (0.6–0.7), fair (0.7–0.8), good (0.8–0.9), or excellent accuracy (0.9–1.0) (Safari *et al.*, 2016). We considered an AUC cutoff  $\geq 0.70$  as a rule-of-thumb criterion to indicate acceptable predictive power for DDS and FVS. The optimal cutoff points were identified by selecting the points that maximized the Youden J statistic (sensitivity + specificity – 1) (the larger the better) (Yin and Tian, 2014). A *p*-value less than 0.05 were considered statistically significant.

## **Results:**

### **Socio demographic and economic characteristics of the respondents**

All the study participants had participated in the study. The mean and SD age of the participants was 26.29 years. More than three-fourths (78.8%) of the respondents could read and write. The family size of the participants ranged from 2 to 6 people. Large proportion of the respondents were Protestant Christians (96%), Sidama ethnic group (99%), in marriage (98.1%) and in poor economic status (65.6%). Almost 90% of households were food insecure, with 36.1% unable to afford food and establish an extra meal time. More than half (52.8%) of the respondents had their meal 1-2 times per 24 hours, and 34.2% skipped a meal at least three times a week (Table 2).

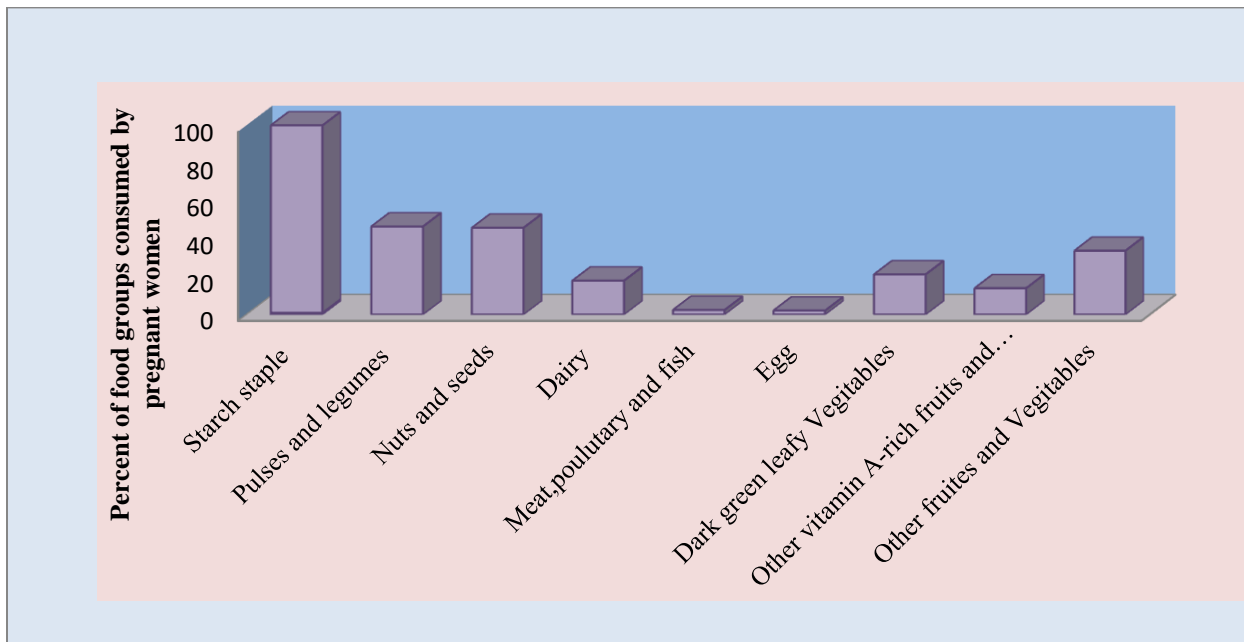
**Table2:** Socio-demographic and economic characteristics of pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424)

<b>Variables</b>	<b>Categories of variables</b>	<b>Frequency</b>	<b>Percent</b>
Age of the women (years)	≤20	142	33.5
	>20	282	66.5
Marital status	Married	418	98.6
	Divorced	6	1.4
Women's educational status	Literate	334	78.8
	Illiterate	90	21.2
Women's educational level	Primary	233	69.8
	Secondary	101	30.2
Spouse's educational status	Literate	323	76.2
	Illiterate	101	23.8
Spouse's educational level	Primary	244	75.5
	Secondary	79	24.5
Residence	Rural	312	73.6
	Urban	112	26.4
Land ownership	Owned	354	83.5
	Not owned	70	16.5
Number of family number (person)	2-4	105	24.8
	≥5	319	75.2
Religion	Protestant	407	96.0
	Others <sup>a</sup>	17	4.0
Ethnicity	Sidama	420	99.0
	Others <sup>b</sup>	4	1.0
	Housewife	372	87.7
Women's occupation	Employed	39	9.2
	Merchant	13	3.1
Spouse occupation	Farmer	352	83.0
	Employed /merchant	72	17.0
Wealth index	Rich	36	8.5
	Medium	110	25.9
	Poor	278	65.6
Affordability for food	Yes	161	38.0
	No	263	62.0
HHFS	Secured	61	14.4
	Not secured	363	85.6

### **Food variety and dietary diversity of the respondents**

The prevalence of DDS (≥5 food groups) and FVS was 39.9% (95% CI: 35.6, 44.3) and 36.3% (95% CI: 31.6, 41.0), respectively. The range of food groups consumed varies from a minimum of one to a maximum of seven food groups with median of 3.0. On average, 3.42 and 4.67 pregnant women achieved DDS and FVS in the last 24 hours of the data collection, with a large majority consuming starchy staple foods, followed by dark leafy vegetables (79.2%). Nutrition-dense food commodities such as flesh food (2.1%), eggs (0.03%), other fruits and vegetables

(13.9%), and milk and milk products (dairy) (18.4%) were the least consumed food groups (Figure 5).



**Figure 5:** Food groups consumed by study participating pregnant women in Northern Zone, Sidama Region, Ethiopia (n=424)

In comparison of the consumption of variety of food and diverse of diets against demographic and economic indicators among the study participants, only 5.4% and 9% among employed women consumed variety of food having  $\geq 5$  food groups and diverse diet, respectively. Likewise, 25% and 28.5% of women  $>20$  years of age consumed variety foods and an adequate diet, respectively. Among the study participants who can afford food, 131(30.9%) consumed variety of food and diverse diet. Moreover, 9.4% and 13.0% of the study participants from urban residents consumed variety of food and diverse diet, respectively, and 26.9% consumed both variety and diverse food groups from rural residents. Among study participants, only 1.7% and 2.8% were in the rich index and consumed variety of food having  $\geq 5$  food groups and diverse diet, respectively. On the other hand, among the study participants who consumed an inadequate diet, 53.1% could not afford their food, 68.9% were from a poor wealth index, and 56.8% were housewives, respectively. Similarly, among the study participants with low food variety, 62.03% were housewives, 56.6% could not afford food, 68.4% had a family size of  $\geq 5$ , and 43.9% were from a poor wealth index, respectively (Table 3).

**Table 3:** Comparison in consumption of food variety and dietary diversity against demographic and economic indicators among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424)

Variables	Categories	Consumption of varieties of food				Consumption of diverse diet			
		1-4 food groups		≥5 food groups		1-4 food groups		≥5 food groups	
		No.	%	No	%	No.	%	No	%
Women's occupation	Employed	29	6.8	23	5.4	38	9.0	14	3.3
	Housewife	256	60.4	116	27.4	241	56.8	131	30.9
Affordability for food	Can afford	30	7.1	131	30.9	30	7.1	131	30.9
	Cannot afford	240	56.6	23	5.4	225	53.1	38	9.0
HHFS	Secured	47	11.1	14	3.3	14	3.3	47	11.1
	Not secured	306	72.2	57	13.4	241	56.8	122	28.8
Age of the women (year)	≤20	94	22.2	48	11.3	94	22.2	48	11.3
	>20 years	176	41.5	106	25	161	38.0	121	28.5
Residence	Urban	72	17.0	40	9.4	57	13.4	55	13.0
	Rural	198	46.7	114	26.9	198	46.7	114	26.9
Land ownership	Owned	257	60.6	97	22.9	242	57.1	112	26.4
	Not owned	57	13.4	13	3.1	57	13.4	13	3.1
Wealth index	Rich	7	1.7	29	6.8	24	5.7	12	2.8
	Medium	62	14.6	48	11.3	56	13.2	54	12.7
	Poor	271	63.9	7	1.7	269	63.4	9	2.1
Family size(person)	≥ 5	219	51.7	100	23.6	186	43.9	133	31.4
	2-4	69	16.3	36	8.5	69	16.3	36	8.5
Marital status	Married	266	62.7	152	35.6	251	59.2	167	39.4
	Divorced	4	1.0	2	0.5	4	1.0	2	0.5
Women's educa.status	Literate	241	56.8	93	21.9	241	56.8	93	21.9
	Illiterate	50	9.4	40	11.8	65	15.3	25	5.9
Spous's educa. status	Literate	260	61.3	63	14.9	260	61.3	63	14.9
	Illiterate	91	21.5	10	2.4	74	17.5	27	6.4
Religion	Protestant	302	71.2	105	24.8	287	67.7	120	28.3
	Others	10	2.0	7	1.7	12	2.8	5	1.2
Ethnicity	Sidama	412	97.2	8	1.9	410	96.7	10	2.4
	Others	4	0.9	0	0.0	4	0.9	0	0.0

### Dietary intakes and nutrient adequacy of the respondents

The study demonstrates that median intakes of micronutrients fall significantly below the EARs for the 11 micronutrients. The estimated intake prevalence is alarmingly low, ranging from 3% to 25% for vitamin C, calcium, vitamin B12, and zinc. It remains low (27-42.1%) for vitamin A, thiamin, vitamin B6, and folate; moderate (51-58%) for iron and riboflavin; and notably high (100%) for niacin. A staggering 84% to 100% of respondents were consuming all nutrients below the EAR. Every single respondent had an intake that failed to meet the EAR for vitamin A, thiamine, folate, vitamin B12, and vitamin C. Moreover, 84% to 97.2% of respondents were below the estimated average requirement for niacin, riboflavin, vitamin B6, zinc, calcium, and iron. The mean of MAR for 11 micronutrients was very low (0.387). The mean of the individual

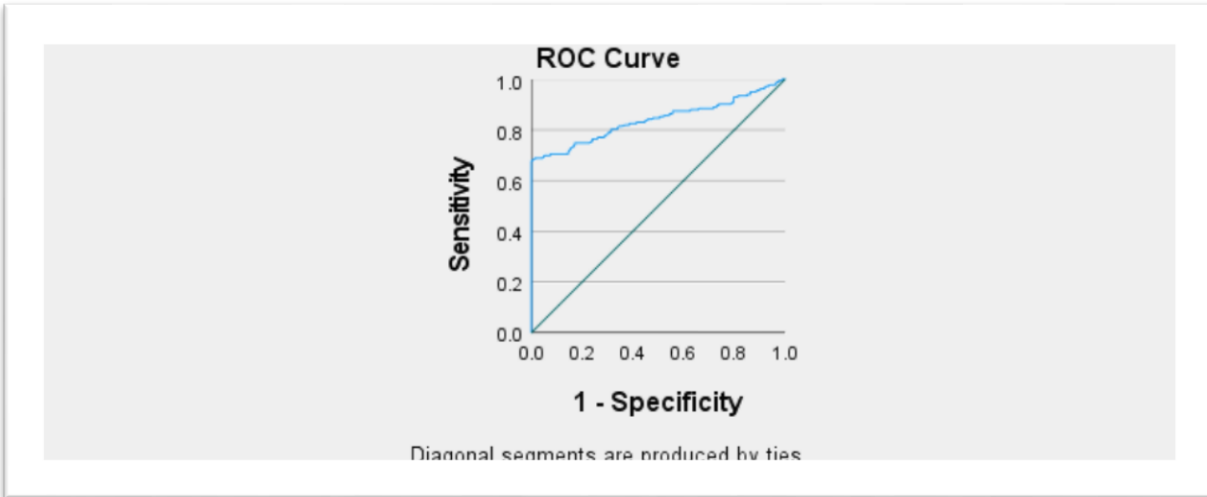
nutrients ranged from 0.03 to 32.27 for the micronutrients (Table 4). More than three-fourths of the study subjects had a MAR of less than 50%, whereas 22% had a MAR of 50-71%. There was no difference between the urban and rural residents ( $P = 0.265$ ); however, a significant difference was noticed in dietary diversity ( $P = 0.001$ ) and food variety ( $P = 0.001$ ) between urban and rural residents (Table 4).

**Table 4:** Intake of nutrients together with safe level of intake and the nutrient adequacy ratio among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424)

Nutrients	Intake/person/day			% of median intake	RDA in kcal		NAR
	Median	Q25	Q75		Mean $\pm$ SD	Mean $\pm$ SD	% of RDA
Calcium, mg	93.70	73.8	141.30	9.9	950 mg	0.10 (0.06)	94.6 %
Iron, mg	13.20	12.4	14.70	50.8	26 mg <sup>2</sup>	0.22 (0.08)	94.8%
Zinc, mg	3.30	2.9	3.60	29.2	11.3 mg <sup>2</sup>	0.31 (0.08)	91.5%
Vitamin A, $\mu$ g	1210	1190	1260	26.9	4500 <sup>d</sup> $\mu$ g	32.27 (10.94)	100%
Thiamine, mg	0.03	0.02	0.04	30	0.1mg/MJ	0.33 (0.15)	100%
Riboflavin mg	1.10	1.10	1.20	57.9	1.9 mg	0.56 (0.26)	89.2
Niacin, mg	1.60	1.10	2.10	100	1.6 NE/MJ	1.06 (0.48)	84.2%
Vitamin B <sub>6</sub> mg	0.80	0.70	0.90	42.1	1.9 mg	0.45 (0.13)	97.2%
Folate, $\mu$ g	185.80	174.8	274.80	31	600 $\mu$ g	0.35 (0.12)	100%
Vitamin B <sub>12</sub> $\mu$ g	1.00	0.70	1.60	22.2	4.5 $\mu$ g	0.24 (0.13)	100%
Vitamin-C, mg	2.60	1.60	19.90	2.5	105 mg	0.10 (0.08)	100%

### Validation of MDD-W in predicting nutrient adequacy of the respondents

A cutoff point of MAR was tested to discriminate between adequate and inadequate diets. In the ROC curve analyses, 100% is ideally an acceptable value (Safari *et al.*, 2016). However, no woman in reached this value; therefore 70% of MAR was used as a cutoff point for nutrient adequacy. In the analysis, DDS exhibited good predictive ability for the adequacy of 11 micronutrients at a 70% cutoff point in  $MAR \geq 0.378$  (AUC = 0.839, 95% CI: 0.80 to 0.88) with the Youden J index of 0.06. Thus, DDS in this analysis was found to be an indicator of the nutrient adequacy, with a sensitivity of 69.9% and a specificity of 5%. This corresponds to a very good quality of prediction, has shown a very good diagnostic performance, and indicated a high (84%) ability to identify those respondents with an adequate DD, significant at a p-value of  $<0.05$ . The proportion of pregnant women with a higher MAR and a lower MAR was indicated by sensitivity and specificity. It was correctly identified using the cutoff point of 70% for each score of the ROC curve (Figure 6).



**Figure 6:** ROC curve model represents dietary diversity score that indicated MAR of the micronutrients at 3.87 in at the cutoffs of 70% sensitivity and specificity among study participants in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424)

In addition, the overall diversity indicators for the nine food groups did not effectively predict individual NAR. Using a 70% cutoff for the area under the curve (AUC), the results were as follows: AUC = 62.5 for calcium, AUC = 62.6 for iron, AUC = 59.9 for zinc, AUC = 65.4 for vitamin B6, AUC = 53.5 for vitamin B9, and AUC = 68.8 for vitamin C. These values indicate poor prediction quality and demonstrate inadequate diagnostic performance at a significance level of  $p < 0.05$ . The model showed less than a 70% chance of correctly ranking a random positive value higher than a random negative value for nutrient adequacy (Table 5).

**Table 5:** Area Under the Curve (AUC) of the Mean Adequacy Ratios (MAR) and dietary diversity score among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424)

Nutrient	Optimal cutoffs	AUC	p- value	Sensitivity and specificity at optimal cutoffs		95% CI of AUC	
				Sensitivity	1-Specificity	Lower limit	Upper limit
MAR (DDS)	3.87	0.839	0.000	69.9%	0.05%	0.80	0.88
MAR (FVS)	3.82	0.709	0.001	86.5%	0.50%	3.49	4.03
Calcium	0.10	0.625	0.000	46.2%	37.3%	0.57	0.68
Iron	0.22	0.626	0.000	56.2%	34.1%	0.57	0.68
Zinc	0.31	0.599	0.001	34.3%	19.6%	0.54	0.66
Vit B <sub>6</sub>	0.45	0.654	0.000	57.4%	35.3%	0.60	0.71
Vit B <sub>9</sub>	0.01	0.535	0.017	57.4%	35.3%	0.48	0.58
Vitamin C	0.10	0.688	0.000	46.2%	37.3%	0.63	0.74

### Validation of FVS in predicting nutrient adequacy of the respondents

On the other hand, the most aggregated food variety indicator of nine food groups remained a poor predictor of 11 micronutrients at  $MAR \geq 0.378$  (AUC = 0.709, 95% CI: 3.49 to 4.03) with the Youden J index of 0.36. This corresponded to a poor quality of prediction, which showed a poor diagnostic performance. There was a lower (71%) ability to identify the respondents with an adequate and inadequate diet (a p-value of  $<0.05$ ). Thus, FVS was a poor indicator of nutrient adequacy with a sensitivity of 87 % and a specificity of 50% (Table 3).

### **Correlation of MAR with DDS and FVS**

A few food groups, like dark green leafy vegetables and legumes, were significantly correlated with MAR. Other groups—some of which were known to be nutrient-dense—were also significantly correlated with MAR (e.g., dairy and eggs). Starchy staples, which provided the majority of micronutrient intakes, were not correlated with MAR. Both the DDS and FVS were significantly correlated with each other ( $\rho = 0.748$ ; 95% CI: 0.702 to 0.787), and the DDS was positively correlated with the MAR of micronutrients ( $\rho = 0.159$ , 95% CI: 0.065-0.250) (P-value = 0.001). DDS was positively correlated with the NAR of calcium ( $r = 2.88$ , 95% CI: 0.198-0.373), zinc ( $\rho = 0.268$ , 95% CI: 0.177-0.354), vitamin B6 ( $\rho = 0.108$ , 95% CI: 0.013-0.201), and vitamin B12 ( $\rho = 0.166$ , 95% CI: 0.178-0.372). The variations in NAR of calcium (28.8%), zinc (26.8%), vitamin B6 (10.8%), and vitamin B12 (16.6%) during pregnancy were accounted for by maternal DD.

On the other hand, DDS was negatively correlated with NAR of vitamin A ( $\rho = -0.106$ , 95% CI: -0.119-0.010). The variation in nutrient adequacy in the nutrient (10.6%) was negatively affected by DD. Additionally; the DDS was not significantly correlated with the NAR of the micronutrients. Iron ( $\rho=0.069$ , 95% CI: -0.026 to 0.164), thiamin ( $\rho=0.047$ , 95% CI: -0.049 to 0.141), riboflavin ( $\rho=0.001$ , 95% CI: -0.094 to 0.096), niacin ( $\rho=0.049$ , 95% CI: -0.46 to 0.144), folate ( $\rho=-0.012$ , 95% CI: -0.107 to 0.083), and vitamin C ( $\rho=-0.046$ , 95% CI: -0.140 to 0.050) were among the nutrients not correlated significantly. However, FVS was positively correlated with NAR of vitamin B12 ( $\rho = 0.137$ , 95% CI: 0.042-0.229), in which the variation in nutrient adequacy of the nutrient (10.6%) was accounted for by DD. The FVS was negatively correlated with the NAR of calcium ( $\rho=-0.120$ , 95% CI: -0.213 to -0.025), in which the variation in NAR of calcium (12.0%) was negatively affected by DD (Table 6).

**Table 6:** Pearson’s correlation coefficient (r) between nutrient adequacy ratio (NAR), mean adequacy ratio; dietary diversity score and food variety score among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424)

MAR or NAR	Correlation coefficient (r)	p-value	95% CI	
			Lower limit	Upper limit
<b>Maternal dietary diversity score</b>				
MAR (micronutrient)	0.159	0.001	0.065	0.0250
Calcium	0.288	0.000	0.198	0.373
Zinc	0.268	0.001	0.177	0.354
Beta-carotene	-0.106	0.030	-0.199	-0.010
Vit-B <sub>6</sub>	0.108	0.026	0.130	0.201
Vit B <sub>12</sub>	0.166	0.001	0.178	0.372
Iron	0.069	0.153	-0.026	0.164
Thiamin	0.047	0.338	-0.049	0.141
Riboflavin	0.001	0.987	-0.094	0.096
Niacin	0.049	0.311	-0.46	0.144
Folate	-0.012	0.803	-0.107	-0.083
Vitamin C	-0.046	0.349	-0.140	0.050
<b>Maternal food variety score</b>				
Vitamin B <sub>12</sub>	0.137	0.005	0.042	0.229
Calcium	-0.120	0.013	-0.213	-0.025

### Factors associated with DDS, FVS and MAR

In a multivariate linear regression analysis, each model explained 33.6%, 21.4%, and 15.1% of the variation in DDS, FVS, and MAR, respectively. The study indicated that a high level of food security (AOR = 12.60, 95% CI: 5.20-30.00), a rich wealth index (AOR = 0.30, 95% CI: 0.10 - 0.80), number of a family member of 2-4 persons (AOR = 2.71, 95% CI: 1.91-3.83), school attendance of the women (AOR = 3.30, 95% CI: 1.80-5.90), high-level education (AOR = 2.20, 95% CI: 1.60-3.10), and employment of the women (AOR = 2.30, 95% CI: 1.40-3.90) were found to be positive predictors of DDS compared to their counterparts. On the other hand, school attendance (AOR = 2.30, 95% CI: 1.20 -4.30) and having a family size of 2-4 (AOR = 3.10, 95% CI: 2.10-4.30) were found to be positive predictors of women’s FVS compared to their counterparts.

Furthermore, ownership of agricultural land (AOR = 1.41, 95% CI: 0.86-1.42) was a positive predictor of the MAR (Table 7). Women aged  $\leq 20$  years old (AOR = 3.17, 1.11-9.04) were 3.17 times more likely to have an adequate DDS compared to those who were  $\geq 20$  years old. There was a significant difference in the means of sociodemographic and economic determinants of DD score, such as wealth index (P=0.059), food insecurity scale (P=0.001), monthly income of

the households (P=0.001), occupation of the respondents (P=0.001), birth interval (P=0.047), and meal frequency (0.039) between urban and rural residents (Table 7).

**Table 7:** The linear regression modeling of predictors of dietary diversity, food variety and mean adequacy among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2024 (n=424)

Variables		Crude odds ratio (COR)				Adjusted odds ratio (AOR)			
		95% Confidence Interval				95% Confidence Interval			
		COR	Lower limit	Upper limit	p-value	AOR	Lower limit	Upper limit	P value
<b>Dietary diversity score</b>									
School attendance	Yes	7.50	4.00	14.20	0.001	3.30	1.80	5.90	0.001
	No	Ref							
Women's Edu/level	Primary	Ref							
	Secondary	3.50	2.60	4.80	0.001	2.20	1.60	3.12	0.001
Women's Occupation	Housewife	Ref							
	Employed	4.40	2.50	7.80	0.001	2.30	1.40	3.90	0.002
HHFS	Secured	4.90	3.21	7.40	0.001	12.60	5.20	30.00	0.001
	Not secured	Ref							
Family size(person)	2-4	4.50	3.32	6.01	0.001	2.71	1.91	3.83	0.001
	≥5	Ref							
<b>Food variety score (FVS)</b>									
School attendance	Yes	5.20	11.70	42.10	0.001	2.30	1.20	4.30	0.014
	No	Ref							
<b>Mean adequacy ratio</b>									
Land ownership	≤Half hectare	Ref							
	>Half hectare	1.13	0.86	1.40	<0.001	1.41	0.86	1.42	<0.001
Source of food	Purchasing	Ref							
	Production	-0.43	-0.64	-0.21	<0.001	-0.42	-0.64	-0.20	<0.001

## Discussion

To maintain a healthy pregnancy, a woman needs a balanced diet of protein, fruits, vegetables, and whole grains (Miele *et al.*, 2021). Nonetheless, the finding highlighted that most of the women consumed starchy staples with little variety, which contributed to the burden of micronutrient deficiencies (FAO and WHO., 2002). This is due to pregnant women being food-insecure, as the household was the lowest on the wealth index. Consistent with this, reports from LMICs and FAO highlighted that monotonous diets based mainly on grains, roots, and tubers are common in areas of high food insecurity that contribute to the burden of malnutrition (FAO and WHO., 2002; Arimond *et al.*, 2011). Therefore, intake of various foods and a diversified diet during pregnancy may ensure adequate essential nutrients (FAO and WHO., 2002; Kennedy, *et al.*, 2013) and promote good health (Tariku and Baye, 2022).

This study reported lower DDS and FVS than the benchmark of MDD-W. The finding was similar to reports from the studies conducted in poor resource settings (Arimond *et al.*, 2011). Nonetheless, a report from rural Mali indicated a higher mean FVS but a slightly higher DDS than the benchmark. The discrepancy might be due partly to the study areas (Arimond *et al.*, 2011). Furthermore, the intake of an adequate and diverse diet and variety of food was low in the study area. Inconsistent with this, some studies in Ethiopia and in other developing countries (Kennedy, *et al.*, 2013; Ali *et al.*, 2014; H, Wilna *et al.*, 2014; Abenwie *et al.*, 2016; Saaka *et al.*, 2017; Shrestha *et al.*, 2021) reported a slightly higher intake of adequate and diverse diets.

The possible reasons for the discrepancy might be economic inflation impacting food expenditures (Demeke and Tenaw, 2021). Variations in sociodemographic characteristics among study participants in Ethiopia and other developing countries may create a difference in having diverse diets. Thus, the studies recommended that the government strengthen women's empowerment, rights, access to education, and economic opportunities to ensure nutrient adequacy and quality of the diet during pregnancy (Tefera *et al.*, 2020; Mekonen *et al.*, 2024). The current study supported the recommendation, in which the finding was significantly associated with food security, wealth index, and women's education.

DD has been identified as a potentially useful candidate and used as an indicator of dietary quality (Arimond *et al.*, 2011; Ruel, 2018). However, a report from rural Mali highlighted that DDS or FVS do not give a full picture of the nutrient adequacy of the diet and which food groups contribute most to the dietary quality (Torheim *et al.*, 2004). This is because the diets of individuals in developing countries may show less day-to-day variation in diversity. The report was supported by the findings from a rural area of Burkina Faso, where the mean DDS of women was increased by 0.7 food groups (Arimond *et al.*, 2011). In line with this, the present analysis indicated that the proportion of pregnant women with a nutrient intake below the recommendations varied between the kinds and intakes of the nutrients.

The finding indicated that the nutrient intakes were inadequate and far below the estimated average requirement (Hoesli, 2010; Arimond *et al.*, 2011). Notably, inadequate intakes were noticed for all micronutrients except for niacin and other micronutrients of public health importance (i.e., zinc and vitamin A) and calcium (Hoesli, 2010). The finding was similar to that reported from the study in a low-resource setting (Arimond *et al.*, 2011), where the median

intakes of riboflavin, niacin, vitamin B12, folate, and vitamin A were below the EAR. Additionally, reports from Mali indicated that calcium intake was below adequate intake (Arimond *et al.*, 2011). Nonetheless, the finding was inconsistent with what was reported from China (Zhong *et al.*, 2022), where the MAR was moderate and significantly higher in participants with a diverse diet. The discrepancy might be due to socioeconomic variations among study participants.

Research evaluating maternal and child undernutrition highlighted an insufficiency of multiple micronutrients, including zinc, folic acid, calcium, and vitamin D (Black *et al.*, 2018). Other research recognized that deficiencies of multiple micronutrients were more common than one in isolation (Karimi *et al.*, 2022). Consistent with this, the present study indicated that there was a wide variation in nutrient adequacy for individual micronutrients, ranging from 0.03 to 32.27. The estimated prevalence of nutrient adequacy was the lowest (0.1) for calcium and vitamin C, ranged from 0.22 to 0.56 for iron, vitamin B12, zinc, thiamin, folate, riboflavin, and vitamin B6, and was 1.06 for niacin and 32.27 for vitamin A.

Inconsistent with this, a report from Mali estimated that the prevalence of nutrient adequacy was highest for zinc, vitamin C, and vitamin B6. The possible reason for the discrepancy was the difference in the study area, in which the research was conducted among urban women who consumed ASF and millet, staple diets that are good sources of zinc and iron (Arimond *et al.*, 2011). However, the estimated prevalence for folate, vitamin B12, riboflavin, and calcium was similarly the lowest in the study from Mali, as found in this analysis.

Furthermore, the prevalence of NAR of calcium and vitamin C was very low. The finding was not similar to that reported from the urban sample of women in Mali (Arimond *et al.*, 2011), where the highest prevalence of vitamin C adequacy was seen. A possible reason for the discrepancy might be poor intake of ASF and citrus fruits, such as oranges, lemons, and strawberries. The nutrient-dense food group was correlated with the MAR of the micronutrients (Darnton-Hill and Mkparu, 2015; Black *et al.*, 2018) providing a summary of the information and underscoring the quality of women's diets (Darnton-Hill and Mkparu, 2015). Reports from low-resource settings indicated that the DDS of pregnant women has a positive correlation with MAR. The report ranged from 35% in Bangladesh, 38% in Burkina Faso, 47% in Mali, 47% in Mozambique, and 32% in the Philippines (Arimond *et al.*, 2011). The current study supports

these findings. Nonetheless, a higher MAR of the 11 micronutrients was reported from Iran (371.07) (Karimi *et al.*, 2022), 63% from South Africa (H, Wilna *et al.*, 2014), and 0.161 to 0.484 from china (Zhong *et al.*, 2022). The possible reason for the discrepancy was differences in socioeconomic status between the study subjects. The majority of the study population of this analysis was from rural areas where intake of nutrient-dense food, particularly ASF, was significantly lower than the RDA.

DDS and FVS were significantly correlated with each other. The DDS was positively correlated with the MAR of the micronutrients. The finding was consistent with this: there was a strong, significantly positive relationship between the NAR of respective micronutrients and the MAR with the DDS in the study done in South Africa (Acham *et al.*, 2012). However, except for calcium, zinc, and vitamin B6, most individual nutrient intakes did not correlate with FVS and DDS indicators. This is inconsistent with reports from Burkina Faso (Arimond *et al.*, 2011), where, except for folate, iron, and zinc, most individual micronutrient intakes were positively correlated with the DDS.

Similarly, the DDS constructed for this analysis had a positive and significant correlation with the composite indicator of the NAR of some individual micronutrients, such as calcium, zinc, vitamin B6, and vitamin B12. This illustrates the potential of a simple score of DD for use as an indicator of the micronutrient adequacy of the diet. These findings were similar to the report from rural Bangladesh and Burkina Faso (Arimond *et al.*, 2011). In both countries, DD indicators were correlated with the MAR of all 11 micronutrient adequacies. Nonetheless, we found that there was a significantly negative relationship between vitamin A and DDS. The finding was in line with the findings reported from India and South Africa (Pathak *et al.*, 2004; Acham *et al.*, 2012).

The risk factors of inadequate dietary intake and nutrient deficiency during pregnancy were multifactorial (Bikila *et al.*, 2023). The relative contribution of each of these factors varied greatly by socioeconomic characteristics, such as wealth indexes, maternal occupation, education level, employment status, monthly income, and the household's food security scale (Tefera *et al.*, 2020; Bikila *et al.*, 2023); geographical location/residences (Zerfu and Biadgilign, 2018; Mesfin *et al.*, 2023); seasonal variations (Pastore *et al.*, 1993; Ndekha *et al.*, 2000; Weerasekara *et al.*, 2020); and dietary practice of the individuals (Weerasekara *et al.*, 2020) in addition, were

contributing factors. Pregnant women in the age group  $\geq 46$  years old had a positive association with adequate DD compared to those in the age group 18-45 years. This is consistent with the local study done in southwest Ethiopia (Tilahun and Kebede, 2021). Similarly, the current study reported that respondents from urban residences and rich households had a positive association with adequate DD and better scores. The finding was consistent with those from urban Mali and Burkina Faso (Arimond *et al.*, 2011).

The current study reported that 33% of the rural and 55% of the urban respondents met the MDD-W. Inconsistent with this, the maximum DDS was achieved, according to reports from Sri Lanka (Weerasekara *et al.*, 2020), Burkina Faso and South Africa (Arimond *et al.*, 2011). The possible reason for the discrepancy might be that high food insecurity was reported in rural areas rather than urban areas in the current study. This, in turn, was due to the agro-ecological, socio-demographic, soil and water conservation, and land cultivation of the society. These conditions could affect food security more in rural than urban areas, where the livelihood could be mostly dependent on trade and employment (Melese *et al.*, 2021). Likewise, pregnant women from households having a monthly income of less than 1000 ETB had an inadequate DDS compared to those having a monthly income of  $> 1000$  ETB. The finding was in line with some local studies (Jemal and Awol, 2019; Mesfin *et al.*, 2023).

This is consistent with primary education had a significant association with inadequate DD compared to those who completed high school. This finding was in line with the findings reported from studies done in northwest Ethiopia (Yeneabat *et al.*, 2019), Addis Ababa (Tefera *et al.*, 2020), and in other developing countries (Arimond *et al.*, 2011). In addition, only 7% of unemployed women had met a MDD. The finding was in line with studies done in Nekemite town (Bikila *et al.*, 2023), northwest Ethiopia (Yeneabat *et al.*, 2019). Alamata General Hospital (Jemal and Awol, 2019), and Dire dawa city (Shenka *et al.*, 2018). Furthermore, pregnant women who had a meal frequency of three or more times a day had achieved adequate DD. This was because a higher meal frequency increases the likelihood of various food items being taken in within 24 hours (Danielewicz *et al.*, 2017). Reports from studies conducted in different parts of Ethiopia (Jemal and Awol, 2019; Yeneabat *et al.*, 2019; Mesfin *et al.*, 2023) confirmed that pregnant women who consumed more than 3 times within 24 hours and established extra meal times were more likely to achieve adequate DD.

## **Conclusions**

Inadequate dietary intake and nutrient deficiency during pregnancy varied with the socioeconomic characteristics of the study participants. MDD-W had a positive correlation and a good predictive ability in determining micronutrient intake adequacy and identifying the respondents having adequate and inadequate DDS. The sensitivity and specificity of the DDS in the  $\geq 5$  food group's standard cutoff were 69.9 and 5.3 percent, respectively. However, FVS remains a poor predictor of nutrient adequacy. The Ethiopian government should improve women's rights, access to education, and economic opportunities to enhance maternal nutrition programs and increase nutrient adequacy. Previous studies have shown varied findings, which also differ from FAO recommendations regarding the standards and cutoffs for assessing WDD-W and its relation to micronutrient adequacy, warranting further investigation.

**CHAPTER V: Effect of Nutrition Education on Improving Micronutrient Adequacy and Serum Levels of Essential Micronutrients among Pregnant Women**

**Submitted Article**

[www.nature.com/scientificreports](http://www.nature.com/scientificreports)

**scientific** reports

**Under Review**

## Abstract

**Background:** A lack of nutritional knowledge and an inadequate diet during pregnancy are significant factors that worsen micronutrient deficiencies. Nutrition education is a vital strategy for enhancing DD; however, existing evidence does not clearly demonstrate its effectiveness in improving micronutrient adequacy. Thus we aimed to assess the effect of nutrition education on the adequacy of micronutrients and serum levels in pregnant women.

**Methods:** A community-based multilevel cRCT was conducted to evaluate the effectiveness of an audio-assisted nutrition education program. The intervention group received this nutrition education based on the HBM, while the control group received standard healthcare services. Data were collected on the nutrition knowledge and dietary practices of pregnant women at both the baseline and endline of the study. The constructs of the HBM were evaluated using a five-point Likert scale. A LMM was employed to analyze the impact of the nutrition education on the adequacy and serum levels of micronutrients, taking into account the clustering effects.

**Results:** There were significant differences in means ( $\pm$ SD) of serum ferritin and serum folate between the intervention and control groups ( $P < 0.001$ ). The multivariable LMM revealed that receiving nutrition education was positively associated with nutrient adequacy of folate ( $\beta = 28.52$ , 95% CI: 14.671, 42.367,  $p < 0.001$ ), iron ( $\beta = 9.320$ , 95% CI: 3.119, 15.536,  $P = 0.003$ ), the serum level of ferritin ( $\beta = 12.107$ , 95% CI: 4.406, 19.809,  $P = 0.004$ ) and serum level of folate ( $\beta = 2.263$ , 95% CI: 1.852, 2.675,  $P = 0.001$ ).

**Conclusions:** Significant improvements were observed in the intake of dietary iron and folate by the end of the study. The average scores for nutrient adequacy and serum levels of ferritin and folate showed notable changes, indicating that nutrition education can effectively address micronutrient deficiencies. Therefore, nutrition education and behavior change communication aimed at combating malnutrition, which leads to these deficiencies, should be integral components of healthcare programs.

**Registration:** The Trial was registered with <https://clinicaltrials.gov/> (ID-IRB/098/16, NCT06521151).

**Key words:** Nutrition Education, HBM, Serum Iron and Folate, Ethiopia

## Introduction

Pregnancy is a unique phase in a woman's life, marked by numerous anatomical, physiological, and biochemical changes. This period also comes with increased nutritional requirements for both the mother and the developing fetus (Bailey, 2000; Darnton-Hill and Mkpuru, 2015; Kazma *et al.*, 2020). Two essential micronutrients during pregnancy are iron and folate, which are crucial for achieving optimal birth outcomes (Yeboah *et al.*, 2022). Folate is required in optimal quantities for DNA synthesis and methylation reactions to function (Molloy *et al.*, 2008), while iron is required for RBC and WBC formation and tissue oxygenation (Banjari, 2018; James, 2021).

Pregnant women in developing countries face a high risk of multiple micronutrient deficiencies. Iron and folate deficiencies arise from physiological and metabolic demands, insufficient nutritional knowledge, and inadequate dietary intake (Harika *et al.*, 2017). The unmet needs for increased micronutrient intake heighten the risk of negative pregnancy and birth outcomes. These outcomes include conditions such as placental abruption, pre-eclampsia, spontaneous abortion, stillbirth, PTB, LBW, early fetal loss, bleeding, IUGR, and serious congenital anomalies like NTD (Harika *et al.*, 2017; Black *et al.*, 2018). To meet the minimum serum level cutoffs for folate and ferritin during pregnancy—specifically 2.6–15.0 ng/mL in the first trimester, 0.8–24.0 ng/mL in the second trimester, and 1.4–20.7 ng/mL in the third trimester (WHO., 2012), daily intake of 30 mg dietary iron from rich sources such as red meats, fish, and poultry (Yeboah *et al.*, 2022), and 600 µg dietary folate from legumes, leafy green vegetables, and fruits (Bailey, 2000; Benoist, 2008) are recommended.

Improving the consumption of a variety of locally available, nutrient-dense foods is essential (FAO, 2021). Additionally, it is recommended to supplement with a standard dose of 30–60 mg of iron during the second and third trimesters, along with 400 µg of folic acid starting as early as possible (WHO, 2012; Bathla and Arora, 2022). When supplementation proves ineffective and dietary intake remains low, fortification of staple foods such as wheat, maize, and rice should be considered to enhance maternal nutritional status and health outcomes during pregnancy (Lindsay *et al.*, 2001; Bathla and Arora, 2022). Furthermore, implementing nutrition behavior change interventions is a crucial strategy. These interventions aim to promote optimal nutritional

practices and improve the acceptance and adherence to recommended supplementation, ultimately reducing the prevalence of IDA and LBW (WHO., 2012)

On the other hand, the intake of dietary iron and folate, as well as IFAS, is low in developing countries. This is primarily due to a lack of knowledge, poor dietary practices, cultural misconceptions about nutrition, and low socioeconomic status. As a result, there is a high prevalence of iron and folate deficiency (Lindsay *et al.*, 2001; Zerfu and Biadgilign, 2018; Diddana, 2019; Bayked *et al.*, 2024). Globally, it is estimated that 41.8% of pregnant women are affected by IDA (WHO., 2012). In Africa, the prevalence of folate deficiency among pregnant women varies significantly, ranging from 0.8% to 57.7%. This deficiency can lead to megaloblastic anemia and NTD (Benoist, 2008; Mgamb *et al.*, 2017; Fatou *et al.*, 2018) In Ethiopia, approximately 41% of pregnant women are estimated to be anemic, and 65 out of every 10,000 births are affected by NTD. Among the pregnant women affected by anemia, 20% are classified as moderately anemic, 18% as mildly anemic, and 3% as severely anemic (Bitew *et al.*, 2020; Woldegebriel *et al.*, 2020).

Nutrition education based on the HBM, which emphasizes perceived susceptibility, perceived severity, perceived benefits of behavioral change, and perceived barriers, is a crucial strategy for enhancing knowledge, attitudes, and practices related to dietary intake (Amare *et al.*, 2012; Diddana *et al.*, 2018; Woldeyohannes *et al.*, 2023). However, most prior studies have focused primarily on pregnant women living in urban areas (Diddana *et al.*, 2018; Beressa *et al.*, 2024; Reshid and Anato, 2024), involved small sample sizes (Diddana *et al.*, 2018; Reshid and Anato, 2024), concentrated on the central highlands (Ferede and Abera, 2020), relied on data from health facilities (Reshid and Anato, 2024) and were observational in nature, assessing only risk factors (Amare *et al.*, 2012; Kebede, 2016; Woldeyohannes *et al.*, 2023).

This has led to inflated findings in those studies As a result; there is a lack of objective evidence confirming the effectiveness of HBM-based nutrition education in improving nutrient adequacy. Consequently, our aim is to evaluate the impact of audio-assisted HBM-based nutrition education on knowledge, attitudes, and practices regarding dietary iron and folate intake. We seek to determine how this approach can enhance the adequacy and serum levels of iron and folate in pregnant women, comparing the results with the standard healthcare practices mandated by the MOH of Ethiopia.

## **Materials and methods**

### **Study design, setting and ethics**

A two-arm parallel group cRCT was conducted between July 2024 and September 2024. In brief, cluster randomization was used over individual-level randomization to decrease information contamination and for pragmatic reasons, as community HEW operate in the clusters (Woldeyohannes *et al.*, 2023). This study obtained favorable ethical approval from the CMHS, Hawassa University IRB (Protocol #: IRB098/2016). Written informed consent was secured from all participants to participate in the trial. Participants provided assent before undergoing the trial procedures. The protocol for this study was registered on <https://clinicaltrials.gov/> (NCT06521151) on 07/22/2024. This study was reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) statement (Hopewell *et al.*, 2025) (Figure1).

### **Study setting**

Shebedino and Boricha districts were chosen at random from the northern zone of the Sidama Region. Shebedino and Boricha districts located at 300 and 337 km from Addis Ababa city, respectively and have 23 and 13 clusters, respectively (Zekaria, 2007). Multistage sampling method was applied to select 12 kebeles (lower administrative unit) equally six into intervention and six control clusters. All trial clusters had qualified personnel including HEW, Nurses and Health officers with experience of working in the community on nutrition and health care. Trial center facilities possess all the relevant equipment for performing relevant assessments and interventions.

### **Participants and recruitment**

The process of recruiting participants and efforts to retain them during the follow-up phase of the trial are briefly described in Chapter Three of this PhD project (Mayisso *et al.*, 2025a). In 2024, there were 6,272 pregnant women residing in the districts studied (Zekaria, 2007). The eligibility criteria for the source population, as well as their consent to participate in the study, are also outlined in Chapter Three (Mayisso *et al.*, 2025a). The study population consisted of pregnant women in the early second trimester, specifically those at 13 weeks of gestation. Women on restrictive diets or those with pregnancy-induced hypertension (PIH), Gestational diabetes mellitus (GDM), or high-risk pregnancies were excluded from the study.

### **Sample size estimation and techniques**

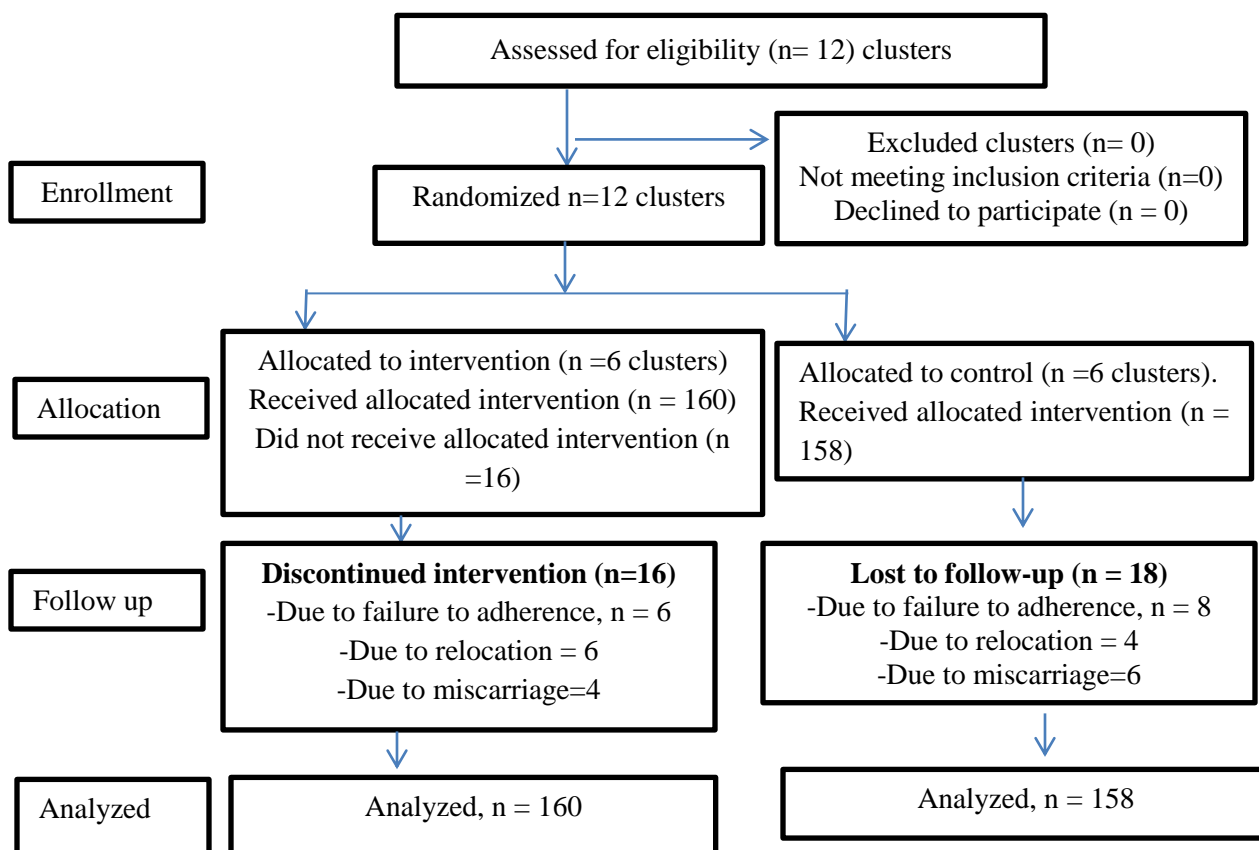
Sample size was calculated for a medium sized effect on the primary outcome with 80% power with an alpha error probability defined as 0.05, a sampling power of 0.5 (Power = 1- $\beta$  err prob) and an effect size of 0.5 (36). The calculated sample size was 120. The ultimate sample size was 156 after taking the largest sample size into account, along with a design effect of 1.3 and a 5% non-response rate, determining a minimum of 328 women (164 participants for each group). Data on births compiled by rural HEW were used to estimate the number of pregnant women in each cluster. Using a probability proportional to size allocation, the sample size was assigned to each cluster. The systematic sampling technique was used to select pregnant women. In the event that a woman missed her interview due to being out of home, the next eligible pregnant woman in the serial number was contacted. The pregnant woman who had been absent from the interview was contacted the next day.

### **Randomization, intervention allocation and blinding**

The methods for calculating gestational age, random assignment of clusters, and the allocation of these clusters to the intervention and control groups in a 1:1 ratio, as well as the recruitment timeframe, were detailed in Chapter Three of the project (Mayisso et al., 2025a). Recruitment began in July 2024 and was completed by the end of September 2024. Due to the significant distance between the clusters, the study was not blinded, and the participants were informed about the intervention. All processes were conducted transparently by the trainers, as the unique characteristics of the cRCT and the nature of the intervention made concealment impractical.

### **Procedure**

Among 424 pregnant women screened in the second trimester of pregnancy, 328 were identified and invited to take part in the study. Not meeting the inclusion criteria, 96 were excluded from the trial. After clarifying the objectives, the intervention, and any other doubts, all 328 women agreed to take part and were allocated into the trial: 164 were allocated to the intervention group, and 164 to the control group. Finally, 318 (160 in intervention group and 158 in the control group) were remained and completed the trial after 10 participants discontinued: 4 in the intervention group and 6 in the control group, with the discontinuation attributed to either time commitments or loss of contact. We reported the findings in accordance with the Consolidated Standards of Reporting Trials (CONSORT) statement (Hopewell *et al.*, 2025) (Fig. 7).



**Figure 7:** Participant flow chart showing the number of participants progressing through the study milestones in Northern Zone, Sidama Region, Ethiopia, 2025

### Interventions allocations

**Intervention arm:** The intervention group received audio-assisted nutrition education, where the researcher created an informative audio lasting for 30min based on content derived from national food and nutrition strategy, FMOH, Ethiopia (FDRE, 2021). They received an additional five the HBM based nutrition education including educating pregnant women to eat one additional meal in addition to their pregnancy meal, supplement pregnant women with iron/folate tablets, and give pregnant women deworming tablets after their third month of pregnancy. The education was held at the community health post, two sessions per month for three months. Health post staff delivered the session under the supervision of two health officers holding Bachelor of Science (BSc) degrees. The health post staffs were trained by project staff from Hawassa University and consist of a kebele HEW, village head/elder, community health volunteer, and health center staff. Health post staff implemented the intervention components using individual and group behavior change communication techniques.

The core contents of the session were on increasing knowledge on iron and folate-rich food sources, use of IFAS, meal frequency and portion size with increasing gestational age; taking day rest; reducing heavy workloads; enhancers and inhibitors of iron absorption; factors leading to iron and folate deficiencies; diet diversifying; diet enriching; and standardizing knowledge regarding intake of fruit and vegetables. Nutrition education sessions included audio-based short messages and presentations prepared in the local language in the form of banners, discussions, demonstrations, and picture-based exercises. An organized work schedule, counseling cards, and nutrition education were provided to the intervention group. Key messages were repeatedly conveyed verbally and with posted material to mothers. Mothers were also given colored pictures of varieties of food to post in their house.

Participatory approaches were utilized by engaging pregnant women in the assessment and analysis of their own difficulties of feeding a variety of food and learning by doing, which encourages pregnant women to devise their own solutions. The strategies were customized to address barriers such as cost, accessibility, preparation, time, and taste preferences. For example, consider choosing inexpensive varieties of food, lowering the perceived obstacles to creating food variety choices, motivating participants to find solutions to the obstacles, enhancing participants' hand washing proficiency, and enhancing participants' knowledge and attitudes on the capacity to adjust feeding patterns. We used realistic activities, including greeting, asking, listening, identifying, and discussing, recommending, agreeing, and making follow-up appointments to transmit key messages.

**Control arm:** A separate control group, comprising subjects who received standard primary health care packages to ensure fairness and achieve a high level of post-recruitment satisfaction. The standard primary health care components were based on the 16 components of Ethiopia's routine HEW packages, including family planning, nutrition, vaccination services, disease prevention and control, hygiene and sanitation, waste disposal management, water supply, food hygiene and safety, control of insects and rodents, and personal hygiene (Assefa *et al.*, 2019). The primary health care packages were delivered at the health post by health post staff according to the health post level guideline of the FMOH of Ethiopia (EFMH, 2021).

## **Outcomes measures**

The primary outcomes of the study were change in iron and folate adequacy and their serum levels to estimate nutritional status of the pregnant women as biochemical indicators. Secondary outcomes of the study were change in knowledge and prevailing attitude on intakes of dietary iron and folate as short-term outcomes and changes in intake practices of dietary iron and folate as medium-term outcomes. Both primary and secondary outcomes were measured at two point times, at base line (13 weeks of gestation) and in the end line (24 weeks of gestation).

## **Data collection and measurements**

Methods and procedures of data collection and supervision, personnel involved, as well as types of socio-demographic and socio-economic data were described in Chapter Three (Mayisso et al., 2025a). Data on dietary iron and folate intake knowledge, attitude and practice and data on DD were collected before the intervention and up on completion 12 weeks of the interventions. Blood samples for analysis of serum folate and ferritin was collected in base line and end-line of the study.

## **Assessment of KAP on intakes of dietary iron and folate**

Women's knowledge and practice of daily intake of iron and folate in the diet and HBM constructs were measured according to KAP model questionnaires of FAO (FAO, 2014). Data on the level of adherence to IFAS was collected using questionnaires adapted from the previous report (Fiedler, 2014). Data on nutritional knowledge was collected by using 15 nutrition knowledge questions. Participants were given score =1, if they correctly answer knowledge question, and score = 0, if they did not correctly answer the question. Dietary intake practices data were collected using 17 dietary habit questions. Participants were given score=1, if they correctly answer question, favorable or healthy for dietary practice, and score =0, if they did not correctly answer the question, not favorable or healthy for dietary practice. HBM constructs were measured using five-point likert scale (strongly agree= 5; through strongly disagree =1). Then, the value of each likert scale scored by participants for each question was summed and the average was calculated.

## **Assessment of 24 hour dietary diversity score**

The methods of MDD-W and the DDS assessments were detailed in Chapter One of the PhD project (Mayisso et al., 2025b).

### **Assessment of iron and folate adequacy**

The methods of assessment of nutritional value, calculation of the nutrient intake and iron and folate adequacy ratio were described in Chapter One (Mayisso et al., 2025b). As nutrient adequacy is a primary indicator of micronutrient status during pregnancy, we used 600 µg of dietary folate and 27 mg of dietary iron as the RDA to calculate the NAR (Bailey, 2000; Yeboah *et al.*, 2022).

### **Assessment of serum levels of folate and ferritin**

The baseline blood sample was collected in July 2024 and end-line samples were collected in September 2024. Before blood samples collection, the women were informed about the required blood sample and each woman was relaxed for safe and precise prick at the cubital vein to prevent minimum risk. Trained laboratory technologists collected each woman's blood sample for baseline and endpoint surveys. 5mL venous blood samples were collected aseptically from the ante cubital vein and placed into anticoagulant-free test tubes. The blood samples were centrifuged, and the serum was separated before being frozen at  $-80^{\circ}\text{C}$  and transported to Addis Ababa clinical laboratory for analysis for respective two survey periods, and the laboratory procedural steps used reported.

The serum level of the micronutrients were analysed using the electrochemiluminescence method on a fully automated Cobas e411-Cobas 4000 analyser series; Germany and Japan immunoassay analyser using commercial kits supplied by Roche (Germany) to analyze serum level of ferritin in Addis Ababa clinical laboratory. A fully automated liquid chromatography-tandem mass spectrometry (LC-MS/MS) method was used to analyses serum level of folate using commercial kits supplied by Roche Company, Germany in Addis Ababa clinical laboratory. The cut-off value for serum ferritin and serum folate were indicated based on international standard of the nutrients for pregnant women based on metabolic indicators with the reference of WOH cut-offs of (14.7–184.3 mg/L) for serum level of ferritin (WHO., 2012) and 10nmol/L (4ng/mL) for serum folate (Rogers, 2018).

### **Data quality assurance**

The way of data quality assurance was were detailed in Chapter Three of this project (Mayisso et al., 2025a).

## Statistical analysis

The data were checked for completeness, consistency, and accuracy and entered into, cleaned, and analyzed using SPSS for Windows version 27. Descriptive statistics, including frequencies, percentages, means, SD, and standard errors were generated for the selected predictors and covariates. The baseline characteristics of the intervention and control groups were assessed using the chi-square test. The independent sample t test and paired sample t test were used to compare DD, dietary intake knowledge and practice, nutrient adequacy and serum levels of folate and ferritin between and within the intervention and control groups, respectively.

We employed a LMM to evaluate the intervention effect on adequacy and serum levels of the micronutrients, accounting for the clustering effect. The identification of clusters and respondents was analyzed as a random effect in the analytic model. The intervention's effectiveness was evaluated using time and intervention interaction. Four models were fitted. The null model (model without predictors), **model I** [( iron/folate) adequacy + study group) and (serum level of ferritin/folate+ study group)], **model II** [(iron/folate) adequacy + group, time, group ×time) and (serum level of ferritin/folate+ group, time, group ×time)], and **model III** [(iron/folate adequacy + study groups + predictors and covariates), and (serum level of ferritin/folate + study groups + predictors and covariates)] were all fitted.

The intra class correlation coefficients (ICC) for all outcome variables in the null model were >0.05 indicating the variability of the conditions attributed to the clustering effect. The Deviance (- 2 LL), Akaike's information criterion (AIC), and Bayesian information criterion (BIC) values were used for model comparison. The deviance values for Model III were the lowest in all outcome variables, indicating that the full model for all outcome variables were best-fit model. As a result, Model III was used to make interpretations. The effect size was expressed as an estimate ( $\beta$ ), along with the standard error (SE) and 95% CI. Sensitivity analysis using per protocol analysis was conducted. However, there was no difference in the effect size. Initially, randomly assigned pregnant women were examined in the groups to which they were assigned (intention-to-treat analysis principle). Pregnant women who discontinued due to adherence failure or relocation or due to miscarriage were included in the intention to treat analysis. The statistical significance of the association was declared at a p value of less than 0.05, and tests were two-sided.

## Results

### Sociodemographic characteristics of participants

A total of 97.5% and 96.3% pregnant women were successfully interviewed and had serum level of ferritin and serum level of folate measured in the intervention and control groups, respectively (Figure 1). There was no substantial difference in baseline characteristics between the intervention and control groups (P value > 0.05). The mean (SD) age of the respondents was 26.38 years for the intervention group and 25.80 years for the control group. Additionally, 35% of households in the intervention group and 31.7% in the control group were classified in the highest wealth index quintile. The study also found that only 22.5% of households in the control group and 17.7% in the intervention group were food secure, which implies that around 60% of the households in the control group and 61% in the intervention group were unable to afford for sufficient food (Table 8).

**Table 8:** Baseline socio-demographic characteristics of pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158)

Variables	Intervention (n=160)		Control (n=158)		P value
	Frequency	Percent	Frequency	Percent	
Age (year)					
<20	12	7.5	26	16.5	0.462
≥20	148	92.5	132	83.5	
Marital status					
Married	159	99.4	156	98.7	0.991
Divorced	1	0.6	2	1.3	
Residence					
Rural	118	74.0	108	68.0	0.264
Urban	42	26.0	50	32.0	
Family number					
2-4	152	95.0	150	95.0	0.792
>4	8	5.0	8	8.0	
Religion					
Protestant	154	96.2	147	93.0	0.462
Others <sup>a</sup>	6	3.8	11	7.0	
Ethnicity					
Sidama	159	99.4	156	98.7	0.464
Others <sup>b</sup>	1	0.6	2	1.3	
Maternal occupation					
Housewife	154	96.2	153	96.8	0.362
Employed	4	2.5	3	1.9	
Merchant	2	1.3	2	1.3	

Spouse occupation					
Farmer	118	73.7	128	81.0	0.781
Employed	32	20.0	18	11.4	
Merchant	10	6.3	12	7.6	
Maternal education					
Illiterate	16	10.0	5	3.2	0.273
Literate	144	90.0	153	96.8	
Wealth index					
Rich	26	16.3	10	6.3	0.001
Medium	59	36.9	62	39.2	
Poor	75	46.9	86	54.4	
Affordability for food					
Can afford	62	38.8	64	40.5	0.819
Cannot afford	98	61.2	94	59.5	

*a Others: Muslim, catholic, b Others: Oromo, Gamo*

### Health belief model scores

The significant improvement was observed in the score of the HBM constructs among the intervention group before and after the intervention. Moreover, significant differences were noticed in the dimensions of all the HBM in the end-line (p-value < 0.001) (Table 9).

**Table 9:** Differences in baseline and end-line measurements of HBM construct among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158)

HBM constructs scores	Base line	End line	MD	95% CI		Pvalue <sup>a</sup>
	Mean(±SD)	Mean(±SD)	Mean (±SD)	Lower	Upper	
Perceived susceptibility						
Control	1.47±1.188	1.49±0.029	0.013±1.373	-0.203	0.228	0.908
Intervention	1.90±0.763	6.73 ±0.785	4.83±1.560	4.581	5.069	0.001
P-value <sup>b</sup>	0.001	0.001				
Perceived severity						
Control	4.47±0.711	4.37±0.793	-0.101±1.158	-0.283	0.081	0.273
Intervention	4.45±0.725	5.75±0.434	1.300±0.930	1.155	1.445	0.001
P-value <sup>b</sup>	0.820	0.001				
Perceived benefit						
Control	2.66±0.737	2.71±0.734	0.044±1.096	-0.128	0.217	0.612
Intervention	2.70±0.734	3.34±0.692	0.644±0.914	0.501	0.786	0.001
P-value <sup>b</sup>	0.668	0.001				
Perceived barrier						
Control	2.10±0.697	1.28±0.516	0.177±0.954	0.027	0.327	0.021
Intervention	2.26±0.532	1.32±0.871	-0.944±1.048	-1.107	-0.780	0.001
P-value <sup>b</sup>	0.021	0.001				
Perceived self-efficacy						
Control	1.12±0.276	1.08±0.509	-0.038±0.596	-0.132	0.056	0.424
Intervention	2.05±0.547	2.12±0.597	0.069±0.254	0.029	0.108	0.001
P-value <sup>b</sup>	0.569	0.001				

0- paired sample t test, b-independent sample t test, SD-standard deviation, CI-confidence interval, MD-mean differences

### **Effect of nutrition education on maternal dietary diversity**

Majority, 98.8% of the pregnant women in intervention and 94.4% in control groups consumed starchy staple before and after the interventions. Next to starch staple, dark green leafy vegetable was consumed by 71.2% in baseline, and 88.8% in endline by the study participants in intervention group before and after the intervention, respectively. A significant change was also noticed in consumption of pulses and legumes in intervention group that shown an increment from 44.4% in base line to 82% in end line. Similarly, consumption of nutrition-dense food commodities, such as flesh food (meat, fish and polluters), eggs and milk and milk products was significantly improved in intervention group (p-value<0.001).

Around half (51%) of the study participants in intervention group consumed diets adequate in micronutrient in baseline, which increased to 63.7% in end line compared to 45.6% in control group, highlighted an improvement in intakes of the micronutrient. Likewise, a significant improvement was noticed in mean DDS 3.06 to 4.67 in intervention group compared to an increment in mean DDS 3.24 to 3.39 in control group (Table 10).

**Table 10:** Baseline and end-line differences in different food groups consumption among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158).

Variables	Study group	Response	Base line					End line				
			No.	%	95% CI		P value	No.	%	95% CI		Pvalue
					Lower	Upper				Lower	Upper	
Starchy staple	Intervention	Yes	158	98.8	96.9	100.0	0.088	158	98.8	96.9	100	0.087
		No	2	1.2	0.0	3.1	0.650	2	1.2	0.0	3.1	0.650
	Control	Yes	157	99.4	98.1	100	0.047	157	99.4	98.1	100.0	0.007
		No	1	0.6	0.0	1.9	0.890	1	0.6	0.0	1.9	0.890
Dark green leafy vegetables	Intervention	Yes	114	71.2	64.4	77.5	0.001	142	88.8	83.8	93.7	0.001
		No	46	28.8	22.5	35.6	0.002	18	11.2	6.3	16.3	0.001
	Control	Yes	123	77.8	71.5	84.2	0.003	100	63.3	55.1	70.9	0.003
		No	35	22.2	15.8	28.5	0.000	58	36.7	29.1	44.9	0.001
Pulses and legumes	Intervention	Yes	71	44.4	36.9	51.9	0.004	130	81.2	75.0	86.9	0.001
		No	89	55.6	48.1	63.1	0.004	30	18.8	13.1	25.0	0.001
	Control	Yes	72	45.8	38.0	53.8	0.027	64	40.5	32.9	48.7	0.026
		No	86	54.4	46.2	62.0	0.004	94	59.5	51.3	67.1	0.001
Vitamin A rich fruits and vegetables	Intervention	Yes	19	11.9	6.9	17.5	0.001	95	59.4	51.2	66.9	0.001
		No	141	88.1	82.5	93.1	0.005	65	40.6	33.1	48.8	0.001
	Control	Yes	38	24.1	17.1	31.0	0.001	30	19.0	13.3	25.3	0.001
		No	120	75.9	69.0	82.9	0.001	128	81.0	74.7	86.7	0.000
Nuts and seeds	Intervention	Yes	38	23.8	16.9	30.6	0.001	142	88.8	83.1	93.7	0.001
		No	122	76.2	69.4	83.1	0.001	18	11.2	6.3	16.9	0.032
	Control	Yes	43	27.2	20.3	34.2	0.045	69	43.7	36.7	51.9	0.045
		No	115	72.8	65.8	79.7	0.001	89	56.3	48.1	63.3	0.001
Other fruits and vegetables	Intervention	Yes	46	28.8	21.9	36.3	0.001	145	90.6	85.6	94.4	0.001
		No	114	71.2	63.7	78.1	0.001	15	9.4	5.6	14.4	0.002
	Control	Yes	57	36.1	29.1	43.7	0.537	52	32.9	25.3	41.1	0.537
		No	101	63.9	56.3	70.9	0.001	106	67.1	58.9	74.7	0.021
Meats, fish and poultry	Intervention	Yes	4	2.5	0.6	5.0	0.001	88	55.0	46.3	62.5	0.001
		No	156	97.5	95.0	99.4	0.006	72	45.0	37.5	53.8	0.012
	Control	Yes	2	1.3	0.0	3.2	0.001	35	22.2	15.8	29.1	0.001

Milk and milk products	Intervention	No	156	98.7	96.8	100	0.005	123	77.8	70.9	84.2	0.002
		Yes	17	10.6	6.3	15.5	0.001	103	64.4	56.3	71.3	0.001
		No	143	89.4	84.4	93.8	0.004	57	35.6	28.7	43.8	0.001
Eggs	Control	Yes	15	9.5	5.1	14.5	0.055	20	12.7	7.6	18.4	0.055
		No	143	90.5	85.5	94.9	0.000	138	87.3	81.6	92.4	0.000
		Yes	3	1.9	0.0	4.4	0.001	133	83.1	76.9	88.8	0.001
DD category	Intervention	No	157	98.1	95.6	100	0.001	27	16.9	11.3	23.1	0.001
		Yes	5	3.2	0.6	6.3	0.001	53	33.5	25.9	41.1	0.001
		No	153	98.8	93.7	99.4	0.002	105	66.5	58.9	74.1	0.001
DD category	Control	Adequate	82	51.2	43.1	58.8	0.000	102	63.7	56.3	71.3	0.001
		Inadequate	78	48.8	41.3	56.9	0.021	58	36.3	28.7	43.8	0.034
		Adequate	58	37.3	29.7	44.3	0.001	72	45.6	38.0	53.8	0.000
DDS	Study groups	Inadequate	100	62.7	55.7	70.3	0.001	86	54.4	46.2	62.0	0.001
				Baseline		End line		95% CI		P		
				Mean	SD	Mean	SD	Lower	Upper	value		
		Intervention	3.06	1.18	4.67	1.83	1.28	1.94	0.001			
		Control	3.24	1.21	3.39	1.15	0.996	1.574	0.001			

*MD- means differences, SD-Standard deviations, and CI-confidence interval, adequate diet: consumed at least five different food groups during the previous day or night, inadequate diet: consumed <5 food groups during the previous day or night*

## Effect of nutrition education on maternal knowledge about dietary iron and folate intake

There was significant difference in mean nutrition knowledge score before and after the intervention ( $P < 0.001$ ), which was increased from 1.02 in base line to 8.24 in end line. However, there was no significant difference in nutritional knowledge categories in base line between intervention and control groups ( $p$ -value=0.340). In end line, 66.3% of the participant in intervention group showed better knowledge on health benefit of intake of more protein rich diet during pregnancy than the participants in control groups, in which only, 22.8% of the participants knew health benefit of intake of more protein rich diet during pregnancy.

In end line, 80% of the participants in intervention group knew the benefits of ASF for mother and fetus in intervention group. Similarly, more than three fourth (79.4%) of the participants in intervention group knew the cause of anemia and 75% of the participants knew about birth defects. Similarly, after NEI, majority, 80% and 81.3 % of the study participants knew the health benefit of intake of IFAS and the dose of the supplements during pregnancy, respectively. Nonetheless, about half of the participants knew dietary sources of iron and folate and consequences of micronutrient deficiency during pregnancy for both mother and fetus after the NEI. Significant difference was noticed between nutritional knowledge in both groups ( $p < 0.05$ ) in end line between intervention and control groups (Table 11).

**Table 11:** Differences in baseline and endline on maternal dietary iron and folate intake knowledge among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158).

Variables	Study period	Intervention		Control		Pvalue
		Frequency	%	Frequency	%	
Know health benefit of intake of protein rich diet	Base line	35	21.9	22	13.9	0.070
	End line	106	66.3	36	22.8	0.001
Know health benefit of intake of animal source diet for mother	Base line	20	12.5	14	8.9	0.292
	End line	128	80.0	37	23.4	0.001
Know health benefit of intake of IFA supplements	Base line	9	6.0	3	6.0	0.081
	End line	128	80.0	15	9.4	0.001
Know the dose of IFA supplements	Base line	16	10.0	10	6.3	0.232
	End line	130	81.3	12	7.6	0.001
Know health benefit of intake of animal source diet for fetus	Base line	9	5.7	8	5.0	0.782
	End line	128	80.0	33	20.9	0.001
Know the cause of anemia during pregnancy	Base line	20	12.5	32	20.3	0.061
	End line	127	79.4	55	34.8	0.001

Know foods that increase iron absorption	Base line	15	9.4	8	5.1	0.141	
	End line	148	92.5	10	6.3	0.001	
Know foods that decrease iron absorption	Base line	8	3.8	6	5.0	0.601	
	End line	111	93.3	8	6.7	0.001	
Know about iron-deficiency anaemia during pregnancy	Base line	57	35.6	29	18.4	0.001	
	End line	135	84.0	57	36.0	0.001	
Know consequences of iron-deficiency anaemia for mother	Base line	9	5.7	7	4.4	0.592	
	End line	101	63.1	23	14.6	0.002	
Know consequences of iron-deficiency anaemia for fetus	Base line	21	15.2	24	13.1	0.601	
	End line	152	95.0	26	16.5	0.001	
Know about birth defect	Base line	8	5.1	9	5.6	0.821	
	End line	120	75.0	4	2.5	0.001	
Know how to prevent birth defect	Base line	21	13.1	12	7.6	0.112	
	End line	153	95.6	36	22.8	0.001	
Know health benefit of more frequently intake	Base line	35	21.9	57	36.0	0.001	
	End line	142	88.8	65	41.1	0.001	
Know the follow up of weight during pregnancy	Base line	27	36.1	57	36.1	0.001	
	End line	27	16.9	33	20.9	0.001	
Nutrition knowledge	Base line	Poor	121	75.6	112	70.9	0.342
		Good	39	24.4	46	29.1	
	End line	Poor	55	34.4	120	75.9	0.001
		Good	105	65.6	38	24.1	
Mean nutrition knowledge	Groups	Baseline	End line		MD		
		Mean ( $\pm$ SD)	Mean( $\pm$ SD)	MD( $\pm$ SD)	Pvalue		
	Intervention	1.02( $\pm$ 1.84)	8.24( $\pm$ 2.44)	7.21( $\pm$ 4.04)	0.001		
	Control	0.91( $\pm$ 1.47)	1.70( $\pm$ 2.53)	0.78( $\pm$ 1.84)	0.001		

SD- standard deviation, MD- means difference

### Effect of nutrition education on meal frequency and dietary intake habits

The finding shown that an average of 0.39 and 0.60 of the study participants get three meals per day in the intervention group. They consumed at least one snacks between main meals in base line and end line, respectively. Pregnant women who had skipped any of the meals during current pregnancy were decreased from 0.59 in baseline to 0.13 in end line in the intervention group. In contrast, daily use of extra meal was increased from 0.08 in baseline to 0.87 in endline in the intervention group. Participants who were having breakfast every morning was increased from 0.32 in baseline to 0.67 in endline in the intervention group. Significant differences in meal frequency and skipping any meal were noticed among the study participants in the intervention and control groups before and after the intervention. Likewise, a significant difference was observed in consuming an extra meal after the intervention of nutrition education in the study participants in the intervention groups (p-value<0.001) (Table 12).

**Table 12:** Differences in baseline and end line in meal frequency and dietary intake habit among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158)

Variables	Baseline	End line	Mean differences	95% Confidence interval		P value
	Mean ( $\pm$ SD)	Mean ( $\pm$ SD)	Mean ( $\pm$ SD)	Lower	Upper	
<b>Get three meals per day and at least one snacks between main meals</b>						
Intervention group	0.39 (0.48)	0.60(0.20)	0.21 (0.48)	0.13	0.29	0.001
Control group	0.53 (0.50)	0.16 (0.37)	-0.37(0.66)	-0.47	-0.26	0.001
<b>Skip any of the meals/day</b>						
Intervention group	0.59 (0.49)	0.13 (0.34)	0.46(0.50)	0.38	0.53	0.001
Control group	0.44 (0.50)	0.85(0.35)	-0.41(0.61)	-0.51	-0.32	0.001
<b>Consumption of extra meal/day</b>						
Intervention group	0.08 (0.274)	0.87(0.34)	0.79 (0.43)	0.72	0.85	0.000
Control group	0.16 (0.37)	0.21 (0.41)	0.04 (0.51)	-0.04	0.12	0.276
<b>Have breakfast every morning</b>						
Intervention group	0.32 (0.47)	0.67(0.47)	0.35 (0.68)	0.25	0.46	0.000
Control group	0.67 (0.47)	0.27 (0.44)	-0.41 (0.51)	-0.06	-0.00	0.001
<b>Consumption of at least 1.5 litter water/day</b>						
Intervention group	0.64 (0.49)	0.84(0.36)	0.21(0.58)	0.12	0.30	0.001
Control group	0.92 (0.27)	0.97(0.18)	0.04 (0.33)	-0.01	0.10	0.090
<b>Consumption of coffee/tea</b>						
Intervention group	0.04 (0.19)	0.03(0.16)	-0.01(0.11)	-0.03	0.01	0.158
Control group	0.03 (0.18)	0.03(0.18)	0.00 (0.16)	-0.03	0.03	1.000
<b>Avoiding any food items</b>						
Intervention group	0.08(0.27)	0.06 (0.23)	0.16(0.01)	-0.05	-0.00	0.045
Control group	0.04(0.19)	0.01 (0.11)	-0.03 (0.24)	-0.06	0.01	0.158

*SD-standard deviation, CI- confidence interval BL- baseline, EL-end-line, SD-standard deviation, SE-standard error, DD-differences in difference, CI-confidence interval, P-valuea-paired sample t test, P valueb-independent sample t test*

### Effect of nutrition education on dietary iron and folate intake practice, nutrient adequacy and serum levels

The mean intake of pulses and legumes was increased from 0.26 to 0.57 in intervention group. The change was statistically significant. However, a significant change was not observed in consumption of fruits and vegetables in the group after NEI. On the other hand, ASF intake was significantly decreased in the intervention group after NEI.

The majority, 87% and 80% of pregnant women did not meet the daily recommended intakes for iron and folate micronutrients, respectively. However, adherence to daily intake of IFAS was good and could have accounted for the positive birth outcomes. However, only 3.8% of the study participants consumed preconceptional IFAS, while a significant change was noticed after NEI in intervention group. In the paired sample T test, the means intake of recommended daily intake of combined IFAS was increased from 0.06 to 0.93 mg after NEI. Likewise, the mean dietary

iron and folate intakes were increased from 13.31 to 18.37 and from 198.82 to 419.82, respectively.

The changes were statistically significant ( $p$ -value $<0.05$ ). In independent sample T test, a significant difference was noticed between the control and intervention groups in intakes of dietary folate and iron ( $p<0.001$ ). However, significant differences in means daily recommended dietary folate and iron intakes were not observed between intervention and control groups ( $p$ -value  $>0.005$ ) in baseline. Nonetheless, the differences in the means were statistically significant in both intervention and control groups ( $p$ -value $<0.005$ ) in the end line.

Within the intervention group, means NAR of iron and folate were improved significantly from 0.494 to 0.706 and from 0.33 to 0.70, respectively ( $p$ -value $<0.005$ ). In independent sample T test, significant differences were noticed in means NAR of iron and folate in end line. Most of the participants in intervention group had serum ferritin and folate levels in the normal range, 75.0% and 90.6% in baseline, 92.5% and 98.8% in end line, respectively. Significant difference in serum levels of folate and ferritin between the control and intervention groups were observed in end line ( $p<0.001$ ). However, in the NAR and serum levels of folate and ferritin significant differences in means were not observed ( $p > 0.05$ ) in base line (Table 13.1).

**Table 13.1:** Comparison of dietary intake practices, nutrient adequacy, and serum levels of iron and folate among pregnant women participated in the study in baseline and endline in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158)

Variables	Baseline	End line	MD	95% CI		Pvalue
	Mean ( $\pm$ SD)	Mean ( $\pm$ SD)	Mean ( $\pm$ SD)	Lower	Upper	
<b>Animal source food intake practice</b>						
Intervention	0.08 (0.27)	0.05 (0.22)	-0.03(0.18)	-0.00	-2.27	0.025
Control	0.03 (0.18)	0.01(0.11)	-0.02(0.21)	-0.05	0.01	0.258
<b>Fruits and vegetables intake practice</b>						
Intervention	0.17 (0.38)	0.10 (0.30)	-0.07(0.48)	-0.14	0.01	0.070
Control	0.75 (0.43)	0.61 (0.49)	0.14 (0.46)	0.07	0.21	0.001
<b>Pulses and legumes intake practice</b>						
Intervention	0.26 (0.44)	0.57(0.50)	-0.31(0.65)	-0.41	-0.21	0.001
Control	0.25 (0.43)	0.13(0.34)	-0.11(0.54)	-0.20	-0.03	0.009
<b>Mean dietary iron and folate intake practice</b>						
Intervention	2.62(1.83)	3.84(1.57)	1.22 (1.83)	0.93	1.51	0.000
Control	3.69(1.64)	3.40(1.47)	-0.29(1.52)	-0.53	-0.05	0.018
<b>Intake of daily recommended dietary iron (mg)</b>						
Intervention	13.31 $\pm$ 1.97	20.82(6.14)	7.51(6.27)	6.53	8.49	0.001
Control	13.89 $\pm$ 2.40	19.38(5.50)	5.48 (6.18)	4.52	6.46	0.001
<b>Intake of daily recommended dietary folate (<math>\mu</math>g)</b>						
Intervention	198.82 $\pm$ 58.88	419.83(306.36)	221.00 (318.36)	171.30	27.71	0.001
Control	201.14 $\pm$ 63.40	193.08 (64.42)	8.06(15.60)	5.61	10.51	0.001
<b>Intake of daily recommended IFAS</b>						
Intervention	0.6 (0.25)	0.93 (0.25)	0.87 (0.48)	0.79	0.94	0.001
Control group	0.06 (0.23)	0.08(0.27)	0.03(0.30)	-0.02	0.07	0.286
<b>Adequacy of iron</b>						
Intervention	49.31 $\pm$ 7.31	77.11(22.74)	27.81(23.23)	24.18	31.43	0.001
Control	51.45 $\pm$ 8.9	71.78 (20.38)	20.33(21.20)	16.98	23.67	0.001
<b>Adequacy Folate</b>						
Intervention	33.14 $\pm$ 9.82	69.97(51.06)	36.84(53.06)	28.55	45.12	0.001
Control	33.52 $\pm$ 10.56	32.18(10.74)	1.34(2.60)	0.93	1.75	0.001
<b>Serum level of ferritin</b>						
Intervention	15.99 $\pm$ 3.73	17.89(4.05)	1.91 $\pm$ 0.43	1.84	1.97	0.001
Control	15.05 $\pm$ 3.52	16.96(3.82)	1.91 $\pm$ 0.41	1.85	1.98	0.001
<b>Serum level of folate</b>						
Intervention	11.51 $\pm$ 3.64	12.16(3.85)	0.64 $\pm$ 1.02	0.48	0.80	0.001
Control	11.66 $\pm$ 4.91	10.70(4.40)	0.96 $\pm$ 1.12	0.78	1.13	0.001

The multivariable LMM revealed that having received NEI was positively association with adequacy of folate ( $\beta$ = 28.52, 95% CI: 14.671, 42.367, p value<0.001), adequacy of iron ( $\beta$ = 9.320, 95% CI: 3.119, 15.536, P=0.003), serum level of folate ( $\beta$ = 2.263, 95% CI: 1.852, 2.675, P<0.001), and serum level of ferritin ( $\beta$ = 12.107, 95% CI 4.406, 19.809, P = 0.004).

Likewise, the multivariable LMM revealed that having higher education ( $\beta$ = 35.620, 95% CI: 13.831, 57.412, p <0.001), having family member of 2-4 ( $\beta$ = 14.201, 95% CI: 1.340, 27.058,

p<0.001) had significantly associated with folate adequacy. Moreover, family size with ( $\beta=10.558$ , 95% CI: 3.890, 17.226, p<0.001 and high school and higher education ( $\beta=364$ , 95% CI: 303, 425, p=0.047) were significantly associated with iron adequacy. High wealth index ( $\beta=8.100$ , 95% CI: 7.371, 8.830, p<0.001) and having family members of 2-4 ( $\beta=1.299$ , 95% CI: 0.373, 2.225, P=0.006) were significantly associated with serum level of folate, while higher education ( $\beta=6.84$  95% CI: 8.360, 14.560, p=0.047) and agricultural land ownership ( $\beta=13.576$ , 95% CI 5.938, 21.214, p<0.001) were significantly associated with serum level of ferritin (Table 13.2).

The variance of the residual errors at the individual level of the average adequacy of folate and iron and serum level of folate and ferritin were determined to be 1686.40, 438.18, 17.22, and 792.18, respectively. These differences in both cases were statistically significant (p< 0.001). The intra-class correlation coefficients (ICC) for adequacy of folate and iron, and for serum level of folate and ferritin in the null model were 0.98, 0.94, 0.98, and 0.98, respectively, indicating the variability of the conditions attributed to the clustering effect. The Deviance (-2 LL=3266.76), Akaike's information criterion (AIC=3272.76), and Bayesian information criterion (BIC=3284.76) values for folate adequacy and for other variables (shown in Table 7.2) were used for model comparison. The deviance value for Model III was the lowest, indicating that the full model for all variables was the best-fit model. As a result, Model III was used to make interpretations.

**Table 13.2:** End line multivariable linear mixed model predicting adequacy of folate and iron and serum level of the micronutrients among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, (n=160)

Fixed effect		Null model		Model I			Model II			Model III			
O/come variables	Predictors	Estimate (SE)	95%CI		Estimate (SE)	95%CI		Estimate (SE)	95 % CI		Estimate(SE)	95 % CI	
			Lower	upper		Lower	Upper		Lower	upper		Lower	Upper
Folate adequacy	Intercept	51.46(3.74)	40.71	62.21	44.04(3.24)	37.65	50.43	29.16(13.26)	3.08	55.23	51.19(2.32)	46.62	55.76
	Intervention				14.21(4.58)	5.21	23.22	45.38(18.32)	9.33	81.43	28.52 (6.90)	14.67	42.37
	Time1							0.22(6.34)	-0.75	1.20			
	Intervention*time1							-0.41(0.68)	-1.76	0.94			
	Family size 2-4										14.20 (6.56)	1.34	27.06
	>high school										35.62 (6.90)	13.82	57.41
Iron adequacy	Intercept	74.46(1.21)	72.06	76.86	72.31(2.76)	64.47	80.14	68.09 (6.45)	55.39	80.79	73.28 (0.28)	59.75	86.83
	Intervention				14.38(3.88)	3.30	25.45	36.39 (8.93)	18.83	53.95	9.320 (2.54)	3.12	15.54
	Time1							0.17 (0.24)	-0.30	0.65			
	Intervention*time1							0.80 (0.33)	0.14	1.45			
	Family size 2-4										10.56 (3.40)	3.89	17.23
	>high school										364.24(2.78)	303.03	425.04
Serum level of folate	Intercept	11.43(0.37)	10.34	12.53	10.70(0.32)	10.06	11.34	9.06 (2.76)	0.46	17.66	19.68(0.22)	18.47	20.89
	Intervention				1.43(0.46)	0.52	2.34	6.44 (1.78)	2.94	9.94	2.263 (0.21)	1.85	2.68
	Time1							0.03(0.047)	-0.58	0.12			
	Intervention*time1							-0.03(0.64)	-0.15	0.94			
	High wealth quintile										8.10 (0.37)	7.37	8.83
	Family size 2-4										1.299 (47)	0.37	2.23
Serum level of ferritin	Intercept	81.94(2.60)	74.89	89.00	76.70(2.21)	72.36	81.05	65.09(8.76)	47.87	82.32	77.38 (1.52)	58.64	96.12
	Intervention				10.05(3.11)	3.93	11.18	46.97(12.12)	23.13	70.81	12.107(3.66)	4.41	19.81
	Time1							-0.24 (0.32)	-0.88	0.40			
	Intervention*time1							-0.30 (0.45)	-1.19	0.59			
	>high school										6.84 (3.67)	8.36	14.06
	Land ownership										13.58 (3.88)	5.94	21.21

low wealth quintile, primary education, control, intervention \* time 0 \*, family size ≤5, Agricultural land ownership (No), SE: standard error; CI: confidence interval, time 0: pre intervention; time 1: post intervention.

#### 4. Discussion

The study included 318 pregnant women selected from 12 clusters in selected districts, and used nutrition educators employed education guides, the HBM, and trimester-based education. NEI based on HBM increase pregnant women's diet knowledge, DD, and nutritional status (Chitsaz *et al.*, 2017), which is supported by other studies done in Ethiopia (Diddana *et al.*, 2018; Beressa *et al.*, 2024). Other studies in different parts of the world agreed that using this strategy to provide nutrition education for people would increase the awareness of intake of appropriate nutrition and diverse diet during pregnancy, and useful to prevent chronic illness (Naghashpour *et al.*, 2014). In contrast, the healthcare system's current education does not include counseling guides, a health behavior model, or a theory (Beressa *et al.*, 2024).

Consequently, intakes of dietary folate and iron, nutrition knowledge, DD, and practices in pregnant women were significantly improved after the intervention of HBM-based nutrition education through increasing perceived susceptibility, severity, and benefits and decreasing perceived barriers. These findings were in agreement with other studies (Zelalem *et al.*, 2017; Diddana *et al.*, 2018; Beressa *et al.*, 2024; Tesfaye *et al.*, 2024). This could be because of after HBM-based NEI women could believe about the severity and the consequences of malnutrition, and they could perceive that the benefits of consuming enough and diverse food outweighed the hurdles to obtaining the diverse diet.

The health education intervention also can influence attitude and actions, and the women's role in raising their intentions to eat a balanced diet (Beressa *et al.*, 2024). The finding of this study justified these issues, in which there were statistically significant differences in the net mean intake of dietary iron and folate between the intervention and control groups, so that dietary iron and folate intake in the intervention group was significantly improved compared to that of control group. The finding is supported by those of other studies conducted in Dessie town northeast Ethiopia (Zelalem *et al.*, 2017; Diddana *et al.*, 2018). The possible explanation might be that nutrition education leads to favorable knowledge, practice and attitudes, thus, changes in nutrition behavior.

NEI increased the mean scores of dietary iron and folate intake differently among pregnant women in urban and rural areas. Nonetheless, the differences were not statistically significant. Other similar study conducted in Ethiopia (Beressa *et al.*, 2024) did not agree with the results,

which approved a substantial improvement in MUAC among pregnant women from urban area after the intervention. This might be because nutrition education provided for urban women by public health specialists was effective in improving the MUAC of pregnant women.

Our study's findings would add to a body of knowledge that education alone may be ineffectual if the environment does not encourage healthy behaviors (Beressa *et al.*, 2024). But, other studies confirmed that providing nutrition education utilizing HBM indicated that significant improvement on the level of knowledge, practice and attitude of pregnant women towards utilization of diverse diets (Diddana *et al.*, 2018). In addition, the effectiveness of nutrition education in changing actual eating behaviors and practices is often limited (Beressa *et al.*, 2024). This is because the nature of NEI is complex (Zelalem *et al.*, 2017), achieving long-term behavior change being more difficult with education alone (Beressa *et al.*, 2024). Additionally, multiple food consumption factors, including seasonality, distance to markets, family poverty, gender inequities, and cultural or religious traditions affect efficacy of NEI (Hirvonen *et al.*, 2016). Therefore, using a mix of education and supplementing strategies and building an enabling atmosphere in which individuals can apply what they've learned is critical to the success of nutrition education programmes (Adeoya *et al.*, 2023).

This study revealed that before the intervention, the mean scores of knowledge and practice were at a lower level for both groups. Nonetheless, moderate change was observed after the intervention in the mean scores of nutrition knowledge and dietary practice. However, findings from other studies conducted Ethiopia (Zelalem *et al.*, 2017; Diddana *et al.*, 2018) indicated that there were high differences in the mean scores in knowledge of nutrition in the end line among intervention and control groups. The reason for the discrepancy might be differences in study areas. Other studies also showed moderate differences in the mean scores of dietary practices (Sharifirad *et al.*, 2009; Diddana *et al.*, 2018).

Similarly, other studies suggested HBM-based NEI for pregnant women would significantly improve nutritional intake (Diddana *et al.*, 2018; Riazi *et al.*, 2024), knowledge, attitude, and practice related to calcium intake among adolescent students (Naghashpour *et al.*, 2014). Other study conducted on pregnant women highlighted that HBM-based nutrition education would be effective in enhancing awareness, better understanding of risks, reducing barriers to healthy

behavior, and ultimately, improving women's health and nutritional performance during pregnancy (Dolatian *et al.*, 2015).

After the intervention, the findings of this study showed that the mean scores of dietary folate and iron intake and DD of pregnant women were significantly different between intervention and control groups. Other studies were in agreement with these findings (Sharifirad *et al.*, 2009; Diddana *et al.*, 2018; Tesfaye *et al.*, 2024). In this study, the mean scores of iron and folate adequacy were significantly increased in the intervention group. Other studies supported the findings, in which there were significant increases in the percentage of recommended daily allowance that was met by intake of nutrients such as energy, carbohydrates, riboflavin, and niacin on the nutritional and dietary profile of adolescents and early adults (Sachithanathan *et al.*, 2012), and nutrition education during pregnancy will combat undernutrition among pregnant women (Beressa *et al.*, 2024).

Similarly, significant differences were noticed in the mean scores of serum levels of ferritin and folate in the intervention group. In another study, it was confirmed that participation in a nutrition education program might positively impact some biochemical indicators among pregnant women (Sharifat *et al.*, 2024). The finding of this study revealed that there was a significant improvement in the score of the HBM constructs among the intervention group after the intervention compared to the control group and a significant difference in the dimensions of all the HBM in the end-line data. The finding was in agreement with other studies (Zelalem *et al.*, 2017; Diddana *et al.*, 2018; Tesfaye *et al.*, 2024). Moreover, with the exception of perceived severity, all of the HBM constructs revealed a strong correlation with serum folate. Other study was in agreement with this finding, in which the HBM constructs showed a strong correlation with dietary practice (Beressa *et al.*, 2024).

## **5. Conclusion**

In the baseline, the intakes and serum levels of ferritin and folate were below reference. After the intervention of HBM-based nutrition education, the most significant improvement was noticed in the dietary intake of iron and folate. Still, the mean scores of the serum levels of iron and folate did not change significantly after the intervention, highlighting household's food insecurity. Findings of this study are informative to decision-makers.

Therefore, nutrition education should be part of programs in food insecure settings aiming at ameliorating food insecurity among communities. Health sector need to work promptly to implement IFAS and social behavioral change, education sector need to arrange parental schooling to improve nutrition outcomes, agriculture sector should demonstrate the power of agricultural biodiversity, and work hard to promote self-production and use of small-scale cultivation of nutrient-dense foods, enterprise diversification, and women's empowerment in improving nutrition in the community. Economic sectors should work hard to empower the women to get involved in income generation activities.

### **Limitation of the study**

Pregnancy naturally is expected to increase women's nutritional requirements, meaning that even previously healthy women may become micronutrient deficient if the increased demand is not met. Due to logistic constraints, we couldn't quantify an increased women's nutritional demand due to physiologic change as sources of micronutrient deficiency. Despite the recruitment was done during the period when ASF were allowed, HBM did not cover alternative sources due to seasonality of recommended animal and or crop sources.

## CHAPTER VI: Effect of Egg-Based Diet Intervention Coupled with Healthy Dietary Advice on Nutritional Status among Pregnant Women

Article published

Mayisso *et al.*  
*Journal of Health, Population and Nutrition* (2025) 44:230  
<https://doi.org/10.1186/s41043-025-00968-2>

Journal of Health, Population  
and Nutrition

RESEARCH

Open Access



## Abstract

**Background:** Pregnant women with poor nutritional status, as indicated by a low BMI, short stature, and micronutrient deficiencies, are at greater risk of poor birth outcomes. Thus, this study aimed to assess the effects of an egg-based diet intervention coupled with healthy dietary advice on nutritional status among pregnant women in the northern zone of the Sidama region, Ethiopia.

**Methods:** A community-based, multilevel, cRCT was employed. A total of 318 pregnant women were included in the study. An egg-based diet and healthy dietary advice were provided to the intervention group, whereas standard healthcare was given to the control group. The baseline and end-line nutrient adequacy and nutritional status were measured via standard questions. A LMM was fitted to evaluate the effects of the intervention on nutrient adequacy and nutritional status, accounting for the clustering effect.

**Results:** There was a significant difference in the MUAC ( $1.634 \pm 1.07$  cm) from baseline to the end line in the intervention group ( $p = 0.001$ ) while it was not significant among the control group ( $0.032 \pm 0.209$  cm) ( $P > 0.05$ ). The multivariable LMM revealed that having received nutrition intervention was positively associated with increments in MUAC ( $\beta = 0.54$ , 95% CI: 0.281, 0.782,  $p < 0.001$ ) and the MAR ( $\beta = 344.019$ , 95% CI: 275.965, 412.073,  $p < 0.001$ ) at the end-line.

**Conclusion:** The evidence from this study indicated that egg intake is an important protein source and provides several key nutrients, including vitamins A and D, folate, iron, and calcium. Thus, it is important to demonstrate the nutritional benefits of egg consumption during pregnancy. Healthcare professionals should be aware of this information, contextualize it, and communicate it to family heads and the community to help alleviate the restricted consumption of eggs during pregnancy.

**Trial registration:** The protocol for this study was registered at <https://clinicaltrials.gov/> with the registration number NCT06521151 on 07/22/2024.

Keywords: Nutrition intervention, nutritional status, pregnant women, Ethiopia

## Introduction

Pregnancy is a period during which a woman's body undergoes numerous physical and hormonal changes, and a woman's normal nutritional needs increase (Marangoni *et al.*, 2016; Kazma *et al.*, 2020). The micronutrient requirements, particularly for folate during the first 28 days after conception, are increased by 0% to 50% to help prevent NTD (Jouanne *et al.*, 2021; Lassi *et al.*, 2022). Owing to their diverse roles in fetal growth and development, the requirements for protein and energy are increased by 54% and 13%, respectively. The requirements for iron and folate, increase during the second and third trimesters (Jouanne *et al.*, 2021; Lassi *et al.*, 2022; Marshall *et al.*, 2022).

Healthy diets that include chicken eggs, fish, lean meats, fruits, vegetables, legumes, whole grains, and healthy fats rich in omega-3 fatty acids are recommended as sources of essential nutrients (Jouanne *et al.*, 2021; Marshall *et al.*, 2022). Chicken eggs are a nutritionally complete food, and natural, nutrient-dense packages provide easily digestible nutrients, including high-quality protein, vitamin D, vitamin A, vitamin B12, folate, choline, and long-chain omega-3 fatty acids (Lutter *et al.*, 2018; Wallace *et al.*, 2023). Additionally, they contain 40–86 µg of folate, which accounts for approximately 13–29% of the recommended daily intake during pregnancy (Marta *et al.*, 2021).

The nutritional status of pregnant women is a measure of health based on their diet, body weight, and biochemical composition, and it plays a role in determining the well-being of the mother and children. A pregnant woman with poor nutritional status, as indicated by a low BMI, short stature, and micronutrient deficiencies, has a greater risk of obstructed labor and LBW, PTB, IUGR, stillbirth, SGA births, birth defects, and reduced physical and mental potential. Approximately two billion people worldwide and 27% of pregnant women in LMICs are at high risk of multiple micronutrient deficiencies (Ramakrishnan *et al.*, 2017; Marshall *et al.*, 2022). As a result, approximately 22% of pregnant women are affected by IDA and NTD (Kassa *et al.*, 2017; Bitew *et al.*, 2020). The deficiencies resulted from the consumption of an unvarying, few-staple, food-based diet and gaps between micronutrient intake and micronutrient requirements (Arimond *et al.*, 2011; Hanson *et al.*, 2015). An estimated 53.8 million pregnant women are affected by IDA and megaloblastic anemia worldwide (WHO, 2012; Darnton-Hill and Mkpuru, 2015).

Malnutrition in Ethiopia remains a public health concern, where 21% and 6% of pregnant women are underweight and overweight, respectively (Harika *et al.*, 2017). Anemia increased by 35.6% in 2017 (Harika *et al.*, 2017; Kassa *et al.*, 2017) 65 babies out of 10,000 births are affected by NTD (Bitew *et al.*, 2020), and vitamin A deficiency remains a common form of malnutrition (FAO and WHO., 2002). Low dietary intake, inequitable distribution of food among household members, dietary taboos, and infectious diseases are common causes of malnutrition in the country (EDHS, 2017). BMI and MUAC are among the most widely used, significant, and reliable methods for assessing nutritional status in developing countries (Venkataraman *et al.*, 2022). BMI, defined as weight/height<sup>2</sup>, is a better indicator of nutritional status than weight alone and is used to determine GWG (Šarac *et al.*, 2022). In Ethiopia, 25% of women have a low BMI, 22% are rural women, and 15% are urban women (EDHS, 2017; FDRE, 2020). Although the MUAC is often used to assess nutritional status, the cutoffs for defining acute malnutrition vary from country to country, typically ranging from 21 cm to 23 cm; thus, values < 23 cm could be used to identify pregnant women at risk (Venkataraman *et al.*, 2022).

Pregnant women's diet in Ethiopia has been linked to poor nutritional status and low intake of ASF, protein, and essential micronutrients (Getaneh *et al.*, 2021). Therefore, programs, including daily oral IFAS, have been designed for healthy eating and lifesaving nutrition (FDRE, 2020; UNICEF, 2022). Additionally, several observational studies have suggested the consumption of locally available nutrient-rich foods and multimicronutrient supplementation (Diddana, 2019; Getaneh *et al.*, 2021). Nonetheless, only 40% and 11% of pregnant women were supplied with iron tablets during their most recent pregnancy and took iron tablets for 90 days or more, respectively (EDHS, 2017). Hence, the consumption of a diet enriched with eggs, which are challenging to find in other everyday foods, should be adapted to the actual situation on the basis of the extent to which pregnant women reach the recommended nutrient intake (Melough *et al.*, 2019).

Although several studies approved the benefits of eggs for pregnant women, linked strongly to socioeconomic status and cultural factors, women in the lowest wealth quintile consume the fewest eggs (Lutter *et al.*, 2018). On the other hand, high-quality data are lacking, and the adequacy of nutrients essential for determining the nutritional status of pregnant women is often undiagnosed and insufficient in low-income contexts. Therefore, this study aimed to evaluate the effectiveness of egg-based diet interventions in improving the adequacy of recommended

nutrients and the overall nutritional status of pregnant women in the northern zone of the Sidama region, Ethiopia.

## **Materials and methods**

### **Study area, design and Aim**

We conducted a two-arm, parallel-group, cRCT from October 2024 to December 2024. In brief, cluster randomization was employed over individual-level randomization to minimize information contamination and for pragmatic reasons, as community HEW typically operate in clusters (Assefa *et al.*, 2019). This study obtained favorable ethical approval from the CMHS, Hawassa University IRB (Protocol #: IRB098/2016). The health offices provided authorization letters. All methods were carried out under the relevant tenets of the Helsinki Declaration and good clinical practice (WMA, 2013). Written informed consent was obtained from all participants to participate in the trial. The protocol for this study was registered at <https://clinicaltrials.gov/> with the registration number NCT06521151 on July 22, 2024. This study was reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) statement (Hopewell *et al.*, 2025) (Figure1).

The trial was embedded in the PhD project, which was ongoing in randomly selected districts, Shebedino and Boricha. The districts were located 300 and 337 km from Addis Ababa, the capital of Ethiopia. In both districts, there were 36 kebeles/clusters (lower administrative units) (Zekaria, 2007). We selected twelve clusters randomly from both districts (six clusters from each district) to the intervention and control groups in a 1:1 ratio to ensure a balance of clusters. The trial center facilities have all the necessary equipment to conduct relevant assessments and interventions.

### **Participants and recruitments**

The community HEW enumerated the women. There were 10,330 pregnant women residing in Shebedino and Boricha districts and considered as the source population. The study population included pregnant women in their third trimester who were permanent residents of the study area and consented to participate. Twelve clusters (six from each district) were randomly allocated to the intervention and control groups. Pregnant women residing in six kebeles (three kebeles from each district) received the intervention (egg based diet), whereas those residing in six kebeles (three kebeles in each district) did not receive the NEI. After the pregnant women were enrolled,

reasonable attempts were made to encourage their retention and full follow-up for the duration of the trial by providing them with incentives to reduce missing data. The women, who were on restrictive diets, as well as those with PIH, GDM and high-risk pregnancies, were not included in the study.

### **Sample size determination and techniques**

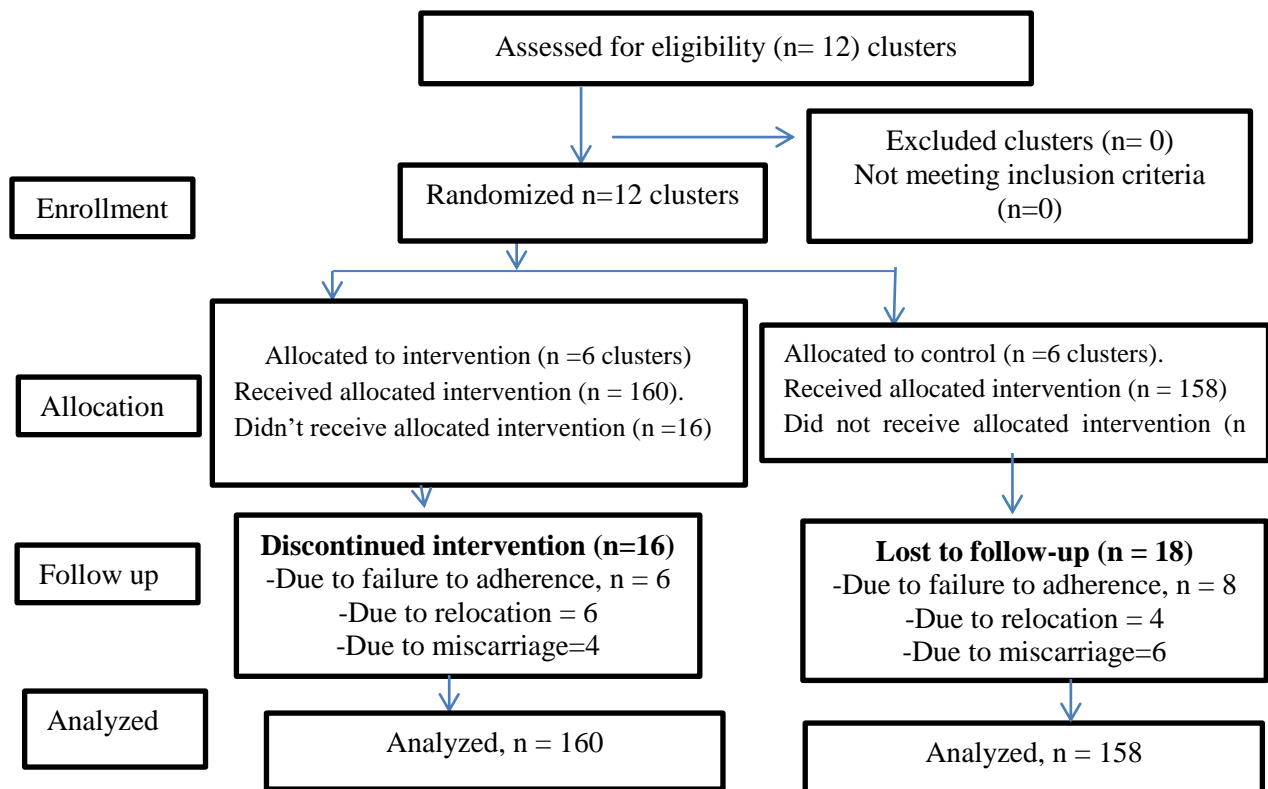
The sample size was calculated via G-Power software version 3.1. The calculation was based on the following assumptions: an effect size of 0.25, a 95% CI, a precision of 0.05, and a power ( $1 - \beta$ ) of 80% (Erdfelder, 2016). The calculated sample size was 120. The ultimate sample size increased to 168 after the largest sample size was considered, along with a design effect of 1.4 and a 5% nonresponse rate. Finally, a total of 352 participants were drawn (intervention = 176, control = 176). Data on births compiled by rural HEW were used to estimate the number of pregnant women in each cluster. Using a probability proportional to size allocation, the sample size was assigned to each cluster. A simple sampling technique was used to select pregnant women. If a woman missed her interview due to being out of the home, the next eligible pregnant woman in the queue was contacted. The pregnant woman who was absent from the interview was contacted the next day (Figure 1).

### **Randomization, intervention allocation and blinding**

The gestational age was calculated by asking about the beginning day of the last menstrual period, and pregnancy was confirmed using a HCG test. After pregnant women were evaluated for eligibility, the primary author randomly assigned clusters to the intervention and control groups in a 1:1 ratio to make a balance of clusters. The allocation sequence was produced via simple randomization techniques, including coin tossing. Recruitment was performed during the period when ASF were allowed (i.e., during the non-fasting period). Enrollment began in October 2024 and was completed by the end of December 2024. Thus, data collection was completed at the end of January 2025. Because the clusters were thus far apart, the study was not blinded. The intervention group was made aware of the intervention but was blinded to the research hypothesis. All the processes were identified by the trainers without concealment in the trial because of the distinctive features of the cRCT and the nature of the intervention being studied.

## Procedure

Among the 424 pregnant women screened in the 12-week gestation, 38 women were excluded from the trial for not meeting the inclusion criteria, and 34 declined to participate. Consequently, 352 women, who were in the early third trimester, were included in the trial. After clarifying the objectives, the intervention, and any other doubts, all 352 women (176 in the intervention) and (176 in the control) groups were allocated in 1:1 ratio. Finally, 318 (160 in intervention group and 158 in the control group) were remained and completed the trial after 34 participants discontinued: 16 in the intervention group and 18 in the control group discontinued from the trial, with the discontinuation attributed to either time commitments or loss of contact. The flow of participants is outlined in Figure 8.



**Figure 8:** Transparent Reporting of Trials: Participant flow chart showing the number of study participants progressing through the study milestones in Northern Zone, Sidama Region, Ethiopia, 2025

## **Intervention allocations**

**Intervention arm:** Subjects in the intervention group were provided an egg-based diet coupled with key nutrition messages in the third trimester (between 25 and 36 weeks of gestation). The intervention was continued at the health facility for 12 weeks, with two sessions per week. The key nutrition messages were adopted from those recommended by the FMOH, Ethiopia (FDRE, 2013). Following recruitment at the health post in each cluster, we provided the intervention group with two boiled eggs and two loaves of bread after orientation with nutrition messages. Community HEW holding diplomas prepared and facilitated the feeding ceremony at the health post. Two health officers with Bachelor of Science (BSc) degrees supervised the feeding program. The core contents of the key nutrition message aimed at changing awareness and dietary intake practices are about diversifying and enriching diets with essential elements, especially nutrient-dense, locally available ASF such as eggs, milk, dark green leafy vegetables, fruits, and legumes.

Participatory approaches involve engaging women in the preparation of food. During the delivery of key nutrition messages, participants were engaged in the assessment of their difficulties in feeding a variety of foods and learning by doing so, which encouraged pregnant women to devise solutions. The strategies were customized to address barriers such as cost, accessibility, preparation, time, and taste preferences. For example, consider choosing inexpensive and locally available varieties of food, lowering the perceived obstacles to creating food variety choices, motivating participants to find solutions to the obstacles (counseling the women not to sell chicken eggs, milk, vegetables, and fruits), enhancing participants' hand washing proficiency, and enhancing participants' knowledge and attitudes on the capacity to adjust their feeding patterns.

Realistic activities, including greeting, asking, listening, identifying, discussing, recommending, agreeing, and making follow-up appointments, were used to transmit key nutrition counseling messages. Periodic conversations about compliance with the intervention during routine meetings and home visits by trainers served to retain interest in the study. Post intervention evaluation was performed two times, after six and twelve weeks of the sessions, at 30 and 36 weeks of gestation. Moreover, home visits were planned to lessen the strain of follow-up visits among pregnant women.

**Control arm:** No set schedule was given to the control groups. At the end of the trial, they did, however, receive standard health care and health education on family planning, nutrition, vaccination services, disease prevention and control, hygiene and sanitation, waste disposal management, water supply, food hygiene and safety, control of insects and rodents, and personal hygiene, which are among the 16 components of Ethiopia's routine health extension program packages to ensure fairness and achieve a high level of post recruitment satisfaction (*Assefa et al.*, 2019).

### **Outcome measures**

A primary outcome of the study was a change in the MAR of key nutrients post-intervention. The secondary outcome of the study was a change in MUAC to estimate nutritional status among pregnant women. Both primary and secondary outcomes were measured at two points: at baseline (at 25 weeks of gestation) and at the end line (37 weeks of gestation).

### **Data collection**

We conducted a face-to-face interview utilizing a pretested structured questionnaire during the baseline and endline phases. Trained data collectors were involved in the data collection process. They recorded the data via the Kobo Toolbox application installed on Android devices. The questionnaire comprises four sections: baseline sociodemographic and reproductive health characteristics, baseline and end-line anthropometric measurements, dietary intake, and nutrient adequacy data. The standardized questionnaire was adapted from various types of literature and prepared in English. The questionnaire was translated into the local language, Sidamifa, for appropriateness and clarity, and ultimately, it was translated back into English by a language expert to verify its consistency. Rigorous supervision, including daily examinations and prompt error correction, was carried out. The collected data were submitted to a central server. All the data were collected before the intervention and at 8--12 weeks after the intervention.

### **Assessment of sociodemographic characteristics**

Before the intervention, information on socioeconomic and demographic characteristics was retrieved from the EPHI via the questionnaire closest to the trial (FDRE, 2020). The wealth index is a composite measure of a household's cumulative living standard, which was calculated using easy-to-use data on a household's ownership of selected assets, such as televisions and bicycles; materials used for housing construction; and types of water access and sanitation facilities

(EDHS, 2017). PCA was used to generate a wealth index. Twenty-one variables were entered into the PCA (Xie *et al.*, 2023).

### **Assessment of reproductive health characteristics**

Before the intervention, data on women's reproductive health factors, such as parity, gravidity, number of antenatal visits, gestational age at recruitment, number of gestations, age at first pregnancy, birth interval, and number of surviving children, were retrieved via questionnaires from previous studies (Mohammed *et al.*, 2019; Oduro *et al.*, 2023).

### **Anthropometric measurements**

The study utilized anthropometric parameters, specifically maternal weight and height, measured at 12 weeks of gestation to calculate pre-pregnancy BMI. Maternal weight and MUAC were measured at least eight times during follow-up, subsequently every trimester until delivery, as recommended by the WHO (WHO, 2018). Standing height and weight were measured via a portable stadiometer (SECA 213) and a digital weighing scale. We recorded the weight to the nearest 100 grams with minimal clothing and barefoot. The height was read to the nearest 0.1 cm. We consider using an estimated weight derived from mathematical models, which are based on the institution of medicine, to estimate BMI more accurately and objectively. We used preconception weight, which was measured at the first trimester visit (Thomas *et al.*, 2014; Mohammed *et al.*, 2019; Oduro *et al.*, 2023). Moreover, we consider the final weight to be measured in the third trimester, and total GWG should be corrected for the length of gestation. We assume a gain of 0.5 to 2 kg in the first trimester for all preconception BMI categories and provide weekly incremental weight gain for the second and third trimesters (Mohammed *et al.*, 2019). The criteria recommended by the WHO for BMI cutoff points were applied, and BMI values of <18.5, 18.5–24.9, 25.0–29.9, and  $\geq 30$  kg/m<sup>2</sup> were used to define underweight, normal weight, overweight, and obese pregnant women, respectively (Gilmore *et al.*, 2016).

A MUAC cutoff point of less than 23 cm is generally considered a standard indicator for potential malnutrition in pregnant women, indicating a need for nutritional intervention (Krukowski *et al.*, 2016). The MUAC of the left arm was measured via a circumference tape. The women were asked to sit or stand with their backs to the measurer and their elbows flexed at approximately 90 degrees. The tip of the acromion (the point of the shoulder) and the olecranon processes were palpated and marked with a skin pencil. The distance between these two points was measured with a flexible measuring tape, and a point midway between the two points was

marked on the skin. This midpoint marked the vertical level at which the circumference was measured with the arm hanging by the side. The measuring tape was placed around the upper arm such that the tape was horizontal to the surface.

### **Assessment of dietary intake and nutrient adequacy**

The nutritional values of the food consumed during the trial were manually converted into weights (in grams) per 100 grams via the EFCT (Agren *et al.*, 1969). For food items not covered by the EFCT, relevant food composition data from African countries were utilized (Hertzmark, 2008). We used the tables to calculate the nutrient intake data because the data had already been processed for cooked foods or ingredients. Finally, the NAR of the diets before and after egg-based diet intake, which contributes essential nutrients, such as protein, vitamin D, vitamin A, vitamin B12, folate, calcium, and iron, was assessed at baseline and at the end of the intervention.

The adequacy of the nutrients was determined by calculating a NAR, % for each nutrient by dividing the daily intake of the nutrient by the RNI. We used the WHO/FAO-recommended intake (FAO and WHO., 2002) which was set at two SD above the average requirements. We also considered nutrient requirement distributions and inter- and intra-individual variations in nutrient intake. As a summary indicator of the overall measure of nutrient adequacy, we calculated the MAR, % as a measure of the adequacy of the overall nutrients, where MAR is the sum of each NAR (truncated at 100%) divided by the number of nutrients (Torheim *et al.*, 2004)

$$MAR = \frac{\sum NAR}{Number\ of\ nutrient}$$
 . MAR is equivalent to a population-level estimate of the prevalence of nutrient adequacy. For both the NAR and MAR, a value of 100% is ideal since the intake is the same as the requirement. We used a RDA of 600 µg/day for folate (Bailey, 2000), 27 mg/day for iron (Yeboah *et al.*, 2022), 1200 mg/day for calcium, 800 mg RE/day for vitamin A (FAO and WHO., 2002), 2.6 micrograms (mcg) per day for vitamin B12 (NMHS, 2022), and a daily intake of 10 µg (400 IU)/day for vitamin D3 (Hollis and Wagner, 2011) for pregnant women.

### **Statistical analysis**

After checking for completeness, consistency, and accuracy, we entered the data, which were then cleaned and analyzed via SPSS version 27 and STATA version 17. We generated descriptive statistics, including frequencies, percentages, means, standard deviations, and standard errors, for the predictors and covariates. Details of the model assumptions have been

described. The baseline characteristics of the intervention and control groups were assessed via the chi-square test. Independent sample t tests and paired t tests were used to compare the adequacy of nutrients—protein, vitamin D, vitamin A, vitamin B12, folate, choline, iodine, selenium, and long-chain omega-3 fatty acids—and the nutritional status of the women in the intervention and control groups. Moreover, we applied linear correlation and calculated Pearson's correlation coefficient to determine the correlation between the model variables.

We employed a LMM to evaluate the intervention effect on the MAR of the nutrients and anthropometric measurements, accounting for the clustering effect. The model was fitted under the assumption that residuals follow a normal distribution. Diagnostic evaluations of two-level linear models were conducted, which included assessments of residual normality, linearity, homogeneity of variance, and the presence of influential outliers.

The identification of the clusters and respondents was analyzed as a random effect in the analytic model. The intervention's effectiveness was evaluated via time and intervention interactions. Four models were fitted. The null models (models without predictors), Model I [(MAR+ group), (MUAC+ group)], Model II [(MAR+ group, time, group × time), (MUAC+ group, time, group × time)], and Model III [(MAR+ groups + predictors and covariates), (MUAC+ groups + predictors and covariates)] were all fitted. The intra-class correlation coefficients (ICCs) for MAR and MUAC in the null model were 81 and 87, respectively, indicating the variability of the conditions attributed to the clustering effect. The deviance ( $-2 LL$ ), Akaike's information criterion (AIC), and Bayesian information criterion (BIC) values were used for model comparison. The deviance values for Model III for all outcome variables were the lowest, indicating that the full model was the best-fit model. As a result, Model III was used to make interpretations (Table 6)

The effect size was expressed as an estimate ( $\beta$ ), along with the standard error (SE) and 95% CI. Sensitivity analysis via per-protocol analysis was conducted. However, there was no difference in the effect size. Initially, randomly assigned pregnant women were examined in the groups to which they were assigned (intention-to-treat analysis principle). Pregnant women who discontinued due to adherence failure, relocation, or miscarriage were included in the intention-to-treat analysis. The statistical significance of the associations was declared at a p value of less than 0.05, and tests were two-sided.

## Results

### Sociodemographic and economic factors of the participants

A total of 91.9% and 88.8% pregnant women were successfully interviewed in the intervention and control groups, respectively, and their BMI and MUAC were measured. There was no substantial difference in baseline characteristics between the intervention and control groups (p value > 0.05). The mean (SD) age of the respondents was 26.41 and 25.76 years for the intervention group and the control group, respectively. Moreover, 35% of the households in the control group and 31.6% in the intervention group were classified in the highest wealth index quintile. The study also revealed that only 22.8% of the households in the control group and 17.5% in the intervention group were food secure. A total of 74.6% of the participants in the control group and 70.2% of those in the intervention group were able to afford sufficient food (Table 14).

**Table 14:** Sociodemographic and economic characteristics of pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158)

Variables	Intervention Group (n=160)		Control Group (n=158)		P value
	Frequency	Percent	Frequency	Percent	
<b>Age (year)</b>					
<20	12	7.5	26	16.5	0.462
≥20	148	92.5	132	83.5	
<b>Marital status</b>					
Married	159	99.4	156	98.7	0.991
Divorced	1	0.6	2	1.3	
<b>Residence</b>					
Rural	118	74.0	108	68.0	0.264
Urban	42	26.0	50	32.0	
<b>Number of family member</b>					
2-4	152	95.0	150	95.0	0.792
>4	8	5.0	8	8.0	
<b>Religion</b>					
Protestant	154	96.2	147	93.0	0.462
Others <sup>a</sup>	6	3.8	11	7.0	
<b>Ethnicity</b>					
Sidama	159	99.4	156	98.7	0.464
Others <sup>b</sup>	1	0.6	2	1.3	
<b>Maternal occupation</b>					
Housewife	154	96.2	153	96.8	0.362
Employed/merchant	6	3.8	5	3.2	
<b>Spouse occupation</b>					
Farmer	118	73.8	128	81.0	0.781
Employed/merchant	42	22.0	30	19.0	
<b>Maternal education</b>					
Illiterate	16	10.0	5	3.2	0.273
Literate	144	90.0	153	96.8	

<b>Wealth index</b>					
Rich	26	16.3	10	6.3	0.001
Medium	59	36.9	62	39.2	
Poor	75	46.9	86	54.4	
<b>Affordability for food</b>					
Yes	62	38.8	64	40.5	0.819
No	98	61.2	94	59.5	

<sup>a</sup> - Muslim, orthodox, Catholic <sup>b</sup> -Oromo, Amhara, Wolayita

### Baseline reproductive health characteristics of the participants

We found that 74.4% and 66.5% of the study participants had experienced prior pregnancies. A total of 81.9% and 78.5% of the respondents had 1–2 pregnancies in the intervention and control groups, respectively. A total of 73% and 65.8% of the participants in the intervention and control groups, respectively, had experienced childbirth before the current pregnancy. Nearly half of the participants had short birth intervals (Table 15).

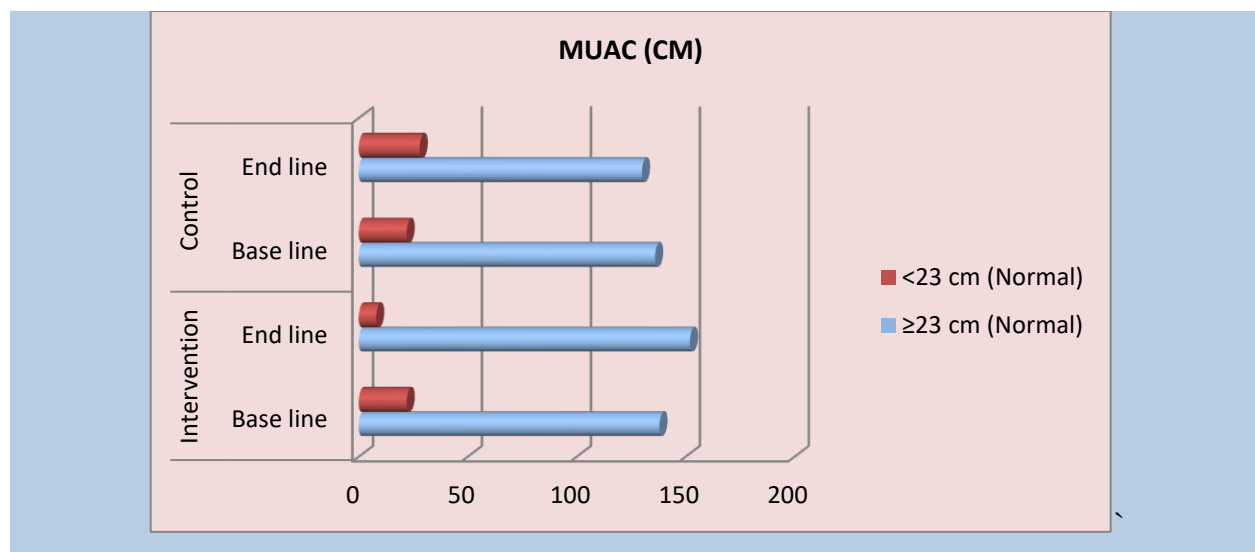
**Table 15:** Comparison of reproductive health characteristics among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158)

Variables	Intervention Group (n=160)		Control Group (n=158)		P value
	Frequency	Percent	Frequency	Percent	
<b>Age at the first marriage (year)</b>					
<18	47	29.4	60	38.0	0.462
≥18	113	70.6	98	62.0	
<b>Ever pregnant before?</b>					
Yes	119	74.4	105	66.5	0.122
No	41	25.6	53	33.5	
<b>Gravidity</b>					
1-2	131	81.9	124	78.5	0.264
3-4	20	12.5	30	19.0	
≥5	9	5.6	4	2.5	
<b>Gestational age</b>					
Preterm	6	3.8	5.0	3.2	0.663
Term	146	91.2	150	94.9	
Post term	8	5.0	3.0	1.9	
<b>Type of gestation</b>					
Single	156	97.5	157	99.4	0.181
Multiple	4	2.5	1	0.6	
<b>ANC follow up</b>					
Yes	156	97.5	153	96.8	0.721
No	4	2.5	5	3.2	
<b>Number of ANC follow</b>					
1-3 contacts	27	16.9	65	35.4	0.001
4-8 contacts	133	83.1	102	64.6	
<b>Ever given birth</b>					
Yes	120	75.0	116	73.4	0.157
No	40	25.0	42	26.6	
<b>Parity</b>					

Nulliparous	40	25.0	42	26.6	0.792
Primiparous	80	50.0	60	38.0	
Multiparous	40	25.0	56	35.4	
<b>Birth interval</b>					
Short birth interval	73	45.6	80	50.6	0.462
Optimal birth interval	87	54.4	78	49.4	
<b>Ideal number of children</b>					
0-2children	132	82.5	122	77.2	0.464
≥3children	28	17.5	36	12.8	

### Anthropometric characteristics of the participants

A mean weight gain of less than 11.5 kg in the third trimester was significantly lower in the intervention group (41.3%) than in the control group (58.7%). A total of 30.6% and 10.8% of the participants experienced GWG within the recommended range in the intervention and the control groups, respectively. The differences in the proportions in a MUAC < 23 cm were not significant ( $p > 0.05$ ) among the participants in the intervention group compared with those in the control group. However, the proportions of the participants with a MUAC > 23 cm at the end line were significantly different ( $p < 0.001$ ) between the intervention group (95%) and the control group (82.3%). On the other hand, the change in the proportion of the participants with a MUAC  $\geq$  23 cm at the end line between the intervention group and the control group was significant ( $p < 0.05$ ). According to the correlation analysis, the relationships between BMI and MUAC among the study subjects in the intervention and control groups were not significant ( $p > 0.05$ ) at baseline (Figure 9).



**Figure 9:** The number of study participants placed under different categories of mid-upper arm circumference in Northern Zone, Sidama Region, Ethiopia, 2025 (intervention=160, control=158)

In the baseline, the mean weight of the study subjects did not significantly differ between the intervention and control groups ( $p > 0.05$ ). Nonetheless, there were significant differences in the mean weight at the end line between the intervention and control groups ( $p < 0.001$ ). Similarly, there was no significant difference in the mean BMI of the study subjects between the intervention and control groups at baseline ( $p > 0.05$ ). At baseline, there was no significant difference in the mean MUAC of  $< 23\text{cm}$  ( $0.032 \pm 0.209$ ) of the participants between the control and intervention groups ( $P > 0.05$ ); nonetheless, at the end line, the difference in the mean MUAC of  $< 23\text{cm}$  ( $1.634 \pm 1.07$ ) of the study subjects between the groups was statistically significant ( $p < 0.001$ ).

There was a significant difference in the mean differences in MUAC of  $< 23\text{cm}$  ( $1.634 \pm 1.07\text{ cm}$ ) between baseline and end line among the participants in the intervention group. The difference was statistically significant ( $p < 0.001$ ). However, the difference in the mean difference in MUAC of  $< 23\text{cm}$  in the participants among the control group in the baseline and the end line was not significant ( $p > 0.05$ ). Correlation analysis revealed a statistically significant relationship between gestational weight in the third trimester and MUAC of  $< 23\text{cm}$  among the participants in the intervention and control groups ( $p = 0.001$ ) at the end line (Table 16).

**Table 16:** Differences between baseline and end-line measurements of nutritional status indicators among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention ( $n = 160$ ) and control ( $n = 158$ )

Indicators	Groups	Baseline	End line	MD	95% CI		Pvalue <sup>a</sup>
		Mean( $\pm$ SD)	Mean( $\pm$ SD)	Mean( $\pm$ SD)	Lower	Upper	
Gestational weight	Control	52.99 $\pm$ 6.88	56.87 $\pm$ 6.43	3.88 $\pm$ 8.98	2.47	5.29	0.001
	Intervention	52.23 $\pm$ 6.44	59.26 $\pm$ 6.31	7.04 $\pm$ 8.74	5.67	8.40	0.001
	P value <sup>b</sup>	0.84	0.001				
MUAC	Control	23.07 $\pm$ 0.72	23.26 $\pm$ 0.95	0.03 $\pm$ 0.21	0.00	0.06	0.059
	Intervention	23.41 $\pm$ 2.41	24.89 $\pm$ 2.50	1.63 $\pm$ 1.07	1.22	2.05	0.001
	P value <sup>b</sup>	0.442	0.001				

<sup>a</sup> - Paired sample t test, <sup>b</sup> -independent sample t test, SD-standard deviation, MD-mean difference, CI-confidence interval

### Dietary intake and nutrient adequacy of the participants

89.3% and 96.9% of the study participants had not consumed an animal-source diet and an egg-based diet before the intervention. In the paired sample t-test, the means and SD of the participants who consumed an animal-source diet and an egg-based diet before the intervention were 0.11 and 0.03. The mean difference was not statistically significant ( $p\text{-value} < 0.05$ ). None

of the study participants refused to consume eggs due to cultural taboos. Nonetheless, six mothers in the intervention group declined to consume an egg-based diet. This was due to personal food preferences, texture, or smell of eggs, and they were unable to stand the taste of eggs, making it challenging to incorporate them into their meals. The means and SD of egg intake in the participants in the low and high wealth index at the baseline were 0.3 and 0.4. The mean differences of egg intakes among low- and high-wealth-index participants were not statistically significant ( $p$ -value  $< 0.05$ ).

Additionally, median intakes of all micronutrients, particularly essential vitamins and nutrients, were below—and often far below—EARs. Despite the average requirement not being met in most cases, the median intake of all the micronutrients improved after they consumed egg-based diets two times a week for three months. The estimated intake was very low (1.97–19.9%) for calcium and vitamin D; (42.1%) for vitamin B12; moderate (64–80.6%) for protein, folate, and vitamin A; and high (95.4%) for iron. However, the median intakes of calcium, vitamin A, and vitamin D significantly increased (p-value < 0.05) at the end of the study. Therefore, 80%, 39.4%, 22.5%, and 21.5% of the participants consumed vitamin A, iron, protein, and folate, respectively, above the average estimated requirements (Table 17).

**Table 17:** Differences between baseline and end-line in nutrient intake among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158).

Nutrients	Group	Nutrient intake/person/day									
		Baseline					End line				
		Median	Q25	Q75	%	Mean ±SD	Median	Q25	Q75	%	Mean ±SD
Protein	Intervention	18.1	12.1	30.5	21.1	23.5 ±21.4	41.4	35.9	47.1	64.0	48.2±2
	Control	11.0	11.0	14.0	25.0	13.2±6.2	15.3	11.2	16.9	30.4	15.3±6.2
Fat	Intervention	6.2	4.1	18.2	1.3	9.7+96.9	17.9	16.2	25.7	3.8	21.1±6.6
	Control	4.7	4.2	4.8	1.1	5.3±3.5	4.0	4.0	8.3	0.8	9.1±9.6
Calcium	Intervention	151.0	93.3	327.3	12.6	217.9± 2.0	235.9	178.8	416.5	19.6	305.0±166.0
	Control	79.5	62.7	135.6	6.6	101.0±57.3	121.0	79.3	144.0	10.1	124.0±60.4
Iron	Intervention	17.1	11.9	21.9	63.1	17.5± 7.2	25.7	21.4	29.1	95.4	25.8±7.0
	Control	12.0	11.0	14.0	44.4	12.6±2.4	12.9	12.0	14.5	47.8	13.5±2.5
Vitamin A	Intervention	1109.0	222.0	1295.0	139.0	934.0 ± 49.0	1192.0	928.0	1264.0	149.0	1291.0±59.0
	Control	1005.0	901.0	1010.0	126.0	951.0± 71.0	1110.0	1020.0	1110.0	139.0	1081.0± 71.0
Folate	Intervention	314.0	181.0	480.0	52.0	397.0± 29.0	391.4	270.0	539.3	65.2	467.0±283.0
	Control	174.0	163.0	205.0	29.0	192.7±64.6	175.8	164.8	204.8	29.3	193.0±64.4
Vitamin B <sub>12</sub>	Intervention	0.0	0.0	0.0	0.0	0.04± 0.20	1.1	1.1	1.1	42.3	1.1±0.2
	Control	0.3	0.2	1.0	11.5	0.5± 0.4	1.0	0.7	1.9	3.8	1.1±0.6
Vitamin D	Intervention	0.0	0.0	0.0	0.0	0.1± 0.1	1.0	1.0	1.0	10.0	1.0±0.0
	Control	0.0	0.0	0.0	0.0	0.1± 0.1	1.0	1.0	1.0	10.0	1.0±0.0

Q25: 25<sup>th</sup> quartile, Q75: 75<sup>th</sup> quantile

The MAR of individual nutrients ranged from  $0.0 \pm 0.3$  to  $116.9 \pm 61.4$  before the intake of the egg-based diet. Additionally, the MAR of the nutrients was below the RDA, which ranged from  $20.0 \pm 0.0$  to  $161.36 \pm 73.6$ , except for vitamin A (116.9). The ratio was improved, with the mean differences in the individual NAR being significant ( $p$ -value  $< 0.001$ ). Similarly, the mean MAR of the nutrients was significantly improved between the baseline and end-line studies ( $p$ -value  $< 0.001$ ) (Table 18).

**Table 18:** Differences between baseline and end-line in nutrient adequacy ratios among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025, intervention (n=160) and control (n=158)

Nutrients	Groups	Nutrient adequacy ratio					Pvalue
		Baseline	End line	Mean Diff.	95% CI		
		Mean + SD	Mean+ SD	Mean Diff.+ SD	Lower	Upper	
Protein	Intervention	42.71 ± 22.10	82.51 ± 19.21	39.82 ± 21.88	36.07	43.53	0.001
	Control	20.88±10.50	31.99 ± 17.00	11.11± 13.55	8.98	13.24	0.001
Fat	Intervention	3.66±2.44	4.12±4.46	0.46±5.63	0.74	1.30	0.052
	Control	2.68±2.94	3.10±4.43	0.42±5.63	-0.47	1.30	0.363
Calcium	Intervention	21.79 ± 16.82	30.53 ± 16.65	8.74 ± 8.31	7.44	10.04	0.001
	Control	14.92±8.31	9.92±4.47	-4.99±9.22	-6.45	-3.55	0.001
Iron	Intervention	64.74 ± 26.75	95.38 ± 25.81	30.74 ± 16.55	24.73	33.22	0.001
	Control	46.62±8.83	49.97±9.33	3.34±12.14	1.43	5.26	0.001
Vit. A	Intervention	116.92 ±61.35	161.36 ±73.58	44.44 ± 96.55	29.37	59.52	0.001
	Control	119.75±8.88	135.24±7.39	15.49±10.45	13.85	17.13	0.001
Folate	Intervention	53.17 ± 25.66	77.90 ± 47.20	24.73 ± 36.04	19.11	30.36	0.002
	Control	32.11±10.76	32.18±10.77	0.08±15.52	-2.37	2.52	0.951
Vit.B <sub>12</sub>	Intervention	1.30 ± 1.92	42.00 ± 7.51	41.60 ± 7.82	40.38	42.82	0.001
	Control	0.80±0.82	0.83±1.20	0.03±1.22	-0.16	0.22	0.782
Vit. D	Intervention	0.00 ± 0.27	20.00 ± 0.00	19.99 ± 0.03	19.99	20.00	0.001
	Control	0.00 ± 0.17	0.00 ± 0.00	0.17 ± 0.03	19.99	20.00	0.801
MAR	Intervention	300.39±103.56	867.16±421.11	566.77±422.18	500.85	632.68	0.002
	Control	237.37±21.11	262.55±18.77	25.18±27.65	20.84	29.53	0.001

#### End line multivariable linear mixed model predicting nutritional status and mean nutrient adequacy among study participants.

The multivariable LMM analysis revealed that having received an egg-based diet was positively associated with MUAC ( $\beta = 0.54$ , 95% CI: 0.281, 0.782,  $p$ -value  $< 0.001$ ) and MAR ( $\beta = 344.019$ , 95% CI: 275.965, 412.073,  $p$ -value  $< 0.001$ ). Likewise, an increase in age by one year could increase the MUAC by 0.024 ( $\beta = 0.024$ , 95% CI: 0.004, 0.044,  $P$  value  $< 0.001$ ), and ownership of agricultural land ( $\beta = 0.47$ , 95% CI: 0.011, 0.935,  $p$ -value  $< 0.001$ ) and having a

family member of 2-4 ( $\beta = 60.912$ , 95% CI: 3.911, 117.893, p-value < 0.001) had significant associations with the MAR.

The variance of the residual errors at the individual level of the average MUAC, BMI, and MAR was determined to be 2.40, 7.08, and 93564, respectively. These differences were statistically significant ( $p < 0.001$ ). The intra-class correlation coefficients (ICCs) in the null model for MUAC and MAR were 0.72, 0.87, and 0.81, respectively, indicating the variability of the conditions attributed to the clustering effect. The deviance values ( $-2LL=2372$ ), Akaike's information criterion (AIC=2378), and Bayesian information criterion (BIC=2391) for MUAC and ( $-2LL=9093$ ), Akaike's information criterion (AIC=9099), and Bayesian information criterion (BIC=9112) for MAR were used for model comparison. The deviance value for Model III was the lowest, indicating that the full model for all variables was the best-fit model. As a result, Model III was used to make interpretations (Table 19).

**Table19:** End-line multivariable LMM analysis for predicting nutritional status and nutrient adequacy among pregnant women participated in the study in Northern Zone, Sidama Region, Ethiopia, 2025 (n=160)

Fixed effect		Null model			Model I			Model II			Model III		
Outcome variables	Predictors	Estimate(SE)	95%I		Estimate (SE)	95% CI		Estimate (SE)	95%I		Estimate (SE)	95%I	
			Lower	upper		Lower	Upper		Lower	Upper		Lower	Upper
MUAC	Intercept	23.46(0.68)	20.51	26.40	23.16(0.68)	20.24	26.07	23.56(0.11)	23.34	23.78	24.02(0.75)	21.58	26.46
	Intervention				0.61(0.12)	0.36	0.83	1.73(0.16)	1.42	2.04	0.54(0.12)	0.281	0.782
	Time1							0.81(0.11)	0.60	1.02			
	Intervention*time1							2.24(0.14)	1.95	2.54			
	Age										0.024(0.10)	0.00	0.04
MAR	Intercept	417.30(104.4)	31.77	866.41	249.91(104.00)	193.20	693.10	262.20(17.34)	228.17	296.30	232.96(121.80)	115.98	581.90
	Intervention				332.70(20.30)	292.80	372.70	601.60(24.44)	553.61	649.60	344.01(34.65)	275.16	412.10
	Time1							24.64 (24.52)	23.52	72.80			
	Intervention*time1							537.80(34.58)	470.08	605.80			
	Family size										60.91(29.01)	3.91	117.80
Random effect		Estimate(SE)		Estimate(SE)		Estimate(SE)		Estimate (SE)					
MUAC	Level two variance	2.4(0.13)		2.3(0.13)		2.3(0.13)		0.9(0.69)					
	ICC	0.72		.71		.71		.44					
	- 2 LL	2372		2348		2332		2122					
	AIC	2378		2356		2354		2134					
	BIC	2391		2374		2402		2161					
	No of parameters	3		4		6		11					
MAR	Level two variance	9356(5255)		65800(3695)		65093(3656)		45540(3618)					
	ICC	0.81		.75		.75		.96					
	- 2 LL	9093		8870		8863		8654					
	AIC	9099		8878		8885		8665					
	BIC	9112		8896		8934		8692					
	No of parameters	3		4		6		11					

Reference categories: age (continuous), control, intervention \* time 0 \*, family size  $\leq 5$ , agricultural land ownership (No), SE: standard error; CI: confidence interval, time 0: preintervention; time 1: post intervention. - 2LL: Log likelihood; AIC: Akaike's information criterion (AIC); BIC: Schwarz's Bayesian criterion; Maximum SE; Maximum likelihood (ML) was applied to estimate the parameters, MUAC-mid upper arm circumference, BMI-body mass index, MAR-mean adequacy ratio, SE-standard error

## Discussion

We aimed to assess the effects of nutritional interventions coupled with healthy dietary advice on nutritional status among pregnant women in the northern zone of the Sidama region, Ethiopia. At the end of the study, the mean intake of several nutrients, including protein, fat, iron, folate, calcium, vitamin A, and vitamin D, significantly increased in the intervention group. This result was in line with the results of studies conducted in Ghana (Amenya *et al.*, 2024) and France (Sophie *et al.*, 2019). These studies demonstrated that egg consumption can fill any gaps between daily nutrient intake and recommendations, particularly in early life stages (Sophie *et al.*, 2019), through increasing the intake of six key nutrients, including choline, docosahexaenoic acid, folate, vitamin D, iodine and iron, which have been identified as important in the maternal diet for child brain development (Cheatham, 2019), with most of these nutrients being found in eggs. In addition, studies have demonstrated that eggs can provide an array of nutrients, including vitamins A, B1, B2, B3, B5, B6, B9, and B12 and D, choline, biotin, calcium, phosphorous, potassium, magnesium, manganese, iron, zinc, iodine, selenium and bioactive components such as lutein and zeaxanthin (Sophie *et al.*, 2019).

In addition, intake was greater, and the prevalence of inadequacy was lower in the egg group than in the control group for iron, folate, calcium, vitamin A, vitamin B<sub>12</sub> and vitamin D at the end line. This result was in line with the results of a study conducted in many resource-poor settings around the world (Iannotti *et al.*, 2014). Although the egg intake intervention increased the intake of protein and several micronutrients, the total intake and MAR of the essential micronutrients remained far below the recommended values. This result was in agreement with the results of a study conducted in many resource-poor settings around the world (Iannotti *et al.*, 2014). In addition, the intake of eggs during pregnancy met adequate intake recommendations for protein, vitamin D and vitamin A in the analysis. This study supports the results of a previous study, in which eggs were the most cost-efficient food for protein, choline and vitamin A, second for vitamin E, and third for vitamin D (Sophie *et al.*, 2019).

The MAR of essential micronutrients, including iron, calcium, folate, vitamin B<sub>12</sub>, vitamin A and vitamins, in this multilevel analysis were strongly related to the ownership of agricultural land. The results highlighted that women in the low wealth quintile were low in egg consumption. These results are in agreement with those of studies conducted in the USA and France (Lutter *et al.*, 2018; Sophie *et al.*, 2019). In both studies, egg consumption was strongly related to

socioeconomic status in a dose–response fashion, with women in the lowest wealth quintile. However, given the current economic climate, eggs provide an affordable, natural, easy, bioavailable and environmentally friendly means of nutrient delivery, and consuming eggs during pregnancy and eggs is a cost-effective, nutrient-dense whole food that provides an array of nutrients that are readily absorbed and metabolized (Derbyshire, 2024).

Current evidence has shown that a high number of pregnant women were underweight in both the intervention and control groups at baseline. Following the intervention, the proportion of the subjects with a mean weight gain of less than 11.5 kg in the third trimester was significantly lower among women in the intervention group than among those in the control group. This finding is in line with those of studies conducted in Indonesia (Aisa *et al.*, 2020) and Nigeria, in which the maternal mean weight gain of 9.24 kg in the experimental group was significantly greater than the mean weight gain of 6.13 kg observed in the control group (Ojofeitimi, 2020).

The findings of this study revealed that egg-based diet interventions were positively associated with MUAC among pregnant women. The net mean MUAC difference between the intervention and control groups was 2.204 cm, which was statistically significant ( $p < 0.05$ ). Compared with that of the control group, the MUAC of the pregnant women in the intervention group significantly improved. This study’s findings support those of other studies conducted in rural Ethiopia (Demilew *et al.*, 2020; Beressa *et al.*, 2024). A possible explanation might be that in addition to being fed a nutrient-dense egg-based diet, healthy dietary advice leads to favorable attitudes and thus changes in nutritional behavior. Nutritional interventions increased the MUAC by 0.318 cm in rural pregnant women. The results disagreed with those of studies conducted in urban Ethiopia and Rwanda (Demilew *et al.*, 2020; Habtu *et al.*, 2022), in which there was a substantial improvement in MUAC among pregnant women after the intervention. This might be because nutritional intervention with dietary advice provided by health extension workers was effective in improving the MUAC of pregnant women.

The average MUAC was significantly greater in the intervention group than in the control group. These results agreed with those of a study conducted in Rwanda (Habtu *et al.*, 2022). The proportion of study subjects with a BMI less than  $18.5 \text{ kg/m}^2$  in the first trimester was significantly lower ( $p = 0.010$ ) among women in the intervention group than among those in the control group. The average weight in the first and third trimesters was also significantly greater

among the participants in the intervention group ( $p < 0.001$ ). However, the average weight gain between the first and third trimesters was greater in the intervention group. The differences were statistically significant ( $p < 0.05$ ) between the two groups. These results are also in agreement with those of a study conducted in Rwanda (Habtu *et al.*, 2022). Maternal undernutrition was defined as low MUAC ( $< 23$  cm) during delivery or low BMI ( $< 18.5$  kg/m<sup>2</sup>) in the first trimester or both (Habtu *et al.*, 2022).

### **Conclusion:**

The results of the multivariable LMM analysis indicated that consuming an egg-based diet was positively linked to improvements in the MUAC of the respondents. An egg-based diet serves as a significant source of protein and enhances the MAR of essential nutrients, such as vitamin A, vitamin D, folate, iron, and calcium. Based on the evidence highlighting the nutritional benefits of egg consumption during pregnancy, healthcare professionals should be knowledgeable and effectively convey this information to family heads and the broader community. This approach will help enhance the consumption of an egg-based diet during pregnancy.

### **Limitation of the study**

The study was conducted in a specific region of Ethiopia. Therefore, results may not be applied to other contexts having different dietary habits or cultural restrictions. Additionally, the 12-week intervention focused solely on the third trimester and may not adequately capture the long-term effects on birth outcomes or postpartum health. On the other hand, the control group received standard care, but not the post-trial provision of eggs. This was due to logistical constraints. The absence of blinding due to the nature of the intervention may lead to performance bias. Additionally, the 24-hour recall method used to assess the women's DDS is subject to recall biases and variability from day to day. To minimize errors caused by memory lapses and distortions, we have implemented careful designs of the initial 24-hour recall protocol and standardized multiple-pass interviewing techniques. We have also utilized memory aids, such as photographs and probing techniques, to help identify the correct species.

**CHAPTER VII: Suboptimal maternal nutrition during pregnancy is associated with increased risk of low serum folate and preterm birth  
Sidama Region, Ethiopia**

**Article Submitted**

Advances in Nutrition 16 (2025) 100447



# Advances in Nutrition

AN INTERNATIONAL REVIEW JOURNAL

journal homepage: <https://advances.nutrition.org/>



**Under review**

## **Abstract**

**Background:** Background: Evidences showed that anthropometric deficits and deficiency of folate are associated with an increased risk of preterm birth. But objective evidence remains limited in low income settings, particularly in the study area. Therefore, we aimed to investigate suboptimal maternal nutrition during pregnancy is associated with increased of risk of low serum folate and preterm birth.

**Methods:** A prospective cohort study assessing anthropometrics at 12 weeks' gestation age and every trimester until delivery along with initial MDD-w assessment and a trimester based 24-hour dietary folate intake and nutrient adequacy from enrollment to delivery. A blood sample was collected at their first prenatal visit and at term for serum folate analysis. Linear regression analyses were fitted to identify predictors of preterm birth.

**Results:** The average gestational age at birth was 37.50 weeks. The prevalence of preterm birth was higher among women who had an inadequate DDS (AOR=0.52, 95% CI: 0.301, 0.890), consumed dietary folate below recommended level (AOR=1.48, 95% CI: 0.741, 2.932), undernourished women (AOR=1.105, 95% CI: 0.98, 1.24), a women with serum folate level <2.6–15 µg/L (AOR=0.760, 95% CI: 0.552–0.933).

**Conclusion:** Preterm birth is a significant problem. Maternal under nutrition, indicated by low MUAC and serum folate due to inadequate dietary diversity, is strongly associated with preterm birth. Strengthening public health interventions, including providing additional food for pregnant mothers, ensuring iron and folic acid supplementations, food fortification with folate, dietary diversity and monitoring anthropometric indicators earlier during antenatal care, is crucial.

**Key words:** Pregnant women, Dietary diversity, Serum folate level, Preterm birth

## Introduction

Preterm birth (PTB) is a significant global health issue and defined as a live birth that occurred before 37 complete weeks of gestation (WHO, 1977; Rogers, 2018). Despite being a global priority (Blencowe *et al.*, 2013), there has been no significant reduction in PTB rates worldwide (Zhang *et al.*, 2019). Recent estimates of PTB incidence range from 3.7 to 7.5% of live births in most European countries (Poulsen *et al.*, 2015), about 9.62% in the United States (The Lancet, 2016), 8.7% in Australia (Hoh *et al.*, 2019) and ~7% in China (Chen *et al.*, 2018). PTB affects 4.84 million infants globally each year, with the highest rates in Southeast Asia and sub-Saharan Africa (Lawn *et al.*, 2010; Chawanpaiboon *et al.*, 2019; Blencowe *et al.*, 2022; Ohuma *et al.*, 2023). In Ethiopia, the prevalence of PTB is a significant public health concern, with regional estimates varying from 2.8% to 11.41% and an overall pooled prevalence of 10.48% (Muchie *et al.*, 2020; Adugna *et al.*, 2022). PTB is associated with neonatal complications and both short- and long-term health problems, such as cerebral palsy, intellectual disabilities, and developmental delays (Goldenberg *et al.*, 2008).

Maternal nutrition significantly affects pregnancy duration and fetal growth, influencing pregnancy outcomes. Animal studies indicate that maternal nutritional status, such as folate levels, may be associated with PTB (Zhao *et al.*, 2013; Scholl and Chen, 2015). Adequate maternal folate is crucial for healthy pregnancies and the synthesis of DNA building blocks (Refsum, 2001; Black *et al.*, 2018), and its requirements increase during pregnancy. To meet the requirement, pregnant women should consume 600 µg of dietary folate to achieve recommended folate concentrations: 2.6–15.0 ng/mL in the first trimester, 0.8–24.0 ng/mL in the second trimester, and 1.4–20.7 ng/mL in the third trimester (Daly *et al.*, 1995). Folate deficiency during pregnancy, often stemming from inadequate intake of folate-rich foods is linked to a higher risk of PTB (Chen *et al.*, 2015). Studies indicate that higher maternal folate levels, whether from supplementation or diet, correlate with a reduced risk of PTB ; specifically, a 28% risk decrease with higher folate levels and approximately a 10% decrease with folic acid supplementation and dietary folate intake (Zhang *et al.*, 2019).

In addition to folate deficiency during pregnancy, maternal anthropometric deficits, is linked to a higher risk of PTB (Kozuki *et al.*, 2015; Bhattacharya *et al.*, 2019; Tang *et al.*, 2020). Maternal short stature ( $\leq 145$  cm) is associated with small for gestational age (SGA) and PTB, especially in

resource-poor settings where SGA and PTB rates are high (Kozuki et al., 2015). A MUAC  $\leq 23.5$ -25.0 cm can indicate underweight; a cutoff  $< 23$  cm, combined with low gestational weight gain (GWG), predicts adverse birth outcomes like PTB and low birth weight (LBW) (Kozuki et al., 2015; Bhattacharya *et al.*, 2019; Tang et al., 2020). Pre-pregnancy or first-trimester BMI influences fetal growth, determines recommended weight gain, identifies weight status, and predicts adverse pregnancy outcomes like PTB (Black et al., 2018).

A recommended range of weight gain is considered to be healthy based on a mother's pre-pregnancy BMI during the second and third trimesters. A woman with a BMI of  $> 18.5$  kg/m<sup>2</sup> with underweight is recommended to gain a total gestational weight of 12.5–18 kg with a mean weekly weight gain of 0.51kg. A woman with a BMI of 18.5–24.9kg, with a normal nutritional status, is recommended to gain a total gestational weight of 11.5–16 kg with a mean weekly weight gain of 0.42kg. A woman with a BMI of 25–29.9, in an overweight status, is recommended to gain a total gestational weight of 7–11.5kg with a mean weekly weight gain of 0.28kg. A woman with a BMI of  $\geq 30$ , in an obese nutritional status, is recommended to gain a total gestational weight of 5–9 kg with a rate of mean weekly weight gain of 0.22kg (Rasmussen et al., 2009). Globally, 7-24% of pregnant women gain weight below the recommended level, and millions suffer from malnutrition, including being underweight or of short stature (UNICEF, 2018). Maternal underweight contributes to inadequate gestational weight gain (GWG), PTB, and other adverse birth outcomes (WHA, 2012), influenced by genetics, health, diet, socioeconomic status, and cultural factors (Britto et al., 2017).

Folate deficiency prevalence exhibits socioeconomic disparities. Many lower-income countries have a prevalence exceeding 20%, while higher-income economies typically report less than 5% (Rogers, 2018). Within Africa, prevalence varies considerably. For example, among pregnant women, it ranges from 0.8% to 57.7% in Kenya, Niger, Senegal, and Sudan (Adam et al., 2009; Mgamb et al., 2017; Ryan et al., 2017; Fatou et al., 2018), and is 46% in Ethiopia (Melaku et al., 2010), representing a potential public health (Seifu et al., 2022; Mamme et al., 2023). However, the studies are limited and yielded conflicting results. Additionally, despite monitoring GWG, maternal anthropometrics indices (Kozuki et al., 2015; Bhattacharya *et al.*, 2019; Tang et al., 2020), and measuring folate (Adam et al., 2009; Melaku et al., 2010; Mgamb et al., 2017; Ryan et al., 2017; Fatou et al., 2018) early in pregnancy can help determine the trends of nutritional status and used to reduce the risk of PTB, the use of self-reported pre-pregnancy weight to

determine PTB (Muchie et al., 2020; Adugna et al., 2022); and conflicting results on folate deficiency in pregnant women (Seifu et al., 2022; Mamme et al., 2023) in prior studies may introduces potential reporting and recall bias, which could affect the reliability of the estimates. In addition, none of the studies established objective evidences in the country characterized by significant variations in dietary consumption practices (Jateno et al., 2023) and to our knowledge, no longitudinal study has investigated the association of the nutritional status (anthropometric deficits coupled with serum folate levels) for measuring PTB which, if found to be associated with increased risk of preterm births, can easily be integrated in public health interventions targeting pregnant women. Therefore, to investigate suboptimal maternal nutrition during pregnancy is associated with increased risk of low serum folate and preterm birth, we conducted a prospective cohort study that followed pregnant women from their first trimester (8 to <14 weeks) of gestation to term. The women were separated into adequate (MDDs-w  $\geq 5$ ) and inadequate (MDDs-w  $\leq 5$ ) dietary diversity groups, and the relative risks of PTB were estimated.

## **Methods and Materials**

### **Study setting and period**

The study was conducted in two randomly selected hospitals in two rural districts that were representative of the different agro ecologic zones of the Northern Sidama zone, Sidama Region, Ethiopia. The districts were selected using cluster sampling method. Of the 36 kebeles (the smallest admiration unit) identified, 12 were selected as study clusters, with six from each district representing both urban and rural areas using purposive sampling. The districts are located at 300 and 337 km from Addis Ababa, the capital of Ethiopia, respectively. The Northern Sidama zone is one of the surplus producing agricultural areas of Ethiopia, with major production of corn, pulses like haricot beans and false banana. The study conducted from March to December 2024.

### **Study design, study population and eligibility criteria**

The study was a longitudinal, prospective cohort study with 2 arms at a ratio of 1:1 adequate (exposed) and inadequate (unexposed) MDDs-w. The source population for the study included all pregnant women residing in the Northern Zone of the Sidama Region. Participants willingness to participate, with confirmed pregnancy and specific gestational age ranges (e.g., < 12 weeks gestation) and residing in the study area were included. Individuals with severe underlying health conditions and potentially women with known major complications that could interfere with exposure variable, such as diabetes, hypertension, cardiovascular disease, chronic kidney disease, cancer, and mental disorders, were excluded. Additionally, individuals with planning to move out of the area, inability to communicate in the study language, or having a different gestational age outside the range were excluded.

### **Sample size and sampling procedure**

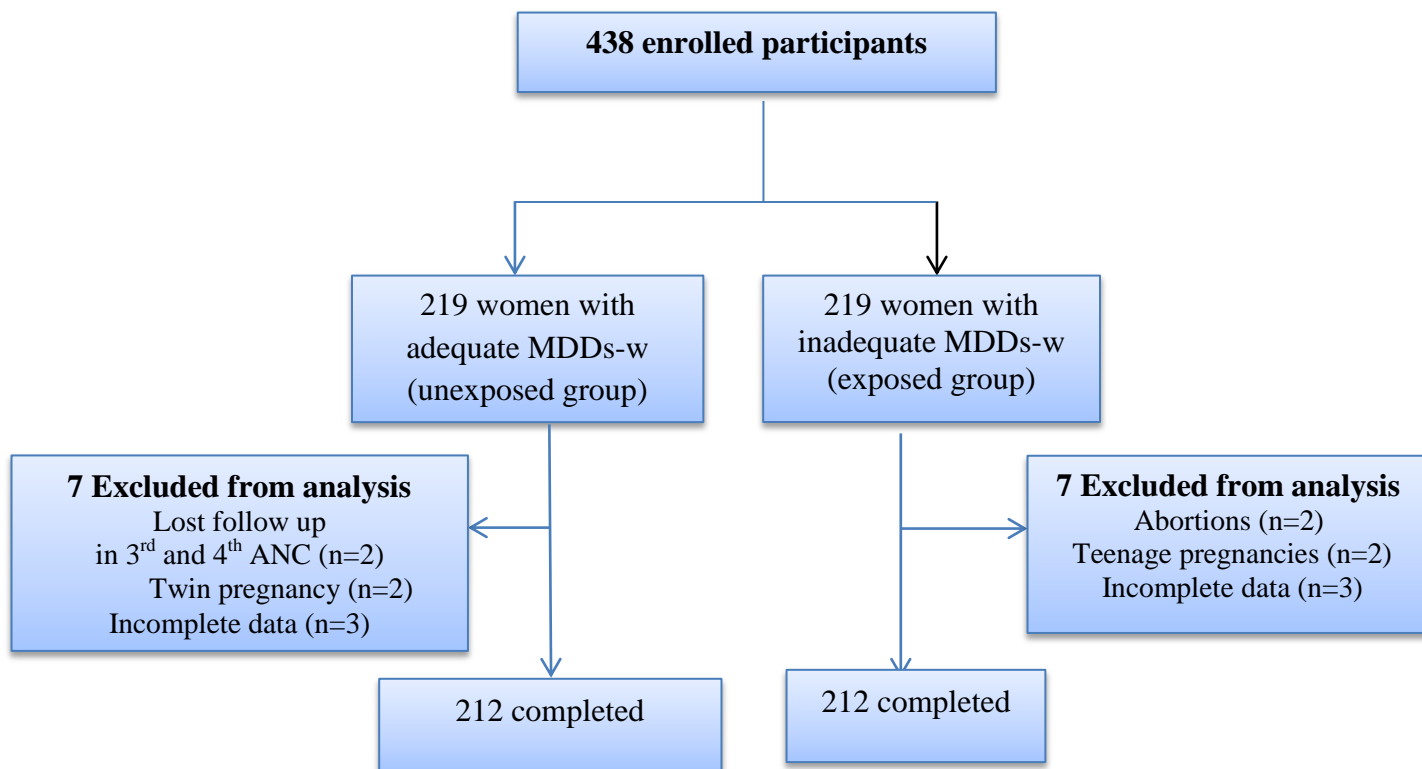
Sample size was calculated using open Epi Info statistical software available at <http://www.openepi.com/SampleSize/SSCohort.htm> with the following parameters and assumptions: a 95% significance level (2-sided), 80% power, and 46% of women had severe folate deficiency ( $\leq 4$  ng/mL) (Melaku et al., 2010) among unexposed group and an anticipated 21.2% lower prevalence of folate among exposed group. This yielded a total of 114 subjects /arm and to allow for  $\leq 20\%$  attrition and a design effect of 1.6 by the end of the study, a sample size of 438 was required.

### **Allocation to study arms and follow-up**

Pregnant women consenting to deliver at designated hospitals were purposively sampled and followed up. The final analysis included 424 pregnant women (212 exposed and 212 unexposed) in a 1:1 ratio. Serum folate levels were also examined in blood samples collected from 318 volunteer participants (158 exposed, 160 unexposed). A study enrolled pregnant women at their first antenatal care (ANC) visit, using births compiled by rural health extension workers, revealed that only 28% initiated ANC in the first trimester, while 32% began their first visit in the fourth or fifth month of pregnancy (EDHS, 2017).

At enrollment, a 24-hour MDDs-w was collected following FAO guidelines (Kennedy, *et al.*, 2013) and participants were categorized as having "adequate" (MDDs-w  $>5$ ) or "inadequate" (MDDs-w  $\leq 5$ ) dietary diversity as reported in the base line study during their first trimester (8 to <14 weeks) (Mayisso et al., 2025b). Consequently, a cohort of 219 pregnant women with

adequate MDDs-w was recruited as unexposed group, while a control of 219 pregnant women with inadequate MDDs-w was recruited as exposed group from similar populations in the same districts. The cohort was followed-up in the second trimester (20 to <24 weeks), third trimester (32 to <34 weeks) and at delivery. The expected date of delivery (EDD) for each participant was recorded. The occurrence of births in the cohort was promptly found and informed by pre-established local community health promoters which the country labeled as “Women Developmental Army (WDA)” and health extension workers (HEW) (**Figure10**).



ANC, antenatal care; MDDs-w, Women's Dietary Diversity Score

**Figure 10: Study participant flow of the prospective cohort of pregnant mothers in northern zone of Sidama Region, Ethiopia**

### Data collection methods

#### Assessment of socio-demographic characteristics

Data on the socio-economic and demographic characteristics were collected by using a pretested questionnaire that was adapted from the Ethiopian Demographic and Health Survey and the FAO (Kennedy, *et al.*, 2013; EDHS, 2017). Data were retrieved at 12 weeks of gestation as a baseline study. If a woman missed her interview due to being out of the home, the next eligible pregnant

woman in the queue was contacted. The pregnant woman who had been absent from the interview was contacted the next day. Principal component analysis (PCA) was used to generate a household's wealth index (Xie et al., 2023). Household's wealth quintiles are compiled by assigning the household score. Twenty-one variables were entered into PCA.

### **Assessment of anthropometric characteristics and gestational weight**

This longitudinal study used anthropometric indices: BMI and MUAC to assess maternal anthropometric deficits. Data on maternal weight and height were collected at first trimester (8 to <14 weeks') gestation to calculate pre-pregnancy BMI. Their height was measured to the nearest millimeter with a portable device equipped with calibrated and standardized height gauges (SECA 206 body meter). The women's MUAC was assessed subsequently every trimester until delivery, at least eight times as recommended by WHO (WHO, 2018) as follows: in the first ante natal contact (12 weeks) of gestation, two contacts in the second trimester (20 and 26 weeks) of gestation, and five contacts in the third trimester (30, 34, 36, 38, and 40 weeks). The MUAC of the left arm was measured to the nearest millimeter with a non-stretch measuring tape. The data were collected by 4 well-trained and experienced midwives who work permanently in the antenatal care service provision units of health centers in the community.

To track gestational weight gain, the weight was taken in the early first trimester (8 to <14 weeks) of gestation. Subsequently, the women were weighed at each visit from enrollment to delivery following the standardized procedures recommended by WHO, to the nearest 100 g using electronic scales with a weighing capacity of 10–140 kg (WHO, 1995). The following schedule was used: second appointment 8 weeks later; the third, 6 weeks later; fourth and fifth 4 weeks apart; and then the rest every 2 weeks was used for assessment of gestational weight gain. Gestational weight gain in relation to gestational age at birth was taken at labor, and total gestational weight gain was estimated by subtracting the early first trimester weight from the last measured weight before delivery (IOM, 1990).

### **Assessment of dietary intake, nutrient adequacy and serum levels of folate**

Alongside initial MDD-w assessment, a trimester based 24-hour dietary folate intake and nutrient adequacy were recorded from enrollment to delivery, during both pre-harvest (March-May) and post-harvest (June-September) seasons. A serum folate data was obtained from a blood sample collected for biochemical analysis in the first trimester. Participants were interviewed and provided blood samples at their first prenatal visit and at term. 5mL venous blood samples were

collected aseptically from the ante cubital vein and placed into anticoagulant-free test tubes by professional laboratory technologists. Serum samples were separated within 6 hour and stored at -80°C until analysis. The blood samples were centrifuged and the serum was separated before being frozen at -80°C and transported to Addis Ababa clinical laboratory for analysis. Serum folate was measured by a fully automated immunoassay analyzer (Cobas e601 (Roche Diagnostics GmbH, Mannheim, Germany)) using a commercial kit (Elecsys Folate III (Roche Diagnostics)) according to the manufacturer's instruction at Addis Ababa clinical laboratory. The cut-off value for serum folate were indicated based on international standard of the nutrients for pregnant women based on metabolic indicators with the reference of WOH cut-offs of 10nmol/L (4ng/mL) for serum folate (Cordero et al., 2015).

### **Outcome assessment**

PTB (<37 weeks of gestation) was tracked through gestational age assessment by trained midwives at health posts by counting from the last menstrual period during the first ANC visits. Gestational age was estimated by physicians using fundal height palpitation and ultrasound in hospitals during the follow up visits until term of gestation. Additionally, birth outcomes, including birth weight, small for gestational age, delivery methods, pregnancy induced hypertension, neonatal mortality, and stillbirth were ascertained by the same professionals at birth. End line information was collected from participants who successfully completed the follow up using questionnaires pretested in a similar setting.

### **Quality control**

All data collectors were trained physicians, laboratory technologists and midwives with at least a diploma in nursing. They also received 5-d training on participants' enrollment, follow-up, anthropometric measurements. The training was conducted just before the study and was followed by practical tests to ensure the skills were transferred. In each of the health posts and hospitals selected, one supervisor (usually the head) was assigned to oversee data collection. In addition, the investigator made a weekly visit to check the completeness and quality of the data collected. Anthropometric measurements were taken only by trained personnel, and all equipment was calibrated with standard weights and length rods on a daily basis. Neither the pregnant women nor the data collectors were aware of the allocation into groups.

### **Statistical analysis**

Data were entered using Epidata statistical software (Version 20). The data were double entered, cleaned and then exported to SPSS (version 27.0) for statistical analyses. All data on singleton pregnancies were analyzed according to their categorization by MDDs-w. All continuous variables were checked for normality by use of the Kolmogorov-Smirnov test. Variables not normally distributed were log-transformed. Means and SEMs were used to describe continuous variables. An independent Student's t test was used to compare means in the adequate and inadequate groups. A  $\chi^2$  test or a Fisher's exact test was used to test for independence in distribution of categorical variables between the 2 study groups. In all comparisons, differences were considered statistically significant at  $P < 0.05$ . The association between PTB and the independent variables like anthropometrics deficits (Pre-pregnancy BMI and MUAC), serum folate levels and gestational weight gain was investigated after adjusting for baseline differences.

The linear regression model was fitted to identify predictors of preterm birth. The goodness of fit was checked by Hosmer Lemeshow statistic and omnibus tests. Possible interactions between covariates were tested. Akaike's information criterion (AIC) and Bayesian information criterion (BIC) were used to test for model fitness. All variables with  $p < 0.25$  in the binary analyses were included in the multivariable analysis after checking for multi-collinearity using variance inflation factors. Adjustments were done for independent variables (age, mid-upper arm circumference, maternal height, sex of neonates) for gestation age at birth. The direction and strength of statistical association were measured using adjusted prevalence ratio (aPR) along with their corresponding 95% confidence interval (CI). An adjusted prevalence ratio (aPR with a 95% confidence interval was reported to show an association at a  $p$ -value  $< 0.05$ . To estimate the economic level of the families, a wealth index was employed. The wealth dispersion was generated by applying principal component analysis (PCA). The index was calculated based on the ownership of the latrine, agricultural land and size, selected household assets, the quantity of livestock, and source of water for drinking containing 41 household variables.

### **Ethical clearance**

This study obtained favorable ethical approval from the college of medicine and health Sciences Hawassa University Institutional Review Board (Protocol #: IRB 098/2016). The health offices provided an authorization letter. All methods were carried out in according with the relevant tenets of Helsinki Declaration and good clinical practice (WMA, 2013). Written informed consent was secured from all participants to participate in the trial.

## Results

### Socio-demographic and economic characteristics

A total of 438 eligible pregnant women (219 from each group) were enrolled. 424 were included in the final analysis with overall dropout rate of 3.2%, which was balanced across both groups. The reasons for dropping out were mainly discontinuation of the ANC visits (n=2), incomplete data (n = 6), twin or multiple pregnancy (n = 2), teenage pregnancy (n=2) and abortions (n=2) (Figure 1). The baseline characteristics of the dropouts and the women who completed the study were not statistically different. The respondents' mean age at marriage was 21.07 years, increasing to 26.40 years at the time of study enrollment, but the ages at marriage and enrollment were not significantly different among the groups ( $p > 0.05$ ). The mean duration of pregnancy was 10.05 week, but women in the adequate group had their first ANC ~0.2wk before those in the inadequate group ( $P < 0.05$ ). The two groups were similar in parity, family size and marital duration ( $P > 0.05$ ). However, the adequate MDD-w group had more years of schooling and higher monthly income, while the inadequate MDD-w group had a higher gestational age at enrollment ( $p < 0.05$ ) (**Table 20**).

**Table 20:** Baseline socio-demographic and economic characteristics of cohort of pregnant women in Northern Sidama zone, Ethiopia (n=424)

Variables	Minimum dietary diversity of women (MDD-w)					P value
	Inadequate	Adequate MDD-	MD ( $\pm$ SED)	95% CI		
	MDD-w (n=212)	w (n=212)		Lower limit	Upper limit	
	Mean( $\pm$ SD)	Mean( $\pm$ SD)				
Family size	3.14 $\pm$ 1.01	3.06 $\pm$ 0.85	-0.080 $\pm$ 0.09	-0.26	0.10	0.375
Age at marriage	20.86 $\pm$ 3.66	21.29 $\pm$ 4.05	0.429 $\pm$ 0.38	-0.31	1.17	0.253
Age at enrollment	26.75 $\pm$ 6.21	26.06 $\pm$ 5.41	-0.689 $\pm$ 0.57	-1.80	0.42	0.224
Level of education	6.30 $\pm$ 3.23	6.71 $\pm$ 2.56	1.307 $\pm$ 0.28	0.75	1.86	0.000*
Marital duration	5.41 $\pm$ 3.48	5.30 $\pm$ 3.28	-0.110 $\pm$ 0.33	0.76	0.54	0.737
Gestational age at enrollment	10.26 $\pm$ 1.60	9.83 $\pm$ 1.40	-0.425 $\pm$ 0.15	-0.71	-0.14	0.004*
Parity	1.54 $\pm$ 1.35	1.49 $\pm$ 1.33	-0.047 $\pm$ 0.13	-0.30	0.21	0.718
Gestational Week for first ANC visit	7.46 $\pm$ 3.27	7.64 $\pm$ 3.38	0.179 $\pm$ 0.32	-0.46	0.81	0.579
Monthly income	760.90 $\pm$ 129.45	889.35 $\pm$ 177.48	198.453 $\pm$ 15.09	168.79	228.11	0.000*

*SD*-standard deviation, *MD*- means differences, *SED*- standard error difference, and *CI*- confidence interval, *Inadequate* means a  $MDD \leq 4$ , and *adequate* means a  $MDD > 4$

## Obstetric characteristics

All respondents experienced singleton pregnancies. 61.8% of women had ever given birth, with 63.4% of those having had three or more births. Most current pregnancies (87.5%) were wanted. Over two-thirds of respondents became pregnant between 18 and 25 years of age. The mean number of pregnancies was 1.68, with mean surviving children and birth intervals of 1.51 and 2.67, respectively. 98% of women had antenatal follow-up, with a mean of  $3.18 \pm 0.96$  visits; 86.8% enrolled at 9-12 weeks of gestation (**Table 21**).

**Table 21:** Base line obstetrics characteristics of cohort of pregnant women in Northern zone of the Sidama region, Ethiopia, 2025 (n=424).

Variables	Frequency	Percent	95%CI	
			Lower	Upper
Gestational weeks at enrollment				
5-8 weeks of gestation	59	13.9	10.8	17.2
9-12 weeks of gestation	365	86.1	82.8	89.2
Risk factors for the current pregnancy				
Yes	100	23.6	19.8	28.1
No	324	76.4	71.9	80.2
Types of the risk factors				
Age below 18 years	57	13.4	10.1	17.0
Others*	43	10.1	7.3	13.2
Fertility intention				
Intended	371	87.5	84.2	90.8
Unintended	53	12.5	9.2	15.8
Age at first pregnancy				
≤18 years	156	36.8	31.8	41.5
19-25 years	268	63.2	58.5	68.2
Ever given birth before				
Yes	310	73.1	67.9	76.2
No	114	26.9	23.8	32.1
Birth interval				
≤2 years	73	17.2	13.9	21.0
3-5 years	237	55.9	50.9	60.8
Number of births				
0-2 births	162	38.2	33.5	42.9
≥3 births	262	61.8	57.1	66.5
Number of surviving children				
No child	128	30.2	25.9	34.7
1-2 children	198	46.7	41.7	51.4
≥3 children	98	23.1	18.9	27.1
ANC follow up				

Yes	416	98.0	96.5	99.3
No	8	2.0	0.7	3.5

### Anthropometric characteristics and gestational weight

At enrollment, the average height and weight of the women were 157.95 m and 53.42 kg, with a mean BMI of 20.74 kg/ m<sup>2</sup>, implying that the average of the women fell under the normal body weight category. Women with adequate MDD had higher BMI and were heavier than those with inadequate MDD (P<0.05). The mean MUAC of the women was 21.98 cm at enrollment, with the adequate MDD group exhibiting a significantly higher MUAC than the inadequate MDD group (P<0.05). By the end of the second trimester, the women's mean weight was 55.97 kg, representing an average weight gain of 2.55 kg, with a weekly weight gain of 0.40 kg. During the third trimester, the women averaged 57.75 kg, having gained a mean of 4.33 kg since enrollment and 0.55 kg per week, inconsistent with healthy weight gain recommendations.

At the term of the gestation, a mean total GWG of 11.64 kg was achieved, with a range of 7-15 kg. Pregnant women in the adequate group had significantly higher weight, higher weight gain in both the second and third trimesters and at the term of gestation (P<0.05). By the end of the second trimester, the women's mean MUAC had increased by 2.10 cm from enrollment to 24.08 cm. In the third trimester, the women's mean MUAC was 25.31cm, a 3.33cm increase since enrollment. The adequate MDD group had a significantly higher MUAC than the inadequate MDD group in both second and third trimesters (P<0.05) (**Table 22**).

**Table 22:** Anthropometric characteristics and gestational weight gain of cohort of pregnant women in baseline and follow up in Northern Sidama zone, Ethiopia (n=424)

Variables	Minimum dietary diversity of women (MDD-w)					P value
	Inadequate(n=212)	Adequate(n=212)	MD (±SED)	95% CI		
	Mean(±SD)	Mean(±SD)		Lower limit	Upper limit	
<b>First trimester (enrollment)</b>						
Height in meter	157.65±6.764	158.25±6.534	0.604±0.646	-0.666	1.873	0.350
Weight in kg	49.56 ± 4.439	57.27 ±3.995	7.717±0.410	6.911	8.523	0.000
Pre-gestational BMI in kg/m <sup>2</sup>	19.86± 2.513	21.64± 2.660	1.775 ± 0.251	1.281	2.269	0.000
MUAC in cm	21.51 ± 1.82	22.44 ± 1.991	0.925±0.185	0.560	1.289	0.000
<b>Second trimester (follow up)</b>						
MUAC in cm	21.89±1.780	26.26±1.465	4.368±0.158	4.057	4.679	0.000
Weight in kg	53.88±6.882	54.42±6.182	0.538±0.635	-0.711	1.787	0.398
Weight gain in kg	2.28±1.129	2.81± 0.850	0.528±0.097	0.338	0.719	0.000
<b>Third trimester (follow up)</b>						

MUAC	24.18±1.379	26.44±1.173	2.259±0.124	2.015	2.504	0.000
Weight in kg	56.72±6.564	58.77± 4.638	2.047±0.552	0.962	3.132	0.000
Weight gain in kg	5.13±1.611	5.42±1.211	0.292±0.138	0.020	0.565	0.035
Total weight gain	11.38±1.384	11.90±1.097	0.514±0.121	0.276	0.753	0.000

*SD*-standard deviation, *MD*- means differences, *SED*- standard error difference, and *CI*- confidence interval  
*Inadequate* means a  $MDD \leq 4$ , and *adequate* means a  $MDD > 4$ ,

### **Dietary intake, nutrient adequacy and serum levels of folate**

A total of 424 eligible participants enrolled in the serum folate level investigation, 318 pregnant women (75%) were included in the final analysis (158 with inadequate and 160 with adequate MDD). The overall dropout rate was 25%, balanced across both groups. Reasons for dropout included refusal to provide a blood sample (n=58), inadequate blood sample collected (n=26), absence during sample collection (n=10), and spoiled blood sample (n=12). Additionally, dietary folate intake and NAR of folate were assessed. At enrollment, the median dietary folate intake was 183.90 (lower-upper quintiles: 174.80-199.30), and at follow-up, it was 201.8 (lower-upper quintiles: 170.6-322.9).

Dietary folate intake did not differ significantly between women with adequate and inadequate MDD at enrollment ( $p > 0.05$ ). Subsequently, women with adequate MDD had significantly higher dietary folate intake than those with inadequate MDD in the follow up ( $p < 0.05$ ). Dietary folate intakes were significantly below the estimated average requirements (EARs) at enrollment (2.2%) and at the end of follow-up (10.1%) in both groups. At enrollment, the mean NAR for folate was 33.33, increasing to 51.12 by the end of the follow-up. Initially, mean NAR was similar between women with adequate and inadequate MDD ( $p > 0.05$ ). However, at the end of follow-up, women with adequate MDD had a significantly higher mean NAR than those with inadequate MDD ( $p < 0.05$ ).

Sixty-six percent of the women had serum folate levels exceeding the World Health Organization's recommended range of 2.6-15.0 ng/ml. The mean serum folate level of all participants was 11.59ng/ml, within the recommended range. Folate levels were significantly higher in women with adequate MDD compared to those with inadequate MDD ( $p < 0.05$ ) at both enrollment and follow-up. The proportion of pregnant women taking IFA tablets was very high (97%). Although the number of weeks women consumed the tablet was slightly higher in the adequate than inadequate group, the difference was not statistically significant at enrollment and in the end of follow up ( $P > 0.05$ ) (**Table 23**).

**Table 23:** Intake of dietary folate, mean nutrient adequacy ratio and serum level of folate in cohort of pregnant women in the northern Sidama zone, Ethiopia, 2025 (n=318)

Variables	Minimum dietary diversity of women (MDD-w)					P value
	Inadequate (n=158)	Adequate (n=160)	MD(±SED)	95% CI		
	Mean (±SD)	Mean(±SD)		Lower	Upper	
<b>First trimester (enrollment)</b>						
Dietary folate intake	201.27± 63.28	198.82± 58.89	-2.45± 6.85	-15.93	11.04	0.721
Intake IFAS/12weeks	9.80±3.65	10.26±3.73	0.46±0.36	-1.17	0.24	0.199
NAR of folate	33.33±10.18	33.10±0.10	-0.01±0.01	-0.03	0.02	0.721
Serum level folate	11.59±4.31ng/ml	13.70±5.77ng/ml	-1.56±0.55	-2.64	-0.47	0.005
<b>Third trimester (follow up)</b>						
Dietary folate intake	193.08±64.42	419.82±306.36	226.74±24.89	177.75	275.73	0.000
Intake IFAS/36week	23.80±6.09	24.37±6.32	0.56±0.60	1.75	0.62	0.352
NAR of folate	32.20±0.11	70.00±0.51	38.79±0.04	0.30	0.46	0.000
Serum level folate	12.23±3.98ng/ml	14.30±5.76ng/ml	-2.06±0.56	-3.16	-0.97	0.000

\*ng/mL: Nano grams per milliliter, NAR-nutrient adequacy ratio, MD-mean difference, SED- standard error difference, Inadequate- a MDD ≤4, and adequate -a MDD >4, IFAS-iron folic acid supplements

### Preterm birth and other birth outcomes

An average gestational age of the participants was 37.12 weeks (range: 35-38 weeks) at the end of follow-up. Most women (76.42%) delivered at term, while 23.6% delivered preterm (2.8% at <32 weeks, 20.8% at 32-36 weeks). Normal birth weight was observed in 68.2% of births. Female infants comprised 51.2% of births, and 13.2% of infants had low birth weight. The outcome variables differed across groups. Women gave birth. Pregnant women in the adequate group had significantly higher gestational age at birth, longer duration of follow-up and gave birth to heavier babies (P<0.05) (**Table 24**).

**Table 24:** Preterm birth and other birth outcomes in cohort of pregnant women in the northern Sidama zone, Ethiopia, 2025, (n=424).

Variables	Minimum dietary diversity of women (MDD-w)					P value
	Inadequate (n=212)	Adequate (n=212)	MD(SED)	95% CI		
	Mean (±SD)	Mean(±SD)		Lower limit	Upper limit	
Gestational age at birth	36.89±0.51	37.34±1.01	0.45±0.08	0.30	0.60	0.00
Birth weight	3157.31±590.61	3275.47±604.61	118.16±58.05	-232.26	-4.04	0.042
Duration of follow up	7.10±1.59	7.38±0.84	0.278 ±0.124	0.04	0.52	0.025

Inadequate means a MDD ≤4, and adequate means a MDD >4, BW- birth weight

## Predictors of preterm birth

In the logistics bivariate analysis, mid upper arm circumferences, dietary diversity score, dietary folate intake, height of the women, pre-pregnancy body mass index (BMI), ANC follow up and school attendance were found to be candidates for multivariable analysis at  $p < 0.05$ . Accordingly, the multivariate model adjustment was done for potential confounders. Therefore, the prevalence of preterm birth was 0.52 (95%CI=0.301, 0.890), 1.48(95% CI= 0.74, 2.93), and 0.048 (95% CI = 0.01–0.161) times higher among pregnant women who had inadequate dietary diversity score, consumed dietary folate below the recommendations of the world health organization and undernourished (MUAC>23cm), respectively compared to those who given birth  $\geq 37$  weeks of gestational age (**Table 25**).

**Table 25:** predictors of preterm birth in cohort pregnant women in the northern zone of the Sidama region, Ethiopia, 2025, (n=424).

Variables	Gestational weight at birth		cPR (95% CI)	aPR (95% CI)	P value
	28-36weeks (n=100)	$\geq 37$ weeks (n=324)			
<b>Dietary diversity score</b>					
Inadequate (1-4)	77(77%)	205(63.3%)	1.66 (1.53–1.82)	0.52( 0.301–0.890)	0.017
Adequate ( $\geq 5$ )	23(23%)	119(36.7%)	Ref	Ref	
<b>Dietary folate intake</b>					
<600(EAR)	77(92.8%)	302(88.6%)	4.86 (3.72–6.34)	1.48(0.74–2.93)	0.026
$\geq 600$ (EAR)	6(7.2%)	39(11.4)	Ref	Ref	
<b>Mid-upper arm circumferences</b>					
<24cmm**	27(27%)	43(13.3)	0.096 (0.001–0.196)	0.048 ( 0.01–0.16)	0.001
$\geq 24$ cm	73(73%)	281(86.7)			

aPR- adjusted prevalence rate, COR-crud odds ratio, \*\*- statistically significant at adjusted prevalence rate, \* not significant at adjusted prevalence rate, MUAC-Mid-upper Arm Circumference, BMI- Body Mass Index

## Discussions

This prospective cohort study involving pregnant women identified significant associations between MUAC and serum folate levels with the increased risk of PTB. It is considered as a public health concern in child mortality (Chawanpaiboon *et al.*, 2019). However, the incidence and mortality due to PTB have shown a declining trend. Low Socio-demographic Index regions increased in annual incidence cases, while high Socio-demographic Index regions decreased in annual incidence cases. The highest annual mortality occurred in SSA (Liang *et al.*, 2024), including Ethiopia, which is one of the countries that accounts for the highest burden of PTB (Kibret *et al.*, 2024). In the present study, approximately 24% of the neonates were born preterm,

which aligned with the findings identified in the systematic analysis of the burden of PTB (Liang *et al.*, 2024) and the observational studies conducted in Ethiopia (Yilkal *et al.*, 2022).

In addition, the finding in the present study revealed that female neonates borne preterm than male new borne. The finding is inconsistent with the systematic analysis (Liang *et al.*, 2024) that shown males neonates were more commonly born preterm than females. Possible reason for the discrepancy could be study settings and design. The gestational age of the newborn neonate was utilized as a cut-off point to determine the outcome variable, which was less than 37 completed weeks of gestation. PTB was determined to be 23.58 percent in this study, with a 95 percent confidence interval of (19.8–27.6), which is higher than the 12.3 and 11.5 percent identified in the Global Action Report for SSA countries and study in Brazil (2016) (Howson *et al.*, 2013; Leal *et al.*, 2016).

In addition the findings of the studies conducted in public health facilities in Dodola, Axum, and Gondar town showed that (13%), (13.3%), and (4.4%) of the births were preterm (Gebreslasie, 2016; Aregawi *et al.*, 2019; Handiso *et al.*, 2019), respectively. This difference is most likely due to differences in study settings and study areas, in which the discrepancy could be because our study area is at a higher risk than others due to various health-related gaps, such as service quality and differences in health-related medical illnesses and pregnancy-related histories of participants from other areas. However, the finding in the present study was higher than the finding of the study conducted in northern Ethiopia, which shown the prevalence rate of PTB was 16.1% (Kibret *et al.*, 2024). The possible reason for discrepancy might be methodological differences employed in this previous study, such that the current study was conducted in rural residences, where there are high risk factors for PTB than the urban area where the other study conducted.

On the other hand, the finding identified in this study was lower than the finding of the studies conducted in Ethiopia and Cameroon (Chiabi *et al.*, 2013; Molla *et al.*, 2017), which revealed 25.5% and 26.5% of neonates born preterm with their index mothers. Similarly, the finding in the present study was lower than the finding of the study conducted in Jimma University Specialized Hospital, which shown that preterm delivery was prevalent in 25.9 percent (Molla *et al.*, 2017). The differences could be due to our study excluded multiple gestations and those with a history of abortion. Another reason for the discrepancy could be a study conducted in Jimma University

Specialized Hospital found high prevalence of alcohol and substance intake during pregnancy. These were other contributing factor to increased PTB the study area, but this was not the case in our study.

However, the finding in the present study was higher than the result identified in the studies conducted in Ethiopia and Kenya public Hospitals, which shown that 13.2%, 10.48% and 20.2% of the mothers gave PTB, respectively (Wagura *et al.*, 2018; Muchie *et al.*, 2020; Ayele *et al.*, 2023). The differences could be due to studies may differ in settings, such as one study performed surgical evacuation of the uterus mechanically stretches the cervix, predisposing such mothers to PTB in subsequent pregnancies; thus, study settings may be the reason for the discrepancies observed. Similarly, the finding of this study is inconsistent with that of other studies conducted in Ethiopia and Malaysia public hospitals, which reported 16.15% and 16.9% of the new borne were preterm, respectively (Deressa *et al.*, 2018; Sutan *et al.*, 2018). The differences could be due to study area and settings, such that our study was conducted in rural areas where the study participants were predisposed to risk factors of PTB, such as participants in our study consume low diverse diet, particularly low dietary folate more likely than the participants in the studies conducted in public hospitals of Addis Ababa and Malaysia.

The result of this study shown lower maternal folate levels in early pregnancy were associated with increased risk of PTB. This finding was in agreement with previous analysis of systematic review and meta-analysis (Zhang *et al.*, 2019), which reported higher maternal folate levels were associated with a 28% reduction in the risk of preterm birth. In addition, present study identified that a significant positive association was observed between dietary folate intake and the risk of PTB. This finding was in line with similar study, which approved a significant negative association between dietary folate intake and the risk of PTB, but no significant relation was seen between IFAS and decreased risk of PTB. The previous study, however, shown higher folic acid supplementation was associated with 10% lower risk of PTB (Zhang *et al.*, 2019).

Additionally, due to our results, a higher score in DD, which led to an increased intake of major nutrients and a greater variety of foods, was correlated with a lower risk of PTB. The finding was consistent with the previous analysis of systematic review, conducted in Ethiopia. However, the finding was inconsistent with the previous analysis of systematic review, conducted in Ethiopia (Tareke *et al.*, 2024), which observed insignificant association between maternal DD and PTB.

The possible reason for the difference could be study design, such that the previous study was meta-analysis.

In addition, maternal undernutrition is highly prevalent in resource-poor settings, generally ranging from 10% to 19%, but reaching up to more than 20% in some areas, such as in SSA where approximately 28.7% of the estimated 134,767, 000 million babies born annually with PTB (Ohuma *et al.*, 2023). The prevalence of PTB birth in the study area in the current study was 23.58%, which was below the South African's estimate that born in the average gestational age at birth of  $37.62 \pm 1.74$  weeks. In consistent with this, approximately 15% of all PTB occurred at less than 32 weeks of gestation, requiring more neonatal care (<28 weeks: 4.2%, 28–32 weeks: 10.4% (Ohuma *et al.*, 2023).

Low GWG, MUAC<24cm, and LBW in the present study showed positive significant association with PTB. Maternal MUAC less than 24 cm were 0.048 times increased risk of developing PTB than mothers with MUAC greater than or equal to 24cm. This finding was in line with the finding of previous studies conducted in northwest Ethiopia (Mekonen *et al.*, 2019), a study in Bangladesh (Shah *et al.*, 2014). The findings were also consistent with reported from the studies conducted in India (Vasundhara *et al.*, 2020), and Switzerland (Ververs *et al.*, 2013), which identified MUAC as relatively strongly associated with PTB. Additionally, previous studies among pregnant women have shown a consistent association between low maternal MUAC and an increased risk of PTB (Tang *et al.*, 2020)

The present study shown maternal height <145 cm was not statistically significant determinant of PTB. The finding is consistent with reported from public hospitals in Addis Ababa (Baye *et al.*, 2020). However, the finding of the study conducted in California singleton, live births between 2007-2010 was inconsistent with the present result (Shachar *et al.*, 2015). The possible reason for the discrepancy was socio economic and methodological differences between the study areas. The reason for the differences could be due to methodological differences, such that our study was conducted in rural communities where there are different factors, like food insecurity and low DD exposing women directly or indirectly to short stature.

On the other hand a study conducted in the Eastern Zone of Newfoundland and Labrador, Canada approved the association between short maternal height and PTB before 37 weeks of gestation. In the study the association varies by type of PTB (spontaneous or indicated) and BMI

class. Short maternal height is associated with spontaneous PTB among women with a normal BMI while an increased risk of indicated PTB has significant association among overweight or obese women (Crane *et al.*, 2025). However, we found no linear and adjusted associations between BMI and PTB. The adjusted risk of any PTB was elevated at both low BMI in the previous analysis of systematic review that was conducted using three UK datasets, two USA datasets and one each from South Australia, Norway and Denmark shown the risk of spontaneous PTB was increased at lower levels of BMI but remained low or increased only slightly with higher BMI (Cornish *et al.*, 2024).

Low pre-pregnancy BMI are predictors of adverse pregnancy outcomes, like PTB (Kalanda, 2007). The findings were consistent with previous studies conducted in low and middle income countries. In the studies, undernutrition in women, before and during pregnancy, is recognized as a key determinant of PTB (Tang *et al.*, 2020). In contrast to that, the present study identified a pre-pregnancy BMI of less than 18.5 kg/m<sup>2</sup> was not associated with increased risk of PTB. GWG throughout pregnancy was a significant predictor of PTB. The finding was in line with the previous study that reported pregnant women with low GWG were with increased risk of idiopathic PTB (Cornish *et al.*, 2024). Similarly, maternal weight gain of less than 6.53 kg during the second and third trimesters posed a risk factor for LBW (Arabzadeh *et al.*, 2024). The present study shown women with high total GWG had a decreased risk overall of PTB < 37 weeks, PTB 32 to 36 weeks and < 32 weeks. The finding was in line with previous analysis of systematic review (McDonald *et al.*, 2011). Additionally, weight gain throughout pregnancy was a significant predictor of PTB. The finding was in line with the analysis in which a GWG rate less than 0.27 kg/week had an increased risk of idiopathic PTB. Pre-pregnancy BMI and maternal height were poor predictors of PTB at <36 weeks' gestation in the current study. The finding was supported by a systematic review, which identified three anthropometric features were poor predictors of PTB (Honest *et al.*, 2005).

### **Conclusion and recommendations**

Preterm birth is a significant problem. Maternal under nutrition, indicated by low MUAC and serum folate due to inadequate dietary diversity, is strongly associated with preterm birth. Strengthening public health interventions, including providing additional food for pregnant mothers, ensuring iron and folic acid supplementations, food fortification with folate, dietary diversity and monitoring anthropometric indicators earlier during antenatal care, is crucial.

**Limitations of the study**

The strength of this study is that being community-based; it could reflect the actual experience of women during the study period. The limitation of this study is the methodological nature of the 24-hour dietary recall method of data collection, which is prone to recall bias. This is because the information was collected by the study participants' self-report. Careful designs of the initial 24-hour recall protocol and standardized multiple-pass interviewing techniques have been used to minimize errors generated by memory lapses and distortions. Additionally, memory aids such as photographs and “probing” have been used to identify the correct species.

CHAPTER VIII: Suboptimal consumption of animal-source food during pregnancy is associated with increased risk of low serum ferritin and low birth weight in rural Ethiopia

**Article submitted to MDPI**

**<https://www.mdpi.com/>**

**Under review**

## **Abstract**

**Background:** Despite intake of animal source food is associated with the birth weight of newborns; longitudinal study assisted by biochemical test of elemental iron has seldom been rigorously evaluated in the study area. Therefore, we aimed to assess suboptimal consumption of animal-source food during pregnancy is associated with increased risk of low serum ferritin and low birth weight in rural Ethiopia.

## **Methods**

A prospective cohort study conducted through baseline assessment of maternal consumption of animal source food as exposure using multiple pass 24 hour dietary recall alongside a trimester based 24-hour dietary folate intake and nutrient adequacy from enrollment to delivery. A blood sample was collected at their first prenatal visit and at term for serum ferritin analysis. Linear regression analyses were fitted to identify predictors of low birth weight.

## **Results**

A low birth weight accounted for 37.3%, with a mean weight of 2875.10gram and 7.5% of the women had a serum ferritin levels of <15 µg/L. The prevalence of low birth weight was higher among women with underweight (AOR=1.126, 95% CI: 1.003, 1.23), short stature (AOR=11.341, 95% CI: 1.097, 11.421), under nutrition (AOR=1.141, 95% CI: 1.025, 1.270), intake of dietary iron below <27(EAR) (AOR=6.348, 95% CI: 4.144-9.724), serum ferritin of below <15 µg/L (AOR=1.588, 95% CI: 1.008, 2.502), and inadequate DDS (AOR=2.148, 95% CI: 1.778-2.596).

## **Conclusion**

Low birth weight is a significant problem. Maternal underweight and under nutrition (indicated by low MUAC and short stature) are significant determinants of low birth weight. Insufficient intake of dietary iron is resulted depletion of total body iron stores (indicated by low serum ferritin) significantly associated with low birth weight. Encouraging women to consume animal source foods and promoting early monitoring of maternal nutritional status during pregnancy are crucial to reduce the risk of low birth weight.

**Key words:** Anthropometrics, Gestational weight gain, Serum ferritin, LBW

## Introduction

World Health Organization (WHO) defined low birth weight as infants whose weight is less than 2500 gram at birth irrespective of gestational age (Unicef, 2004; WHO, 2012). Low birth weight is the most significant risk factor for neonatal and infant mortality. It is one of the major public health problems globally, with a higher prevalence in developing countries (WHO, 2012; Katiso et al., 2020). Reports showed that 14.7% of all births globally were low birth weight, representing more than 20 million births a year (Katiso et al., 2020; Krasevec et al., 2022). Despite there have been important reductions in the prevalence of low birth weight in low and middle income countries, the progress has been uneven across regions. The prevalence is still high in sub-Saharan Africa and South Asia (UNICEF, 2013; Victora *et al.*, 2021). The pooled prevalence of low birth weight in Ethiopia was 14.1%, ranging from 6% to 29.1%, It was reported that 16.5% of the newborns were born with LBW in the Sidama region (Gebremedhin et al., 2012; Katiso et al., 2020).

Iron is a vital constituent of hemoglobin, which is involved in tissue oxygenation, and essential for blood formation (Jeong-Ok et al., 2014; Banjari, 2018). Iron-deficiency anemia affected 29.9 percent of women worldwide, associated with low concentration of serum ferritin that is considered as a reliable indicator of total body iron stores (Merialdi et al., 2003; Bukowski et al., 2007). Serum ferritin level of less than 15µg/L leads to iron deficiency anemia, determined at about 16.7 weeks' gestation and significantly associated with higher risks of low birth weight (Mei *et al.*, 2023). Daily intake of 30 mg dietary iron from rich sources such as red meats, fish, and poultry is recommended to reduce the risk of adverse pregnancy outcomes, including iron deficiency anemia, preterm birth and low birth weight. The demand is 3 times higher as pregnancy advances (IOM, 1990; Bothwell, 2000; Jans *et al.*, 2015; Abegaz *et al.*, 2018; Black *et al.*, 2018). Compared to plant source foods (PSFs), ASF is regarded to have higher nutritional value (Murphy et al., 2003). Animal source foods are not only a nutritionally dense source of energy and readily digested protein but are also a compact and efficient source of an array of bioavailable micronutrients, including iron, zinc, calcium, retinol (preformed vitamin A), vitamin B12, riboflavin, and folic acid that are difficult to obtain in adequate quantities from foods of plant origin alone (Schönfeldt et al., 2013).

In resource poor settings, women's diet is dominated by starchy staples that is lacking in diversity, with limited intake of fresh fruits and vegetables, and minimal or no inclusion of

animal products, which is resulted in iron deficiency that leads adverse pregnancy outcomes (Torheim et al., 2010; Arimond et al., 2011; Gernand et al., 2016). Maternal nutritional status determines weight gain patterns during the course of pregnancy (Devaki and Shobha, 2018; Victora *et al.*, 2021; Marshall *et al.*, 2022). A pre-pregnancy BMI is calculated by using a woman's height and weight before conception or approximated by a weight measured no more than two months before conception or during the first trimester of pregnancy, affects fetal growth and predicts adverse pregnancy outcomes (Rasmussen et al., 2009; Kozuki et al., 2015; Black et al., 2018; Bhattacharya *et al.*, 2019). Between 7 and 24% of pregnant women in resource poor settings gained less weight during pregnancy than recommended by IOM (WHA, 2012; UNICEF, 2018). A recommended range of weight gain is considered to be healthy based on a mother's pre-pregnancy BMI during the second and third trimesters. A woman with BMI of  $>18.5\text{kg/m}^2$  is recommended to gain a total gestational weight of 12.5–18 kg with rate of mean weekly weight gain of 0.51kg. A woman with BMI of 18.5–24.9kg is recommended to gain a total gestational weight of 11.5–16 kg with rate of mean weekly weight gain of 0.42kg. A woman with BMI of 25–29.9 is recommended to gain a total gestational weighty of 7–11.5kg with rate of mean weekly weight gain of 0.28kg. A woman with BMI of  $\geq 30$ , is recommended to gain a total gestational weighty of 5–9 kg with rate of mean weekly weight gain of 0.22kg (Rasmussen et al., 2009).

Existing evidence from Ethiopia and other sub-Saharan African countries indicates a focus on the prevalence of low birth weight and its association with anemia (Unicef, 2004; Endalamaw *et al.*, 2018; Katiso et al., 2020; Quansah and Boateng, 2020). The studies used evidences, from expert opinion to population-based observational data, primarily using evidence from mothers' reporting, needless the estimate might not be trustworthy. Moreover, the results might be insufficient to account for the complex behavior of food consumption and nutrient interactions during pregnancy (Loy and Jan Mohamed, 2013). To date, objective evidence is lacking as there is no longitudinal study using laboratory data has objectively assessed the risk of suboptimal dietary intake on pregnancy outcomes. Therefore, we investigated whether suboptimal consumption of animal-source food during pregnancy is associated with increased risk of low serum ferritin and low birth weight. The evidence provides sound technical advice on the utilization of locally available ASF as routine nutrition education topics in primary health care, especially in resources limited setting.

## **Materials and Methods**

### **Study setting and period**

The study was conducted in two randomly selected hospitals in two rural districts that were representative of the different agro ecologic zones of the Northern Sidama zone, Sidama Region, Ethiopia. The districts were selected using cluster sampling method. Of the 36 kebeles (the smallest administration unit) identified, 12 were selected as study clusters, with six from each district representing both urban and rural areas using purposive sampling. The districts are located at 300 and 337 km from Addis Ababa, the capital of Ethiopia, respectively. The Northern Sidama zone is one of the surplus producing agricultural areas of Ethiopia, with major production of corn, pulses like haricot beans and false banana. The study conducted from March to December 2024.

### **Study design, study population and eligibility criteria**

The study was a longitudinal, prospective cohort study with 2 arms at a ratio of 1:1, using animal source food consumed (unexposed) and not consumed (exposed). The source population for the study included all pregnant women residing in the Northern Zone of the Sidama Region. Participants willingness to participate, with confirmed pregnancy and specific gestational age ranges (e.g., < 12 weeks gestation) and residing in the study area were included. Individuals with severe underlying health conditions and potentially women with known major complications that could interfere with exposure variable, such as diabetes, hypertension, cardiovascular disease, chronic kidney disease, cancer, and mental disorders, were excluded. Additionally, individuals with planning to move out of the area, inability to communicate in the study language, or having a different gestational age outside the range were excluded.

### **Sample size estimation and techniques**

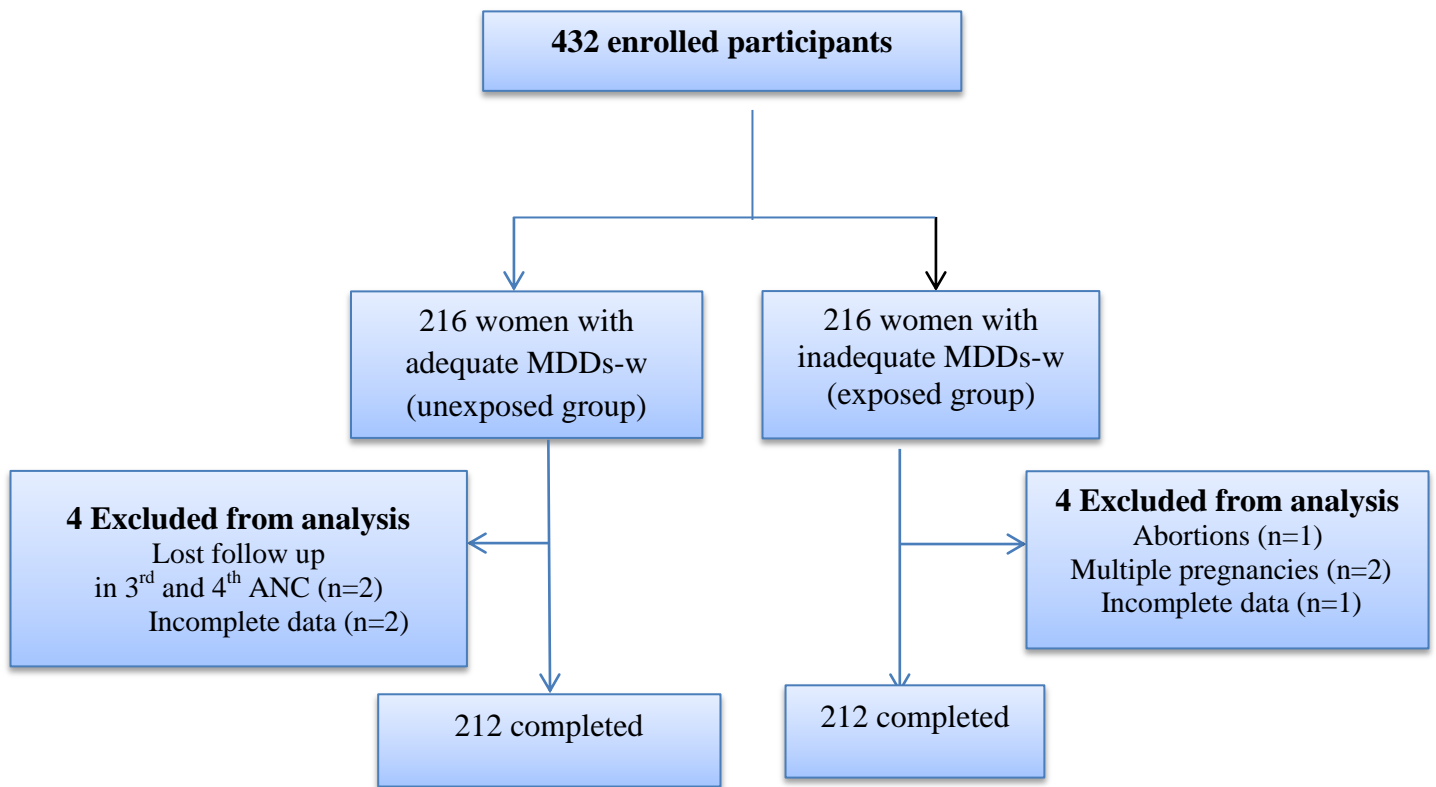
Sample size was calculated using open Epi Info statistical software available at <http://www.openepi.com/SampleSize/SSCohort.htm> with the following parameters and assumptions: a 95% significance level (2-sided), 80% power, with 29.77% low birth weight prevalence (Tesfa *et al.*, 2023) among exposed pregnant women and an anticipated 10% lower prevalence of low birth weight among unexposed pregnant women. This yielded a total of 146 subjects /arm and to allow for 16% attrition and a design effect of 1.3 by the end of the study, a sample size of 440 was required. Data on pregnancies compiled by rural health extension

workers were used to estimate the number of pregnant women in each cluster. Using a probability proportional to size allocation, the sample size was assigned to each cluster. The simple sampling technique was used to select pregnant women. The pregnant woman who had been absent from the interview was contacted the next day.

### **Allocation to study arms and follow-up**

Pregnant women consenting to deliver at designated hospitals were purposively sampled and followed up. The final analysis included 424 pregnant women (212 exposed and 212 unexposed) in a 1:1 ratio. Serum folate levels were also examined in blood samples collected from 318 volunteer participants (158 exposed, 160 unexposed). A study enrolled pregnant women at their first antenatal care (ANC) visit, using births compiled by rural health extension workers, revealed that only 28% initiated ANC in the first trimester, while 32% began their first visit in the fourth or fifth month of pregnancy.

At enrollment, a 24-hour MDDs-w was collected following FAO guidelines (Kennedy, et al., 2013) and participants were categorized as “0” (No ASF consumption) and “1” (ASF consumption) as reported in the base line study in their first trimester (8 to <14 weeks) (Mayisso et al., 2025b). Consequently, a cohort of 220 pregnant women with adequate ASF was allocated as unexposed group; while a control of 220 pregnant women with inadequate ASF was recruited as exposed group from similar populations in the same districts. The cohort was followed-up in the second trimester (20 to <24 weeks), third trimester (32 to <34 weeks) and at delivery. The expected date of delivery (EDD) for each participant was recorded. The occurrence of births in the cohort was promptly found and informed by pre-established local community health promoters which the country labeled as “Women Developmental Army (WDA)” and health extension workers (HEW) (Figure 1).



ANC, antenatal care; MDDs-w, Women’s Dietary Diversity Score

**Figure 11:** Study participant flow of the prospective cohort of pregnant mothers in northern zone of Sidama Region, Ethiopia.

## Data collection and measurements

### Socio-demographic and economic data

Data on the socio-economic and demographic characteristics were collected by using a pretested questionnaire that was adapted from the Ethiopian Demographic and Health Survey and the FAO (Kennedy, *et al.*, 2013; EDHS, 2017). Data were retrieved at 12 weeks of gestation as a baseline study. If a woman missed her interview due to being out of the home, the next eligible pregnant woman in the queue was contacted. The pregnant woman who had been absent from the interview was contacted the next day. Principal component analysis (PCA) was used to generate a household’s wealth index (Xie *et al.*, 2023). Household’s wealth quintiles are compiled by assigning the household score. Twenty-one variables were entered into PCA.

### Assessment of anthropometric characteristics and gestational weight

This longitudinal study used anthropometric indices: BMI and MUAC to assess maternal anthropometric deficits. Data on maternal weight and height were collected at first trimester (8 to

<14 weeks') gestation to calculate pre-pregnancy BMI. Their height was measured to the nearest millimeter with a portable device equipped with calibrated and standardized height gauges (SECA 206 body meter). The women's MUAC was assessed subsequently every trimester until delivery, at least eight times as recommended by WHO as follows: in the first ante natal contact (12 weeks) of gestation, two contacts in the second trimester (20 and 26 weeks) of gestation, and five contacts in the third trimester (30, 34, 36, 38, and 40 weeks). The MUAC of the left arm was measured to the nearest millimeter with a non-stretch measuring tape. The data were collected by 4 well-trained and experienced midwives who work permanently in the antenatal care service provision units of health centers in the community.

To track gestational weight gain, the weight was taken in the early first trimester (8 to <14 weeks) of gestation. Subsequently, the women were weighed at each visit from enrollment to delivery following the standardized procedures recommended by WHO, to the nearest 100 g using electronic scales with a weighing capacity of 10–140 kg (WHO, 1995). The following schedule was used: second appointment 8 weeks later; the third, 6 weeks later; fourth and fifth 4 weeks apart; and then the rest every 2 weeks was used for assessment of gestational weight gain. Gestational weight gain in relation to gestational age at birth was taken at labor, and total gestational weight gain was estimated by subtracting the early first trimester weight from the last measured weight before delivery (IOM, 1990).

### **Assessment of fertility and obstetric characteristics of the respondents**

Medical professionals diagnosed the pregnancies. The obstetrics history of the women, including gravidity that refers to the total number of pregnancies (includes current pregnancy and all term, preterm, therapeutic abortions, and miscarriages). Term pregnancy refers to all births gave at full term (i.e.: after completion of 37 wks. of gestation), preterm: all births gave preterm. (i.e.: from 20wks to 37wks of gestation) and abortion: include all miscarriages or medical abortions and surgical abortions before 20wks of gestation. Parity that refers to the number of births after 28 weeks of gestation whether or not the baby born was alive and number of living children (total number of living children (here every child [i.e. twins, triplets] were included in the assessment. Common risk factors and certain health conditions that can make a pregnancy at risk: age of the women (being over 35 or under 18 when pregnant), obesity, depression, birth interval, low birth weight, fertility intension and birth interval were included.

### **Assessment of intake of animal source food, nutrient adequacy and serum levels of ferritin**

Dietary Diversity Score (DDS) was assessed using validated the multiple-pass 24-hour dietary recall method with the standard nine-food group score (Mayisso et al., 2025b). Alongside initial MDD-w assessment, a trimester based 24-hour dietary iron intake from ASF and nutrient adequacy were recorded from enrollment to delivery, during both pre-harvest (March-May) and post-harvest (June-September) seasons. ASF was categorized into “0” (No ASF consumption) and “1” (ASF consumption). The questionnaire asked women the types of foods she had eaten in the 24 h prior to the survey. Eggs, fish, yogurt, cheese, milk, meat (including beef, poultry, pork, lamb, and any other meat not mentioned), and organ meats (e.g., liver) were the ASFs included in the questionnaire. Consumption of any amount and/or type of the ASFs listed above was considered as ASF consumption (UNICEF/WHO, 2021).

The nutrient adequacy ratio of dietary iron was determined as described in base line study (Mayisso et al., 2025b). The multiple-pass 24-hour dietary recall method questionnaire was initially prepared in English language and translated to the local language (Sidamifa) by individuals with good command of both languages. A serum folate data was obtained from a blood sample collected at their first prenatal visit and at term for biochemical analysis. 5mL venous blood samples were collected aseptically from the ante cubital vein and placed into anticoagulant-free test tubes by professional laboratory technologists. Serum samples were separated within less than 6 hour and stored at -80°C until analysis. The blood samples were centrifuged and the serum was separated before being frozen at -80°C and transported to Addis Ababa clinical laboratory for analysis and the serum level of ferritin was measured.

The serum level of ferritin was analyzed on a fully automated Cobas e411 (German, Japan Cobas 4000 analyzer series) immunoassay analyzer by the electro-chemiluminescence (ECL) method using commercial kits supplied by Roche Company, Germany in Addis Ababa clinical laboratory. The cut-off value for serum ferritin was indicated based on international standard of the micronutrients for pregnant women based on metabolic indicators with the reference of WOH cut-offs of (14.7–184.3 mg/L) for serum level of ferritin (Mei *et al.*, 2023). The tests were performed by trained and experienced medical laboratory technologists. Two levels of quality control were performed at least once every 24 hour when the test is in use, once per reagent kit, and following each calibration to evaluate the functionality of the instrument and reagent, and

the results of were evaluated using the Levey–Jennings chart (Wesgard rules). The calibration method has been standardized against the WHO International Standard NIBSC code: 03/178, 1<sup>st</sup> International Standard (IS) NIBSC (National Institute for Biological Standards and Control) "Reagent for Ferritin (human liver)" 80/602, and Reference preparation of the IRMM (Institute for Reference Materials) for serum ferritin. Calibration was performed as per the standard operating procedures (SOPs). The high ferritin cut-off point (SF < 15 µg/L) recommended by WHO for developing countries was used to define ID to compensate for the effect of infection, which can lead to elevation of the level of ferritin (Mei *et al.*, 2023).

### **Outcome assessment**

Birth weight data was collected from women in the hospitals from November to December, 2024. Birth weight was gauged within 72 h of birth on a Salter scale to the nearest 100 grams by trained midwives and physicians. The infants were weighed with minimum clothing while the child was restful. A low birth weight was defined as a live birth baby born with a birth weight of < 2500 g, and a normal birth weight was defined as a live birth baby born with a birth weight of ≥ 2500g (Verhoeff *et al.*, 1997). Additionally, birth outcomes, including preterm birth, small for gestational age, delivery methods, pregnancy induced hypertension, neonatal mortality, and stillbirth were ascertained by the same professionals at birth. End line information was collected from participants who successfully completed the follow up using questionnaires pretested in a similar setting.

### **Quality control**

All data collectors were trained physicians, laboratory technologists and midwives with at least a diploma in nursing. They also received 5-day training on participants' enrollment, follow-up, anthropometric measurements. The training was conducted just before the study and was followed by practical tests to ensure the skills were transferred. In each of the health posts and hospitals selected, one supervisor (usually the head) was assigned to oversee data collection. In addition, the investigator made a weekly visit to check the completeness and quality of the data collected. Anthropometric measurements were taken only by trained personnel, and all equipment was calibrated with standard weights and length rods on a daily basis. Data were collected through face-to-face interviews by trained research assistants using a standard pretested

questionnaire. Neither the pregnant women nor the data collectors were aware of the allocation into groups.

### **Statistical analysis**

Data were entered using Epidata statistical software (Version 20). The data were double entered, cleaned and then exported to SPSS (version 27.0) for statistical analyses. All data on singleton pregnancies were analyzed according to their categorization by MDDs-w. All continuous variables were checked for normality by use of the Kolmogorov-Smirnov test. Variables not normally distributed were log-transformed. Means and SEMs were used to describe continuous variables. An independent Student's t test was used to compare means in the adequate and inadequate groups. A  $\chi^2$  test or a Fisher's exact test was used to test for independence in distribution of categorical variables between the 2 study groups. In all comparisons, differences were considered statistically significant at  $P < 0.05$ . The association between PTB and the independent variables like anthropometrics deficits (Pre-pregnancy BMI and MUAC), serum folate levels and gestational weight gain was investigated after adjusting for baseline differences.

The linear regression model was fitted to identify predictors of preterm birth. The goodness of fit was checked by Hosmer Lemeshow statistic and omnibus tests. Possible interactions between covariates were tested. Akaike's information criterion (AIC) and Bayesian information criterion (BIC) were used to test for model fitness. All variables with  $p < 0.25$  in the binary analyses were included in the multivariable analysis after checking for multi-collinearity using variance inflation factors. Adjustments were done for independent variables (age, mid-upper arm circumference, maternal height, sex of neonates) for gestation age at birth. The direction and strength of statistical association were measured using adjusted prevalence ratio (aPR) along with their corresponding 95% confidence interval (CI). An adjusted prevalence ratio (aPR with a 95% confidence interval was reported to show an association at a  $p$ -value  $< 0.05$ . To estimate the economic level of the families, a wealth index was employed. The wealth dispersion was generated by applying principal component analysis (PCA). The index was calculated based on the ownership of the latrine, agricultural land and size, selected household assets, the quantity of livestock, and source of water for drinking containing 41 household variables.

### **Ethical considerations**

The ethical clearance for the study and authorization letter for the field work, and the consent obtained from the participants were described in Chapter One (Mayisso et al., 2025b). All

methods were carried out in according with the relevant tenets of Helsinki Declaration and good clinical practice (WMA, 2025).

## Results

### Socio-demographic characteristics of the respondents

A total of 440 eligible pregnant women (220 from each group) were enrolled. 424 were included in the final analysis with overall dropout rate of 3.64%, which was balanced across both groups. The reasons for dropping out were mainly discontinuation of the follow up (n=2), incomplete data (n = 10), twin or multiple pregnancy (n = 3) and abortions (n=1) (**Figure 11**). The baseline characteristics of the dropouts and the women who completed the study were not statistically different. The respondents' mean age at marriage was 21.07 years, increasing to 26.40 years at the time of study enrollment, but the ages at marriage and enrollment were not significantly different among the groups ( $p > 0.05$ ). The mean duration of pregnancy at enrollment was 10.05 weeks.

**Table 26** showed the means age at marriage, age at enrollment and gestational age during recruitment of retained and dropout participants, who were varied significantly in the base line of the study ( $p < 0.05$ ). However, the completed and dropout groups were similar in means of family size, level of education, and wealth index of ( $p > 0.05$ ). Majority, (91.7%) of the respondents were living in household with family member of 2-4 people. 95.8 percent of the study participants were married, with 96.5% of were  $\geq 18$  years old. Housewives and women ever attended school account for 94.9 and 86.6 percent, respectively. Food insecurity was reported in 87.5% of households, with 45.4% of these belonging to the poorest wealth quintiles.

**Table 26:** Baseline socio-demographic and economic characteristics of cohort of pregnant women in Northern Sidama zone, Ethiopia (n=424)

Variables	Completed (n=424)	Dropout (n=16)	MD (SED)	95%CI		P value
	Mean( $\pm$ SD)	Mean( $\pm$ SD)		Lower	Upper	
Age at marriage	21.07(3.86)	29.38 (4.24)	8.30(0.99)	6.36	10.24	0.000
Age at enrollment	26.40(5.83)	29.31(0.60)	2.91(0.32)	2.28	3.54	0.000
GA at enrollment	10.26 $\pm$ 1.60	9.83 $\pm$ 1.40	-0.43 $\pm$ 0.15	-0.71	-0.14	0.004
Marital duration	5.36 (3.38)	9.69(3.32)	0.08 (0.33)	-0.57	0.73	0.805
Family size	3.10 (0.93)	3.75 (1.13)	0.07(0.09)	-0.11	0.24	0.450
Parity	1.51(1.34)	1.19 (1.22)	0.050 (0.13)	-0.20	0.30	0.695
Level of education	6.96 (2.98)	6.00 (4.20)	-0.96 (0.77)	-2.47	0.56	0.217
Monthly income	790.13(184.23)	795.31(190.33)	5.18 (46.97)	-87.13	97.50	0.912

According to animal source food consumption in the bases of key socio-demographic and economic characteristics, women who consumed at least one animal source food had their first ANC~1wk before those did not consume animal source food ( $P<0.05$ ). The two groups were similar in parity, age at enrollment and marriage, family size and marital duration ( $P > 0.05$ ). However, women who consumed at least one group of animal source food had more years of schooling and higher monthly income, while women did not consumed animal source food had a higher gestational age at enrollment ( $p<0.05$ ) (**Table 27**).

**Table 27:** Base line socio-demographic and obstetric characteristics of cohort of pregnant women by animal source food consumption status in Northern Sidama zone, Ethiopia (n=424)

Variables	Consumption of animal source food					P value
	Consumed (n=212)	Not consumed (n=212)	MD ( $\pm$ SED)	95% CI		
	Mean( $\pm$ SD)	Mean( $\pm$ SD)		Lower limit	Upper limit	
Family size	3.14 $\pm$ 1.01	3.06 $\pm$ 0.85	-0.080 $\pm$ 0.09	-0.26	0.10	0.375
Age at marriage	20.86 $\pm$ 3.66	21.29 $\pm$ 4.05	0.429 $\pm$ 0.38	-0.31	1.17	0.253
Age at enrollment	26.75 $\pm$ 6.21	26.06 $\pm$ 5.41	-0.689 $\pm$ 0.57	-1.80	0.42	0.224
Educational level	6.30 $\pm$ 3.23	6.71 $\pm$ 2.56	1.307 $\pm$ 0.28	0.75	1.86	0.000
Marital duration	5.41 $\pm$ 3.48	5.30 $\pm$ 3.28	-0.110 $\pm$ 0.33	0.76	0.54	0.737
GA at enrollment	10.26 $\pm$ 1.60	9.83 $\pm$ 1.40	-0.425 $\pm$ 0.15	-0.71	-0.14	0.004
Parity	1.54 $\pm$ 1.35	1.49 $\pm$ 1.33	-0.047 $\pm$ 0.13	-0.30	0.21	0.718
GW at 1 <sup>st</sup> ANC	6.74 (3.18)	7.64 $\pm$ 3.38	0.179 $\pm$ 0.32	-1.35	-0.09	0.024
Monthly income	760.90 $\pm$ 129.45	889.35 $\pm$ 177.48	198.453 $\pm$ 15.09	168.79	228.11	0.000

### Obstetric characteristics

All respondents experienced singleton pregnancies. 61.8% of women had ever given birth, with 63.4% of those having had three or more births. Most current pregnancies (87.5%) were wanted. Over two-thirds of respondents became pregnant between 18 and 25 years of age. The mean number of pregnancies was 1.68, with mean surviving children and birth intervals of 1.51 and 2.67, respectively. 98% of women had antenatal follow-up, with a mean of 3.18  $\pm$  0.96 visits; 86.8% enrolled at 9-12 weeks of gestation (**Table 28**).

**Table 28:** Base line obstetrics characteristics of cohort of pregnant women in Northern zone of the Sidama region, Ethiopia, 2025 (n=424).

Variables	Frequency	Percent	95%CI	
			Lower	Upper
<b>Gestational weeks at enrollment</b>				
5-8 weeks of gestation	59	13.9	10.8	17.2
9-12 weeks of gestation	365	86.1	82.8	89.2
<b>Risk factors for the current pregnancy</b>				
Yes	100	23.6	19.8	28.1

No	324	76.4	71.9	80.2
<b>Types of the risk factors</b>				
Age below 18 years	57	13.4	10.1	17.0
Others*	43	10.1	7.3	13.2
<b>Fertility intention</b>				
Intended	371	87.5	84.2	90.8
Unintended	53	12.5	9.2	15.8
<b>Age at first pregnancy</b>				
≤18 years	156	36.8	31.8	41.5
19-25 years	268	63.2	58.5	68.2
<b>Ever given birth before</b>				
Yes	310	73.1	67.9	76.2
No	114	26.9	23.8	32.1
<b>Birth interval</b>				
≤2 years	73	17.2	13.9	21.0
3-5 years	237	55.9	50.9	60.8
<b>Number of births</b>				
0-2 births	162	38.2	33.5	42.9
≥3 births	262	61.8	57.1	66.5
<b>Number of surviving children</b>				
No child	128	30.2	<b>25.9</b>	<b>34.7</b>
1-2 children	198	46.7	41.7	51.4
≥3 children	98	23.1	18.9	27.1

\*others: - history of abortion, multiple birth, history of still birth, ANC:- Antenatal care,

### **Anthropometric characteristics and gestational weight**

At enrollment, the average height and weight of the women were 157.95 m and 53.42 kg, with a mean BMI of 20.74 kg/ m<sup>2</sup>, implying that the average of the women fell under the normal body weight category. Women consumed ASF had higher BMI and were heavier than those who did not consume ASF (P<0.05). The mean MUAC of the women was 22.48 cm at enrollment, with ASF consumed group exhibiting a significantly higher MUAC than those who did not consume ASF (P<0.05). By the end of the second trimester, the women's mean weight was 55.97 kg, representing an average weight gain of 2.55 kg, with a weekly weight gain of 0.40 kg. During the third trimester, the women averaged with 57.75 kg, having gained a mean of 4.33 kg since enrollment and 0.55 kg per week, inconsistent with healthy weight gain recommendations.

At the term of the gestation, a mean GWG of 11.64 kg was achieved totally, with a range of 7-15 kg. Pregnant women consumed ASF had significantly higher weight, higher weight gain in both the second and third trimesters and at the term of gestation (P<0.05). By the end of the second trimester, the women's mean MUAC had increased by 1.60 cm from enrollment to 24.08 cm. In the third trimester, the women's mean MUAC was 25.31cm, a 2.83cm increase since enrollment.

The women who consumed ASF had a significantly higher MUAC than those who did not consume ASF in both second and third trimesters ( $P < 0.05$ ) (**Table 29**).

**Table 29:** Anthropometric characteristics and gestational weight gain of cohort of pregnant women by ASF consumption status in baseline and follow up in Northern Sidama zone, Ethiopia (n=424)

Variables	Consumption of animal source food (ASF)					P value
	Not consumed (n=212)	Consumed (n=212)	MD ( $\pm$ SED)	95% CI		
	Mean( $\pm$ SD)	Mean( $\pm$ SD)		Lower limit	Upper limit	
<b>First trimester (enrollment)</b>						
Height in meter	157.65 $\pm$ 6.764	158.25 $\pm$ 6.534	0.604 $\pm$ 0.646	-0.666	1.873	0.350
Weight in kg	49.56 $\pm$ 4.439	57.27 $\pm$ 3.995	7.717 $\pm$ 0.410	6.911	8.523	0.000
Pre-GBMI in kg/m <sup>2</sup>	19.86 $\pm$ 2.513	21.64 $\pm$ 2.660	1.775 $\pm$ 0.251	1.281	2.269	0.000
MUAC in cm	21.51 $\pm$ 1.82	22.44 $\pm$ 1.991	0.925 $\pm$ 0.185	0.560	1.289	0.000
<b>Second trimester (follow up)</b>						
MUAC in cm	21.89 $\pm$ 1.780	26.26 $\pm$ 1.465	4.368 $\pm$ 0.158	4.057	4.679	0.000
Weight in kg	53.88 $\pm$ 6.882	54.42 $\pm$ 6.182	0.538 $\pm$ 0.635	-0.711	1.787	0.398
Weight gain in kg	2.28 $\pm$ 1.129	2.81 $\pm$ 0.850	0.528 $\pm$ 0.097	0.338	0.719	0.000
<b>Third trimester (follow up)</b>						
MUAC	24.18 $\pm$ 1.379	26.44 $\pm$ 1.173	2.259 $\pm$ 0.124	2.015	2.504	0.000
Weight in kg	56.72 $\pm$ 6.564	58.77 $\pm$ 4.638	2.047 $\pm$ 0.552	0.962	3.132	0.000
Weight gain in kg	5.13 $\pm$ 1.611	5.42 $\pm$ 1.211	0.292 $\pm$ 0.138	0.020	0.565	0.035
Total weight gain	11.38 $\pm$ 1.384	11.90 $\pm$ 1.097	0.514 $\pm$ 0.121	0.276	0.753	0.000

*SD-standard deviation, MD- means differences, SED- standard error difference, and CI- confidence interval*

*Inadequate means a MDD  $\leq$  4, and adequate means a MDD  $>$  4,*

### Dietary iron intake, nutrient adequacy and serum ferritin level

A total of 424 eligible participants enrolled in the serum ferritin level investigation, 318 pregnant women (75%) were included in the final analysis (158 with inadequate and 160 with adequate MDD). The overall dropout rate was 25%, balanced across both groups. Reasons for dropout were refusal to provide a blood sample (n=58), inadequate blood sample collected (n=26), absence during sample collection (n=10), and spoiled blood sample (n=12). Additionally, dietary iron intake and its NAR were assessed. The median dietary iron intake was 13.15, with 12.10 lower quartile and 19.40 upper quartile at enrollment, it was 17.7, with 13.0 the lower quartile, and 22.7 the upper quartile in the end line, which fell below the estimated average requirements (EARs) significantly. The means nutrient adequacy ratio was 66.79  $\pm$  23.49 overall groups. Participants consumed an average of 1.32 animal-source foods (ASF) at enrollment, with significant differences between groups ( $p < 0.05$ ). The "ASF consumed" group had a mean of 2.25

ASF, while the "not consumed ASF" group had a mean of 0.4, representing zero food group consumption.

Dietary iron intake differs significantly between women consumed and did not consumed ASF at enrollment ( $p<0.05$ ). Similarly, women consumed ASF had significantly higher dietary iron intake than those who did not consume ASF in the follow up ( $p<0.05$ ). Dietary iron intakes were significantly below the estimated average requirements (EARs) of  $27\mu\text{g}/\text{day}$  at enrollment (2.2%) and at the end of follow-up (9.1%) in both groups. The mean NAR for iron was 0.527 at enrollment, increased to 0.613 by the end of the follow-up. In base line, mean NAR was similar between women with adequate and inadequate MDD ( $p>0.05$ ). But, at the end of follow-up, women consumed ASF had a significantly higher mean NAR than those who did not consume ASF ( $p<0.05$ ).

At enrollment, 92.5% of the women had higher serum ferritin levels compared to the recommended estimates ( $\geq 15 \mu\text{g}/\text{L}$ ), which is increased in to 98.4% at the end of the follow up. The mean serum ferritin level of all participants was  $76.73\mu\text{g}/\text{dl}$  at enrollment; it was increased in to  $84.37$  at the end of follow up. Serum ferritin levels were significantly higher in women who consumed ASF compared to those who did not consume ( $p<0.05$ ) at both enrollment and follow-up. Majority, (83.5%) of the participants had taken iron and folate (IFAS) supplements after conception; however, none of them consumed the supplements three months prior to the onset of pregnancy. Although the number of weeks women consumed the tablet was slightly higher in the consumed ASF than who did not consume ASF, the difference was not statistically significant at enrollment and at the end of follow up ( $P> 0.05$ ) (**Table 30**).

**Table 30:** Intake of dietary iron, nutrient adequacy ratio and serum level of ferritin in cohort of pregnant women by ASF consumption status in baseline and follow up in the northern Sidama zone, Ethiopia, 2025 (n=318)

Variables	Consumption of animal source food (ASF)					P value
	Not consumed (n=158)	Consumed (n=160)	MD( $\pm$ SED)	95% CI		
	Mean ( $\pm$ SD)	Mean( $\pm$ SD)		Lower	Upper	
<b>First trimester (enrollment)</b>						
Dietary iron intake	13.31(1.97)	13.89 (2.39)	0.58 (0.24)	0.904	1.06	0.019
Intake IFAS/12weeks	9.80 $\pm$ 3.65	10.26 $\pm$ 3.73	0.46 $\pm$ 0.36	-1.17	0.24	0.199
NAR of iron	0.53 (0.08)	0.53 (0.07)	0.01(0.01)	-0.01	0.02	0.550
Serum level ferritin	68.07(23.48)	85.29(30.54)	17.22 (3.06)	11.20	23.24	0.000
<b>Third trimester (follow up)</b>						

Dietary iron intake	13.49 (2.52)	18.37 (9.56)	4.88 (0.78)	3.33	6.43	0.000
Intake IFAS/36week	23.80±6.09	24.37±6.32	0.56±0.60	1.75	0.62	0.352
NAR of iron	0.52(0.10)	0.71(0.37)	0.19(0.03)	0.13	0.25	0.000
Serum level ferritin	80.05(29.46)	88.64(26.22)	8.59 (3.13)	2.44	14.74	0.006

\*ng/mL: Nano grams per milliliter, NAR-nutrient adequacy ratio, MD-mean difference, SED- standard error difference, Inadequate- a MDD ≤4, and adequate -a MDD>4, IFAS-iron folic acid supplements

### Pregnancy and birth outcomes at term of pregnancy

At the end of follow up, all (100%) of the births were singleton. Average gestational age at birth was 37.12 weeks, having a birth weight of 3057.63 grams. 23.6% of the births was preterm (2.8% at <32 weeks, 20.8% at 32-36 weeks), with an average birth weights of 1650.18 grams. Among the newborn babies, 68.2% was normal birth weight, with 1.7%, 17.5% and 12.7% extremely low, very low and low birth weights, respectively. The mean birth weight of the newborn babies in both groups was 2883.94 grams. Female infants comprised 51.2% of births, with 13.2% having low birth weight. The mean birth weight of male and female neonates was 2838.45 and 2932.57grams, with no statistically significant differences in means differences (p-value > 0.05). The birth outcomes were differed across both groups, in which women consumed animal source food had significantly higher gestational age at birth, longer duration of follow-up and gave birth to heavier babies (P<0.05) (**Table 31**).

**Table 31:** Pregnancy and birth outcomes of pregnant women by animal source food consumption status at end line (term) in Northern Zone, Sidama Region, Ethiopia, 2025 (n=424)

Variables	Consumption of animal source food (ASF)					P value
	Not consumed (n=212)	Consumed (n=212)	MD(±SED)	95% CI		
	Mean (±SD)	Mean(±SD)		Lower	Upper	
GA at birth	36.89±0.51	37.34±1.01	0.45±0.08	0.30	0.60	0.00
Birth weight	3157.31±590.61	3275.47±604.61	118.16±58.05	-232.26	-4.04	0.042
Duration of follow up	7.10±1.59	7.38±0.84	0.278 ±0.124	0.04	0.52	0.025

### Determinants of low birth weight

Women's school attendance, antenatal care follow-up, intake of dietary iron, dietary diversity score, experience of previous birth, fertility intention, gestational age at term, number of antenatal care follow-ups, iron adequacy ratio and serum level of ferritin were found to be candidates for multivariable analysis at p < 0.05. Accordingly, the multivariate model adjustment was done for potential confounders. Therefore, prevalence of low birth weight was higher among women who had ever given birth (aPR=0.083; 95% CI=0.002, 0.169), not attended formal school (aPR=2.25; 95% CI=1.23–4.14), experienced un intended pregnancy (aPR=2.989;

95% CI=1.293, 6.909), taken dietary iron below EAR (aPR=6.348; 95% CI=4.144-9.724), had inadequate dietary diversity score (DDS<5) (aPR=2.148; 95% CI=1.778-2.596), had low level of serum ferritin (a PR=1.588 (95%CI=1.008-2.502), underweight (pre-pregnancy body mass index < 18.5kg) ( aPR=1.126(95%CI=1.003-1.23), maternal short stature (aPR=11.341(95%CI=1.097-11.421) and under nutrition (MUAC>23) (aPR=1.141(95%CI=1.025-1.270) compared to those who given birth normal body weight baby (**Table 32**).

**Table 32:** Determinants of low birth weight in cohort of pregnant women in the northern zone of the Sidama region, Ethiopia, 2025, (n=424).

Variable	Birth weight		cPR (95% CI)	aPR (95% CI)	P value
	Low (n=135)	Normal (n=289)			
<b>Ever given birth</b>					
Yes**	96(71.1%)	211 (73%)	3.52(2.62–4.70)	0.083(0.002 –0.169)	0.001
No	39(28.9%)	78(27%)	Ref		
<b>Intention to fertility</b>					
Unintended**	18(13.3%)	35(12.1%)	4.300(2.161–8.557)	2.989(1.293– 6.909)	0.010
Intended	117 (86.7%)	254(87.9%)	Ref		
<b>Dietary diversity score</b>					
Inadequate (1-4)**	74(54.8%)	183(63.3%)	7.89(4.898-12.724)	2.148 (1.778-2.596)	0.001
Adequate (≥5)	61 (45.2%)	106(36.7%)	Ref		
<b>Intake of dietary iron</b>					
<27(EAR)**	123(91.1%)	256(88.6%)	4.219(3.269–5.445)	6.348(4.144-9.724)	0.001
≥27(EAR)	12(8.9%)	33(11.4%)	Ref		
<b>Serum level of ferritin (n=318)</b>					
<15µg/L**	3(2.2%)	21(11.5%)	0.068 (0.502–0.913)	1.588(1.008–2.502)	0.046
≥15µg/L	132(97.8%)	162(88.5%)	Reference		
<b>School attendance</b>					
No**	14 (10.4%)	14(4.8%)	4.14(3.20–5.35)	2.25 (1.23–4.14)	0.009
Yes	121(89.6)	275(95.2%)	Ref		
<b>Pre-pregnancy BMI</b>					
<18.5-24.9 kg/m <sup>2</sup> **	14(10.4%)	34(11.8%)	1.068(1.056–1.081)	1.126 (1.003 – 1.23)	<0.007
≥18.5-24.9 kg/m <sup>2</sup>	121(89.6%)	255(88.2%)	Ref		
<b>Height of the women</b>					
<145cm**	4(3.0%)	1(0.4%)	1.008(1.007–1.010)	11.341(1.097– 11.421)	0.042
≥145cm	131(97.0%)	288(99.6%)	Ref		
<b>Mid-Upper Arm Circumference</b>					
<23cm**	10(7.4%)	58(20%)	1.056(1.046–1.066)	1.141(1.025–1.270)	0.016
≥23 cm	125(92.6%)	231(80%)	Ref		

Ref. Reference group, AOR- Adjusted Odd Ratio, COR-Crude Odd Ratio, \*\*- statistically significant at adjusted prevalence rate,

## Discussions

We aimed to assess the association of anthropometric indicators, GWG, and serum ferritin deficiency during pregnancy and the risk of low birth. LBW is regarded as a public health concern when it exceeds 15% (EDHS, 2017). In addition, maternal undernutrition is highly prevalent in resource-poor settings, generally ranging from 10% to 19% but reaching 20% in SSA, in which more than 95% of the estimated 20 million babies born annually have LBW (Tang *et al.*, 2016). The current study reported a prevalence of LBW at 31.8%, which lied above the range of resource-poor countries, and reported in previous studies conducted in eastern (Komicha *et al.*, 2021; Fite *et al.*, 2023) and southern Ethiopia (Endalamaw *et al.*, 2018). Possible discrepancy may be attributed to differences in sociocultural factors and the study designs used.

Additionally, the prevalence of LBW was higher than that reported in studies conducted in Iran (Moghadda *et al.*, 2012), Ethiopia (Mulatu *et al.*, 2017) and Malaysia (Yilgwan *et al.*, 2010). The possible reason for the discrepancy might be the differences in socioeconomic status. All three studies were conducted in urban settings; however, the majority of participants in the current study were from rural settings. Therefore, higher prevalence was identified in the study area where the burden of the problem is expected to be the highest. The current study reported that pre-pregnancy BMI was a significant predictor of LBW. The report was consistent with reported from previous studies conducted in developing countries (Kalanda, 2007; Singh *et al.*, 2009) that approved low pre-pregnancy BMI as a significant predictor of adverse pregnancy outcomes, like LBW.

The current study found that maternal short stature and lower MUAC were significant predictors of LBW of the new born. The findings were consistent with previous studies conducted in LMICs, in which under nutrition in women, before and during pregnancy, is recognized as a key determinant of LBW babies (Tang *et al.*, 2016). Additionally, maternal short stature, low pre-pregnancy BMI, low GWG, MUAC of less than 23 cm at two time points, and gestational age at delivery showed positive correlation with LBW. The findings are consistent with those reported from the studies conducted in India (Vasundhara *et al.*, 2020) and from public hospitals in Addis Ababa (Mulu *et al.*, 2020). Possible reason for the discrepancy was socio economic and methodological differences. The current study was conducted in rural communities where there

are different determinants influencing the height of the women directly or indirectly, like food insecurity and low DD. However, the finding of the study conducted in California singleton, live births in (2007-2010) was inconsistent with the present result (Shachar *et al.*, 2015).

Similarly, women with a height of 157.5 cm or less had an increased risk of idiopathic preterm labor, as did those with a pre-pregnancy BMI less than 19.8 kg/m<sup>2</sup>. Findings reported in the retrospective study conducted in Canada revealed that among women with a normal BMI, short maternal height is associated with spontaneous PTB. Among women who are overweight or obese, short maternal height is associated with an increased risk of indicated PTB (Crane *et al.*, 2025). The current study identified that the mid-upper-arm circumference was significantly associated with LBW. The finding was in line with another study conducted in Switzerland (Ververs *et al.*, 2013); MUAC was identified as the preferred indicator because of its relatively strong association with LBW. Additionally, previous studies among pregnant women have shown a consistent association between low maternal MUAC and an increased risk of having a LBW baby (Tang *et al.*, 2016).

The current study reported that mothers who failed to gain sufficient weight during their pregnancy were at a higher risk of having a LBW baby. The finding was supported by the previous studies that suggested insufficient GWG was significantly associated with an increased risk of anemia, premature rupture of membranes (PRoM), IUGR, and lower gestational age at delivery (Montvignier *et al.*, 2022). Inconsistent with our findings, another study conducted in China indicated that increased GWG is associated with a higher risk of abnormal birth weight in singleton pregnancies (Hu *et al.*, 2024). The possible reasons for the discrepancy might be differences in the socio-economic status of the study subjects.

The study subjects from China, a well-developed nation, were from urban settings. However, the majority of participants in our study were from rural areas, which highlighted a relatively low weight gain during pregnancy. Gestational weight indicators from early pregnancy through 9 lunar months demonstrated high odds ratios for LBW; a strong effect size was attained for birth weight when applied to women with below-average weight during early gestation.

The finding was in line with previous analysis of systematic review (McDonald *et al.*, 2011). Additionally, weight gain throughout pregnancy was a significant predictor of PTB. The finding was in line with the previous study that reported pregnant women with low GWG were with

increased risk of idiopathic preterm labor (Cornish *et al.*, 2024). Similarly, maternal weight gain of less than 6.53 kg during the second and third trimesters posed a risk factor for LBW (Arabzadeh *et al.*, 2024). An umbrella review examining the risk of LBW also recommended a healthy diet to achieve optimal birth weight (K C *et al.*, 2020).

Our findings indicated a statistically significant relationship between serum ferritin levels and both birth weight and gestational age. The findings were consistent with previous studies conducted in Iran (Bazmamoun *et al.*, 2022) and in a Spanish population (Gaspar *et al.*, 1993; Milasinović *et al.*, 2013). The studies suggested that the value of ferritin, hemoglobin, hematocrit, and erythrocytes was significantly higher in women with LBW babies. In mothers with LBW newborns, serum ferritin level was on average 6.4 g/l higher than in mothers with normal-weight newborns. The proportion of ferritin level in all term groups was significantly higher than that in the preterm group, but there was no difference among the preterm groups. In addition, ferritin levels in each preterm group were statistically significantly higher than those in the term pregnancy group at the same gestational age. These findings were inconsistent with findings of a previous study conducted in Mahdih Hospital in Tehran (Jahedbozorgan *et al.*, 2020). Possible reasons for variations may be due to the differences in sociocultural and study designs used.

Our study reported that PTB (28-36 weeks), inadequate dietary iron intake, low DD scores, unintended fertility, ever having given birth, and not attending formal education were found to be the risk factors for LBW. The findings were consistent with those reported in previous studies conducted in Ethiopia (Girma *et al.*, 2019; Deriba and Jemal, 2021), which confirmed that insufficient meal intake, maternal undernutrition, anemia, and inadequate DDS were independently linked to LBW. Previous studies conducted in Malaysia (Yilgwan *et al.*, 2010), Uttar Pradesh (Barman *et al.*, 2021) and India (Pal *et al.*, 2020) also supported the report, which found that the educational status of the mother, the duration of pregnancy, and the intake of additional meals were significantly associated with LBW. Likewise, another study conducted in eastern India indicated that mothers who gave birth to preterm babies are at an increased risk of having LBW infants. However, mothers who receive regular antenatal checkups, as well as those with primary and secondary education, have a lower risk of having LBW babies (Panda *et al.*, 2022). Findings from previous studies in Pakistan indicated that maternal illiteracy and unintended pregnancies significantly increased the risk of LBW (Jalil *et al.*, 2015; Hall *et al.*,

2017). Our findings supported this report, suggesting that LBW may be more prevalent in unintended pregnancies.

We found that there was an increased risk of LBW in neonates born to mothers with serum ferritin deficiency ( $<15 \mu\text{g/L}$ ). The finding is in line with the finding reported from a previous study in eastern Ethiopia (Fite *et al.*, 2023) and in a tribal district of Odisha, India (Bishnu *et al.*, 2022) that mothers who had a hemoglobin level  $< 11 \text{ mg/dl}$  and had no additional diet during pregnancy had an increased risk of having a LBW baby. Iron deficiency is associated with adverse pregnancy outcomes, including increased maternal illness, LBW, and prematurity (Georgieff, 2020) which supports our finding. We found that PTB was a statistically significant factor for LBW babies. Previous randomized trials of iron supplements evaluating iron status during pregnancy supported our findings, which confirmed that when detected early in pregnancy, iron deficiency anemia (IDA) is associated with a less than 2-fold increase in the risk of preterm delivery (Scholl, 2005).

Maternal anemia, when diagnosed before mid-pregnancy, is also associated with an increased risk of PTB. Results of recent RCT in the United States, which involved early supplementation with iron, showed minimal reduction in the risk of LBW or preterm low birth weight. But, during the 3rd trimester, maternal anemia is usually not associated with increased risk of adverse pregnancy outcomes (CDC, 2002).

### **Conclusion**

Low birth weight is a significant problem. Maternal underweight and under nutrition (indicated by low MUAC and short stature) are significant determinants of low birth weight. Insufficient intake of dietary iron is resulted depletion of total body iron stores (indicated by low serum ferritin) significantly associated with low birth weight. Encouraging women to consume animal source foods and promoting early monitoring of maternal nutritional status during pregnancy are crucial to reduce the risk of low birth weight.

### **Strengths and limitations of the study**

The strength of this study is that being community-based; it could reflect the actual experience of women during the study period. The limitation of this study is the methodological nature of the 24-hour dietary recall method of data collection, which is prone to recall bias. This is because the information was collected by the study participants' self-report. Careful designs of the initial 24-hour recall protocol and standardized multiple-pass interviewing techniques have been used

to minimize errors generated by memory lapses and distortions. Additionally, memory aids such as photographs and “probing” have been used to identify the correct species.

## CHAPTER IX: DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

### 9.1. General Discussion

An adequate intake of essential nutrients is crucial for optimal health. Proper maternal nutrition is vital for healthy pregnancy progression, optimal fetal development, and achieving a normal birth weight for the baby. A well-balanced diet during pregnancy should provide sufficient energy and all essential nutrients, including protein, fats, carbohydrates, vitamins, and minerals (Maqbool *et al.*, 2019). Nutritional adequacy is reached when nutrient needs are fulfilled, such as meeting RDAs or adequate intakes (Yari *et al.*, 2022). Therefore, the purpose of this study is to assess whether maternal diets during pregnancy are sufficient in micronutrients. The study aims to encourage mothers to consume a variety of foods through nutrition education and dietary interventions, which will enhance the adequacy of nutrients and serum levels of essential micronutrients. This, in turn, would improve the nutritional status of mothers and the outcomes for their newborns.

The NFFS (EPHI, 2021; Habte *et al.*, 2022), along with the NNP-II micronutrient deficiency reduction target setting (FDRE, 2016), and initiatives for bio-fortification (Habte *et al.*, 2022) aims to promote dietary diversity (DD) in Ethiopia (Jateno *et al.*, 2023). However, the findings of the study indicate a notable inconsistency: the range of food groups consumed by the participants varied from a minimum of one to a maximum of seven. The median DDS was 3.0, with a SD of  $\pm 1.48$ . On average, 3.42 pregnant women met the DDS, while 4.67 met the FVS in the 24 hours preceding data collection. The majority of the participants consumed starchy staple foods, with dark leafy vegetables being the second most common at 79.2%. In contrast, nutrition-dense food groups such as animal products, eggs, other fruits and vegetables, and dairy were consumed much less frequently, at 2.1%, 0.03%, 13.9%, and 18.4%, respectively. These findings align with a report from UNICEF, which highlighted that micronutrient deficiencies occur when people lack access to micronutrient-rich foods, such as fruits, vegetables, animal products, and fortified foods, often due to their high cost or unavailability (UNICEF, 2009).

Micronutrient deficiencies represent a significant global public health issue, impacting over 2 billion people worldwide, with the majority residing in LMICs. These individuals often suffer from deficiencies in multiple essential vitamins and minerals (UNICEF, 2009). This study found that a considerable number of pregnant women—specifically, 139 (87%) and 128 (80%)—did

not meet the WHO recommended RDA for iron and folate, respectively. As a result, the levels of these micronutrients were alarmingly low in the study area, underscoring the prevalence of folate and iron deficiencies as critical public health concerns.

The findings are consistent with a study conducted in Ethiopia, which revealed that among women of reproductive age, the prevalence of vitamin B12 deficiency is 15.1%, and serum folate deficiency is 17.3% (Samuel *et al.*, 2025). This aligns with the Ethiopian national micronutrient survey, which reported prevalence rates of vitamin B12, serum folate, and RBC folate deficiencies among these women at 15.1%, 17.3%, and 32%, respectively (Abera Hailu, 2017). Given the variation in micronutrient deficiency levels between intervention and control groups, targeted interventions are essential to address these issues. Recommendations for such interventions include food fortification, micronutrient supplementation, health promotion, and disease prevention programs. These strategies are consistent with the Ethiopian National Nutrition Program (NNP), which aims to strengthen efforts to combat the high prevalence of micronutrient deficiencies and related health issues in Ethiopia (Abera Hailu, 2017).

Maternal intake of adequate nutrients from a variety of foods was assessed over a month-long period using a standard DD assessment tool. This was done through 24-hour consumption recalls prior to the survey date (FANTA, 2007; FAO, 2021), which addressed the primary focus of this study. The results indicated that only 39.9% and 36.3% of pregnant women consumed a diverse diet with a variety of foods, resulting in low means and SD for both the DDS and the FVS. This finding aligns with previous research (Kennedy, *et al.*, 2013; H, Wilna *et al.*, 2014), which reported similarly low means and SDs for DDS and FVS, highlighting issues of household food insecurity within the South African community. The mean DDS among women showed a positive correlation and demonstrated a strong predictive ability for the MAR of micronutrients, indicating its effectiveness in assessing micronutrient adequacy. This finding is consistent with reports from other low-resource settings (Arimond *et al.*, 2011). However, higher MAR values for micronutrients were reported in Iran (371.07) (Karimi *et al.*, 2022) (50), 63% from South Africa (H, Wilna *et al.*, 2014) and ranges from 0.161 to 0.484 in China (Zhong *et al.*, 2022).

The nutrient adequacy of the micronutrients was assessed by calculating the (NAR, %) for each of the 11 micronutrients, as outlined by FAO and WHO (FAO and WHO., 2002). There was significant variation in nutrient adequacy across individual micronutrients, with values ranging

from 0.03 to 32.27. Calcium and vitamin C had the lowest estimated prevalence of nutrient adequacy at 0.1, while iron, vitamin B12, zinc, thiamin, folate, riboflavin, and vitamin B6 showed a range from 0.22 to 0.56. Niacin had an adequacy of 1.06, and vitamin A had the highest at 32.27. This finding contrasts with a report from Mali, which indicated that the highest prevalence of nutrient adequacy was observed for zinc, vitamin C, and vitamin B6 (Kennedy, *et al.*, 2013).

Research on maternal and child undernutrition has revealed a deficiency in multiple micronutrients, including zinc, folic acid, calcium, and vitamin D (Black *et al.*, 2018). Additional studies have shown that deficiencies in multiple micronutrients are more prevalent than deficiencies in any single nutrient alone (Karimi *et al.*, 2022). The findings of the current study align with these observations, indicating a significant variation in nutrient adequacy for individual micronutrients, with values ranging from 0.03 to 32.27. This variance may be attributed to differences in socioeconomic status among the study participants. Notably, the majority of subjects in this analysis resided in rural areas, where the consumption of nutrient-dense foods, particularly ASF, was significantly below the RDA.

Data on micronutrient deficiencies in Ethiopia is expected to inform the design, implementation, and evaluation of the country's NFFS and the NNP Phase II micronutrient deficiency reduction targets. This information will also support initiatives for bio-fortification and other programs aimed at promoting DD in Ethiopia. Additionally, it will contribute to local and regional planning, as well as enhance the teaching and learning processes in academic institutions (Abera Hailu, 2017). In line with this, the current study found that 97.9% of pregnant women did not consume meat, 99.7% did not consume eggs, and 81.6% did not consume dairy products over a one-month period. These findings are consistent with the repr of previous study (H, Wilna *et al.*, 2014), which indicated that the inclusion of nutrient-dense food groups in the diets of pregnant women in LMICs is limited. However, the current study's findings are inconsistent with that of Arimond and his colleagues (Arimond *et al.*, 2011), which reported that the consumption of nutrient-dense food groups ranged from 32% in the Philippines to 47% in both Mali and Mozambique, 38% in Burkina Faso, and 35% in Bangladesh. The discrepancy may be attributed to differences in the study areas; the referenced research focused on urban women who consumed animal source foods and millet—both staple diets that are good sources of zinc and iron (Kennedy, *et al.*, 2013).

Enhancing the production and marketing of micronutrient-rich foods, combined with nutrition education, food fortification, bio-fortification of staple foods, supplementation, and disease control measures, has been identified as the primary interventions to prevent micronutrient deficiencies (Samuel *et al.*, 2025). The current study supports this report, indicating that nutrition education significantly improved the intake of dietary iron and folate. Additionally, there were notable changes in the average scores for nutrient adequacy and serum levels of ferritin and folate. In line with these findings, the Ethiopian government, along with its development partners, has demonstrated a steadfast commitment to combating malnutrition and addressing micronutrient deficiencies (Abera Hailu, 2017). Consequently, the government has developed a NNP and established targets to prevent and control micronutrient deficiencies among pregnant and lactating women (Abera Hailu, 2017).

The MOH of Ethiopia has implemented various nutritional programs and services aimed at reducing micronutrient deficiencies in the country. These initiatives include micronutrient supplementation, community health days, and other nutrition-related programs (Abera Hailu, 2017). Our study supported by policy, utilized nutrition educators who employed educational guides, the HBM, and trimester-based nutrition education to enhance maternal consumption of a diverse diet. The NEI, based on the HBM, improves pregnant women's knowledge of diet, DD, and nutritional status (Chitsaz *et al.*, 2017). This is further corroborated by studies conducted in Ethiopia (Diddana *et al.*, 2018; Beressa *et al.*, 2024). Research from various parts of the world supports the idea that using this strategy for providing nutrition education can raise awareness about appropriate nutrition intake and DD during pregnancy, which is useful in preventing chronic illnesses (Naghashpour *et al.*, 2014).

The existing education offered for pregnant by the healthcare system lacks counseling guides, a health behavior model, or a theoretical framework (Beressa *et al.*, 2024). However, previous studies revealed that the implementation of HBM-based nutrition education, significantly improved intakes of dietary folate and iron, as well as nutrition knowledge and dietary practices among pregnant women. This improvement occurred through increased perceptions of susceptibility, severity, and benefits, along with decreased perceptions of barriers. These findings align with those of other studies (Zelalem *et al.*, 2017; Diddana *et al.*, 2018; Beressa *et al.*, 2024; Tesfaye *et al.*, 2024). The observed enhancement in knowledge and practices may be attributed to the fact that, following HBM-based NEI, women began to recognize the severity and

consequences of malnutrition. Also they came to believe that benefits of consuming a varied and adequate diet outweighed the challenges associated with obtaining a diverse diet.

The health education intervention can positively affect attitudes and behaviors, particularly in women's intentions to adopt a balanced diet (Beressa *et al.*, 2024). The findings of this study support these claims, showing statistically significant differences in the net mean intake of dietary iron and folate between the intervention and control groups. Specifically, the intervention group demonstrated a significant improvement in dietary iron and folate intake compared to the control group. These results are consistent with other studies conducted in Dessie town, northeast Ethiopia (Zelalem *et al.*, 2017; Diddana *et al.*, 2018). A possible explanation for this improvement is that nutrition education fosters better knowledge, practices, and attitudes, leading to changes in nutritional behavior.

Studies have confirmed that providing nutrition education using the HBM significantly improves women's knowledge, practices, and attitudes toward diverse diets (Diddana *et al.*, 2018). However, the effectiveness of nutrition education in changing actual eating behaviors is often limited (Beressa *et al.*, 2024). The nature of NEI is complex (Zelalem *et al.*, 2017), making a long-term behavior change challenging when relying solely on education alone (Beressa *et al.*, 2024). This is because various factors, such as seasonality, distance to markets, family poverty, gender inequities, and cultural or religious traditions, influence the effectiveness of NEI (Hirvonen *et al.*, 2016). Therefore, it is essential to use a combination of education and supplementary strategies while creating an environment that supports individuals in applying what they have learned. This approach is crucial for the success of nutrition education programs (Adeoya *et al.*, 2023).

The serum levels of folate and ferritin were evaluated using blood samples collected aseptically from the antecubital vein. The cut-off values for serum ferritin and serum folate were determined based on international standards for pregnant women, referencing the WHO cut-off values: 14.7–184.3 mg/L for serum ferritin (WHO., 2012) and 10 nmol/L (4 ng/mL) for serum folate (Rogers, 2018). Four months after the intervention, the results indicated a significant difference in the mean scores of dietary folate and iron intake, as well as DD, between the intervention and control groups. Other studies have also supported these findings (Diddana *et al.*, 2018; Tesfaye *et al.*, 2024). More specifically, the mean scores for iron and folate adequacy were notably

higher in the intervention group. Additional research corroborates these results, showing significant increases in the percentage of the RDA met for various nutrients, such as energy, carbohydrates, riboflavin, and niacin, in the nutritional profiles of adolescents and young adults (Sachithanathan *et al.*, 2012). Furthermore, nutrition education during pregnancy has been shown to help combat undernutrition among pregnant women (Beressa *et al.*, 2024).

Significant differences were observed in the mean serum levels of ferritin and folate within the intervention group. These results are parallel with other study, which confirmed that participating in a nutrition education program can have a positive impact on various biochemical indicators among pregnant women (Sharifat *et al.*, 2024). The findings of this study revealed a notable improvement in HBM constructs in intervention group after the program, compared with control group. Furthermore, there was a significant difference in all dimensions of HBM based on the end-line data. These results align with previous research (Zelalem *et al.*, 2017; Diddana *et al.*, 2018; Tesfaye *et al.*, 2024). Additionally, with the exception of perceived severity, all the HBM constructs demonstrated a strong correlation with serum folate levels. This finding is consistent with another study that showed a strong correlation between HBM constructs and dietary practices (Beressa *et al.*, 2024).

The EDHS report indicated that a higher proportion of pregnant women are anemic, with a prevalence of 22% (EDHS, 2017). Additionally, a survey providing nationally representative estimates on anemia and deficiencies of key micronutrients—such as iron, vitamin A, iodine, zinc, B12, and folate—revealed that micronutrient deficiencies are more pronounced among rural residents. Specifically, the prevalence of iron deficiency among women of reproductive age, as measured by ferritin and adjusted for inflammation, was 17.8%, 9.1%, and 10.0%, respectively. The prevalence rates for vitamin B12, serum folate, and RBC folate among women of reproductive age were 15.1%, 17.3%, and 32%, respectively (Abera Hailu, 2017). Using the findings of this survey as a benchmark, the current study implemented dietary interventions that included egg-based diet supplementation along with healthy nutrition advice to enhance the nutritional status and micronutrient adequacy of pregnant women. As a result, the intake of an egg-based diet improved the adequacy of iron, folate, calcium, vitamin A, vitamin B12, and vitamin D at the end of the study.

In the intervention, cluster randomization was used instead of individual-level randomization to minimize information contamination. At the end of the study, the average intake of several nutrients significantly increased in the intervention group. This finding aligns with studies conducted in Ghana and France. These studies demonstrated that egg consumption can help bridge the gap between daily nutrient intake and recommended levels, particularly during early life stages (Sophie *et al.*, 2019). This is achieved by increasing the intake of six key nutrients—choline, docosahexaenoic acid, folate, vitamin D, iodine, and iron—identified as crucial in the maternal diet for child brain development (Cheatham, 2019), most of which are found in eggs. Additionally, research has shown that eggs provide a wide range of nutrients, including vitamins A, B1, B2, B3, B5, B6, B9, B12, and D, as well as choline, biotin, calcium, phosphorus, potassium, magnesium, manganese, iron, zinc, iodine, selenium, and bioactive components such as lutein and zeaxanthin (Sophie *et al.*, 2019).

Additionally, the intake of nutrients was higher, and the prevalence of deficiencies was lower in the egg group compared to the control group for iron, folate, calcium, vitamin A, vitamin B12, and vitamin D by the end of the study. This finding aligns with the results of a study conducted in Malawi (Caswell *et al.*, 2021). While the egg intake intervention led to increased consumption of protein and several micronutrients, the overall intake and MAR of essential micronutrients still remained significantly below the recommended levels. This observation is consistent with findings from the same Malawi study (Caswell *et al.*, 2021). Moreover, during pregnancy, egg consumption met the recommended intake levels for protein, vitamin D, and vitamin A. This study supports previous research indicating that eggs are the most cost-effective food source for protein, choline, and vitamin A, ranking second for vitamin E and third for vitamin D (Sophie *et al.*, 2019).

The analysis of essential micronutrient intake, including iron, calcium, folate, vitamin B12, vitamin A, and various vitamins, showed a strong correlation with agricultural land ownership. The findings highlighted that women in the lowest wealth quintile had a low consumption of eggs. This aligns with studies conducted in the USA and France (Lutter *et al.*, 2018; Sophie *et al.*, 2019), which indicated that egg consumption was significantly associated with socioeconomic status, demonstrating a dose-response relationship among women in the lowest wealth quintile. Given the current economic climate, eggs offer an affordable, natural, easy-to-prepare, bioavailable, and environmentally friendly source of nutrition. Consuming eggs during

pregnancy is a cost-effective way to obtain a nutrient-dense whole food that provides a wide array of nutrients, which are readily absorbed and metabolized (Derbyshire, 2024).

Current evidence indicates that a significant number of pregnant women in both groups were underweight at the beginning of the study. After the intervention, the proportion of participants who gained less than 11.5 kg in the third trimester was notably lower in the intervention group compared to the control group. This finding aligns with studies conducted in Indonesia (Aisa *et al.*, 2020) and Nigeria (Ojofeitimi, 2020), which reported that the maternal mean weight gain was 9.24 kg in the experimental group, significantly higher than the 6.13 kg observed in the control group.

The findings of this study indicated that egg-based diet interventions were positively associated with mid-upper arm circumference (MUAC) among pregnant women. The net mean difference in MUAC between the intervention and control groups was 2.204 cm, which was statistically significant ( $p < 0.05$ ). Pregnant women in the intervention group showed a significant improvement in MUAC compared to those in the control group. These findings align with other studies conducted in rural Ethiopia (Demilew *et al.*, 2020; Beressa *et al.*, 2024). One possible explanation for this outcome is that, in addition to receiving a nutrient-dense egg-based diet, the provision of healthy dietary advice may encourage favorable attitudes and lead to positive changes in nutritional behavior. In fact, nutritional interventions resulted in an increase of 0.318 cm in MUAC among rural pregnant women. However, the results contrast with studies conducted in urban Ethiopia and Rwanda (Demilew *et al.*, 2020; Habtu *et al.*, 2022), where a significant improvement in MUAC was observed among pregnant women after the intervention. This discrepancy may be attributed to the effectiveness of the nutritional intervention, which included dietary advice provided by HEWs for improving the MUAC of pregnant women.

The average MUAC was significantly greater in the intervention group compared to the control group. These results align with findings from a study conducted in Rwanda (Habtu *et al.*, 2022). The proportion of participants with a BMI less than 18.5 kg/m<sup>2</sup> in the first trimester was significantly lower ( $p = 0.010$ ) among women in the intervention group than in the control group. Additionally, the average weight during the first and third trimesters was significantly higher among participants in the intervention group ( $p < 0.001$ ). Moreover, the average weight gain from the first to the third trimester was also greater in the intervention group, with the

differences being statistically significant ( $p < 0.05$ ) between the two groups. These findings are consistent with the results of the study conducted in Rwanda (Habtu *et al.*, 2022). Maternal undernutrition was defined as having a low MUAC  $< 23$  cm during delivery, a low BMI ( $< 18.5$  kg/m<sup>2</sup>) in the first trimester, or both (Habtu *et al.*, 2022).

The neonatal mortality rate in Ethiopia for 2024 is reported to be 27 deaths per 1,000 live births. This statistic signifies the number of deaths of infants under 28 days old for every 1,000 live births in a given year (Tekeba *et al.*, 2024). Several factors have been associated with PTB, including the inability to access IFAs, not consuming additional meals, food restrictions, a lack of dark green leafy vegetables, and a maternal MUAC of less than 23 cm (Deriba, 2021). This rate remains relatively high compared to the Sustainable Development Goal (SDG) target of 12 deaths per 1,000 live births by 2030 (United Nation, 2020). Current studies support findings that highlight the nutritional status of mothers, including anthropometric indicators and serum levels of essential micronutrients (such as iron and folate), as risk factors for poor pregnancy outcomes.

Data on serum folate was collected from blood samples taken during the first trimester for biochemical analysis. Participants were interviewed personally, and blood samples were collected during their initial antenatal visit to assess the relationship between anthropometric indicators, GWG and serum folate levels during pregnancy, as well as the risk of PTB. PTB is considered a public health concern due to its impact on child mortality (Chawanpaiboon *et al.*, 2019). Although the incidence and mortality rates associated with PTB have shown a declining trend, regions with a low Socio-demographic Index (SDI) have experienced an increase in annual incidence cases, while high SDI regions have reported a decrease. The highest annual mortality rates from PTB occur in SSA (Liang *et al.*, 2024), including Ethiopia, which is among the countries facing the greatest burden of PTB (Kibret *et al.*, 2024). In the current study, approximately 24% of the neonates were born preterm, a figure that aligns with findings from a systematic analysis of the burden of PTB (Liang *et al.*, 2024) and observational studies conducted in Ethiopia (Yilkal *et al.*, 2022).

The findings of the present study indicate that female neonates are more likely to be born preterm compared to male neonates. This result contradicts the systematic analysis by Liang *et al.* (Liang *et al.*, 2024) which showed that male neonates are more commonly born preterm than females. A possible explanation for this discrepancy could be related to the different study

settings and designs. In this study, gestational age was used as a cut-off point to determine the outcome variable, defined as being less than 37 completed weeks of gestation. The rate of PTB was found to be 23.58%, with a 95% CI of 19.8% to 27.6%. This rate is notably higher than the 12.3% and 11.5% identified in the Global Action Report for SSA countries and a study conducted in Brazil in 2016 (Howson *et al.*, 2013; Leal *et al.*, 2016).

The studies conducted in public health facilities in Dodola, Axum, and Gondar town revealed that the rates of PTB were 13%, 13.3%, and 4.4%, respectively (Gebreslasie, 2016; Aregawi *et al.*, 2019; Handiso *et al.*, 2019). These differences may be attributed to variations in study settings and locations, suggesting that our study area carries a higher risk due to various health-related issues, such as service quality and differences in the medical history related to health and pregnancy among participants from other regions. Moreover, the findings of this study indicate a higher prevalence of preterm births compared to a previous study conducted in northern Ethiopia, which reported a prevalence rate of 16.1% (Kibret *et al.*, 2024). The discrepancy may result from methodological differences; the current study was conducted in rural areas, which typically exhibit more risk factors for PTB than the urban settings of the earlier research.

The findings of this study were lower than those reported in other studies conducted in Ethiopia and Cameroon, which indicated that 25.5% and 26.5% of neonates were born preterm to their index mothers (Chiabi *et al.*, 2013; Israel *et al.*, 2017). Similarly, the prevalence of preterm delivery in the present study was lower than the 25.9% reported in a study conducted at Jimma University Specialized Hospital (Israel *et al.*, 2017). These differences may be attributed to our study's exclusion of multiple gestations and participants with a history of abortion. Additionally, the study at Jimma University found a high prevalence of alcohol and substance use during pregnancy, which could contribute to an increased rate of preterm birth in that area. In contrast, such factors were not prevalent in our study.

The findings of the present study indicate a higher prevalence of preterm birth (PTB) compared to studies conducted in public hospitals in Ethiopia and Kenya, which reported rates of 13.2%, 10.48%, and 20.2% respectively (Wagura *et al.*, 2018; Muchie *et al.*, 2020; Ayele *et al.*, 2023). These differences may be attributed to varying study conditions; for instance, some studies involved surgical evacuation of the uterus, a procedure that mechanically stretches the cervix and could predispose mothers to PTB in subsequent pregnancies. Moreover, the results of our study

contradict those of other investigations in public hospitals in Ethiopia and Malaysia, which reported PTB rates of 16.15% and 16.9%, respectively (Deressa *et al.*, 2018; Sutan *et al.*, 2018). These inconsistencies might be due to the specific study areas and settings. Our research was conducted in rural regions, where participants were more susceptible to risk factors for PTB. In particular, individuals in our study were found to consume a less diverse diet, with notably lower levels of dietary folate compared to participants from studies conducted in public hospitals in Addis Ababa and Malaysia.

The results of this study indicated that lower maternal folate levels in early pregnancy are associated with an increased risk of preterm birth (PTB). This finding is supported by previous analyses from a systematic review and meta-analysis (Zhang *et al.*, 2019), which reported that higher maternal folate levels were linked to a 28% reduction in the risk of PTB. Additionally, our study found a significant positive association between dietary folate intake and the risk of PTB. This lines up with similar research, which identified a significant negative relationship between dietary folate intake and PTB risk. However, no significant relationship was observed between IFAS and a decreased risk of PTB. In contrast, prior research showed that higher IFAS was associated with a 10% lower risk of PTB (Zhang *et al.*, 2019).

In our study, we found that a higher score in DD, which was associated with increased consumption of major nutrients and a greater variety of foods, correlated with a lower risk of PTB. This finding is in agreement with a previous systematic review conducted in Ethiopia. However, it contradicts another systematic review from Ethiopia (Tareke *et al.*, 2024), which reported no significant association between maternal DD and PTB. The disparity in findings may be attributed to differences in study design; the previous study was a meta-analysis. Moreover, maternal undernutrition is highly prevalent in resource-poor settings, with rates typically ranging from 10% to 19%, and exceeding 20% in some areas. For instance, in SSA, approximately 28.7% of an estimated 134,767,000 babies born annually are classified as PTB (Ohuma *et al.*, 2023).

The prevalence of PTB in the study area was found to be 23.58%, which is lower than the South African average, where the estimated gestational age at birth is  $37.62 \pm 1.74$  weeks. Consistent with this finding, approximately 15% of all PTB cases occurred before 32 weeks of gestation, necessitating additional neonatal care. Specifically, 4.2% of births were before 28 weeks, and

10.4% occurred between 28 and 32 weeks (Ohuma *et al.*, 2023). The present study identified significant associations between low GWG, maternal MUAC of less than 24 cm, and LBW with the occurrence of PTB. Mothers with a MUAC of less than 24 cm had a 0.048 times increased risk of developing PTB compared to those with a MUAC of 24 cm or greater. This finding aligns with previous studies conducted in northwest Ethiopia (Mekonen *et al.*, 2019), as well as studies in Bangladesh (Shah *et al.*, 2014). Furthermore, the results were consistent with findings from research conducted in India (Vasundhara *et al.*, 2020), and Switzerland (Ververs *et al.*, 2013), both of which identified a strong association between MUAC and PTB. Additionally, past studies on pregnant women have consistently demonstrated that low maternal MUAC is linked to an increased risk of PTB (Tang *et al.*, 2016).

The present study found that a maternal height of less than 145 cm was not a statistically significant predictor of PTB. This result is supported by reports from public hospitals in Addis Ababa (Mulu *et al.*, 2020). However, it contrasts with findings from a study conducted in California involving singleton live births between 2007 and 2010 (Shachar *et al.*, 2015). The discrepancy may be attributed to socioeconomic and methodological differences. The current study was conducted in rural communities, where various factors, such as food insecurity and low DD, can directly or indirectly influence women's height.

Similarly, women with a height of 157.5 cm or less had an increased risk of idiopathic preterm labor, as did those with a pre-pregnancy BMI less than 19.8 kg/m<sup>2</sup>. Findings reported in the retrospective study conducted in Canada revealed that among women with a normal BMI, short maternal height is associated with spontaneous PTB. Among women who are overweight or obese, short maternal height is associated with an increased risk of indicated PTB (Crane *et al.*, 2025). However, this study reported that there were no linear and adjusted associations between BMI and PTB. The adjusted risk of any PTB was elevated at both low BMI in the previous analysis of systematic review that was conducted using three UK datasets, two USA datasets and one each from South Australia, Norway and Denmark shown the risk of spontaneous PTB was increased at lower levels of BMI but remained low or increased only slightly with higher BMI (Cornish *et al.*, 2024).

Low pre-pregnancy BMI are predictors of adverse pregnancy outcomes, like PTB (Kalanda, 2007). The findings were consistent with previous studies conducted in LMICs. In the studies,

undernutrition in women, before and during pregnancy, is recognized as a key determinant of PTB (Tang *et al.*, 2016). In contrast to that, the present study identified a pre-pregnancy BMI of less than 18.5 kg/m<sup>2</sup> was not associated with increased risk of PTB. However, maternal height, pre-pregnancy weight, and GWG demonstrated the adjusted risk of any PTB and MPTB was elevated at both low and high BMIs, whereas the risk of spontaneous PTB was increased at lower levels of BMI but remained low or increased only slightly with higher BMI (Cornish *et al.*, 2024).

Attained GWG from pre-pregnancy through nine lunar months demonstrated low odds ratios for PTB. The finding is consistent with the previous study on association between GWG and PTB (Zhu *et al.*, 2023). Additionally, the present study shown women with high total GWG had a decreased risk overall of PTB < 37 weeks, PTB 32 to 36 weeks and < 32 weeks. The finding was in line with previous analysis of systematic review (McDonald *et al.*, 2011). Additionally, weight gain throughout pregnancy was a significant predictor of PTB. The finding was in line with the previous study that reported pregnant women with low GWG were with increased risk of idiopathic preterm labor (Cornish *et al.*, 2024). Pre-pregnancy BMI and maternal height were poor predictors of PTB at <36 weeks' gestation in the current study. The finding was supported by a systematic review, which identified three anthropometric features were poor predictors of PTB (Honest *et al.*, 2005).

Data of serum ferritin was obtained from a blood sample collected for biochemical analysis in the first trimester. Participants were personally interviewed and had a blood sample collected during their initial antenatal visit aiming to assess the association between anthropometric indicators, GWG, and serum ferritin deficiency during pregnancy and the risk of low birth. LBW is regarded as a public health concern when it exceeds 15% (EDHS, 2017), In addition, maternal undernutrition is highly prevalent in resource-poor settings, generally ranging from 10% to 19% but reaching 20% in SSA, in which more than 95% of the estimated 20 million babies born annually have LBW (Tang *et al.*, 2016).

The current study reported a prevalence of LBW at 31.8%, which lied above the range of resource-poor countries, and reported in previous studies conducted in eastern (Komicha *et al.*, 2021; Fite *et al.*, 2023) and southern Ethiopia (Endalamaw *et al.*, 2018). The possible discrepancy may be attributed to differences in sociocultural factors and the study designs used.

Additionally, the prevalence of LBW was higher than that reported in studies conducted in Iran (Moghaddam *et al.*, 2015), Ethiopia (Mulatu *et al.*, 2017) and Malaysia (Yilgwan *et al.*, 2010). The possible reason for the discrepancy might be the differences in socioeconomic status. All three studies were conducted in urban settings; however, the majority of participants in our study were from rural settings, which identified a relatively higher prevalence where the burden of the problem is expected to be the highest. The current study reported that pre-pregnancy BMI was a significant predictor of LBW. The report was consistent with reports from previous studies conducted in developing countries (Kalanda, 2007; Singh *et al.*, 2009) that approved low pre-pregnancy BMI as a significant predictor of adverse pregnancy outcomes, like LBW.

The multiple pathways through which agriculture and nutrition are related increase the need for implementation of collaborative multi-sectorial activities to improve food and nutrition conditions. The current study mainly focused on the need for a nutrition education and supplementation of nutrient dense diet in the diet of pregnant women aiming at improving nutrient adequacy and micronutrient bioavailability, thereby improved maternal nutritional status and optimization of pregnancy and birth outcomes. With the limitation, the interventions have demonstrated positive effect of nutrition education that was delivered with a HBM based method on the consumption of nutrient (iron and folate) dense diets and DD of pregnant women. Additionally, dietary intervention (egg based diet) supplementation that was delivered coupled with healthy nutrition advice demonstrated positive effect on improving nutritional status of the mother, thereby on optimizing pregnancy and birth outcomes.

## **9.2. Strength and Limitations of the study**

The strength of this study lies in its community-based approach, which reflects the actual experiences of women during the study period. However, the findings, which validate MDD-W and FVS as key indicators of nutrient adequacy, may not be generalizable to other low-income settings due to the specific cultural context in Ethiopia. Additionally, the exclusion of anemic women could impact the applicability of the findings to that population. All studies, including Chapter One, utilized the 24-hour recall method to assess the women's DDS, but this method is subject to recall biases and variability from day to day since the information was obtained through self-reporting by the participants. To minimize errors caused by memory lapses and distortions, the initial 24-hour recall protocol was carefully designed, and standardized multiple-

pass interviewing techniques were employed. Furthermore, memory aids, such as photographs and probing questions, were used to help participants accurately identify the foods consumed.

The study that examined the effect of nutrition education on improving nutrient adequacy and serum levels of essential nutrients during pregnancy may have certain limitations. Pregnancy naturally increases women's nutritional requirements, meaning even previously healthy women could become micronutrient deficient if their heightened demands are not met. Additionally, due to logistical constraints, the study could not measure the increased nutritional demands arising from physiological changes as a source of micronutrient deficiency. While recruitment occurred during a time when ASFs were permitted, the HBM did not account for alternative sources of nutrients due to the seasonal availability of recommended animal and plant sources foods.

The study, which focused on the impact of nutrition interventions combined with healthy dietary advice on the nutritional status of pregnant women, was conducted in a specific region of Ethiopia. As such, the results may not be applicable to other contexts with different dietary habits or cultural restrictions. The 12-week intervention concentrated solely on the third trimester, which may not adequately capture the long-term effects on birth outcomes or postpartum health. Due to logistical reasons, the control group received standard care instead of the post-trial provision of eggs. Furthermore, the absence of blinding—inherent to the nature of the intervention—may lead to performance bias

### **9.3. Conclusion**

Inadequate dietary intake and nutrient deficiencies during pregnancy varied according to the socioeconomic characteristics of the study participants. The MDD-W had a positive correlation with nutrient intake adequacy and demonstrated good predictive ability. Specifically, the sensitivity and specificity of the MDD-W at the  $\geq 5$  food group standard cutoffs were 69.9% and 5.3%, respectively. Similarly, the DDS had the same sensitivity and specificity at this cutoff. However, the FVS remained a poor predictor of nutrient adequacy. Additionally, the intakes and serum levels of ferritin and folate showed significant improvement following the intervention based on HBM-based nutrition education. Nonetheless, the mean serum levels of iron and folate did not change significantly after the intervention, indicating issues related to household food insecurity. Conversely, an egg-based diet was positively associated with improvements in the MUAC of the respondents. This diet is a significant source of protein and enhances the MAR of

essential nutrients, including vitamin A, vitamin D, folate, iron, and calcium. Despite this, the incidence of PTB and LBW in this study was considerable. Key determinants of LBW included a low DDS, low dietary folate intake, serum folate levels below the recommended threshold, a total weight gain of less than 11.5-16 kg, and a MUAC of 23 cm. Furthermore, factors such as underweight, short stature, malnutrition, PTB, low total GWG, and low serum ferritin levels were significant determinants of LBW

#### **9.4. Recommendations**

The findings from the sensitivity and specificity analysis of MDD-w in determining nutrient adequacy differ from those of other studies and show discrepancies with FAO recommendations, highlighting the need for further investigation. The government should enhance women's rights, access to education, and economic opportunities to improve maternal nutrition programs and increase nutrient adequacy. Additionally, the study examining the effect of nutrition education on the adequacy of essential micronutrients provided valuable insights for decision-makers. It emphasized that nutrition education should be included in programs targeting food insecurity within communities. The health sector must act quickly to implement IFAS and social behavioral change communication. The education sector should organize parental education to improve nutrition outcomes, while the agriculture sector should showcase the benefits of agricultural biodiversity and promote small-scale cultivation of nutrient-dense foods, diversification of enterprises, and women's empowerment to address community nutrition. Economic sectors must also strive to empower women to participate in income-generating activities.

On another note, the evidence underscores the nutritional benefits of consuming eggs during pregnancy. Therefore, healthcare professionals need to be well-informed and effectively communicate this information to family heads and the wider community to encourage an egg-based diet during pregnancy. Given the substantial rates of PTB and LBW, it is crucial to strengthen public health interventions by considering factors such as providing additional food for pregnant mothers and ensuring IFAS. Raising awareness about the benefits of tracking pregnancy early and monitoring anthropometric indicators during ANC follow-up is also essential.

## References

- Abegaz *et al.* (2018) *Consumption of animal-source foods in Ethiopia: Patterns, changes, and determinants*.
- Abenwie *et al.* (2016) 'Knowledge and attitudes of pregnant mothers towards maternal dietary practices during pregnancy at the Etoug-Ebe Baptist Hospital, Yaounde', *Health Sciences and Disease*, 17(2), pp. 24–29.
- Abera Hailu, A. (2017) 'Ethiopian National Micro nutrient survey Impact Evaluation of Seqota Declartion Innovation Phase interventions View project Nutrition and Forest Project View project', (April).
- Acham *et al.*, (2012) 'Dietary diversity , micronutrient intake and their variation among black women in informal settlements in South Africa : A cross-sectional study', 4(February), pp. 24–39. Available at: <https://doi.org/10.5897/IJNAM11.059>.
- Adam *et al.* (2009) 'Anaemia, folate and vitamin B12 deficiency among pregnant women in an area of unstable malaria transmission in eastern Sudan.', *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 103(5), pp. 493–496. Available at: <https://doi.org/10.1016/j.trstmh.2008.10.007>.
- Adeoya *et al.*, (2023) 'Effectiveness of nutrition education in enhancing knowledge and attitude of pupils on choice of school mid- - day meal in', (March), pp. 3758–3766. Available at: <https://doi.org/10.1002/fsn3.3359>.
- Adikari *et al.* (2016) 'Assessment of nutritional status of pregnant women in a rural area in Sri Lanka', *Tropical Agricultural Research*, 27(2), p. 203. Available at: <https://doi.org/10.4038/tar.v27i2.8168>.
- Adubra *et al.* (2019) '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.', *Current developments in nutrition*, 3(3), p. nzz002. Available at: <https://doi.org/10.1093/cdn/nzz002>.
- Adugna *et al.* (2022) 'Maternal and neonatal factors associated with low birth weight among neonates delivered at the University of Gondar comprehensive specialized hospital, Northwest Ethiopia', *Frontiers in Pediatrics*, 10(August), pp. 1–9. Available at: <https://doi.org/10.3389/fped.2022.899922>.
- Agren, G. *et al.* (1969) *Food Composition Table for Use in Ethiopia: Amino acid content and biological data on proteins in Ethiopian foods*. (CNU report). Available at: <https://books.google.com.et/books?id=ID33zwEACAAJ>.
- Ahmed *et al.*, (2018) 'A health facility based case-control study on determinants of low birth weight in Dassie town, Northeast Ethiopia: the role of nutritional factors.', *Nutrition journal*, 17(1), p. 103. Available at: <https://doi.org/10.1186/s12937-018-0409-z>.
- Ahmed *et al.*, (2013) 'Global Burden of Maternal and Child Undernutrition and Micronutrient Deficiencies', *Annals of Nutrition and Metabolism*, 61(Suppl. 1), pp. 8–17. Available at: <https://doi.org/10.1159/000345165>.
- Ahsan *et al.*, (2022) 'Alive & Thrive.The Global Cost of Not Breastfeeding', (August).

- Aisa, S., *et al.*, (2020) ‘Effectiveness of providing raced chicken eggs on the nutrition for pregnant women in chronic energy deficiency in Kendari City, Sulawesi, Tenggara: Raced Chicken Eggs on the Nutrition’, *Indonesian Journal of Health Sciences research and Development (IJHSRD)*, 2, pp. 34–42. Available at: <https://doi.org/10.36566/ijhsrd/Vol2.Iss2/36>.
- Alehegn *et al.*, (2021) ‘Exploring maternal nutrition counseling provided by health professionals during antenatal care follow-up: a qualitative study in Addis Ababa, Ethiopia-2019’, *BMC Nutrition*, 7(1), pp. 1–16. Available at: <https://doi.org/10.1186/s40795-021-00427-1>.
- Alemu, A. (2018) ‘Impact of Microcredit on Selected Livelihood Assets of Rural Households : The Case of Shebedino District Omo Microfinance Institution , Sidama Zone of Southern Ethiopia’, *Journal of Economics and Sustainable Development*, 9(3), pp. 1–9.
- Ali *et al.* (2014) ‘Assessment of dietary diversity and nutritional status of pregnant women in Islamabad, Pakistan.’, *Journal of Ayub Medical College, Abbottabad : JAMC*, 26(4), pp. 506–509.
- Aliwo *et al.*. (2019) ‘Dietary diversity practice and associated factors among pregnant women in North East Ethiopia.’, *BMC research notes*, 12(1), p. 123. Available at: <https://doi.org/10.1186/s13104-019-4159-6>.
- Alwan *et al.*, (2015) ‘Maternal Iron Status in Pregnancy and Long-Term Health Outcomes in the Offspring.’, *Journal of pediatric genetics*, 4(2), pp. 111–123. Available at: <https://doi.org/10.1055/s-0035-1556742>.
- Amare *et al.* (2012) ‘Nutritional status and dietary intake of urban residents in Gondar, Northwest Ethiopia’, *BMC Public Health*, 12(1). Available at: <https://doi.org/10.1186/1471-2458-12-752>.
- Amenya *et al.* (2024) ‘The effectiveness of egg supplementation on nutritional status, physical fitness and cognition of school-aged children (8–12 Years) in Ho Municipality, Ghana’, *Human Nutrition & Metabolism*, 35, p. 200246. Available at: <https://doi.org/https://doi.org/10.1016/j.hnm.2024.200246>.
- Ansari, *et al* (2020) ‘Association of Maternal Dietary Diversity and Nutritional Status with Child’s Dietary Diversity and Nutritional Status (2-5 years) in India’, *World Nutrition*, 11(1), pp. 110–128. Available at: <https://doi.org/10.26596/wn.2020111110-128>.
- Arabzadeh *et al.* (2024) ‘The maternal factors associated with infant low birth weight: an umbrella review’, *BMC Pregnancy and Childbirth*, 24(1), p. 316. Available at: <https://doi.org/10.1186/s12884-024-06487-y>.
- Aregawi *et al.* (2019) ‘Preterm births and associated factors among mothers who gave birth in Axum and Adwa Town public hospitals, Northern Ethiopia, 2018’, *BMC research notes*, 12, pp. 1–6.
- Arimond *et al.* (2011) ‘Dietary diversity as a measure of the micronutrient adequacy of women’s diets in resource-poor areas: summary of results from five sites’, *Washington, DC: FANTA-2 Bridge, FHI*, 360, p. 2011.
- Asefa, F. *et al.* (2020) ‘Gestational weight gain and its effect on birth outcomes in sub-Saharan

- Africa: Systematic review and meta-analysis.’, *PloS one*, 15(4), p. e0231889. Available at: <https://doi.org/10.1371/journal.pone.0231889>.
- Asefa *et al.*, (2016) ‘Gestational weight gain and its associated factors in Harari Regional State: Institution based cross-sectional study, Eastern Ethiopia’, *Reproductive Health*, 13(1), p. 101. Available at: <https://doi.org/10.1186/s12978-016-0225-x>.
- Assefa *et al.* (2019) ‘Community health extension program of Ethiopia, 2003-2018: successes and challenges toward universal coverage for primary healthcare services.’, *Globalization and health*, 15(1), p. 24. Available at: <https://doi.org/10.1186/s12992-019-0470-1>.
- Ayele *et al.*, (2020) ‘Prevalence of Undernutrition and Associated Factors among Pregnant Women in a Public General Hospital, Tigray, Northern Ethiopia: A Cross-Sectional Study Design.’, *Journal of nutrition and metabolism*, 2020, p. 2736536. Available at: <https://doi.org/10.1155/2020/2736536>.
- Ayele *et al.* (2023) ‘Prevalence of preterm birth and associated factors among mothers who gave birth in public hospitals of east Gojjam zone, Ethiopia’, *Bmc Pregnancy and Childbirth*, 23(1), p. 204. Available at: <https://eurekamag.com/research/090/072/090072929.php>.
- Bailey *et al.*,(2000) ‘New standard for dietary folate intake in pregnant women<sup>123</sup>’, *The American Journal of Clinical Nutrition*, 71(5), pp. 1304S-1307S. Available at: <https://doi.org/https://doi.org/10.1093/ajcn/71.5.1304s>.
- Bailey *et al.* (2015) ‘Biomarkers of Nutrition for Development-Folate Review.’, *The Journal of nutrition*, 145(7), pp. 1636S-1680S. Available at: <https://doi.org/10.3945/jn.114.206599>.
- Banjari (2018) ‘Iron Deficiency Anemia and Pregnancy’, in. Available at: <https://api.semanticscholar.org/CorpusID:80269900>.
- Barman *et al.* (2021) ‘Factors associated with low birth weight among deliveries at a tertiary healthcare hospital in Bundelkhand region of Uttar Pradesh’, *International Journal of Research in Medical Sciences*, 9(9), p. 2662. Available at: <https://doi.org/10.18203/2320-6012.ijrms20213404>.
- Bathla *et al.*, (2022) ‘Prevalence and approaches to manage iron deficiency anemia (IDA)’, *Critical Reviews in Food Science and Nutrition*, 62(32), pp. 8815–8828. Available at: <https://doi.org/10.1080/10408398.2021.1935442>.
- Bayked *et al.* (2024) ‘Dietary knowledge, attitude, practice, and associated factors among pregnant mothers in Ethiopia: a systematic review and meta-analysis.’, *Frontiers in public health*, 12, p. 1393764. Available at: <https://doi.org/10.3389/fpubh.2024.1393764>.
- Bazmamoun *et al.* (2022) ‘Evaluation of the Relationship Between Serum and Urine Ferritin Level of Low Birth Weight Infants.’, *Iranian journal of pathology*, 17(3), pp. 323–327. Available at: <https://doi.org/10.30699/IJP.2022.546540.2807>.
- Beal *et al.* (2017) ‘Global trends in dietary micronutrient supplies and estimated prevalence of inadequate intakes.’, *PloS one*, 12(4), p. e0175554. Available at: <https://doi.org/10.1371/journal.pone.0175554>.
- Bell *et al.* (2014) ‘Estimation of choline intake from 24 h dietary intake recalls and contribution of egg and milk consumption to intake among pregnant and lactating women in Alberta’, *British Journal of Nutrition*. 2014/04/08, 112(1), pp. 112–121. Available at:

- <https://doi.org/DOI: 10.1017/S0007114514000555>.
- Benoist (2008) 'Conclusions of a WHO Technical Consultation on folate and vitamin B 12 deficiencies', 29(2), pp. 238–244.
- Beressa *et al.*, (2024) 'Effect of nutrition education integrating the health belief model and theory of planned behavior on dietary diversity of pregnant women in Southeast Ethiopia: a cluster randomized controlled trial.', *Nutrition journal*, 23(1), p. 3. Available at: <https://doi.org/10.1186/s12937-023-00907-z>.
- Bezabih *et al.* (2018) 'Demand and supply side barriers that limit the uptake of nutrition services among pregnant women from rural Ethiopia: An exploratory qualitative study', *Nutrients*, 10(11). Available at: <https://doi.org/10.3390/nu10111687>.
- Bhattacharya *et al.* (2019) 'Assessment of nutritional status using anthropometric variables by multivariate analysis.', *BMC public health*, 19(1), p. 1045. Available at: <https://doi.org/10.1186/s12889-019-7372-2>.
- Bikila *et al.* (2023) 'Prevalence and factors associated with adequate dietary diversity among pregnant women in Nekemte town, Western Ethiopia, 2021', *Frontiers in Nutrition*, 10(December), pp. 1–12. Available at: <https://doi.org/10.3389/fnut.2023.1248974>.
- Bishnu *et al.* (2022) 'A cross sectional study to identify factors determining low birth weight babies observed in a tribal district of Odisha, India', *GSC Biological and Pharmaceutical Sciences*, 20(1), pp. 227–240. Available at: <https://doi.org/10.30574/gscbps.2022.20.1.0292>.
- Bitew *et al.* (2020) 'Magnitude and Associated Factors of Neural Tube Defects in Ethiopia: A Systematic Review and Meta-Analysis.', *Global pediatric health*, 7, p. 2333794X20939423. Available at: <https://doi.org/10.1177/2333794X20939423>.
- Bitew *et al.* (2021) 'Dietary diversity and practice of pregnant and lactating women in Ethiopia: A systematic review and meta-analysis.', *Food science & nutrition*, 9(5), pp. 2686–2702. Available at: <https://doi.org/10.1002/fsn3.2228>.
- Black *et al.* (2018) 'Maternal and child undernutrition: global and regional exposures and health consequences', *The Lancet*, 371(9608), pp. 243–260. Available at: [https://doi.org/10.1016/S0140-6736\(07\)61690-0](https://doi.org/10.1016/S0140-6736(07)61690-0).
- Blencowe *et al.* (2013) 'Born Too Soon: The global epidemiology of 15 million preterm births', *Reproductive Health 2013*, 10(Suppl 1), pp. 1–14.
- Blencowe *et al.* (2022) 'Study protocol for UNICEF and WHO estimates of global, regional, and national low birthweight prevalence for 2000 to 2020', *Gates Open Research*, 6, pp. 1–24. Available at: <https://doi.org/10.12688/gatesopenres.13666.1>.
- Bothwell (2000) 'Iron requirements in pregnancy and strategies to meet them.', *The American journal of clinical nutrition*, 72(1 Suppl), pp. 257S-264S. Available at: <https://doi.org/10.1093/ajcn/72.1.257S>.
- Britto *et al.* (2017) 'Nurturing care: promoting early childhood development.', *Lancet (London, England)*, 389(10064), pp. 91–102. Available at: [https://doi.org/10.1016/S0140-6736\(16\)31390-3](https://doi.org/10.1016/S0140-6736(16)31390-3).

- Bruce (2017) 'Revised Edition Anthropometric Indicators Measurement Guide', (March).
- Bukowski *et al.* (2007) 'Fetal growth in early pregnancy and risk of delivering low birth weight infant: prospective cohort study.', *BMJ (Clinical research ed.)*, 334(7598), p. 836. Available at: <https://doi.org/10.1136/bmj.39129.637917.AE>.
- Castell *et al.* (2015) 'Household food insecurity access scale (HFIAS)', *Nutricion hospitalaria*, 31, pp. 272–278. Available at: <https://doi.org/10.3305/nh.2015.31.sup3.8775>.
- Caswell *et al.* (2021) 'Impacts of an egg intervention on nutrient adequacy among young Malawian children', *Maternal and Child Nutrition*, 17(3), pp. 1–16. Available at: <https://doi.org/10.1111/mcn.13196>.
- CDC (2002) 'Iron deficiency--United States, 1999-2000.', *MMWR. Morbidity and mortality weekly report*, 51(40), pp. 897–899.
- Chadha, V.K. (2006) 'Sample size determination in health studies', pp. 55–62.
- Chakona *et al.*, (2017) 'Minimum Dietary Diversity Scores for Women Indicate Micronutrient Adequacy and Food Insecurity Status in South African Towns.', *Nutrients*, 9(8). Available at: <https://doi.org/10.3390/nu9080812>.
- Champion *et al.*, (2020) 'Gestational Weight Gain: Update on Outcomes and Interventions', *Current Diabetes Reports*, 20(3), pp. 1–10. Available at: <https://doi.org/10.1007/s11892-020-1296-1>.
- Chawanpaiboon, S. *et al.* (2019) 'Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis', *The Lancet global health*, 7(1), pp. e37–e46.
- Cheatham (2019) 'Nutritional Factors in Fetal and Infant Brain Development.', *Annals of nutrition & metabolism*, 75 Suppl 1, pp. 20–32. Available at: <https://doi.org/10.1159/000508052>.
- Chen *et al.* (2018) 'Epidemiology of preterm birth in China in 2015 and 2016: a nationwide survey', *The Lancet*, 392, p. S73.
- Chen *et al.* (2015) 'Maternal Folate Status, but Not That of Vitamins B-12 or B-6, Is Associated with Gestational Age and Preterm Birth Risk in a Multiethnic Asian Population<sup>1,2</sup>', *The Journal of Nutrition*, 145(1), pp. 113–120. Available at: <https://doi.org/https://doi.org/10.3945/jn.114.196352>.
- Chiabi, A. *et al.* (2013) 'Risk factors for premature births: a cross-sectional analysis of hospital records in a Cameroonian health facility', *African journal of reproductive health*, 17(4), p. 77–83. Available at: <http://europepmc.org/abstract/MED/24558784>.
- Chitsaz *et al.*, (2017) 'The Predictors of Healthy Eating Behavior among Pregnant Women : An Application of the Theory of Planned Behavior', 5(46), pp. 5897–5905. Available at: <https://doi.org/10.22038/ijp.2017.25576.2176>.
- Copelton (2007) "'You are What You Eat": Nutritional Norms, Maternal Deviance, and Neutralization of Women's Prenatal Diets', *Deviant Behavior*, 28(5), pp. 467–494. Available at: <https://doi.org/10.1080/01639620701252571>.
- Cordero *et al.* (2015) 'Optimal serum and red blood cell folate concentrations in women of

- reproductive age for prevention of neural tube defects: World Health Organization guidelines.’, *MMWR. Morbidity and mortality weekly report*, 64(15), pp. 421–423.
- Cornish *et al.* (2024) ‘Maternal pre-pregnancy body mass index and risk of preterm birth: a collaboration using large routine health datasets.’, *BMC medicine*, 22(1), p. 10. Available at: <https://doi.org/10.1186/s12916-023-03230-w>.
- Crane *et al.*, (2025) ‘Impact of short maternal height on preterm birth: A retrospective cohort study’, *International Journal of Gynecology & Obstetrics*, n/a(n/a). Available at: <https://doi.org/https://doi.org/10.1002/ijgo.70379>.
- CSA (2007) ‘Central Statistical Agency. Population and Housing Census for Oromia Regional State of Ethiopia’, *Federal democratic republic of Ethiopia population census commission*, pp. 1–1084.
- Cunningham *et al.* (2014) *Williams Gynecology, 24th ed. McGraw- Hill, New York, 2014*.
- Daba *et al.* (2013) ‘Assessment of Knowledge of Pregnant Mothers on Maternal Nutrition and Associated Factors in Guto Gida Woreda, East Wollega Zone, Ethiopia’, *Journal of Nutrition & Food Sciences*, 03(06). Available at: <https://doi.org/10.4172/2155-9600.1000235>.
- Daly *et al.* (1995) ‘Folate levels and neural tube defects. Implications for prevention.’, *JAMA*, 274(21), pp. 1698–1702. Available at: <https://doi.org/10.1001/jama.1995.03530210052030>.
- Danielewicz *et al.* (2017) ‘Diet in pregnancy-more than food.’, *European journal of pediatrics*, 176(12), pp. 1573–1579. Available at: <https://doi.org/10.1007/s00431-017-3026-5>.
- Darnton-Hill and Mkparu (2015) ‘Micronutrients in pregnancy in low- and middle-income countries.’, *Nutrients*, 7(3), pp. 1744–1768. Available at: <https://doi.org/10.3390/nu7031744>.
- Demeke, H. and Tenaw, D. (2021) ‘Sources of recent inflationary pressures and interlinkages between food and non-food prices in Ethiopia.’, *Heliyon*, 7(11), p. e08375. Available at: <https://doi.org/10.1016/j.heliyon.2021.e08375>.
- Demilew *et al.* (2020) ‘Dietary practices and associated factors among pregnant women in West Gojjam Zone, Northwest Ethiopia’, *BMC Pregnancy and Childbirth*, 20(1), p. 18. Available at: <https://doi.org/10.1186/s12884-019-2702-z>.
- Derbyshire (2024) ‘The role of egg consumption in the first 1001 days of life: a narrative review’, 32(5).
- Deressa *et al.* (2018) ‘Factors associated with spontaneous preterm birth in Addis Ababa public hospitals, Ethiopia: cross sectional study’, *BMC pregnancy and childbirth*, 18, pp. 1–5.
- Deriba (2021) ‘Nutritional-Related Predictors of Preterm Birth in North Shewa Hospitals, Central Ethiopia: A Case–Control Study’, *Pediatric Health, Medicine and Therapeutics*, 12(null), pp. 315–324. Available at: <https://doi.org/10.2147/PHMT.S319867>.
- Deriba *et al.*, (2021) ‘Determinants of Low Birth Weight Among Women Who Gave Birth at Public Health Facilities in North Shewa Zone: Unmatched Case-Control Study’, *Inquiry (United States)*, 58, pp. 1–11. Available at: <https://doi.org/10.1177/00469580211047199>.

- Derso *et al.* (2021) ‘Household dietary diversity in rural households of Oromia Regional state , Ethiopia : A cross-sectional study’, 13(December), pp. 304–313. Available at: <https://doi.org/10.5897/JDAE2020.1187>.
- Devaki *et al.*, (2018) ‘Maternal anthropometry and low birth weight: A review’, *Biomedical and Pharmacology Journal*, 11(2), pp. 815–820. Available at: <https://doi.org/10.13005/bpj/1436>.
- Diddana *et al.* (2018) ‘Effect of Nutrition Education Based on Health Belief Model on Nutritional Knowledge and Dietary Practice of Pregnant Women in Dessie Town, Northeast Ethiopia: A Cluster Randomized Control Trial.’, *Journal of nutrition and metabolism*, 2018, p. 6731815. Available at: <https://doi.org/10.1155/2018/6731815>.
- Diddana (2019) ‘Factors associated with dietary practice and nutritional status of pregnant women in Dessie town, northeastern Ethiopia: a community-based cross-sectional study’, *BMC Pregnancy and Childbirth*, 19(1), p. 517. Available at: <https://doi.org/10.1186/s12884-019-2649-0>.
- Diemert, A. *et al.* (2016) ‘Maternal nutrition, inadequate gestational weight gain and birth weight: results from a prospective birth cohort’, *BMC pregnancy and childbirth*, 16(1), pp. 1–9.
- Diriba, K.D. (2013) ‘Characterizing the Predictability of Seasonal Climate in Ethiopia’, *Water Resources Research*, (December), pp. 1–17.
- Dolatian, M. *et al.* (2015) ‘Effects of Education Based on Health Belief Model on Dietary Behaviors of Effects of Education Based on Health Belief Model on Dietary Behaviors of Iranian Pregnant Women’, (December). Available at: <https://doi.org/10.5539/gjhs.v8n2p230>.
- EDHS (2017) *Ethiopia Demographic and Health Survey (2016 EDHS)*., *International Food Research Journal*.
- EFMH (2021) ‘Health Post Level Guidelines to Implement the Reaching Every District (RED) Strategy’, *Practical guide for health post level* [Preprint], (June).
- EFSA (2015) ‘Scientific opinion on dietary reference values for iron’, *Efsa Journal*, 13(10), p. 4254.
- EFSA (2019) *Dietary Reference Values for nutrients Summary report*. Available at: <https://doi.org/10.2903/sp.efsa.2017.e15121>.
- Emond, J.A. *et al.* (2018) ‘Better Diet Quality during Pregnancy Is Associated with a Reduced Likelihood of an Infant Born Small for Gestational Age: An Analysis of the Prospective New Hampshire Birth Cohort Study.’, *The Journal of nutrition*, 148(1), pp. 22–30. Available at: <https://doi.org/10.1093/jn/nxx005>.
- Endalamaw *et al.* (2018) ‘Low birth weight and its associated factors in Ethiopia: a systematic review and meta-analysis.’, *Italian journal of pediatrics*, 44(1), p. 141. Available at: <https://doi.org/10.1186/s13052-018-0586-6>.
- Enyew *et al.* (2023) ‘Micronutrient intake and associated factors among pregnant women in East Africa: Multilevel logistic regression analysis.’, *PloS one*, 18(4), p. e0281427. Available at: <https://doi.org/10.1371/journal.pone.0281427>.

- EPHI (2013) ‘Ethiopian Public Health Institute. Ethiopia National Food Consumption Survey 2013’, (March), p. 87. Available at: [www.eph.gov.et](http://www.eph.gov.et).
- EPHI (2020) ‘National Nutrition Program ( 2016-2020 ): Progress Analysis : Evidence for the Development of the Food and Nutrition Strategy’.
- EPHI (2021) ‘Monitoring and Evaluation Steering Committee ( MER SC )’, (March).
- Erdfelder *et al.* (2016) ‘Statistical power analyses using G\*Power 3.1: Tests for correlation and regression analyses’, *Behavior Research Methods*, 41(4), pp. 1149–1160. Available at: <https://doi.org/10.3758/BRM.41.4.1149>.
- Fallah, F. *et al.* (2013) ‘Effects of nutrition education on levels of nutritional awareness of pregnant women in Western iran.’, *International journal of endocrinology and metabolism*, 11(3), pp. 175–178. Available at: <https://doi.org/10.5812/ijem.9122>.
- FANTA (2007) ‘Household Food Insecurity Access Scale (HFIAS) for measurement of food access: indicator guide’, *Washington, DC: Food and Nutrition Technical ...*, (August), p. Version 3.
- FAO (2011) *Guidelines for measuring household and individual dietary diversity. Nutrition and Consumer Protection Division, Food and Agriculture Organization of the United Nations, Fao*. Available at: <https://doi.org/613.2KEN>.
- FAO (2014) ‘Guidelines for assessing nutrition-related Knowledge, Attitudes and Practices’, *Food and Agriculture Organization of the United Nations*, 66(October), pp. 1–188. Available at: [www.fao.org/docrep/019/i3545e/i3545e00.htm](http://www.fao.org/docrep/019/i3545e/i3545e00.htm).
- FAO (2016) ‘Country Profile – Ethiopia. Food and Agriculture Organization of the United Nations (FAO). Rome, Italy’, *FAO, AQUASAT reports*, pp. 11–12.
- FAO (2020) ‘Food and Nutrition Education for Healthy Diets. Why food and Nutrition Education needed ?’, *The United Nations* [Preprint].
- FAO (2021) *Minimum Dietary Diversity for Women: An updated guide for measurement: from collection to action*. Available at: <https://doi.org/10.4060/cb3434en>.
- FAO and WHO. (2002) ‘Vitamin and mineral requirements. Report of a Joint FAO/WHO Expert Consultation. Rome: FAO, 2002.’, pp. 1–20. Available at: <https://doi.org/9241546123>.
- Farpour-Lambert *et al.*, 2018 (2018) ‘Obesity and Weight Gain in Pregnancy and Postpartum’, *Frontiers in Endocrinology*, 9(September). Available at: <https://doi.org/10.3389/fendo.2018.00546>.
- Fatou *et al.* (2018) ‘Folate Deficiency and Anemia Among Women of Reproductive Age (15-49 Years) in Senegal: Results of a National Cross-Sectional Survey.’, *Food and nutrition bulletin*, 39(1), pp. 65–74. Available at: <https://doi.org/10.1177/0379572117739063>.
- Faul, F. *et al.* (2009) ‘Statistical power analyses using G\*Power 3.1: tests for correlation and regression analyses.’, *Behavior research methods*, 41(4), pp. 1149–1160. Available at: <https://doi.org/10.3758/BRM.41.4.1149>.
- FDRE (2013) ‘Training of trainers Manual for Counseling on Maternal, Infant and Young Child Nutrition Ethiopia’, (December), pp. 1–224.
- FDRE (2016) ‘Government of Ethiopia National Nutrition Program 2016 - 2020.’, *Published*, p.

- FDRE (2020) ‘National Nutrition Program ( 2016-2020 ): Progress Analysis : Evidence for the Development of the Food and Nutrition Strategy’.
- FDRE (2021) ‘National Food and Nutrition Strategy: Addis Ababa, Ethiopia.’
- Ferede *et al.*, (2020) ‘Effect of nutrition behaviour change intervention on improving micronutrients concentration and linear growth of children age 6 to 59 months in central highland of Ethiopia: Cluster randomized control trial’, *Integrative Food, Nutrition and Metabolism*, 7(3), pp. 1–8. Available at: <https://doi.org/10.15761/ifnm.1000287>.
- Fiedler *et al* (2014) ‘A simple method for making a rapid, initial assessment of the consumption and distribution of iron-folic acid supplements among pregnant women in developing countries’, *Usaid* [Preprint], (U).
- Fite *et al.* (2023) ‘Co-occurrence of iron, folate, and vitamin A deficiency among pregnant women in eastern Ethiopia: a community-based study’, *BMC Nutrition*, 9(1), p. 72. Available at: <https://doi.org/10.1186/s40795-023-00724-x>.
- FMOH (2022) ‘Ethiopia: Food-Based Dietary Guidelines–2022.’, *Federal Government of Ethiopia, Ministry of Health, Ethiopian Public Health Institute*, p. 108.
- Forgie *et al.* (2020) ‘The impact of maternal and early life malnutrition on health: a diet-microbe perspective’, *BMC Medicine*, 18(1), p. 135. Available at: <https://doi.org/10.1186/s12916-020-01584-z>.
- Foster, E. and Bradley, J. (2018) ‘Methodological considerations and future insights for 24-hour dietary recall assessment in children.’, *Nutrition research (New York, N.Y.)*, 51, pp. 1–11. Available at: <https://doi.org/10.1016/j.nutres.2017.11.001>.
- Gaspar *et al.*, (1993) ‘Relationship between iron status in pregnant women and their newborn babies. Investigation in a Spanish population.’, *Acta obstetricia et gynecologica Scandinavica*, 72(7), pp. 534–537. Available at: <https://doi.org/10.3109/00016349309058158>.
- Gebregzabihherher *et al.* (2017) ‘The Prevalence and Risk Factors for Low Birth Weight among Term Newborns in Adwa General Hospital, Northern Ethiopia.’, *Obstetrics and gynecology international*, 2017, p. 2149156. Available at: <https://doi.org/10.1155/2017/2149156>.
- Gebremedhin *et al.* (2012) ‘Independent and Joint Effects of Prenatal Zinc and Vitamin A Deficiencies on Birthweight in Rural Sidama, Southern Ethiopia: Prospective Cohort Study’, *PLoS ONE*, 7(12). Available at: <https://doi.org/10.1371/journal.pone.0050213>.
- Gebremedhin, M. *et al.* (2015) ‘Maternal associated factors of low birth weight: a hospital based cross-sectional mixed study in Tigray, Northern Ethiopia.’, *BMC pregnancy and childbirth*, 15, p. 222. Available at: <https://doi.org/10.1186/s12884-015-0658-1>.
- Gebremichael *et al.*, (2023) ‘Dietary Diversity, Nutritional Status, and Associated Factors Among Pregnant Women in Their First Trimester of Pregnancy in Ambo District, Western Ethiopia’, *Nutrition and Metabolic Insights*, 16. Available at: <https://doi.org/10.1177/11786388231190515>.

- Gebreslasie (2016) 'Preterm birth and associated factors among mothers who gave birth in Gondar town health institutions', *Advances in Nursing*, 2016(1), p. 4703138.
- Georgieff (2020) 'Iron deficiency in pregnancy', *American Journal of Obstetrics & Gynecology*, 223(4), pp. 516–524. Available at: <https://doi.org/10.1016/j.ajog.2020.03.006>.
- Gernand *et al.* (2016) 'Micronutrient deficiencies in pregnancy worldwide: health effects and prevention Alison', *Nature reviews. Endocrinology*, 12(5), pp. 274–289. Available at: <https://doi.org/10.1038/nrendo.2016.37.Micronutrient>.
- Getaneh *et al.* (2021) 'Predictors of malnutrition among pregnant women in Ethiopia: A systematic review and meta-analysis', *Human Nutrition & Metabolism*, 26, p. 200131. Available at: <https://doi.org/https://doi.org/10.1016/j.hnm.2021.200131>.
- Gilmore *et al.* (2016) 'Weight gain in pregnancy and application of the 2009 IOM guidelines: toward a uniform approach', 23(3), pp. 507–511. Available at: <https://doi.org/10.1002/oby.20951.Weight>.
- Girard *et al.*, (2012) 'Nutrition Education and Counselling Provided during Pregnancy : Effects on Maternal , Neonatal and Child Health Outcomes', 26, pp. 191–204. Available at: <https://doi.org/10.1111/j.1365-3016.2012.01278.x>.
- Girma *et al.* (2019) 'Factors associated with low birthweight among newborns delivered at public health facilities of Nekemte town, West Ethiopia: a case control study', *BMC Pregnancy and Childbirth*, 19(1), p. 220. Available at: <https://doi.org/10.1186/s12884-019-2372-x>.
- Goldenberg *et al.* (2008) 'Epidemiology and causes of preterm birth.', *Lancet (London, England)*, 371(9606), pp. 75–84. Available at: [https://doi.org/10.1016/S0140-6736\(08\)60074-4](https://doi.org/10.1016/S0140-6736(08)60074-4).
- Goldstein *et al.* (2017) 'Association of Gestational Weight Gain With Maternal and Infant Outcomes: A Systematic Review and Meta-analysis.', *JAMA*, 317(21), pp. 2207–2225. Available at: <https://doi.org/10.1001/jama.2017.3635>.
- Goshu *et al.*, .2018 (2018) 'Maternal dietary and nutritional characteristics as predictor of newborn birth weight in Jimma Town, Southwest Ethiopia, 2017', *Journal of Public Health and Epidemiology*, 10(5), pp. 155–164. Available at: <https://doi.org/10.5897/jphe2017.0977>.
- Gray (2019) 'Egg consumption in pregnancy and infancy: Advice has changed', *Journal of Health Visiting*, 7(2), pp. 68–77. Available at: <https://doi.org/10.12968/johv.2019.7.2.68>.
- Gudeta *et al.* (2022) 'Determinants of Dietary Diversity Practice among Pregnant Women in the Gurage Zone, Southern Ethiopia, 2021: Community-Based Cross-Sectional Study.', *Obstetrics and gynecology international*, 2022, p. 8086793. Available at: <https://doi.org/10.1155/2022/8086793>.
- Gyimah *et al.* (2021) 'Nutritional status and birth outcomes among pregnant adolescents in Ashanti Region, Ghana', *Human Nutrition & Metabolism*, 26, p. 200130. Available at: <https://doi.org/https://doi.org/10.1016/j.hnm.2021.200130>.
- H, Wilna *et al.* (2014) *Food Variety and Dietary Diversity as Indicators of the Dietary Adequacy*

- and Health Status of an Elderly Population in Sharpeville , South Africa.* Available at: <https://doi.org/10.1080/01639360802060140>.
- Habte *et al.* (2022) ‘Lessons learned from the implementation of large-scale fortification programs’, pp. 1–7.
- Habtu *et al.* (2022) ‘Effect of integrated nutrition-sensitive and nutrition-specific intervention package on maternal malnutrition among pregnant women in Rwanda.’, *Maternal & child nutrition*, 18(3), p. e13367. Available at: <https://doi.org/10.1111/mcn.13367>.
- Halala *et al.* (2020) ‘Low dietary diversity and its determinants among adolescent girls in Southern Ethiopia’, *Cogent Food & Agriculture*. Edited by F. Yildiz, 6(1), p. 1832824. Available at: <https://doi.org/10.1080/23311932.2020.1832824>.
- Hall *et al.* (2017) ‘Pregnancy Intention and Pregnancy Outcome: Systematic Review and Meta-Analysis’, *Maternal and Child Health Journal*, 21(3), pp. 670–704. Available at: <https://doi.org/10.1007/s10995-016-2237-0>.
- Handiso *et al.* (2019) ‘Factors Associated with Preterm Birth among Mothers Who gave Birth in Dodola Town Hospitals, Southeast Ethiopia: Institutional Based Cross Sectional Study’. Available at: <https://doi.org/10.4172/2090-7214.1000317>.
- Hanson *et al.* (2015) ‘The International Federation of Gynecology and Obstetrics (FIGO) recommendations on adolescent, preconception, and maternal nutrition: “think Nutrition First”’, *International Journal of Gynecology and Obstetrics*, 131, pp. S213–S253. Available at: [https://doi.org/10.1016/S0020-7292\(15\)30023-0](https://doi.org/10.1016/S0020-7292(15)30023-0).
- Harika *et al.* (2017) ‘Micronutrient status and dietary intake of iron, Vitamin A, iodine, folate and zinc in women of reproductive age and pregnant women in Ethiopia, Kenya, Nigeria and South Africa: A systematic review of data from 2005 to 2015’, *Nutrients*, 9(10). Available at: <https://doi.org/10.3390/nu9101096>.
- Hatløy *et al.*, (1998) ‘Food variety--a good indicator of nutritional adequacy of the diet? A case study from an urban area in Mali, West Africa.’, *European journal of clinical nutrition*, 52(12), pp. 891–898. Available at: <https://doi.org/10.1038/sj.ejcn.1600662>.
- Haugen *et al.* (2014) ‘Associations of pre-pregnancy body mass index and gestational weight gain with pregnancy outcome and postpartum weight retention: a prospective observational cohort study.’, *BMC pregnancy and childbirth*, 14, p. 201. Available at: <https://doi.org/10.1186/1471-2393-14-201>.
- Hendrixson *et al.* (2025) ‘Treatment of Undernutrition in Pregnancy Requires Adequate Food and Inflammation Control’, *Advances in Nutrition*, 16(8), p. 100479. Available at: <https://doi.org/https://doi.org/10.1016/j.advnut.2025.100479>.
- Herring *et al.* (2018) ‘Impacts of maternal dietary protein intake on fetal survival, growth, and development.’, *Experimental biology and medicine (Maywood, N.J.)*, 243(6), pp. 525–533. Available at: <https://doi.org/10.1177/1535370218758275>.
- Hertzmark (2008) ‘Tanzania Food Composition Tables - brothsvit\_090406’, *muhimbili university of allied science, Tanzania food and nutrition centre and Havard school of public health* [Preprint], (January 2008). Available at: <https://core.ac.uk/download/pdf/77101563.pdf>.

- Hirvonen *et al.*, (2016) ‘Seasonality and household diets in Ethiopia.’, *Public health nutrition*, 19(10), pp. 1723–1730. Available at: <https://doi.org/10.1017/S1368980015003237>.
- Ho *et al.* (2021) ‘Data Science in Stata 16: Frames, Lasso, and Python Integration’, *Journal of Statistical Software*, 98(1 SE-Software Reviews), pp. 1–9. Available at: <https://doi.org/10.18637/jss.v098.s01>.
- Hoang (2019) ‘Undernutrition during Pregnancy’, *Complications of Pregnancy* [Preprint], (January 2019). Available at: <https://doi.org/10.5772/intechopen.82727>.
- Hoesli, I. (2010) ‘Nutritional Requirements for Health throughout Life Span. Module 4.3. Nutritional Requirements in Pregnancy and Lactation (old)’, *ESPEN LLL Programme*, pp. 1–12.
- Hoh *et al.* (2019) ‘Preterm birth rate and dilemma of preterm labor treatment in Asia.’, *Placenta*, 79, pp. 68–71. Available at: <https://doi.org/10.1016/j.placenta.2019.01.005>.
- Hollis *et al.*, (2011) ‘Vitamin D requirements and supplementation during pregnancy.’, *Current opinion in endocrinology, diabetes, and obesity*, 18(6), pp. 371–375. Available at: <https://doi.org/10.1097/MED.0b013e32834b0040>.
- Honest *et al.* (2005) ‘The accuracy of maternal anthropometry measurements as predictor for spontaneous preterm birth--a systematic review.’, *European journal of obstetrics, gynecology, and reproductive biology*, 119(1), pp. 11–20. Available at: <https://doi.org/10.1016/j.ejogrb.2004.07.041>.
- Hopewell *et al.* (2025) ‘CONSORT 2025 Statement: Updated Guideline for Reporting Randomized Trials’, *JAMA*, 333(22), pp. 1998–2005. Available at: <https://doi.org/10.1001/jama.2025.4347>.
- Howson *et al.* (2013) ‘Born too soon: preterm birth matters.’, *Reproductive health*, 10 Suppl 1(Suppl 1), p. S1. Available at: <https://doi.org/10.1186/1742-4755-10-S1-S1>.
- Hu, D. *et al.* (2024) ‘Effect modification of pre-pregnancy body mass index on association of gestational weight gain with birth weight’, *Heliyon*, 10(19), p. e38478. Available at: <https://doi.org/https://doi.org/10.1016/j.heliyon.2024.e38478>.
- Iannotti *et al.* (2014) ‘Eggs: the uncracked potential for improving maternal and young child nutrition among the world’s poor.’, *Nutrition reviews*, 72(6), pp. 355–368. Available at: <https://doi.org/10.1111/nure.12107>.
- Ibikunle *et al.*, (2021) ‘Pre-natal nutrition education: Health care providers’ knowledge and quality of services in primary health care centres in Lagos, Nigeria’, *PLOS ONE*, 16(11), pp. 1–14. Available at: <https://doi.org/10.1371/journal.pone.0259237>.
- IFPRI (2016) ‘Global Nutrition Report 2016: From Promise to Impact: Ending Malnutrition by 2030.’, p. 182.
- Imbard *et al.*, (2013) ‘Neural tube defects, folic acid and methylation.’, *International journal of environmental research and public health*, 10(9), pp. 4352–4389. Available at: <https://doi.org/10.3390/ijerph10094352>.
- Imdad, A. *et al.* (2017) *Prenatal Nutrition and Nutrition in Pregnancy: Effects on Long-Term Growth and Development, Early Nutrition and Long-Term Health: Mechanisms*,

- Consequences, and Opportunities*. Available at: <https://doi.org/10.1016/B978-0-08-100168-4.00001-X>.
- IOM. (2000) *Dietary Reference Intakes: Applications in Dietary Assessment*. Washington, DC: The National Academies Press. Available at: <https://doi.org/10.17226/9956>.
- IOM (1990) *Nutrition during pregnancy: Part I: weight gain, Part II: nutrient supplements*. National Academies Press.
- IOM (2007) *Preterm birth: Causes, Consequences, and prevention, Preterm Birth: Causes, Consequences, and Prevention*. Available at: <https://doi.org/10.17226/11622>.
- Israel *et al.* (2017) ‘Prevalence of Preterm Birth and its Associated Factors among Mothers Delivered in Jimma University Specialized Teaching and Referral Hospital, Jimma Zone, Oromia Regional State, South West Ethiopia’, *Journal of Women’s Health Care*, 06. Available at: <https://doi.org/10.4172/2167-0420.1000356>.
- Jahedbozorgan *et al.*, (2020) ‘Comparison of serum ferritin levels in pregnant women with preterm and term deliveries’, *Immunopathologia Persa*, 6, pp. e25–e25. Available at: <https://doi.org/10.34172/ipp.2020.25>.
- Jalil *et al.*, (2015) ‘A Secondary Analysis of Maternal Factors Determining Low Birth Weight in Pakistan.’, *Iranian journal of public health*, 44(1), pp. 136–137.
- James (2021) ‘Iron Deficiency Anemia in Pregnancy.’, *Obstetrics and gynecology*, 138(4), pp. 663–674. Available at: <https://doi.org/10.1097/AOG.0000000000004559>.
- Jans *et al.* (2015) ‘Maternal micronutrient deficiencies and related adverse neonatal outcomes after bariatric surgery: a systematic review.’, *Advances in nutrition (Bethesda, Md.)*, 6(4), pp. 420–429. Available at: <https://doi.org/10.3945/an.114.008086>.
- Jateno *et al.* (2023) ‘Household dietary diversity across regions in Ethiopia : Evidence from Ethiopian socio- economic survey data’, pp. 1–14. Available at: <https://doi.org/10.1371/journal.pone.0283496>.
- Jemal, K. and Awol, M. (2019) ‘Minimum Dietary Diversity Score and Associated Factors among Pregnant Women at Alamata General Hospital, Raya Azebo Zone, Tigray Region, Ethiopia.’, *Journal of nutrition and metabolism*, 2019, p. 8314359. Available at: <https://doi.org/10.1155/2019/8314359>.
- Jeong-Ok *et al.* (2014) ‘Prevalence and risk factors for iron deficiency anemia in the Korean population: results of the fifth Korea National Health and Nutrition Examination Survey.’, *Journal of Korean medical science*, 29(2), pp. 224–229. Available at: <https://doi.org/10.3346/jkms.2014.29.2.224>.
- Jouanne *et al.* (2021) ‘Nutrient requirements during pregnancy and lactation’, *Nutrients*, 13(2), pp. 1–17. Available at: <https://doi.org/10.3390/nu13020692>.
- K C, *et al.*, (2020) ‘Low birth weight and its associated risk factors: Health facility-based case-control study.’, *PloS one*, 15(6), p. e0234907. Available at: <https://doi.org/10.1371/journal.pone.0234907>.
- Kalanda (2007) ‘Maternal anthropometry and weight gain as risk factors for poor pregnancy outcomes in a rural area of southern Malawi.’, *Malawi medical journal : the journal of*

- Medical Association of Malawi*, 19(4), pp. 149–153. Available at: <https://doi.org/10.4314/mmj.v19i4.10945>.
- Karimi *et al.* (2022) ‘Maternal dietary diversity and nutritional adequacy in relation with anthropometric measurements of newborns at birth : a cohort study in Tehran city’, *BMC Pediatrics*, pp. 1–11. Available at: <https://doi.org/10.1186/s12887-021-03102-3>.
- Kassa *et al.* (2017) ‘Prevalence and determinants of anemia among pregnant women in Ethiopia; a systematic review and meta-analysis.’, *BMC hematology*, 17, p. 17. Available at: <https://doi.org/10.1186/s12878-017-0090-z>.
- Katenga *et al.* (2021) ‘Enhancing nutrition knowledge and dietary diversity among rural pregnant women in Malawi: a randomized controlled trial’, *BMC Pregnancy and Childbirth*, 21(1), p. 644. Available at: <https://doi.org/10.1186/s12884-021-04117-5>.
- Katiso *et al.* (2020) ‘Prevalence and Determinants of Low Birth Weight in Ethiopia: A Systematic Review and Meta-Analysis’, *Advances in Public Health*, 2020. Available at: <https://doi.org/10.1155/2020/7589483>.
- Kazma *et al.* (2020) ‘Anatomical and physiological alterations of pregnancy.’, *Journal of pharmacokinetics and pharmacodynamics*, 47(4), pp. 271–285. Available at: <https://doi.org/10.1007/s10928-020-09677-1>.
- Kebede (2016) ‘Ethiopian National Micronutrient Survey Report, september 2016.’, *Jurnal Penelitian Pendidikan Guru Sekolah Dasar*, 6(August), p. 128.
- Kebede *et al.*, (2022) ‘Dietary Diversity and Associated Factors Among Pregnant Women in Addis Ababa, Ethiopia, 2021.’, *International journal of public health*, 67, p. 1605377. Available at: <https://doi.org/10.3389/ijph.2022.1605377>.
- Kelishadi *et al.*, (2015) ‘Relationship of the intake of different food groups by pregnant mothers with the birth weight and gestational age: Need for public and individual educational programs’, *Journal of Education and Health Promotion*, 4(1), p. 23. Available at: <https://doi.org/10.4103/2277-9531.154109>.
- Kennedy *et al.* (2013) *Food and agricultur organization guidelines for measuring household and individual dietary diversity. FAO, Rome,Italy:Nutrition and consumenrs protection Division,food and Agriculture organization of the United Nations., Fao.* Available at: <https://doi.org/613.2KEN>.
- Kibret *et al.* (2024) ‘Magnitude of preterm birth and associated factors Among mothers who gave birth in Debre Berhan comprehensive specialized hospital’, *Frontiers in Global Women’s Health*, 5(May), pp. 1–9. Available at: <https://doi.org/10.3389/fgwh.2024.1375196>.
- Koletzko *et al.* (2013) ‘German national consensus recommendations on nutrition and lifestyle in pregnancy by the “Healthy Start - Young Family Network”.’, *Annals of nutrition & metabolism*, 63(4), pp. 311–322. Available at: <https://doi.org/10.1159/000358398>.
- Komicha *et al.* (2021) ‘Magnitude of Low Birth Weight and Associated Factors among Women who gave Birth in Public Hospitals of Harari Regional State, Eastern Ethiopia’, 10, p. 534.
- Kountz (2009) ‘Strategies for improving low health literacy’, *Postgraduate Medicine*, 121(5),

- pp. 171–177. Available at: <https://doi.org/10.3810/pgm.2009.09.2065>.
- Kozuki *et al.* (2015) ‘Short Maternal Stature Increases Risk of Small-for-Gestational-Age and Preterm Births in Low- and Middle-Income Countries: Individual Participant Data Meta-Analysis and Population Attributable Fraction.’, *The Journal of nutrition*, 145(11), pp. 2542–2550. Available at: <https://doi.org/10.3945/jn.115.216374>.
- Krasevec *et al.* (2022) ‘Study protocol for UNICEF and WHO estimates of global, regional, and national low birthweight prevalence for 2000 to 2020.’, *Gates open research*, 6, p. 80. Available at: <https://doi.org/10.12688/gatesopenres.13666.1>.
- Krukowski *et al.* (2016) ‘Are early first trimester weights valid proxies for preconception weight?’, *BMC Pregnancy and Childbirth*, pp. 10–15. Available at: <https://doi.org/10.1186/s12884-016-1159-6>.
- Kuche *et al.* (2015) ‘Nutritional Status and Associated Factors among Pregnant Women in Wondo Genet District, Southern Ethiopia’, *Journal of Food Science and Engineering*, 5(2). Available at: <https://doi.org/10.17265/2159-5828/2015.02.005>.
- Kumera *et al.* (2018) ‘Undernutrition and its association with socio-demographic, anemia and intestinal parasitic infection among pregnant women attending antenatal care at the University of Gondar Hospital, Northwest Ethiopia’, *Maternal Health, Neonatology and Perinatology*, 4(1), p. 18. Available at: <https://doi.org/10.1186/s40748-018-0087-z>.
- Kushi *et al.*, (2023) ‘Antenatal care follow-up was significantly associated with a higher probability of high dietary diversity score among pregnant women in okra-producing areas of western Ethiopia: proportional odds model.’, *Food & nutrition research*, 67. Available at: <https://doi.org/10.29219/fnr.v67.9608>.
- Lassi *et al.* (2022) ‘Prenatal nutrition and nutrition in pregnancy: Effects on long-term growth and development’, in J.M. Saavedra and A.M. Dattilo (eds) *Early Nutrition and Long-Term Health (Second Edition)*. Second Edi. Woodhead Publishing, pp. 397–417. Available at: <https://doi.org/https://doi.org/10.1016/B978-0-12-824389-3.00013-1>.
- Lassi *et al.*, (2020) ‘Impact of dietary interventions during pregnancy on maternal, neonatal, and child outcomes in low-and middle-income countries’, *Nutrients*, 12(2). Available at: <https://doi.org/10.3390/nu12020531>.
- Lawn *et al.* (2010) ‘Global report on preterm birth and stillbirth (1 of 7): definitions, description of the burden and opportunities to improve data’, *BMC pregnancy and childbirth*, 10(Suppl 1), p. S1.
- Leal *et al.* (2016) ‘Prevalence and risk factors related to preterm birth in Brazil’, *Reproductive Health*, 13(3), p. 127. Available at: <https://doi.org/10.1186/s12978-016-0230-0>.
- Lee *et al.* (2013) ‘Dietary intakes of women during pregnancy in low-and middle-income countries’, *Public health nutrition*, 16(8), pp. 1340–1353.
- Li *et al.*, (2009) ‘Vitamin B(12) and birth defects.’, *Molecular genetics and metabolism*, 98(1–2), pp. 166–172. Available at: <https://doi.org/10.1016/j.ymgme.2009.06.004>.
- Li, *et al.* (2021) ‘Healthy dietary patterns and common pregnancy complications: a prospective and longitudinal study.’, *The American journal of clinical nutrition*, 114(3), pp. 1229–1237. Available at: <https://doi.org/10.1093/ajcn/nqab145>.

- Liang, X. *et al.* (2024) ‘Global, regional, and national burden of preterm birth, 1990-2021: a systematic analysis from the global burden of disease study 2021.’, *EClinicalMedicine*, 76, p. 102840. Available at: <https://doi.org/10.1016/j.eclinm.2024.102840>.
- Lindsay *et al.* (2001) *What Works ? A Review of the Efficacy and Effectiveness of Nutrition Interventions*.
- Lisa (2010) ‘Learning zone. Continuing Professional Development. Recommendations for the use of eggs in the diet’.
- Loy *et al.* (2013) ‘Relative validity of dietary patterns during pregnancy assessed with a food frequency questionnaire’, *International Journal of Food Sciences and Nutrition*, 64(6), pp. 668–673. Available at: <https://doi.org/10.3109/09637486.2013.787398>.
- Lukmanji, Z. *et al.* (2008) ‘Tanzania food composition tables’, *muhimbili university of allied science, Tanzania food and nutrition centre and Havard school of public health*, (November), p. 259. Available at: <http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Tanzania+Food+Composition+Tables#0>.
- Lutter *et al.* (2018) ‘The potential of a simple egg to improve maternal and child nutrition.’, *Maternal & child nutrition*, 14 Suppl 3(Suppl 3), p. e12678. Available at: <https://doi.org/10.1111/mcn.12678>.
- Mahmoud *et al.*, (2019) ‘Dietary Knowledge, Practices and Adequacy among Bedouin Pregnant Women’, *INTERNATIONAL JOURNAL OF NURSING* [Preprint]. Available at: <https://api.semanticscholar.org/CorpusID:213681303>.
- Mamme *et al.* (2023) ‘Serum folate deficiency and associated factors among pregnant women in Haramaya District , Eastern Ethiopia : a based study community- -’, pp. 1–8. Available at: <https://doi.org/10.1136/bmjopen-2022-068076>.
- Maqbool, M. *et al.* (2019) ‘MATERNAL HEALTH AND NUTRITION IN PREGNANCY: AN INSIGHT’, *WORLD JOURNAL OF PHARMACY AND PHARMACEUTICAL SCIENCES*, 8, pp. 450–459. Available at: <https://doi.org/10.20959/wjpps20193-13290>.
- Marangoni, F. *et al.* (2016) ‘Maternal Diet and Nutrient Requirements in Pregnancy and Breastfeeding. An Italian Consensus Document.’, *Nutrients*, 8(10). Available at: <https://doi.org/10.3390/nu8100629>.
- Marshall *et al.* (2022) ‘The importance of nutrition in pregnancy and lactation: lifelong consequences.’, *American journal of obstetrics and gynecology*, 226(5), pp. 607–632. Available at: <https://doi.org/10.1016/j.ajog.2021.12.035>.
- Marta *et al.* (2021) ‘Folate Content and Yolk Color of Hen Eggs from Different Farming Systems.’, *Molecules (Basel, Switzerland)*, 26(4). Available at: <https://doi.org/10.3390/molecules26041034>.
- Martin-prevel *et al.* (2017) ‘Development of a Dichotomous Indicator for Population-Level Assessment of Dietary Diversity in Women of Reproductive Age’, (4), pp. 1–10.
- Martin *et al.* (2016) ‘The Assessment of Diet Quality and Its Effects on Health Outcomes Pre-pregnancy and during Pregnancy.’, *Seminars in reproductive medicine*, 34(2), pp. 83–92. Available at: <https://doi.org/10.1055/s-0036-1571353>.

- Mayisso *et al.* (2025a) ‘Effect of nutrition education on improving adequacy and serum levels of essential micronutrients in pregnancy in the northern zone of Sidama Region , Ethiopia : Cluster randomized controlled trial’.
- Mayisso *et al.* (2025b) ‘Validation of food variety and dietary diversity scores as indicators of micronutrient adequacy among pregnant women in the northern zone of Sidama region,Ethiopia’, *Front. Public Health* 13:1536419. [Preprint], (June). Available at: <https://doi.org/10.3389/fpubh.2025.1536419>.
- McDonald *et al.* (2011) ‘High gestational weight gain and the risk of preterm birth and low birth weight: a systematic review and meta-analysis.’, *Journal of obstetrics and gynaecology Canada : JOGC = Journal d’obstetrique et gynecologie du Canada : JOGC*, 33(12), pp. 1223–1233. Available at: [https://doi.org/10.1016/S1701-2163\(16\)35107-6](https://doi.org/10.1016/S1701-2163(16)35107-6).
- Mei, Z. *et al.* (2023) ‘Comparison of Current World Health Organization Guidelines with Physiologically Based Serum Ferritin Thresholds for Iron Deficiency in Healthy Young Children and Nonpregnant Women Using Data from the Third National Health and Nutrition Examination Survey’, *The Journal of nutrition*, 153(3), pp. 771–780. Available at: <https://doi.org/10.1016/j.tjnut.2023.01.035>.
- Mekonen, D. *et al.* (2019) ‘Proportion of Preterm birth and associated factors among mothers who gave birth in Debretabor town health institutions, northwest, Ethiopia’, *BMC Research Notes*, 12, p. 2. Available at: <https://doi.org/10.1186/s13104-018-4037-7>.
- Mekonen *et al.*, (2024) ‘Maternal dietary diversity increases with women’s high decision-making autonomy in Northwest Ethiopia, 2022’, *Heliyon*, 10(11), p. e31735. Available at: <https://doi.org/https://doi.org/10.1016/j.heliyon.2024.e31735>.
- Melaku *et al.* (2010) ‘Folate deficiency in women of reproductive age in nine administrative regions of Ethiopia: An emerging public health problem’, *South African Journal of Clinical Nutrition*, 23, pp. 132–137. Available at: <https://doi.org/10.1080/16070658.2010.11734327>.
- Melese *et al.*, (2021) ‘Household food insecurity and coping strategies in Southern Ethiopia’, *Agriculture and Food Security*, 10(1), pp. 1–13. Available at: <https://doi.org/10.1186/s40066-021-00296-8>.
- Melough *et al.* (2019) ‘Association of eggs with dietary nutrient adequacy and cardiovascular risk factors in US adults.’, *Public health nutrition*, 22(11), pp. 2033–2042. Available at: <https://doi.org/10.1017/S1368980019000211>.
- Merialdi *et al.* (2003) ‘Nutritional interventions during pregnancy for the prevention or treatment of impaired fetal growth: an overview of randomized controlled trials.’, *The Journal of nutrition*, 133(5 Suppl 2), pp. 1626S–1631S. Available at: <https://doi.org/10.1093/jn/133.5.1626S>.
- Mesfin *et al.* (2023) ‘Minimum Dietary Diversity and Associated Factors Among Pregnant Women Living in Arba Minch Health and Demographic Surveillance Sites, Southern Ethiopia, 2022.’, *Health services research and managerial epidemiology*, 10, p. 23333928231166670. Available at: <https://doi.org/10.1177/23333928231166671>.
- Mgamb *et al.* (2017) ‘Folate deficiency and utilization of folic acid fortified flour among

- pregnant women attending antenatal clinic at Pumwani Maternity Hospital, Kenya, 2015.’, *The Pan African medical journal*, 28(Suppl 1), p. 8. Available at: <https://doi.org/10.11604/pamj.supp.2017.28.1.9296>.
- Miele *et al.* (2021) ‘Maternal Nutrition Status Associated with Pregnancy-Related Adverse Outcomes’, *Nutrients*, 13. Available at: <https://doi.org/10.3390/nu13072398>.
- Milasinović, L. *et al.* (2013) ‘[Significance of serum ferritin level in the prediction of delivery of low birth weight newborns for gestational age].’, *Srpski arhiv za celokupno lekarstvo*, 141(5–6), pp. 337–343. Available at: <https://doi.org/10.2298/sarh1306337m>.
- Milman (2012) ‘Oral iron prophylaxis in pregnancy: not too little and not too much!’, *Journal of pregnancy*, 2012, p. 514345. Available at: <https://doi.org/10.1155/2012/514345>.
- Misgina *et al.* (2021) ‘Pre-conception and prenatal factors influencing gestational weight gain: a prospective study in Tigray region, northern Ethiopia’, *BMC Pregnancy and Childbirth*, 21(1), pp. 1–13. Available at: <https://doi.org/10.1186/s12884-021-04171-z>.
- Moghaddam *et al.*, (2015) ‘Maternal Hemoglobin Levels during Pregnancy and their Association with Birth Weight of Neonates.’, *Iranian journal of pediatric hematology and oncology*, 5(4), pp. 211–7. Available at: <http://www.ncbi.nlm.nih.gov/pubmed/26985354> <http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC4779156>.
- Moghaddam *et al.*, (2012) ‘Maternal anthropometric measurements and other factors: relation with birth weight of neonates.’, *Nutrition research and practice*, 6(2), pp. 132–137. Available at: <https://doi.org/10.4162/nrp.2012.6.2.132>.
- MOH, M. (2021) *National Coordinating Committee on Food and Nutrition (NCCFN)*.
- Mohammed, S. *et al.* (2019) ‘Maternal obstetric and socio-demographic determinants of low birth weight: a retrospective cross-sectional study in Ghana’, *Reproductive Health*, 16(1), p. 70. Available at: <https://doi.org/10.1186/s12978-019-0742-5>.
- Molloy *et al.* (2008) ‘Effects of folate and vitamin B12 deficiencies during pregnancy on fetal, infant, and child development.’, *Food and nutrition bulletin*, 29(2 Suppl), pp. S101-11; discussion S112-5. Available at: <https://doi.org/10.1177/15648265080292S114>.
- Montvignier *et al.* (2022) ‘In Underweight Women, Insufficient Gestational Weight Gain Is Associated with Adverse Obstetric Outcomes.’, *Nutrients*, 15(1). Available at: <https://doi.org/10.3390/nu15010057>.
- Muchie *et al.* (2020) ‘Epidemiology of preterm birth in Ethiopia: Systematic review and meta-analysis’, *BMC Pregnancy and Childbirth*, 20(1), pp. 1–12. Available at: <https://doi.org/10.1186/s12884-020-03271-6>.
- Mulatu *et al.* (2017) ‘Magnitude and factors associated with low birth weight among new born in selected public hospitals of Addis Ababa, Ethiopia, 2016’, *Glob J Med Res*, 15(5), p. 3.
- Mulu *et al.* (2020) ‘Determinants of Low Birth Weight Among Newborns Delivered in Public Hospitals in Addis Ababa, Ethiopia: Case-Control Study.’, *Pediatric health, medicine and therapeutics*, 11, pp. 119–126. Available at: <https://doi.org/10.2147/PHMT.S246008>.
- Murimi (2013) ‘Healthy literacy, nutrition education, and food literacy’, *Journal of Nutrition*

- Education and Behavior*, 45(3), p. 195. Available at: <https://doi.org/10.1016/j.jneb.2013.03.014>.
- Murphy et al. (2003) 'Nutritional Importance of Animal Source Foods', *J. Nutr*, 133, pp. 3965–3971.
- Mursil, M. et al. (2024) 'Maternal Nutritional Factors Enhance Birthweight Prediction: A Super Learner Ensemble Approach', *Information*, 15(11). Available at: <https://doi.org/10.3390/info15110714>.
- Naghashpour, M. et al. (2014) 'Nutrition education based on health belief model improves dietary calcium intake among female students of junior high schools.', *Journal of health, population, and nutrition*, 32(3), pp. 420–429.
- Nankumbi et al., (2018) 'Maternal Nutrition Education Provided by Midwives: A Qualitative Study in an Antenatal Clinic, Uganda.', *Journal of nutrition and metabolism*, 2018, p. 3987396. Available at: <https://doi.org/10.1155/2018/3987396>.
- Nayak, M.U. et al. (2001) 'Nutrition Communication Using Social-Marketing Techniques to Combat Vitamin A Deficiency: Results of Summative Evaluation', *Food and Nutrition Bulletin*, 22(4), pp. 454–465. Available at: <https://doi.org/10.1177/156482650102200419>.
- Ndekha, M. et al. (2000) 'Seasonal variation in the dietary sources of energy for pregnant women in Lungwena, rural Malawi', *Ecology of Food and Nutrition*, 38(6), pp. 605–622. Available at: <https://doi.org/10.1080/03670244.2000.9991599>.
- Niguse, H. and Mebratu, T. (2023) 'Determinants of avocado commercialization among smallholder farmers in Shebediono Woreda, Sidama Zone SNNPRS of Ethiopia', *International Journal of Agricultural Research, Innovation and Technology*, 13, pp. 89–95. Available at: <https://doi.org/10.3329/ijarit.v13i1.68054>.
- NMHS (2022) 'Obstetrics and Gynaecology Clinical Practice Guideline: Vaginal Procedure', *North Metropolitan Health Service* [Preprint].
- NNPI (2016) 'National Nutrition Program Multi-sectoral Implementation Guide National Nutrition Program Multi-sectoral Implementation Guide June 2016', *National Nutrition Program Multi-sectoral Implementation Guide* [Preprint], (June).
- Oduro, A.R. et al. (2023) 'Birth preparedness and complications readiness among women in disadvantaged rural districts of Ghana', *BMC Pregnancy and Childbirth*, 23(1), p. 728. Available at: <https://doi.org/10.1186/s12884-023-06041-2>.
- Ohuma, E.O. et al. (2023) 'National, regional, and global estimates of preterm birth in 2020, with trends from 2010: a systematic analysis', *The Lancet*, 402(10409), pp. 1261–1271. Available at: [https://doi.org/10.1016/S0140-6736\(23\)00878-4](https://doi.org/10.1016/S0140-6736(23)00878-4).
- Ojofeitimi, E.O. (2020) 'The effect of maternal nutrition on pregnancy outcomes in Osum state, Nigeria', 8(2), pp. 25–34.
- Olmedo-Requena, R. et al. (2019) 'Association between low dairy intake during pregnancy and small for gestational age infants.', *European journal of clinical nutrition*, 73(12), pp. 1642–1645. Available at: <https://doi.org/10.1038/s41430-019-0513-y>.
- Omer, A.M. et al. (2020) 'Effectiveness of a nutrition education and counselling training

- package on antenatal care: a cluster randomized controlled trial in Addis Ababa.’, *Health policy and planning*, 35(Supplement\_1), pp. i65–i75. Available at: <https://doi.org/10.1093/heapol/czaa101>.
- Ota, E. *et al.* (2015) ‘Antenatal dietary education and supplementation to increase energy and protein intake.’, *The Cochrane database of systematic reviews*, (6), p. CD000032. Available at: <https://doi.org/10.1002/14651858.CD000032.pub3>.
- Pal, A. *et al.* (2020) ‘The risk of low birth weight and associated factors in West Bengal, India: a community based cross-sectional study’, *Egyptian Pediatric Association Gazette*, 68(1). Available at: <https://doi.org/10.1186/s43054-020-00040-0>.
- Panda, R. *et al.* (2022) ‘Determinants of Low Birth Weight in a Tertiary Care Hospital in Eastern India’, *National Journal of Community Medicine*, 13(1), pp. 37–42. Available at: <https://doi.org/10.5455/njcm.20211207094736>.
- Parets, S.E. *et al.* (2014) ‘Preterm birth and its long-term effects: methylation to mechanisms.’, *Biology*, 3(3), pp. 498–513. Available at: <https://doi.org/10.3390/biology3030498>.
- Pastore, G. *et al.* (1993) ‘Seasonal energy stress in an Ethiopian rural community: an analysis of the impact at the household level.’, *European journal of clinical nutrition*, 47(12), pp. 851–862.
- Pathak, P. *et al.* (2004) ‘Prevalence of multiple micronutrient deficiencies amongst pregnant women in a rural area of Haryana.’, *Indian journal of pediatrics*, 71(11), pp. 1007–1014. Available at: <https://doi.org/10.1007/BF02828117>.
- Poulsen *et al.* (2015) ‘Exploring educational disparities in risk of preterm delivery: a comparative study of 12 European birth cohorts.’, *Paediatric and perinatal epidemiology*, 29(3), pp. 172–183. Available at: <https://doi.org/10.1111/ppe.12185>.
- Procter (2014) ‘Position of the academy of nutrition and dietetics: Nutrition and lifestyle for a healthy pregnancy outcome’, *Journal of the Academy of Nutrition and Dietetics*, 114(7), pp. 1099–1103. Available at: <https://doi.org/10.1016/j.jand.2014.05.005>.
- Quansah *et al.*, (2020) ‘Maternal dietary diversity and pattern during pregnancy is associated with low infant birth weight in the Cape Coast metropolitan hospital, Ghana: A hospital based cross-sectional study’, *Heliyon*, 6(5), p. e03923. Available at: <https://doi.org/https://doi.org/10.1016/j.heliyon.2020.e03923>.
- Rahman, M. *et al.* (2020) ‘Body mass index in early-pregnancy and selected maternal health outcomes: Findings from two cohorts in Bangladesh.’, *Journal of global health*, 10(2), p. 20419. Available at: <https://doi.org/10.7189/jogh.10.020419>.
- Ramakrishnan *et al.* (2012) ‘Effect of women’s nutrition before and during early pregnancy on maternal and infant outcomes: A systematic review’, *Paediatric and Perinatal Epidemiology*, 26(SUPPL. 1), pp. 285–301. Available at: <https://doi.org/10.1111/j.1365-3016.2012.01281.x>.
- Ramakrishnan *et al.*,(2017) ‘Maternal Nutrition and Birth Outcomes’, in, pp. 487–502. Available at: [https://doi.org/10.1007/978-3-319-43739-2\\_22](https://doi.org/10.1007/978-3-319-43739-2_22).
- Rasmussen *et al.* (2009) *Institute of Medicine (US) and National Research Council (US) Committee to Reexamine IOM Pregnancy Weight Guidelines. Weight Gain During*

- Pregnancy: Reexamining the Guidelines*. Edited by K.M. Rasmussen and A.L. Yaktine. Washington (DC). Available at: <https://doi.org/10.17226/12584>.
- Refsum (2001) 'Folate, vitamin B12 and homocysteine in relation to birth defects and pregnancy outcome', *British Journal of Nutrition*. 2007/03/09, 85(S2), pp. S109–S113. Available at: <https://doi.org/DOI: 10.1049/BJN2000302>.
- Reshid, M. and Anato, A. (2024) 'Community-based nutrition education and counselling provided during pregnancy: effects on knowledge and attitude towards iron-folic acid supplementation.', *Journal of nutritional science*, 13, p. e58. Available at: <https://doi.org/10.1017/jns.2024.59>.
- Riazi, S. *et al.* (2024) 'The effect of nutrition education based on the Health Belief Model ( HBM ) on food intake in pregnant Afghan immigrant women : a semi - experimental study', *BMC Pregnancy and Childbirth* [Preprint]. Available at: <https://doi.org/10.1186/s12884-024-06728-0>.
- Rogers *et al.* (2018) 'Global folate status in women of reproductive age: a systematic review with emphasis on methodological issues.', *Annals of the New York Academy of Sciences*, 1431(1), pp. 35–57. Available at: <https://doi.org/10.1111/nyas.13963>.
- Roos *et al.*, (2015) 'Animal Source Foods to Improve Micronutrient Nutrition and Human Function in Developing Countries Small Indigenous Fish Species in Bangladesh: Contribution to Vitamin A, Calcium and Iron Intakes 1,2', (March).
- Ruel *et al.* (2013) 'Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition?', *Lancet (London, England)*, 382(9891), pp. 536–551. Available at: [https://doi.org/10.1016/S0140-6736\(13\)60843-0](https://doi.org/10.1016/S0140-6736(13)60843-0).
- Ruel (2003) 'Operationalizing Dietary Diversity: A Review of Measurement Issues and Research Priorities', *The Journal of Nutrition*, 133(11), pp. 3911S-3926S. Available at: <https://doi.org/https://doi.org/10.1093/jn/133.11.3911S>.
- Ruel (2018) 'Animal Source Foods to Improve Micronutrient Nutrition and Human Function in Developing Countries Operationalizing Dietary Diversity : A Review of Measurement Issues', (May).
- Ruxton (2010) 'Recommendations for the use of eggs in the diet.', *Nursing standard (Royal College of Nursing (Great Britain) : 1987)*, 24(37), pp. 47–55; quiz 56. Available at: <https://doi.org/10.7748/ns2010.05.24.37.47.c7780>.
- Ruxton (2013) 'Learning zone.Ccontinuing Professional Development. Value of eggs during pregnancy and early childhood.', *Nursing Standard*, 27(24), pp. 41–50.
- Ryan *et al.* (2017) 'Micronutrient Status among Pregnant Women in Zinder, Niger and Risk Factors Associated with Deficiency.', *Nutrients*, 9(5). Available at: <https://doi.org/10.3390/nu9050430>.
- Saaka, M. *et al.* (2017) 'Dietary Diversity Is Not Associated with Haematological Status of Pregnant Women Resident in Rural Areas of Northern Ghana', *Journal of Nutrition and Metabolism*, 2017. Available at: <https://doi.org/10.1155/2017/8497892>.
- Sachithanathan, V. *et al.* (2012) 'Impact of nutrition education on the nutritional status',

- Nutrition and Food Science*, 42(3), pp. 173–180. Available at: <https://doi.org/10.1108/00346651211228469>.
- Safari, S. *et al.* (2016) ‘Evidence based emergency medicine; part 5 receiver operating curve and area under the curve’, *Emergency*, 4(2), p. 111.
- Sahu, P. *et al.* (2022) ‘Chapter -4 Nutrition Education’, in, pp. 55–73.
- Samuel, A. *et al.* (2025) ‘Potential Impact of Large-Scale Food Fortification in Ethiopia: Coverage and Knowledge of Fortifiable Foods’, *Maternal and Child Nutrition*, pp. 1–11. Available at: <https://doi.org/10.1111/mcn.70055>.
- Santos, S. *et al.* (2018) ‘Gestational weight gain charts for different body mass index groups for women in Europe, North America, and Oceania.’, *BMC medicine*, 16(1), p. 201. Available at: <https://doi.org/10.1186/s12916-018-1189-1>.
- Šarac, J. *et al.* (2022) ‘Testing the Institute of Medicine (IOM) recommendations on maternal reproductive health and associated neonatal characteristics in a transitional, Mediterranean population.’, *Annals of human biology*, 49(2), pp. 91–99. Available at: <https://doi.org/10.1080/03014460.2022.2080863>.
- Schiavone *et al.*, (2011) ‘Egg enrichment with vitamins and trace minerals’, in F. Van Immerseel, Y. Nys, and M. Bain (eds) *Improving the Safety and Quality of Eggs and Egg Products*. Woodhead Publishing (Woodhead Publishing Series in Food Science, Technology and Nutrition), pp. 289–320. Available at: <https://doi.org/10.1533/9780857093929.3.289>.
- Scholl, T.O. (2005) ‘Iron status during pregnancy: setting the stage for mother and infant’, *The American Journal of Clinical Nutrition*, 81(5), pp. 1218S-1222S. Available at: <https://doi.org/10.1093/ajcn/81.5.1218>.
- Scholl *et al.*, (2015) ‘Maternal Nutrition and Preterm Delivery BT - Preventive Nutrition: The Comprehensive Guide for Health Professionals’, in A. Bendich and R.J. Deckelbaum (eds). Cham: Springer International Publishing, pp. 705–731. Available at: [https://doi.org/10.1007/978-3-319-22431-2\\_33](https://doi.org/10.1007/978-3-319-22431-2_33).
- Schönfeldt *et al.* (2013) ‘The impact of animal source food products on human nutrition and health’, *South African Journal of Animal Science*, 43(3), pp. 394–412. Available at: <https://doi.org/10.4314/sajas.v43i3.11>.
- Sebastian *et al* (2022) ‘Strengthening Nutrition Knowledge of Pregnant Women Through Nutrition Education During Public Health Emergencies.’, *Journal of Medicine, University of Santo Tomas*, 6(1), pp. 906–915. Available at: <https://doi.org/10.35460/2546-1621.2021-0091>.
- Seid *et al.*, (2022) ‘Dietary diversity, nutritional status and associated factors among lactating mothers visiting government health facilities at Dessie town, Amhara region, Ethiopia’, *PLoS ONE*, 17(2 February), pp. 1–14. Available at: <https://doi.org/10.1371/journal.pone.0263957>.
- Seifu *et al.* (2022) ‘Red blood cell folate level and associated factors of folate insufficiency among pregnant women attending antenatal care during their first trimester of pregnancy in Addis Ababa, Ethiopia.’, *SAGE open medicine*, 10, p. 20503121221118988. Available

at: <https://doi.org/10.1177/20503121221118987>.

- Shachar *et al.* (2015) ‘Maternal height and risk for spontaneous preterm birth across BMI categories’, *American Journal of Obstetrics & Gynecology*, 212(1), p. S83. Available at: <https://doi.org/10.1016/j.ajog.2014.10.178>.
- Shah, R. *et al.* (2014) ‘Incidence and risk factors of preterm birth in a rural Bangladeshi cohort.’, *BMC pediatrics*, 14, p. 112. Available at: <https://doi.org/10.1186/1471-2431-14-112>.
- Sharifat, R. *et al.* (2024) ‘Nutritional education on health beliefs , metabolic profiles , and quality of life among high-risk pregnant women for gestational diabetes mellitus : a randomized controlled trial’, pp. 1–16.
- Sharifirad, G. *et al.* (2009) ‘The effectiveness of nutritional education on the knowledge of diabetic patients using the health belief model.’, *Journal of research in medical sciences : the official journal of Isfahan University of Medical Sciences*, 14(1), pp. 1–6.
- Sharma *et al.*, (2014) ‘Effects of Maternal Health and Nutrition on Birth Weight of Infant’, *International Journal of Science and Research*, 3(6), pp. 855–858.
- Shenka *et al.* (2018) ‘Dietary Diversity and Nutritional Status of Pregnant Women Attending Public Hospitals in Dire Dawa City Administration, Eastern Ethiopia’, *East African Journal of Health and Biomedical Sciences*, 2(1), pp. 10–17.
- Shieh, A. *et al.* (2024) ‘Comparing the performance of pediatric weight estimation methods’, *The American Journal of Emergency Medicine*, 82, pp. 26–32. Available at: <https://doi.org/https://doi.org/10.1016/j.ajem.2024.04.053>.
- Shiferaw, K. *et al.* (2021) ‘Adequacy and timeliness of antenatal care visits among Ethiopian women: a community-based panel study’, *BMJ Open*, 11. Available at: <https://api.semanticscholar.org/CorpusID:245444736>.
- Shrestha, V. *et al.* (2021) ‘Factors associated with dietary diversity among pregnant women in the western hill region of Nepal: A community based crosssectional study’, *PLoS ONE*, 16(4 April), pp. 1–17. Available at: <https://doi.org/10.1371/journal.pone.0247085>.
- Singh *et al.*, (2009) ‘Maternal Factors for Low Birth Weight Babies.’, *Medical journal, Armed Forces India*, 65(1), pp. 10–12. Available at: [https://doi.org/10.1016/S0377-1237\(09\)80045-2](https://doi.org/10.1016/S0377-1237(09)80045-2).
- Soma-Pillay, P. *et al.* (2016) ‘Physiological changes in pregnancy.’, *Cardiovascular journal of Africa*, 27(2), pp. 89–94. Available at: <https://doi.org/10.5830/CVJA-2016-021>.
- Sommer *et al.*, 2015 (2015) ‘Effects of early pregnancy BMI, mid-gestational weight gain, glucose and lipid levels in pregnancy on offspring’s birth weight and subcutaneous fat: A population-based cohort study’, *BMC Pregnancy and Childbirth*, 15(1), pp. 1–9. Available at: <https://doi.org/10.1186/s12884-015-0512-5>.
- Sophie *et al.* (2019) ‘The golden egg: Nutritional value, bioactivities, and emerging benefits for human health’, *Nutrients*, 11(3), pp. 1–26. Available at: <https://doi.org/10.3390/nu11030684>.
- Suryani, S. *et al.* (2022) ‘Nutrition Education Models in Pregnancy To Increase Knowledge and Dietary Patterns: a Systematic Review’, *Nsc Nursing*, 3(1), pp. 1–27. Available at:

- <https://doi.org/10.32549/opi-nsc-568>.
- Sutan, R. *et al.* (2018) ‘A 5 year trend and predictors of preterm births in single referral centre of the Greater Kuala Lumpur, Malaysia’, *Int J Pregn & Chi Birth*, 4(6), pp. 196–201.
- Tadesse, T. *et al.* (2023) ‘Magnitude and associated factors of low birth weight among term newborns delivered in Addis Ababa public hospitals, Ethiopia, 2021’, *Journal of Obstetrics and Gynaecology*, 43(1), p. 2114332. Available at: <https://doi.org/10.1080/01443615.2022.2114332>.
- Tamene *et al.*, 2020 (2020) ‘Ethno-medicinal study of plants in Boricha district : Use , preparation and application by traditional healers ,Southern Ethiopia’, *Journal of Medicinal plant research*, 14(7), pp. 343–353. Available at: <https://doi.org/10.5897/JMPR2020.6906>.
- Tang *et al.* (2016) ‘Determining a Global Mid-Upper Arm Circumference Cutoff to Assess Malnutrition in Pregnant Women’, (June).
- Tang *et al.* (2020) ‘Determining a global mid-upper arm circumference cut-off to assess underweight in adults (men and non-pregnant women).’, *Public health nutrition*, 23(17), pp. 3104–3113. Available at: <https://doi.org/10.1017/S1368980020000397>.
- Tareke *et al.* (2024) ‘Association between maternal dietary diversity during pregnancy and birth outcomes: evidence from a systematic review and meta-analysis.’, *BMC nutrition*, 10(1), p. 151. Available at: <https://doi.org/10.1186/s40795-024-00960-9>.
- Tariku, Y. and Baye, K. (2022) ‘Pregnant Mothers Diversified Dietary Intake and Associated Factors in Southwest Ethiopia: A Cross-Sectional Study.’, *Journal of nutrition and metabolism*, 2022, p. 4613165. Available at: <https://doi.org/10.1155/2022/4613165>.
- Tebekaw, *et al.* (2014) ‘The burden of underweight and overweight among women in Addis Ababa, Ethiopia’, *BMC Public Health*, 14(1). Available at: <https://doi.org/10.1186/1471-2458-14-1126>.
- Tefera *et al.*, (2020) ‘Dietary diversity practice and associated factors among pregnant women attending ANC in Kolfe Keranyo sub city health centers, Addis Ababa, Ethiopia’, *medRxiv*, pp. 1–30. Available at: <https://www.medrxiv.org/content/10.1101/2020.04.27.20081596v1%0Ahttps://www.medrxiv.org/content/10.1101/2020.04.27.20081596v1.abstract>.
- Tekeba, B. *et al.* (2024) ‘Early neonatal mortality and determinants in Ethiopia: multilevel analysis of Ethiopian demographic and health survey, 2019.’, *BMC pediatrics*, 24(1), p. 558. Available at: <https://doi.org/10.1186/s12887-024-05027-z>.
- Tesfa, N.A. *et al.* (2023) ‘Anthropometric Measurements of Singleton Live Full-Term Newborns in Comparison to Who Standard at University of Gondar Comprehensive Specialised Hospital, Ethiopia’, *Journal of mother and child*, 27(1), p. 198—208. Available at: <https://doi.org/10.34763/jmotherandchild.20232701.d-23-00043>.
- Tesfaye *et al* (2024) ‘Effect of nutrition counseling on nutritional status and gestational weight gain of pregnant adolescents in West Arsi , Central Ethiopia : a cluster randomized controlled trial’, *Scientific Reports*, (0123456789), pp. 1–12. Available at: <https://doi.org/10.1038/s41598-024-55709-y>.

- Tesfaye, B. (2011) 'RURAL HOUSEHOLD FOOD SECURITY SITUATION ANALYSIS: THE CASE OF BORICHA WEREDA', *Экономика Региона*, 53(9), pp. 167–169.
- Teweldemedhin, L.G. *et al.* (2021) 'Effect of nutrition education by health professionals on pregnancy-specific nutrition knowledge and healthy dietary practice among pregnant women in Asmara, Eritrea: a quasi-experimental study.', *BMJ nutrition, prevention & health*, 4(1), pp. 181–194. Available at: <https://doi.org/10.1136/bmjnph-2020-000159>.
- The Lancet (2016) 'The unfinished agenda of preterm births.', *Lancet (London, England)*. England, p. 2323. Available at: [https://doi.org/10.1016/S0140-6736\(16\)32170-5](https://doi.org/10.1016/S0140-6736(16)32170-5).
- Thomas, D. *et al.* (2014) 'Prediction of pre-pregnancy weight from first trimester visit', *The FASEB Journal*, 28. Available at: [https://doi.org/10.1096/fasebj.28.1\\_supplement.1031.2](https://doi.org/10.1096/fasebj.28.1_supplement.1031.2).
- Thomas *et al.*, (2008) 'The benefits of integrating nutrition into clinical medicine.', *The Israel Medical Association journal : IMAJ*. Israel, pp. 730–732.
- Tilahun *et al.*, (2021) 'Maternal minimum dietary diversity and associated factors among pregnant women, Southwest Ethiopia, 2021', *BMC Nutrition*, 7(1), p. 66. Available at: <https://doi.org/10.1186/s40795-021-00474-8>.
- Torheim *et al.* (2010) 'Women in resource-poor settings are at risk of inadequate intakes of multiple micronutrients.', *The Journal of nutrition*, 140(11), pp. 2051S–8S. Available at: <https://doi.org/10.3945/jn.110.123463>.
- Torheim *et al.*, (2004) 'Nutrient adequacy and dietary diversity in rural Mali: Association and determinants', *European Journal of Clinical Nutrition*, 58(4), pp. 594–604. Available at: <https://doi.org/10.1038/sj.ejcn.1601853>.
- Tran, N.T. *et al.* (2019) 'Maternal nutritional adequacy and gestational weight gain and their associations with birth outcomes among Vietnamese women', *BMC Pregnancy and Childbirth*, 19(1), pp. 1–10. Available at: <https://doi.org/10.1186/s12884-019-2643-6>.
- Tsegaye, B. and Kassa, A. (2018) 'Prevalence of adverse birth outcome and associated factors among women who delivered in Hawassa town governmental health institutions, south Ethiopia, in 2017', *Reproductive Health*, 15(1), pp. 1–10. Available at: <https://doi.org/10.1186/s12978-018-0631-3>.
- UNICEF/WHO (2021) *Indicators for Assessing Infant and Young Child Feeding Practices*, World Health Organization.
- Unicef (2004) *Low Birthweight: Country, Regional and Global Estimates*. World Health Organization, UNICEF, Eds. WHO, Geneva; UNICEF, New York., Man. Available at: <https://doi.org/10.2307/2800038>.
- UNICEF (2009) *Tracking Progress on Child and Maternal Nutrition, A survival and development priority*.
- UNICEF (2013) 'Undernourishment in the womb can lead to diminished potential and predispose infants to early death. UNICEF data: monitoring the situation of children and women,' 2013, <http://www.w3.org/data/unicef.org/nutrition/low-birthweight#sthashBG4Ivr>, (September).
- UNICEF (2018) 'Global Nutrition Report', p. 161.

- UNICEF (2022) *Ethiopia Humanitarian Situation Report No. 12 including Northern Conflict and Drought responses*.
- Unicef, E. union (2015) ‘Multi-sectoral Approaches to Nutrition ’, pp. 1–4.
- United Nation (2020) ‘Sustainable development goals’, *Essential Concepts of Global Environmental Governance*, (82), pp. 251–253. Available at: <https://doi.org/10.4324/9780367816681-102>.
- USAID (2014) ‘Multi-Sectoral Nutrition Strategy’, *Multi-Sectoral Nutrition Strategy 2014-2025*, p. 11.
- USDA. (2007) ‘United States Department of Agriculture. Table of Nutrient Retention Factors, Release 6’, *National Academy Press*, p. 18. Available at: [www.nal.usda.gov/fnic/foodcomp/Data/retn6/retn06.pdf](http://www.nal.usda.gov/fnic/foodcomp/Data/retn6/retn06.pdf).
- Vasundhara, D. *et al.* (2020) ‘Maternal MUAC and fetal outcome in an Indian tertiary care hospital: A prospective observational study.’, *Maternal & child nutrition*, 16(2), p. e12902. Available at: <https://doi.org/10.1111/mcn.12902>.
- Venkataraman *et al.* (2022) ‘Study on Assessment of Nutritional Status of Pregnant Women Leading to Malnutrition’, *International Journal of Pharmaceutical Sciences Review and Research*, 75(14), pp. 79–85. Available at: <https://doi.org/10.47583/ijpsrr.2022.v75i01.014>.
- Verhoeff *et al.* (1997) ‘Gestational age assessment by nurses in a developing country using the Ballard method, external criteria only.’, *Annals of tropical paediatrics*, 17(4), pp. 333–342. Available at: <https://doi.org/10.1080/02724936.1997.11747907>.
- Ververs, M.-T. *et al.* (2013) ‘Which anthropometric indicators identify a pregnant woman as acutely malnourished and predict adverse birth outcomes in the humanitarian context?’, *PLoS currents*, 5. Available at: <https://doi.org/10.1371/currents.dis.54a8b618c1bc031ea140e3f2934599c8>.
- Victora, C.G. *et al.* (2008) ‘Maternal and child undernutrition: consequences for adult health and human capital’, *The Lancet*, 371(9609), pp. 340–357. Available at: [https://doi.org/10.1016/S0140-6736\(07\)61692-4](https://doi.org/10.1016/S0140-6736(07)61692-4).
- Victora, C.G. *et al.* (2021) ‘Revisiting maternal and child undernutrition in low-income and middle-income countries: variable progress towards an unfinished agenda’, *The Lancet*, 397(10282), pp. 1388–1399. Available at: [https://doi.org/10.1016/S0140-6736\(21\)00394-9](https://doi.org/10.1016/S0140-6736(21)00394-9).
- Wagura, P. *et al.* (2018) ‘Prevalence and factors associated with preterm birth at kenyatta national hospital’, *BMC pregnancy and childbirth*, 18, pp. 1–8.
- Wallace, T.C. *et al.* (2023) ‘Comparison of the nutrient composition of eggs produced in the Guatemalan highlands during the wet and dry seasons.’, *Food science & nutrition*, 11(12), pp. 8163–8173. Available at: <https://doi.org/10.1002/fsn3.3736>.
- Wang *et al.*, 2018 (2018) ‘Effects of pre-pregnancy body mass index and gestational weight gain on neonatal birth weight in women with gestational diabetes mellitus.’, *Early human development*, 124, pp. 17–21. Available at: <https://doi.org/10.1016/j.earlhumdev.2018.07.008>.

- Wang, H. *et al.* (2017) 'Vitamin D and Chronic Diseases.', *Aging and disease*, 8(3), pp. 346–353. Available at: <https://doi.org/10.14336/AD.2016.1021>.
- Weerasekara, P.C. *et al.* (2020) 'Understanding Dietary Diversity, Dietary Practices and Changes in Food Patterns in Marginalised Societies in Sri Lanka.', *Foods (Basel, Switzerland)*, 9(11). Available at: <https://doi.org/10.3390/foods9111659>.
- WHA (2012) 'Nutrition of women in the preconception period, during pregnancy and the breastfeeding period', p. Provisional agenda item 13.3.
- WHO. (2011) 'Guideline: Vitamin A supplementation in pregnant women. Geneva, World Health Organization.'
- WHO. (2012) *Iron Deficiency Anaemia: Assessment, Prevention and Control: a Guide for Programme Managers*. World Health Organization.
- WHO (1977) 'Recommended Definitions, Terminology and Format for Statistical Tables Related to The Perinatal Period And Use of A New Certificate For Cause of Perinatal Deaths', *Acta Obstetrica et Gynecologica Scandinavica*, 56. Available at: <https://api.semanticscholar.org/CorpusID:42435941>.
- WHO (1995) 'Physical status: the use of and interpretation of anthropometry. Geneva (Switzerland): WHO; 1995.'
- WHO (2012) 'Daily iron and folic acid supplementation guideline in pregnant women', *World Health Organization*, 46, pp. 323–329.
- WHO (2015) 'Serum and Red Blood Cell Folate Concentrations for Assessing Folate Status in Populations', *Vitamin and Mineral Nutrition Information System*, pp. 1–7.
- WHO (2017) *Proper maternal nutrition during pregnancy planning and pregnancy: a healthy start in life: recommendations for health care professionals – the experience from Latvia*. World Health Organization. Regional Office for Europe.
- WHO (2018) 'Global Nutrition Report- Shining a Light to Spur Action on Nutrition', *Global Nutrition Report*, (June), p. 118. Available at: [http://www.segeplan.gob.gt/2.0/index.php?option=com\\_content&view=article&id=472&Itemid=472](http://www.segeplan.gob.gt/2.0/index.php?option=com_content&view=article&id=472&Itemid=472).
- WHO (2020) 'Global nutrition policy review 2016-2017: country progress in creating enabling policy environments for promoting healthy diets and nutrition: summary', in *Global nutrition policy review 2016-2017: country progress in creating enabling policy environments for promoting healthy diets and nutrition: summary*.
- WHO (2023) *Trends in maternal mortality 2000 to 2020: estimates by WHO, UNICEF, UNFPA, World Bank Group and UNDESA/Population Division.*, WHO, Geneva. Available at: <https://www.who.int/publications/i/item/9789240068759>.
- WMA (2013) 'Declaration of Helsinki: ethical principles for medical research involving human subjects.[https:// doi. org/ 10. 1001/](https://doi.org/10.1001)', *JAMA*, 310(20), pp. 2191–2194. Available at: <https://doi.org/10.1001/jama.2013.281053>.
- WMA (2025) 'World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Participants.', *JAMA*, 333(1), pp. 71–74. Available

- at: <https://doi.org/10.1001/jama.2024.21972>.
- Woldeamanuel, G.G. *et al.* (2019) 'Effect of nutritional status of pregnant women on birth weight of newborns at Butajira Referral Hospital, Butajira, Ethiopia', *SAGE Open Medicine*, 7. Available at: <https://doi.org/10.1177/2050312119827096>.
- Woldegebriel, A.G. *et al.* (2020) 'Determinants of Anemia in Pregnancy: Findings from the Ethiopian Health and Demographic Survey', *Anemia*, 2020(1), p. 2902498. Available at: <https://doi.org/https://doi.org/10.1155/2020/2902498>.
- Woldeyohannes, M. *et al.* (2023) 'Ethiopia National Food and Nutrition Survey to inform the Ethiopian National Food and Nutrition Strategy: a study protocol.', *BMJ open*, 13(4), p. e067641. Available at: <https://doi.org/10.1136/bmjopen-2022-067641>.
- Wondmeneh, T.G. (2022) 'Dietary diversity practice and its influencing factors among pregnant women in Afar region of Ethiopia: mixed method study.', *BMC pregnancy and childbirth*, 22(1), p. 291. Available at: <https://doi.org/10.1186/s12884-022-04641-y>.
- Workie *et al* (2013) 'The Health Extension Program in Ethiopia', *The Health Extension Program in Ethiopia* [Preprint], (10). Available at: <https://doi.org/10.1596/13280>.
- Workneh *et al*, . (2021) 'Dietary Practices Among Pregnant Women in Rural Amhara, Ethiopia', *Current Developments in Nutrition*, 5, p. 698. Available at: [https://doi.org/10.1093/cdn/nzab045\\_080](https://doi.org/10.1093/cdn/nzab045_080).
- Xie *et al.* (2023) 'Alternative approaches for creating a wealth index: The case of Mozambique', *BMJ Global Health*, 8(8), pp. 1–10. Available at: <https://doi.org/10.1136/bmjgh-2023-012639>.
- Yang, J. *et al.* (2022) 'Gestational weight gain during the second and third trimesters and adverse pregnancy outcomes, results from a prospective pregnancy cohort in urban Tanzania', *Reproductive Health*, 19(1), p. 140. Available at: <https://doi.org/10.1186/s12978-022-01441-7>.
- Yari, Z. *et al.* (2022) 'Dietary diversity and its relationship with nutritional adequacy in 24 to 59 months old children in Iran: study protocol.', *BMC nutrition*, 8(1), p. 118. Available at: <https://doi.org/10.1186/s40795-022-00616-6>.
- Yeboah, A. *et al.* (2022) 'Maternal Dietary Iron and Folate Intake in the Third Trimester and Birth Outcomes: A Prospective Cohort Study at a Teaching Hospital in Accra, Ghana.', *The American journal of tropical medicine and hygiene*, 106(4), pp. 1072–1077. Available at: <https://doi.org/10.4269/ajtmh.21-0627>.
- Yeneabat, T. *et al.* (2019) 'Maternal dietary diversity and micronutrient adequacy during pregnancy and related factors in East Gojjam Zone, Northwest Ethiopia, 2016.', *BMC pregnancy and childbirth*, 19(1), p. 173. Available at: <https://doi.org/10.1186/s12884-019-2299-2>.
- Yilgwan, C. *et al.* (2010) 'Prevalence and risk factors of low birth weight in Jos', *Jos Journal of Medicine*, 4(1). Available at: <https://doi.org/10.4314/jjm.v4i1.55095>.
- Yilkal *et al.* (2022) 'The bayesian approach of factors associated with preterm birth among mothers delivered at public hospitals in Southeast Ethiopia.', *Frontiers in public health*, 10, p. 881963. Available at: <https://doi.org/10.3389/fpubh.2022.881963>.

- Yin, J. and Tian, L. (2014) 'Joint inference about sensitivity and specificity at the optimal cut-off point associated with Youden index', *Computational Statistics & Data Analysis*, 77, pp. 1–13.
- Yismaw, A.E. *et al.* (2022) 'Iron-folic acid adherence and associated factors among pregnant women attending antenatal care at Metema District, Northwest Ethiopia.', *Frontiers in public health*, 10, p. 978084. Available at: <https://doi.org/10.3389/fpubh.2022.978084>.
- Zahangir, M.S. *et al.* (2017) 'Malnutrition and non-communicable diseases among Bangladeshi women: an urban-rural comparison.', *Nutrition & diabetes*, 7(3), p. e250. Available at: <https://doi.org/10.1038/nutd.2017.2>.
- Zekaria (2007) 'National Electoral Board , Population Census Commission ii'. Available at: <http://www.csa.gov.et/census-report/complete-report/census-2007.html>.
- Zelalem, A. *et al.* (2017) 'Effect of Nutrition Education on Pregnancy Specific Nutrition Knowledge and Healthy Dietary Practice among Pregnant Women in Addis Ababa', *Clinics in Mother and Child Health*, 14(3). Available at: <https://doi.org/10.4172/2090-7214.1000265>.
- Zerfu *et al.*, (2018) 'Pregnant mothers have limited knowledge and poor dietary diversity practices, but favorable attitude towards nutritional recommendations in rural Ethiopia: Evidence from community-based study', *BMC Nutrition*, 4(1), pp. 1–9. Available at: <https://doi.org/10.1186/s40795-018-0251-x>.
- Zerfu *et al.*, (2016) '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', *American Journal of Clinical Nutrition*, 103(6), pp. 1482–1488. Available at: <https://doi.org/10.3945/ajcn.115.116798>.
- Zhang *et al.* (2019) 'Folic Acid and Risk of Preterm Birth: A Meta-Analysis.', *Frontiers in neuroscience*, 13, p. 1284. Available at: <https://doi.org/10.3389/fnins.2019.01284>.
- Zhao, M. *et al.* (2013) 'Folic acid protects against lipopolysaccharide-induced preterm delivery and intrauterine growth restriction through its anti-inflammatory effect in mice.', *PLoS one*, 8(12), p. e82713. Available at: <https://doi.org/10.1371/journal.pone.0082713>.
- Zhong, W. *et al.* (2022) 'Dietary Diversity, Micronutrient Adequacy and Bone Status during Pregnancy: A Study in Urban China from 2019 to 2020.', *Nutrients*, 14(21). Available at: <https://doi.org/10.3390/nu14214690>.
- Zhu, Y. *et al.* (2023) 'Association between gestational weight gain and preterm birth and post-term birth: a longitudinal study from the National Vital Statistics System database.', *BMC pediatrics*, 23(1), p. 127. Available at: <https://doi.org/10.1186/s12887-023-03951-0>.

## **Annexes**

### **Annex I: Policy Brief**

#### **Egg-Based Diet Intervention Coupled with Healthy Dietary Advice: Impacts on Nutritional Status of Pregnant Women in Rural Sidama**

##### **Background and Context**

Maternal under nutrition remains a pressing public health issue in the rural districts of Sidama Regional State, Ethiopia. Poor maternal nutrition — indicated by low BMI, MUAC, and micronutrient deficiencies — is linked to adverse birth outcomes, including low birth weight, preterm birth, and maternal complications. Animal-source foods (ASF), particularly eggs, offer essential nutrients like high-quality protein, vitamin D, vitamin B12, folate, and omega-3 fatty acids, which are critical during pregnancy. However, the diet of pregnant women in rural Sidama is predominantly plant-based, and nutrient-dense foods such as eggs are consumed infrequently. To address this gap, a project was conducted in Shebedino and Boricha districts, assessing the effect of an egg-based diet intervention coupled with healthy dietary advice on the nutritional status of pregnant women. The study involved 424 pregnant women and aimed to improve nutrient adequacy and anthropometric outcomes such as MUAC and weight gain.

##### **Key Findings**

###### **○ Nutritional Status and Anthropometry**

###### **Baseline Status:**

Pregnant women in the study had generally low MUAC and BMI scores, indicating moderate levels of under nutrition.

###### **Impact of Intervention:**

- A significantly higher proportion of women in the intervention group had MUAC > 23 cm at end line (95%) compared to the control group (82.3%) ( $P < 0.001$ ).
- Gestational weight gain within the recommended range was achieved by 30.6% of the intervention group vs. 10.8% of the control group.
- The average weight at end line and MUAC improvements were statistically significant in the intervention group.

The intervention effectively improved maternal nutritional status indicators, particularly in the third trimester, highlighting the benefits of egg-based diets with concurrent dietary education.

###### **○ Dietary Diversity and Egg Consumption**

- Pre-Intervention Diet:
  - A large majority of pregnant women did not meet minimum dietary diversity.
  - Over 96% had not consumed eggs, and about 89% had not consumed any animal-source foods prior to the intervention.
- **Barriers to Egg Consumption:**
  - Economic factors: Eggs were perceived as unaffordable compared to plant-based foods.
  - Cultural factors: No religious or cultural taboos were found against egg consumption, though a few women reported personal aversions (taste, smell).
- **Post-Intervention Outcomes:**
  - Consumption of eggs twice per week for three months significantly improved dietary diversity and nutrient adequacy.
  - The intervention helped overcome habitual exclusion of eggs from the diet, enhancing acceptance and regular inclusion in meals.
- **Nutrient Adequacy Improvements**

Although baseline intakes of essential micronutrients (calcium, vitamin D, folate, B12) were far below Estimated Average Requirements (EARs), post-intervention measurements showed significant improvement.

**Improved Intake Post-Intervention:**

- Vitamin A: 80% met or exceeded EARs.
- Iron: 39.4%, Protein: 22.5%, Folate: 21.5%.
- Notably, calcium, vitamin A, and vitamin D intakes significantly improved ( $P < 0.05$ ).

These findings show that incorporating a modest amount of eggs into traditional plant-based diets can significantly enhance overall nutritional intake for pregnant women.

**Determinants of Nutritional Status and Diet Quality**

Several socio-demographic and household factors were associated with improved diet quality and better nutritional outcomes:

**Positive Drivers:**

- Higher wealth index and food security
- Smaller family sizes (2–4 members)
- Women’s education and school attendance
- Women’s employment and participation in income-generating activities

These factors were indirectly linked to increased intake of animal-source foods and better maternal nutrition, highlighting the importance of addressing structural and socio-economic barriers alongside dietary interventions.

### **Policy Implications and Recommendations**

The project results underscore that diet-based interventions—especially those incorporating ASF like eggs—must be supported by broader, multispectral policy strategies to effectively improve maternal nutrition in rural Ethiopia.

- Promote Egg inclusion in maternal Diets
  - Raise awareness of the nutritional value of eggs, especially among pregnant women, through targeted nutrition education.
  - Include messages about egg consumption during pregnancy in health extension training materials, especially addressing taste preferences and preparation methods.
- Improve Egg Affordability and Accessibility
  - Promote backyard poultry production in rural households to boost local availability and reduce reliance on market prices.
  - Encourage community-level egg production and distribution schemes through cooperatives or women’s groups.
- Empower women through Education and Income
  - Increase school retention for girls and support women’s access to vocational education and training.
  - Facilitate small-scale business ventures like poultry farming or egg selling to enhance women’s income and purchasing power.
- Integrate ASF (Egg based diet) in National Nutrition Programs
  - Revise nutrition guidelines and community-based programs to emphasize regular inclusion of ASF, especially eggs, in the diets of vulnerable groups.
  - Incorporate egg-based recipes and meal plans into antenatal counseling sessions delivered by health workers.
- Strengthen Reproductive Health Services
  - Provide comprehensive reproductive health services, including family planning, to help women plan pregnancies and manage family size, which is linked to improved maternal nutrition outcomes.

- Build Nutrition-Agriculture Linkages
  - Integrate nutrition-sensitive agriculture into development programs, particularly focusing on small livestock and poultry systems.
  - Support initiatives that improve agricultural productivity, especially of nutrient-dense foods like eggs and leafy greens.

## **Conclusion**

Under nutrition among pregnant women in rural Sidama remains a medium-level public health issue, largely due to inadequate dietary diversity and insufficient intake of nutrient-dense animal-source foods. The introduction of a modest egg-based diet—coupled with healthy dietary advice—has shown significant improvements in nutritional status, including increased MUAC, weight gain, and nutrient adequacy.

However, sustainable improvement requires addressing root causes such as affordability, education, gender empowerment, and food access. A coordinated, multi-sectorial approach—linking health, agriculture, education, and women's empowerment—is vital to ensure that pregnant women in rural Ethiopia meet their nutritional needs. Policies must focus on enabling environments where nutritious foods like eggs are not only available and affordable but also accepted and encouraged through culturally relevant education and support systems

## **Annex-II: Data Collection Tool English Version**

### **Information Sheet and Consent Form**

My name is (Data Collector's Name). I am working as data collector of study being conducted by Mr. Kaleb Mayisso from Hawassa University.

**Introduction:** We will conduct of nutritional status of pregnant women in three assessment methods (dietary, clinical, and chemical) to gather data during baseline, follow-up, and end-line studies. We will utilize baseline data for a cross-sectional study in the 12 weeks of gestation. We will use a follow up data for two prospective cohort studies. We used end-line data in interventional and prospective cohort studies. The baseline survey consists of sociodemographic and socioeconomic data, fertility and obstetric data, dietary diversity data, assessment of knowledge, attitude, and practice of dietary iron and folate intake, nutrient adequacy of the diets, investigation of serum folate and ferritin status, household food security, and household wealth index.

The follow-up study focused on the dietary intake of pregnant women during the second and third trimesters and included a monthly survey of gestational weight gain and blood pressure assessment throughout pregnancy, as well as trimester-based anthropometric evaluations during the planned study period. End-line studies focused on post-interventional assessment of change in dietary iron and folate intake knowledge, attitude, and practice; assessment of change in anthropometric measurements; assessment of change in nutrient adequacy of the diets, change in serum levels of ferritin and folate; and assessment of gestational weight gain and pregnancy and birth outcomes (gestational age and birth weight of the newborns) in the northern zone of the Sidama region, where you and other study participants reside. You are selected randomly as a participant in the study.

**Purpose:** The purpose of this study is to assess the current dietary behaviours related to the consumption of diverse diet, especially nutrient dense food to improve the adequacy and bioavailability of certain micronutrients to enhance nutritional status of mothers and achieve optimal birth outcomes for new-borns involves increasing maternal intake of diverse diets through nutrition education and dietary interventions at your household. This information will allow us to understand the factors that affect your consumption of diverse diet as well as to develop appropriate nutrition interventions to overcome the barriers to nutrient dense diet, particularly animal source food consumption.

**Risks:** The interview, anthropometric measurement and blood sample collection will cause you no harm.

**Benefit:** After this survey, we will have at least continuous and frequent dietary diversification, animal source foods consumption promotion and supplementation of selected diet (egg based diet intervention) sessions which you will attend for free. By the anthropometric measurements we can easily identify your nutritional status and if there is an urgent problem we will tell you what to do and where to go, link with health facility. In the promotion session you can raise issue specific to your nutritional status and experts will discuss on it. In selected animal source food supplementation intervention (egg based food) session you can be provided with different nutrients. On top of the mentioned for free personal benefits, it will help you play roles and contribute for the advancement of science. In turn, the expected positive outcome of the study will potentially benefit the larger community beyond study participants like you!

**Data communication concern:** As much as possible, the to be collected information, from you, will be kept confidential. We will provide a code which is different from other participants and not matching with your personal identity. In case, if a need arises it will be anonymous. Hence in this respect you should have no worry.

**Participation:** Participation: Your participation in this study is based on voluntary will, any time you can quit and withdraw from the study. You may refuse to answer specific question during the interview. When further discussion is needed I may probe you for more information. The expected duration that this

discussion will take may vary but expected to be 90 minutes. In some cases based on the situation we can arrange more time based on your will.

Contact address: Kaleb Mayisso

+251919532392

[Kalebm@hu.edu.et](mailto:Kalebm@hu.edu.et)

Are you willing to participate? Yes [  ] No [  ]

Dear participant, in order to achieve our objectives, we need your collaboration to complete this questionnaire. Please try to answer questions as honest as you can and according to your opinion. Do not worry about right or wrong answers, as your opinion and perspective is the right answer. The questionnaire you are about to answer consists of 12 parts and ten sections.

## Part I: Baseline assessment

### Section I: Socio-demographic and economic variables

No	Questions	Responses (circle all that apply)
1	How old are you?	-----
2	Have you ever attended school?	1. Yes 2. No
3.	What is the highest level of school you attended:	-----
4.	Do you read a newspaper or magazine at least once a week, less than once a week or not at all	1. Yes 2. No
5.	Do you listen to the radio at least once a week, less than once a week or not at all?	1. Yes 2. No
6.	Do you watch television at least once a week?	1. Once a week 2. < Once a week 3. Not at all
7.	Marital status of the women	1. Single 2. Married 3. Divorced 4. Widowed
8.	Marital duration of the women	1. 0-4 years 2. 5-9 years 3. 10-14 years 4. 15-19 years 5. 20-24 years 6. 25+ years
9.	Occupation of the women	-----
10.	Occupation of the husband	-----
11.	Residence of the women	1. Urban 2. Rural
12.	Does the woman involved in economic activity?	1. Yes 2. No
13.	Does the woman have decision-making capacity?	1. Yes 2. No
14.	Does this household own any livestock, herds, other farm animals, or poultry?	1. Yes 2. No
15.	Does any member of this household own any agricultural land?	1. Yes 2. No.
16.	How many hectares of agricultural land do members of this household own?	1. No of hectares----- 2. Don't know
17.	Monthly family income (ETB)	-----
18.	Is your area is access to transportation	1. Yes 2. No

### Section II: Fertility and obstetric related variables of the women

No	Questionnaire	Responses (circle all that apply)
1.	Age at marriage (in year)	-----
2.	Age at first pregnancy	-----
3.	Have you ever given birth before?	1. Yes 2. No
4.	The number of pregnancy	1. Primi gravida 2. Second gravida 3. Third gravid 4. Four & more
5.	Birth order	1. 1 <sup>st</sup> 2. 2 <sup>nd</sup> -3 <sup>rd</sup> 3. 4 <sup>th</sup> -6 <sup>th</sup> 4. 7+
6.	Birth interval in year	1. 1 year 2. 2-3 years 3. 3 years 4. 4+ years
7.	The number of deliver the women experienced	1. One 2. Two 3. Three 4. ≥Four
8.	How many surviving children do you have	1. Zero 2. One 3. Two-three 4. ≥Four
9.	Gestational weeks of the pregnancy	-----weeks
10.	How many months pregnant are you?	-----months
11.	When you got pregnant, did you want to get pregnant?	1. Yes 2. No

12.	Had you experienced any of the risk factors during previous pregnancy	1. Yes 2. No
13.	Types of risk factors during previous pregnancy?	1. History of recurrent abortion 2. History of still birth 3. History of hypertension 4. >35 years during 1 <sup>st</sup> pregnancy 5. Short stature 6. Multiple births
14.	How often you had ANC follow up during this pregnancy?	1. Regular 2. <3 visit 3. None
15.	Where did you receive antenatal care for this pregnancy?	1. Home 2. Public Hospital 3. Public HC 4. Health Post 5. NGO health facility 6. Private HF
16.	Had you experienced any of these medical/obstetrics conditions during this pregnancy	1. Hyperemesis gravidarum 2. Anorexia 3. Bulimia nervosa 4. Bariatric surgery
17.	Had you have history of prior obstetric cx	1. Yes 2. No
18.	Types of obstetrics complication	1. Pre-eclampsia, 2. Gestational htn 3. GDM 4. High birth weight baby 5. Induction of labor 6. 3 <sup>rd</sup> & 4 <sup>th</sup> degree tears 7. APH 8. PPH 9. Emergency C/S 10. Wound infection

### Section III: Baseline DD assessment using 24 hour recall

Food categories	Description/examples to be adapted	Yes/No
1. Did you have foods made from grains (corn, barely, wheat, teff, sorghum)?	Porridge, bread, rice, pasta & foods made from grains	
2. Did you have food made from white roots and tubers?	White potatoes	
3. Did you have food made from pulses (beans, peas and lentils)?	Mature beans or peas, lentils or bean/pea products,	
4. Did you have food made from nuts and seeds?	Groundnut/peanut or nut/seed “butters” or pastes	
5. Did you have milk and milk products (dairy)?	Milk, cheese, yoghurt	
6. Did you have food made from organ meat?	Liver, kidney, heart or other organ meats	
7. Did you have food made from meat and poultry?	Beef, lamb, goat, wild game meat, chicken	
8. Did you have fish and seafood?	Fresh or dried fish	
9. Did have food made from eggs?	Eggs from poultry	
10. Did you have food made from dark green leafy vegetables?	Any medium-to-dark green leafy vegetables (cabbage)	
11. Did you have food made from Vitamin A-rich vegetables, roots and tubers?	Pumpkin, carrots, sweet potatoes	
12. Did you have food made from other vegetables?	Tomato, onion, beetroot, green beans, green pepper	
13. Did you have vitamin A-rich fruits?	Mango, papaya, apple, avocado, banana, pineapple, orange	
14. Did you have other fruits?	List examples of any other fruits like mandarin, orange, lemon	

## 24 hours dietary recall

1. ID#:		2. Date Taken:						
3. Participant Name:								
4. Pregnant? Yes [ ] No [ ] 5. How was your food yesterday? About usual [ ] Social occasion/holiday [ ] Sickness [ ] Fasting [ ] No appetite [ ] Other (Please specify)_____ 6. Are you vegetarian/fasting Animal Source Foods? Yes [ ] No [ ]								
8. What did Participant eat and drink in the last 24 hours?				11. Number of serving to be calculated by staff. (List whole or half servings in each cell, then sum at bottom.)				
FOOD ITEMS AND DESCRIPTION (List all foods and beverages consumed as meals or snacks. List separately main ingredients in mixed dishes.)			AMOUNT EATEN	BREADS & FRUITS	VEGETABLES	MEATS	MILK	OTHER
Food Quick list		Place of Consumption						
	Breakfast:							
	Snack:							
	Lunch:							
	Dinnar							
9. Total Number of Different Meals/Snacks: <input type="text"/>			Total Servings					
10. How many cups of water did you have Yesterday? <input type="text"/>								

### Section VI: Maternal dietary iron and folate intake practice

No	Variables	Yes/No
1.	Do you take folate rich foods (pulses and legumes) daily?	
2.	Do you take folic acid supplements daily?	
3.	Do you take iron rich food daily?	
4.	Do you take iron supplements daily?	
5.	Have you been experienced of changing food choices?	
6.	Have you ever used fruits?	
7.	Have ever used vegetables?	
8.	Have ever used fish?	
9.	Do you include some vitamin-C-rich foods in meals	
10.	Do you take $\geq 3$ servings of milk products daily between meals	
11.	Do you eat small to moderate-sized meals at regular intervals,?	
12.	Items of diet included in your meal and snacks every day	1. Fruits 2. Vegetables 3. Grains 4. Meat 5. Milk 6. Legumes
13.	Do you eat dietary nutrients according RDA?	1. Folate (RDA=600 $\mu$ g) 2. Fe (RDA=33mg)
14.	How many full meals do you eat daily?	1. 1 meal 2. 2 meal 3. 3 meal
15.	How much coffee or other caffeinated beverages you drink	1. $>3$ 2. 2 to 3 3. $<2$ servings daily
16.	How many serving you consumes meat, fish or poultry every day	1. $\geq 1$ 2. $\geq 2$ 3. Eggs 4. $\geq 2$ fruit/day 5. $\geq 2$ vegetables/day
17.	How much fluid (water, juice, and tea) do you consumed	1. $<3$ cups 2. 3 to 5 cups 3. $>5$ cups
18.	Other micronutrient intake from diet against RDA	1. Ca (RDA=100mg) 2. VC(RDA=55mg) 3. VA(RDA=800 $\mu$ g)

**Section V: Base line maternal dietary iron and folate intake knowledge**

No.	Variables	Yes/No
1	Know the dietary source of folate?	
2	Know health benefit of intake of folate rich food?	
3	Know the dietary source of iron?	
4	Know health benefit of intake of iron rich food?	
5	Know health benefit of intake of animal source food for mother?	
6	Know health benefit of intake of IFA supplements?	
7	Know the dose of IFA supplements?	
8	Know health benefit of intake of animal source diet for fetus?	
9	Know the cause of anemia during pregnancy?	
10	Know foods that increase iron absorption?	
11	Know foods that decrease iron absorption?	
12	Know about iron-deficiency anaemia during pregnancy?	
13	Know consequences of iron-deficiency anaemia for mother	
14	Know consequences of iron-deficiency anaemia for fetus?	
15	Know about birth defect?	
16	Know how birth defect can be prevented?	
17	Know health benefit of intake of diet more frequently during pregnancy	

**Section VI: Assessment of household food insecurity and hunger scale**

No	Food insecurity experience and hunger scale	
	During the last one year, was there a time when:	Responses (circle all that apply)
1	The last 12 MONTHS, you were worried you would not have enough food to eat because of a lack of money or other resources.	1. Yes                      2. No 3. Do not know        4. Refused
2	The last 12 MONTHS, you were unable to eat healthy and nutritious food because of a lack of money or other resources?	1. Yes                      2. No 3. Do not know        4. Refused
3	You ate only a few kinds of foods because of a lack of money or other resources.	1. Yes                      2. No 3. Do not know        4. Refused
4	You had to skip a meal because there was not enough money or other resources to get food.	1. Yes                      2.No. 3. Do not know        4.Refused
5	The last 12 MONTHS, you ate less than you thought you should because of a lack of money or other resources?	1. Yes                      2. No. 3.Do not know        4.Refused
6	Your household ran out of food because of a lack of money or other resources	1.Yes                        2.No 3.Do not know        4.Refused
7	You were hungry but did not eat because there was not enough money or other resources for food?	1.Yes                        2.No 3.Do not know        4.Refused
8	Finally, you went without eating for a whole day because of a lack of money or other resources	1. Yes                      3. Do not know 2. No                        4. Refused
	<b>Household hunger scale</b>	
9	How often did this happen in the last past 30 days? Respondent Answer: Four, maybe five times	1. Rarely (once in the past 30 days) 2. Sometimes (3–10 times/30 days) 3. Often (more than 10 times /30 days)

## Section VII: Base line anthropometric assessment

No	Questionnaire	Responses(circle that all apply)
1	Gestational age at recruitment (weeks)-----	-----
2.	Height at recruitment in cm	-----
3.	Preconceptional weight (kg)	-----
4	BMI at 12 weeks of gestation (kg/m <sup>2</sup> ) estimate it using the woman's height and recalled pre-conventional weight	-----
5	How was the women's preconceptional BMI categorized (from records)	1. Low (BMI <19.8) 2. Normal (BMI 19.8 to 26) 3. High (BMI >26.0 to 29.0) 4. Obese (BMI >29.0)
6	Current weight of the women (kg)	-----
7	How was the women's height was categorized (cm)	1. Short (<150 cm) 2. Normal (162 cm) 3. Tall (>5 feet,4 inch)
8	Is there any weight gain in early pregnancy (first trimester)	1. Yes 2. No
9	How much weight do you think you should gain?	-----

## Part two: Follow up and end line assessment

### Section I: Maternal dietary iron and folate intake knowledge

No	Variables	Yes/No
1	Know the dietary source of folate?	
2	Know health benefit of intake of folate rich food?	
3	Know the dietary source of iron?	
4	Know health benefit of intake of iron rich food?	
5	Know health benefit of intake of animal source food for mother?	
6	Know health benefit of intake of IFA supplements?	
7	Know the dose of IFA supplements?	
8	Know health benefit of intake of animal source diet for fetus?	
9	Know the cause of anemia during pregnancy?	
10	Know foods that increase iron absorption?	
11	Know foods that decrease iron absorption?	
12	Know about iron-deficiency anaemia during pregnancy?	
13	Know consequences of iron-deficiency anaemia for mother	
14	Know consequences of iron-deficiency anaemia for fetus?	
15	Know about birth defect?	
16	Know how birth defect can be prevented?	
17	Know health benefit of intake of diet more frequently during pregnancy	

## Section II: Maternal dietary iron and folate intake practices

No	Variables	Yes/No
1.	Do you take folate rich foods (pulses and legumes) daily?	
2.	Do you take folic acid supplements daily?	
3.	Do you take iron rich food daily?	
4.	Do you take iron supplements daily?	
5.	Have you been experienced of changing food choices?	
6.	Have you ever used fruits?	
7.	Have ever used vegetables?	
8.	Have ever used fish?	
9.	Do you include some vitamin-C-rich foods in meals	
10.	Do you take $\geq 3$ servings (one cup) of milk products daily with or between meals	
11.	Do you eat small to moderate-sized meals at regular intervals, and eat nutritious snacks?	
12.	Items of diet included in your meal and snacks every day	1. Fruits 2. Vegetables 3. Grains 4. Meat 5. Milk products 6. Legumes
13.	Do you eat nutrients according to daily recommendation allowance (RDA)?	1. Dietary folate (RDA=600 $\mu\text{g}$ ) 2. Dietary iron(RDA=33mg)
14.	How many full meals do you eat daily?	1. 1 meal 2. 2 meal 3. 3 meal
15.	How much coffee or other caffeinated beverages (such as cola) you drink	1. >3 servings daily 2. 2 to 3 servings daily 3. < 2 servings daily
16.	How many serving you consumes meat, fish or poultry every day	$\geq 1$ serving 2. $\geq 2$ servings of legumes 3. Eggs/ week 4. $\geq 2$ servings of fruit/day 5. $\geq 2$ servings vegetables/day
17.	How much fluid do you consumed per day	1. <3 cups 2. 3 to 5 cups 3. > 5 cups
18.	Other micronutrient intake from diet against recommended daily allowance	1. Calcium (RDA=100mg) 2. Vitamin C(RDA=55mg) 3. Vitamin A(RDA=800 $\mu\text{g}$ )

## Section III: Anthropometric measurement (follow up and endline)

No	Variables	Responses (circle that all apply)
1.	Weight of the women in kilograms	-----
2.	Height of the women in centimeters	-----
3.	Weight for height (BMI) of the women based on pre-pregnancy or early pregnancy	1. <18.5kg/m <sup>2</sup> 2. 18.5–24.9 kg/m <sup>2</sup> 3. BMI: 25–29.99 kg/m <sup>2</sup> 4. $\geq 30$ kg/m <sup>2</sup> )
4.	The nutritional status of the women BMI< 12 weeks	1. <18.5 2. 18.5-24.9) 3. $\geq 25$ ) 4. $\geq 30$ kg/m <sup>2</sup> )
5.	MUAC of the woman during pregnancy (cm)	1. <21 2. 21 to 22 3. >22
6.	Was a woman measured MUAC every three months?	1. Yes 2. No
7.	Was there any MUAC gain per three months?	1. Yes 2. No
8.	How much cm of MUAC gained?	-----
9.	Was there higher weight gain during pregnancy?	1. Yes 2. No
10.	The reason for higher weight gain	1. Low 2. Young age 3. Multiple 4. Short ht.
11.	Any change noted in weight change during follow up	1. Yes 2. No
12.	Obesity classes of the pregnant women	1. 30 to < 35 2. 35 to < 40 3. BMI of 40
13.	What is your self-view of nutritional status?	1. Views self as being malnourished 2. Is uncertain of nutritional status 3. Views self as having no malnutritional



## Section V: Assessment of pregnancy and birth outcomes

No	Questions	Responses (circle that all apply)
1.	Age of the mother at birth?	1. 15-19      2. 20-24      3. 25-29      4. 30-34 5. 35-40      6. 41-44      7. 45-49
2.	Where did you give birth?	1. Home      2. Health care facility
3.	Neonate's date and time of delivery?	-----
4.	Estimated gestational age (weeks)	-----
5.	Method of gestational age determination	1. LMP      2. Fundal height      3. Ultrasound
6.	The labor started at a gestational age of	1. Preterm (<37) weeks 2. Early term (37-38) weeks, 6 days 3. Full term (39 -40), weeks, 6 days. 4. Late term (41- 41) weeks, 6 days 5. Post term(>42weeks)
7.	If preterm birth (<37 weeks of gestation), type of preterm was?	1. Spontaneous preterm birth 2. Extremely preterm (less than 28 weeks) 3. Very preterm (28 to less than 32 weeks) 4. Moderate to late preterm (32 to 37 weeks)
8.	The reasons for preterm birth labor	1. Spontaneously      2. Multiple pregnancies 3. Infections      4. Diabetes 5. Pregnancy cx      6. High blood pressure
9.	If "pregnancy complications", which?-	1. High BP      2. Anxiety      3. Anemia 4. STI      5. GD      6. Stillbirth 7. Miscarriage      8. Depression      9. Cancer 10. Infections      11. Preeclampsia      12. Epilepsy
10.	When the baby was born, the size of the baby was	1. Premature birth      2. Smaller than average 3. Normal baby      4. Very large 5. Neo -natal death,      6. Don't know
11.	Age of the new borne in hour/day	-----
12.	Sex of the new borne	1. Male      2. Female
13.	Types of the gestation was:-	1. Singleton      2. Multiple
14.	Conditions of the birth	1. Live birth      2. Fetal death
15.	Was your baby weighed at birth?	1. Yes      2. No      3. Don't know
16.	The weight of the new borne was measured:	1. Within an hour      2. In the first 48 h of life 3. In the first 72 h of life      4. In the first week of life
17.	Birth weight (gr) of the new borne	1. <2500g      2. 2500-4000g      3. >=4000g

## Annex-III: Translated tool for data collection (Sidamifa Version)

### Mashalaqete shematu forme

Su'mya (Tajete gambisanchu su'ma). Ani tene Kalaa Kaleb Mayissohu Hawwasi yuniversiten xinxalano xinxallo taje gamba assate looso loosani noomo.

**Bitima:** Ninke godowi noo ama sagaleta amangootita hanafote, harunsotenna jeefote taje sasewa band buuxo assineemo (saga'late, klinikalena chemikale). Hanafote xinxalora criss-sectionale xinxalote hayo horonsi'neemoha ikana, gamba asineemohu ama godobunkun 12 lamala giddo noo tajeeti. Harunsote xinxalo prospective cohort xinxalo hayo horonsi'neemo. Jeefote xinxalora interventionale na prospective cohort xinxalo hayo horonsi'nemo. Hanafote xinxalo amadano dagomu na-ilamate minju taje, sirotena

godowate yana taje, sagaletе hamanyoti taje, sagaletе ironena folate adhate egeno, laona rosichi taje, nutrient adequase, serumete folate and ferritin geesha, minoomu sagale hee’rana jirote indekse.

Harunsote xinxalo ilachi godowi noo ama laynkina sayki trimesterera sagaletе adhitano garana, ama godowi hedhena leltano ayirote ledо, mundeete xiwo xinxalo hatono trimesiterete ledо xadino anthropometrikete sooro iimati. Jeefote xinxalo ilachishanohu interventionete gedensani asinanita sagaletе ironena folate adhate egeno, laona rosicho; anthropometrikete soro bika; nutrient adequasete soro, serumete ferritinena folate bika, godowate yana amate ayro ledо hatono godowatena ilate ledо xaadino jeefote guma (godowa adhitino yananna marqu qaaqi ayira). Ate tene xinxalora dooronihehu randometeti.

**Mixo:** Tene xinxalo mixo saga’late akatana sagaletе hamagnote afateti. Baxinohuni, nutrientete sagale akata adequasese woyesatena micronutrientetena amanita sagaletе amangooti woyesateni gowate jefote guma woyesateti. Kunino ikanohu sagaletе rosicho aatena godowii noo amara ikitano sagale aatenniti. Hakuyi gedensaani afi;nani mashalaqe wo’ma sagale saga’la holtano heko maatiro badatena amuwu godowano yannara saga’le hasiisanonsa sagale mixo qixeesateti.

**Heko:** Taje adhineemo woyte ate iima mite heko woyi gawajo di-illitanohe

**Horo:** tene xinxalo gedensaani, sufantinotana uumantinota sagale hamango, baxinohuni sadate wiini afinani sagale (qupichu sagale) horonsha huwachishate ledate. Amate anthropometrikete biko amanita sagaletе amangoti dera hawaqisano daafira amate winamuniti sagaletе gatto heedhuro kulateno kalitana fayimate uursha ledо xaadisate horontano. Quuphu sagale uynani woytewoyabino nutrente ama afidhano. Koni gedensani agarannihu positive xinxalote gume ha’laladu dagoomira horomano!

**Taje xaadisate hajo:** atewini adhineemo taje dahote maanxani. Ateta halangu taje Kode uuyne manxeemo daafira ayno diafano.

**Beeqo:** Ati tene xinxalora qeeqatahu umiki fajoniiti, aye yanarano agurte harana murte fula dandaata. Xamote dawaro qolano giwa dandaata. Ledote malama hassisuro lede xa’ma dandemo. Kone hasawa assate 90 lipheesi callu hasiisano.

Xandanihu : Kaleb Mayisso, Tele. +251919532392, Email. Kalebm@hu.edu.et

Beeqate eeyamoota? Eeye [ ] Dee’ni [ ]

Beeqancho, hexonke gafa ganate, ateta eeyamate beeqanchima hasi’neemo. Dawaro qolate amanamate shiqinke ballo. Qolatanke dawaro ada woy xara ika dandiitano. Qolatara shiqano xa’mo 12 gafa afidhinote:

Gola I: Hanafote Taje

Gafa I: Dagoomu ilamishunna minju taje

Kiro	Xa’mo	Dawaro (dawaro ikitinota qoqowi )
1	Diriki me’’eho?	-----
2	Roso rosoota?	1. Eeye 2. Dee’ni

3.	Aliidihu rosiki deeru me'eho:	-----
4.	Lamalate gido gazexa nabawata	1. Eeye 2. Dee'ni
5.	Lamalate gido radoone maccishata?	1. Eeye 2. Dee'ni
6.	Lamalate giddu Televisione me''e hige la''ata?	1. Mite hige 2. < Mite hige 3. Horonta dila''eema
7.	Adhamate gari	1. Callichote 2. Adhamooma 3. Tirooma 4. Shi'rooma
8.	Adhamitankun mageesh diroti?	1. 0-4 diro 2. 5-9 diro 3. 10-14 diro 4. 15-19 diro 5. 20-24 diro 6. 25+ diro
9.	Loosiki maati	-----
10.	Gashaniki loosi maati	-----
11.	Hee'ratahu hiikoti	1. Quchumaho 2. Baadiyete
12.	Miinju milimora beeqata?	1. Eeye 2. Dee'ni
13.	Mini gashste haja iima muru aata?	1. Eeye 2. Dee'ni
14.	Mine saada, gerewu, me''u woy lokuwu no?	1. Eeye 2. Dee'ni
15.	Loosidhinani baato noo'ne?	1. Eeye 2. Dee'ni
16.	Me'e hektare baato noo'ne?	1. Hektarete deera----- 2. Diafooma
17.	Maateniti aganu eo (ETB) ?	-----
18.	Hodhishu injo noo'ne	1. Eeye 2. Dee'ni

## Gafa II. Amanita sirate godowate ledo xaadano taje

Kiiro	Xa'mo	Dawaro (dawaro ikitata qowowi)
1.	Diriki mine asirita woyte me'eho	-----
2.	Dirik umiha godowita waro me'eho	-----
3.	Koni albani ilte egenoota?	1. Eeye 2. Dee'ni
4.	Me'e hige godowota koni albaani	1. Umiho 2. laynkiho 3. Saykiho 4. Shoole na ale
5.	Me'iki ilati tin	1. Umi 2. 2 <sup>nk</sup> -3 <sup>ki</sup> 3. 4 <sup>ki</sup> -6 <sup>ki</sup> 4. 7+
6.	Ilate xeertigniki diruni	1. 1 Diro 2. 2 -3 Diro 3. 3 Diro 4. 4+ Diro
7.	Me'e hige iloota?	1. Mitte 2. Lame 3. Sese 4. ≥Shoole
8.	Lubote me'u qaaquli noohe xa?	1. Zero 2. Mittu 3. Lamu-sasu geeshi 4. ≥Shoolu
9.	Godowu gatihenku me'e lamalaati?	-----
10.	Godowu gatihenku me'e aganaati?	-----
11.	Godowu hasidheena gantohe?	1. Eeye 2. Dee'ni
12.	Koni albaani godowatea woyte heko xaade egentinohe?	1. Eeye 2. Dee'ni
13.	Godowata woyte xadinohe heko?	1. Marro marro hige umo ka'a 2. Reynoha ila 3. Mundete xiiwo 4. >35 diri ale ikkena umiha godowa 5. Hojaha'ra'ma 6. Mittu ali qaaqo godowa
14.	Gadowu harunso me'e hige ass'rita?	1. Uume 2. <3 hige 3. horonta
15.	Godowu harunso hiiko ass'rita?	1. Mine 2. Hospitalete 3. Faymate xawira 4. Faymate keelira 5. Mo/Ik/urinshara 6. Ha'lagnootu urishara
16.	Koni godowi yannara koriuu xaadinohe ?	1. Qaxxarote xisso 2. Sagale giwisa
17.	Konni albaani godowate yanna xisso xaadanohe?	1. Eeye 2. Dee'ni
18.	Xaadanoheha ikkiro hiikuriiti?	1. Pre -eclampsia, 2. Gestational hypertension, 3. GDM 4. High birth weight baby 5. Induction of labor 6. 6. 3 <sup>rd</sup> and 4 <sup>th</sup> degree tears, 7. APH 8. PPH 9. Emergency C/S 10. 10. Wound infection

**Gafa III: Hanafote sagaleta hamangooti taje 24 saate hurbaate qaagateni**

Sagaleta gaamo	Xawisha	Eeye/Dee'n
1. Gidu sagale (badala, hayxe, qamade, gashe, bashanqa) itoota?	Sherko, daabo, pasta& Tima	
2. Rumudate sagale itoota?	Dincha,	
3. Palsete sagale (baqeela, Atara,wahe, shimbirana misira) itoota?	baqeela, Atara,wahe,shimbirana misira ,	
4. zayte loonsani sagale itoota ?	Shalaala, nuuge	
5.Adona adote laalo itoota?	Errero, Geinto, Ayibe	
6. Giddo uduuni sagale/ maala itoota?	Afale, mule, wodana	
7.Saadate woy lukuwu maala itoota?	Saadate, Ge'rewu, me'u / lukuwu maala	
8.Qulxu'mete mala itoota?	Qulxu'me	
9.Quuphe itoota?	Lukuwu quuphe	
10.Haanja daro sagale itoota?	Shaananna shana labono daro	
11. Vitamin A-lalo, rumuda woy gomma?	baqula, karote, maxaxeesa	
12. Wole laalo sagale itoota?	Timatime, tuma, duumo rumusho, qaariya	
13 Vitamin A-rich laalo itoota?	Mango , papaya, apple, avocado, Muuze, Ananaase,	
14. woludani laalo itoota?	mandarin, hope, loome	

**24 saate hurbaati taje gamba assinani shae**

1. T/k#:		2. Barra :						
3. beeqanchu Su'ma:								
4. Godowi no? Eeye [ ] Dee'ni [ ] 5. Bero hurbatik hiitoti? Basho garaati [ ] Ayaanu barati [ ] xisamoota [ ] qatu'mata [ ] sagale giwisaaha [ ] wolelere (badi) _____ 6. Mu'rote saga'lanchooti/saadate sagale qatu'mta? Eeye [ ] Dee'ni [ ]								
7. 24 saate giddo beeqqancho maa hurbaxitino?				8. Hurbatu kiir.				
SAGALETE DANI XAWISHA (Baala sagale woy ago koye diri. Qaxamuru sagaleta mite mitenta sagaleta dana koye diri.)			deera	Dabo & Gide	Laalo	VEG ETA BLE	Maal	Ado Wolo ota
<b>Sagaleta dira</b>		Intoni darga						
	Shooma							
	Murso:							
	Barisagale							
	Hashisagale							
<b>9.xaphooma:</b>			<b>xaphooma</b>					
<b>10.Waa me'e birciqo agaota bero kawa?</b>								

**Gafa IV: Hanafonita Amate sagalet iron and folate adha gari taje**

Kiiri	Variabloota	Eeye/Dee'ni
1.	Folate sagale (pulses and legumes) baruni itata?	
2.	Folic acide xagicha baru baala adhata ?	
3.	Ironete sagale baru baala adhata?	
4.	Irone baru baala adhata?	
5.	Sagale doorshaki soorota?	
6.	Hurbatiki yanara laalo itata?	
7.	Vegetablete sagale itte egenoota?	
8.	Qulxu'me itte egenoota?	
9.	Vitamin-C-sirch sagale iata?	
10.	Ado $\geq$ 3 (one birciqo) sagalet ledo horonsi'rata	
11.	Shiimate mereerima sagale uumte itata ?	
12.	Mursoho woy hurbatu yannaara itata sagale	1. Laalo 2. Vegetable 3. Gide 4. Maala 5. Ado 6. Wahe
13.	Baruni fajinoo garini itata (RDA)?	1. Dietary folate (RDA=600 $\mu$ g) 2. Dietary iron(RDA=33mg)
14.	Hurbaateki barun me'e hige itata?	1. 1 hurbaate 2. 2 hurbaate 3. 3 hurbaate
15.	Buna woy koka me'e hige agata?	1. >3 hige 2. 2 to 3 hige 3. < 2 hige
16.	Maala, qulxu'me/ lukuwa baru me'e hige itata?	1. $\geq$ 1 hige 2. $\geq$ 2 hige
17.	Baruni du'namaano me'e birciqo agata	1. <3 birciqo 2. 3 to 5birciqo 3. > 5 birciqo
18.	Wolota micronutrient shiila	1. Calcium (=100mg) 2. Vitamin C(=55mg) 3. Vitamin A(=800 $\mu$ g)

**Gafa V: Amanita sagalet iron and folate adha egeno taje**

Variabloota	Eeye/Dee'ni
Ama folatenita sagalet buicho affino ?	
Ama foletete dureete sagale uytanota faymate horo affino?	
Ama ironenita sagale buicho affino?	
Ama ironete dureete sagale ita uytanota faymate horo affino?	
Ama sadate wini afi'nani sagale ita umisera uytano horo affino?	
Ama IFA ledota faymate horo affino?	
Ama IFA ledota dose affino?	
Ama sadate wini afi'nani sagale ita ootu gido qaaqira uytano horo affino?	
Ama godwi he'nena daano anemia korkata affino ?	
Ama ironete xuuxamara kaa'litano sagale affino?	
Ama ironete xuuxama itisano sagale affino ?	
Ama godowi he'nena daano ironete-gato anaemia affino ?	
Ama ironete-gatoni daano anaemia amate iilishano heko affino ?	
Ama ironete-gatoni daano anaemia qaaqoho iilishano heko affino ?	
Ama haro ilamino qaaqi bisu muso affino ?	
Ama haro ilamino qaaqi bisoho dagano muso itinsanita ikase affino?	
Ama godowi heedhe sagale yana yanate ita uytanota faymate horo affino	

**Gafa VI: Maatete sagaleta xe'nena hudete deeritaje**

<b>Kiiri</b>	<b>Sagaleta Xe'nena hudete deera</b>	
	Sai dirira; togooyanara:	Responses (circle all that apply)
<b>1</b>	Saihu 12 Agani gido, womasha hogateni sagale ajano yite yaade egenoota?	1. Eeye 2. Dee'ni 3. Diaffoma 4. Diqoleema
<b>2</b>	Saihu 12 Agani gido, womasha hogateni fayyona maname sagale hoogota?	1. Eeye 2. Dee'ni 3. Diaffoma 4. Diqoleema
<b>3</b>	Saihu 12 Agani gido, womashu hogena boode sagale callai toota?	1. Eeye 2. Dee'ni 3. Diaffoma 4. Diqoleema
<b>4</b>	Saihu 12 Agani gido, womashu hogeena hurbaaxitaki sae egenoota?	1. Eeye 2. Dee'ni 3. Diaffoma 4. Diqoleema
<b>5</b>	Saihu 12 Agani gido, woxu hogeena ita hasiisahehu worooni itoota?	1. Eeye 2. Dee'ni 3. Diaffoma 4. Diqoleema
<b>6</b>	Saihu 12 Agani gido, womashu hogeena maateki sagale weelo saino?	1. Eeye 2. Dee'ni 3. Diaffoma 4. Diqoleema
<b>7</b>	Saihu 12 Agani gido, womashu hogena hudidhay heedhe ititaki sae egenoota?	1. Eeye 2. Dee'ni 3. Diaffoma 4. Diqoleema
<b>8</b>	Saihu 12 Agani gido, womashu hogeena mito bara wo'ma ititaki saoota ?	1. Eeye 2. Dee'ni 3. Diaffoma 4. Diqoleema
	Maatete hudete mashalage	
<b>9</b>	Saihu 30 bari gido, sagaleta hoongi me'e hige xaadino'ne?	1. Sae sae 2. Bari-barita 3. Duchaage

**Gola II: Harunsotenna jeefote taje**

**Gafa 1: Amate sagaleta ironena folate itate egenno taje**

<b>T/k</b>	<b>Variabloota</b>	<b>Eeye/Dee'ni</b>
<b>1</b>	Ama sagaleta folatete buicho affino?	
<b>2</b>	Ama sagaleta folatete itate afi'nanita fayimate horo affino?	
<b>3</b>	Ama sagaleta iron buicho affino?	
<b>4</b>	Ama sagaleta iron itate af'nanita fayimate horo affino?	
<b>5</b>	Ama sadate afinani sagale umisera uytanota faymate horo affino?	
<b>6</b>	Ama IFA adha uyitano fayimate horo affino?	
<b>7</b>	Ama IFA xagichi dose affino?	
<b>8</b>	Ama sadate afinani sagale qaqisera uytanota faymate horo affino??	
<b>9</b>	Ama godowi henena daganota anemia kora affino?	
<b>10</b>	Ama ironete xuxamara kalitano sagale affino ?	
<b>11</b>	Ama ironete xuxama itisano sagale affino ?	
<b>12</b>	Ama godowate yannara ironiete-gatoni daano anaemia affino?	
<b>13</b>	Ama godowate yannara ironete-gatoni daano anaemia umisera abano hekko affino?	
<b>14</b>	Ama godowate yannara ironete-gatoni daano anaemia qaaqoho abano hekko affino?	
<b>15</b>	Ama haro ilamino qaaqi iima kalaqantano bisu muso affino?	
<b>16</b>	Ama haro ilamino qaaqi iima kalaqantano bisu muso itinsanta ikkase affino ?	
<b>17</b>	Ama godowate yannara sagele bashowini roorsine ita faymate uytano horo affino?	

### Gafa II: Amate sagalette ironenna folate itate gari taje

T/k	Variabloota	Eeye/Dee'ni
1.	Barabaal folatete dureete sagale itoota (pulses and legumes)?	
2.	Baru baala folicacidete xagicho adhata?	
3.	Barabaala ironete dureete sagale itata?	
4.	Barabaala ironete xagicho adhata?	
5.	Sagalette dorshaki soorite egenoota?	
6.	Lalo horonsidhe egenoota?	
7.	Vegetables horonsidhe egenoota?	
8.	Qulxume horonsidhe egenota?	
9.	Vitamin -C-dureete sagale hurbaatikira wodhite egenota?	
10.	≥3 (mitte birciqo) ado sagalette yanara age egenoota?	
11.	Shimateni mereerima sagale geeshita umte itata?	
12.	Baru baali hurbatira horonsiratahu sagale dani	1. Laalo 2. Vegetables 3. Gide 4. Maala 5. Ado 6. Legumes
13.	Barubaala zayte fultano sagale fajinooni (RDA) garini itata?	1. Dietary folate (RDA=600 µg) 2. Dietary iron(RDA=33mg)
14.	Wo'ma hurbate barun me'e hige itata?	1. 1 hurbate 2. 2 hubate 3. 3 hurbate
15.	Baruni buna woy koka me'e hige agata	1. >3 hige 2. 2 to 3 hige 3. < 2 hige
16.	Barunni mala/lokuwa me''e hige itata	1. ≥1hige 2. ≥2 hige 3. 3 hige
17.	Baruni dunamano me''e birciqo agata	1. <3 2. 3 to 5 3. > 5
18.	Woloota micronutrientete shilla baruni fajinooni garini itata	1. Calcium (RDA=100mg) 2. Vitamin C(RDA=55mg) 3. Vitamin A(RDA=800µg)

### Gafa III: Amate anthropometrikete bika (harunsona jeefote) taje

T/k	Variabloota	Dawaro
1.	Amate ayro kilogramete	-----
2.	Amatete hoja sentimetirete	-----
3.	Aju godowi hedheena amate BMI (<12 lamala)	1. Wofimate <18.5kg/m <sup>2</sup> 2. Kerancho (BMI: 18.5–24.9 kg/m <sup>2</sup> ). 3. Gotimate ( 25–29.99 kg/m <sup>2</sup> ) 4. Obese (≥30 kg/m <sup>2</sup> )
4.	Amaniha nutritional gara (godowate albi BMI/< 12 lamalani)	1. Shalado (BMI<18.5) 2. kerancho (BMI 18.5-24.9) 3. Gotima (BMI ≥25) 4. Obese (BMI: ≥30 kg/m <sup>2</sup> )
5.	Amate (MUAC) godowi hedhena (cm)	1. MUAC <21 2. MUAC 21 to 22 3. MUAC > 22
6.	Ama MUAC sayk sayk aganira bikinooni?	1. Eeye 2. Dee'ni
7.	Amate MUAC sasu sasu aganini lexitino?	1. Eeye 2. Dee'ni
8.	Amate MUAC magesha lexitinjo?	-----
9.	Ayirase lexiinohu gotimate?	1. Eeye 2. Dee'ni
10.	Ayirase lexitinohu korkatu maata?	1. Wofima BMI, 2. Dirise aja ikka 3. Lakkuwa godowa 4. Harancho ikka
11.	Harunsote yanara ayrate sooro leltino?	1. Eeye 2. Dee'ni
12.	Godowate albiiditi danimale misate gaamo?	1. BMI (30- < 35) 2. BMI (35 -< 40) 3. BMI ≥40
13.	Nutritional garaki ati hiito assite la'ata?	1. Sagalette gatto 2. Ani diafooma 3. Sagalette gatto dinoe

**Gafa IV: Godowate yanara ayrate lexxa (harunsonna jeefote)xinxalo**

T/k	Xa'mo	Dawaro
1.	Godowate albiidi ayroki (KG) afoota?	1. Eeye 2. Dee'ni
2	Godowate albiidi ayroki?	Kg -----
3	Godowate albiidi BMI (Kg/cm <sup>2</sup> ) afoota?	(Kg/cm <sup>2</sup> ) -----
4.	Sayki sayki aganira ayraka bikinoni ?	1. Eeye 2. Dee'ni
5.	Ayraki lexxitani no ?	1. Eeye 2. Dee'ni
6.	Mageeshi kg ayra lexoota?	1. 28–40 (kg) 2. 4.84 ± 1.29(kg) 3. 3.23 ± 0.91(kg) 4. .43 ± 1.19 (kg)
7.	Ayra lexaki kg/aganuni hiito gaamata?	1. Lowo geeshi gotiima ayra lexate, 2. Aliidi ayra lexate 3. keraanch ayra lexa 4. lowo geesh wofima ayra lexa
8.	Gotiima ayra lexakira korkaatu maati?	-----
9	Wofima ayra lexakira korkaatu maati?	-----
10	Fajantino ayra lexate ikadona fayyo hurbaate itata?	1. Eeye 2. Dee'ni
11.	Mererima ayrate lexaki kg/umi sasu aganira mageeshite	1. <0.5kg 2. 0.5–2 kg 3. >2kg
12.	Umihu sasu agani mereerima ayrate dira mageeshite	1. <0.5kg 2. 0.5–2 kg 3. >2kg
13.	Koni albanii ayrate lexaki hiito la'ata?	1. Suutuni lexa 2. Hedewelcho lexxa 3. Hedewelcho dira 4. Eefulcho lexa
14.	Amate ayra wofimate (underweight)?	1. Eeye 2. Dee'ni
15.	Laynki sayki trimesterera ayra lexino	1. Eeye 2. Dee'ni
16.	Laynk trimesterera mageesh kg ayra lexitino?	1. Ikadomale (<11.0 kg) 2. Ikado (11.5 -15.8kg) 3. Bae (>18.0 kg)
17.	Sayki trimesterera mageeshi kg ayra lexitino?	1. Ikadomale (<11.0 kg) 2. Ikado (11.5 -15.8kg) 3. Bae (>18.0 kg)
18.	Laynki trimester mageesh ayra diritu?	1. >3 kg 2. Diafooma 3. 1 and 3 4. Didirtino
19.	Sayki trimester mageeshi ayra diritino?	1. >3 kg 2. Diafooma 3. 1 and 3 4. didirtino
20.	Jeefote xaphoomuni ayrate lexa mageeshita ikitano	-----

### Gafa V: Godowate ilate jeefote guma

T/k	Xa'muwa	Dawaro
1.	Iltaa woyte amate diri me'echo?	1. 15-19 2. 20-24 3. 25-29 4. 30-34 5. 35-40 6. 41-44 7. 45-49
2.	Ama mama iltino ?	1. Mine 2. Faymate urinshara
3.	Daimu ilami barana yana?	-----
4.	Daimu me'u aganini ilami ?	-----
5.	Godawate yana hiito murooni	1. LMP 2. Fundal height 3. Ultrasound
6.	Ilate game me'u aganini hanafu?	1. Aleesoho (<37 lam) 2. 37-38 lam aleso 3. Wo'ma yanara (39 -40 lam) 4. Shima yana saena (41- 41 lam) 5. Lowo yana saena (>42 lam)
7.	Yana iiltuki (<37lam), ikituro?	1. Hedewelcho yanimale ilati 2. Umo ka'ate (<28 lam) 3. Yanimale (28 -<32 lam) 4. Mererima yanimale (32 -37)
8.	Yanimale ilara korkatu maati	1. Hedewelima 2. Lako godowa 3. harfama 4. Sukarete xiso 5. Godowate cx 6. Gotiima MX
9.	Godowate cx, ikitu?-	1. Gotiima MX 2. Tiiu mitima 3. Anemia 4. STI 5. GD 6. Reyno ila 7. Umo ka'a 8. Depression 9. Cancer 10. Harfama 11. Preeclampsia 12. Hawunate
10	Qaaqu ilami yanara mageeshiho?	1. Aleesoho 2. Mereerimate woro 3. Keerancho 4. Lowo du'maati 5. Basente reyno, 6. Diafooma
11	Daimu diro	-----
12	Daimu koo-tee	1. Labaaho 2. Meyate
13	Godowu	1. Mito 2. Lakko 3. ≥Sasoo
14	Daimu ilami woyte	1. Lubote nooho 2. Ree ilaminoho
15	Daimu ilami yanara ayrosi bikinoni?	1. Eeye 2. Dee'ni 3. Diafooma
16	Daimu ayro mamote bikini:	1. Mite saateni 2. 48 saateni 3. 72 saateni 4. umi lamalara
17	Daimu ayra (gr)	1. <2500g 2. 2500-4000g 3. ≥4000g

### Gafa 7: Anthropometrikete

K/r	X'mo	Dawaro
1	Godowu gatihenu me'e lamalati?	-----
2.	Hojase sentimeterete me'ete(cm)?	-----
3.	Godawate albiidi ayirose me'ete (kg)	-----
4	BMI 12 lamala giddo me'ete(kg/m2)	-----
5	Godowate albiidi BMI hiito gamamtano?	1. Wofima(BMI <19.8) 2. Kerancho (BMI 19.8 to 26) 3. Gotima (BMI >26.0 to 29.0) 4. Du'ma (BMI >29.0)
6	Xa yana ayirose me'ete (kg)	-----
7	Amate hoja hiito gamamtano (cm)?	1. Harancho (<150 cm) 2. Kerancho (162 cm) 3. Seeda (>5 feet)
8	Aju godowi hedhena amate ayirose lexitino?	1. Eeye 2. Dee'ni
9	Aju godowi heedh me'e kg ayro lexataro affota ?	-----

## Annex IV: Standard operating procedure (SOP)

The Standard Operating Procedure (SOP) for the nutrition education and egg based dietary intervention  
Implementation date: February 2024

Authorization	Full Name	Position	Date
Written by	Kaleb Mayisso	PI	
Approved by	Dr. Tafese Bosha	Co- advisor	

### Introduction

Standard operating procedure (SOP) is a written technique suggested for repetitive use as a procedure, under agreed-upon specifications aimed at attaining the desired outcome. These are a specific set of procedures that are needed to be introduced and followed when specific situations arise. The SOP is developed for the nutrition education and egg based dietary intervention based on the public health research standards for the researchers and members. It includes separate sets of processes for the intervention at the community level.

The SOP aims to provide a clear and detailed description of step-by-step routine actions of the researchers and intervention implementers providing intervention in the community. It is important to remind intervention protocol, incorporate all aspects of intervention, ensure whether or not attention is given, monitor intervention protocol compliance, added advantage for quality control, increased transparency, and protected from malpractice. It should be used as a hands-on reference for the nutrition education and egg based dietary intervention implementers providing intervention, thereby helping to standardize the procedure in all intervention sites, with the ultimate goal of optimizing intervention.

### 1. Purpose

This SOP explains the process of how the nutrition education and egg based dietary intervention procedure is implemented in this research that is interested in creating well-structured intervention provision methods about this research area(s). The goal of this SOP is to clarify the nutrition education and egg based dietary intervention procedure and to provide guidance for the researcher and members (study participants, intervention implementers, data collectors, and supervisors) to facilitate the execution of the intervention. These procedures are to ensure that intervention in the study area is ready to implement in a timely, consistent and effective manner. This SOP describes the scope of nutrition education and egg based diet interventions to assess

the effect dietary intake, nutrient adequacy, and weight gain and birth outcomes among pregnant women among pregnant women in sidama region, Ethiopia.

### **1. Scope:**

This SOP is applicable for nutrition education instructors, survivors and data collector's and sets minimum standards to the researcher's execution procedure and describes the specific steps of providing nutrition education and egg based dietary intervention to pregnant women at the community level with essential records and reporting systems.

### **2. Prerequisites:**

From pregnant women: the women's last menstrual period /gestational age summary. For supervisors and others: the women's nutrition education and egg based diet interventions /follow up form, educational tools (pre-recorded audio based lecture)

### **3. Responsibilities:**

This SOP applicable to researchers and members involved in the research (the nutritionist and health extension workers) and other staff members who may be participated in the procedure nutrition education and egg based diet interventions (e.g., Enrollment, education and dietary intervention or compliance, IRB).

### **5. Terms of Reference (TOR)**

**I.** Nutrition education interventions should be conducted via face-to-face in the first place, and egg based diet should be prepared by the study participants after eggs are supplied by the project in the community setting.

**II.** All the participants should be seen on an appointment-basis

**III.** All the sessions should be completed within 40 minutes while the discussion should be completed within 20 minutes.

**IV.** Subsequent education session should be done within the range of 2 weeks with the egg based diet intervention should be done three times a week for six months

**V.** Follow up session is required, where the assessment of the participants' progress should be done using objective tools (e.g. questionnaires)

### **6. Procedures**

**Step 1:** Volunteer health extension workers and community health development armies who can read and write the Sidamifa language and are willing to participate in the intervention will be recruited to deliver the intervention.

**Step 2:** Following recruitment, intensive training will be given for one week on the topics such as normal pregnancy and childbirths, dietary diversity and minimum meal frequency during pregnancy.

**Step3:** Collect base line details of the participants, including personal background and sociodemographic/economics data.

**Step 4:** Perform base line nutritional assessment using: - Anthropometric data (current height, weight and body mass index measurement; weight history, recent weight changes and weight goals). - Biochemical data (daily calorie intakes during pregnancy according to their pre-pregnancy body weight, physical activity level, and week of gestation. The levels of micronutrients (B vitamins (folic acid and B12), vitamins A, C, iron, zinc) will be assessed. - Dietary methods (dietary history/intake and dietary diversity (a measure of the number of food groups consumed over a reference period, usually 24 hours)

**Step 5:** - define energy and protein requirements and plan appropriate prenatal nutrition education and egg-based diet interventions that are tailored to the participants' needs.

**Step 6:** The pre-recorded audio-based education lecturer will be prepared by the midwife and Sidama Media Network (SMN) female experts. The implementation of nutrition education will be facilitated by HEW at a small community meeting place using pre-recorded audio and poster based short messages two times a month for six months using a tape player or portable Bluetooth devices. One session will take one hour, 20 minutes will be allowed for lecture supported by posters and the remaining 40 minutes will be allowed for discussion.

A short key message nutrition education session will consist of healthy diet during pregnancy (1) whole grains, legumes, nuts and an abundance and variety of fruits and vegetables; (2) moderate amounts of eggs, dairy, poultry and fish; and small amounts of red meat; (5) include safe and clean drinking water as the fluid of choice, (6) dark green leafy vegetable (7) Vitamin A-rich fruits and vegetables and dietary diversity (fruits, vegetables, and energy-source food daily) and minimum meal frequency.

After the session, some of the women will be selected to carry out role play which is basic to demonstrate the important messages and share experiences. This will be done to repeat the information provided to enable them to internalize the key message. The message will be also prepared by posters to strengthen the session message or to cover the missed information during

audio lecturer. Any questions, confusions, rumors, and misunderstandings during the session will be recorded and reported to the midwife. The midwife will be actively involved one time per month in women meeting to clarify the issues for them.

**Step 7:** Perform nutrition education monitoring and evaluation - Select appropriate indicators or measures - Compare the current outcomes (diet intake) with the previous outcomes and define what the progress toward expected outcomes is

**Step 8:** Egg-based dietary intervention will be implemented by HEW at a small community setting with a short message of nutrition education that will take half an hour, and an overall 36 sessions. The community health development army (HAD) will take a role of motivation of the women and their families to utilize nutrition education and egg-based dietary intervention. Each study participants will be supplied two eggs by the project and the egg-based diet will be prepared with homemade flour prepared from corn/wheat three times a week for six months.

**Step 9:** Perform nutrition education and egg-based dietary intervention monitoring and evaluation - select appropriate indicators or measures - compare the current outcomes (nutrient adequacy, and gestational weight gain and birth outcomes) with the previous outcomes and define what the progress toward expected outcomes is. The follow-up will be conducted every month or more repeatedly if any potential problems are indicated.

**Step 10:** Set the date of next appointment

**Step 11:** Record the study participants' case using the participants' dietary consultation/follow up form

### **Policy statement**

This SOP is to help clarify the nutrition education and egg-based dietary intervention implementation procedure, as well as provides recommended content and use language for the intervention procedure.

1. **Base line study descriptions:** mixed methods (both quantitative and qualitative) methods will be used.

**Base line nutritional assessment:** - baseline nutritional assessment will be conducted during first trimester. The assessment includes subjective and objective data. Subjective data will be gathered during the client interview (focused group discussion, in-depth interview and key informant interviews) includes data about food habits and customs (dietary intake habits,

nutrition adequacy, dietary diversity, and dietary practice), food security situation, meal patterns, food beliefs and skills, and medical conditions) affecting nutritional status. Objective data assessment includes the components of anthropometric measurements, laboratory measurements, and dietary methods of assessing nutritional status.

**Anthropometric assessment:** Common anthropometric measurements include weight (pre-pregnancy weight), height, MUAC, head circumference, and skinfold. Weighing requires a functional weighing scale that measures weight in kg to within the nearest 100 g. Measuring length or height requires a height board or measuring tape marked in centimeters (cm). Head circumference, body mass index (BMI), skinfold thickness and middle arm circumferences (MUAC) will be measured. Equipment required for a physical examination includes a scale, fixed and flexible measures, a skin marker, and skinfold caliper.

MUAC is the circumference of the left upper arm measured at the mid-point between the tip of the shoulder and the tip of the elbow, using a measuring or MUAC tape. The MUAC is defined as adequate (25.75–28.10 cm (in 19–21 weeks), 25.75–28.70 cm (in 27–29 weeks) and 25.75–29.45 cm (in 37–39 weeks) of gestation. MUAC is less than 23.5cm are considered to be underweight. For infant's weight, length, and head circumference are indicated anthropometric measurements at birth or within one day of birth. Transferrin is produced in the liver. It is a transport protein for iron and zinc, and can also be used as an indicator for the iron status in the body. In iron-deficiency, the serum transferrin increases

1.2. **Laboratory measurements:** Nutrient adequacy assessment in base line and post intervention study includes assessment of protein-calorie and micronutrient intakes of the women. Laboratory measurements vary in their sensitivity to nutritional changes. Checking levels of nutrients and their metabolites in body tissues and fluids (blood, urine and stool) samples as the consequence of the variations in quantity and nutrient composition of food consumed and utilized by the body is known. Lab test results can give trained medical professionals useful information about medical problems that may affect appetite or nutritional status. The measurements vary in their sensitivity to nutritional changes. Pregnant women's nutrient adequacy including iron, zinc, folate, vitamin A, vitamin D, iodine, and calcium will be assessed using biochemical test of micronutrient.

Pregnant women are advised to increase their daily calorie intakes during pregnancy according to their pre-pregnancy body weight, physical activity level, and week gestation. The suggested calorie increase for women who conceive at a body weight in the normal range is 360 calories a day in the second trimester and 475 calories a day in the third trimester. The Institute of Medicine (IOM) recommends  $\geq 175$  g/d of carbohydrate intake during pregnancy; however, many women are consuming lower carbohydrate (LC) diets ( $< 175$  g/d of carbohydrate or  $< 40\%$  of EI) within pregnancy. The alternate EAR values of protein correspond to intake of 1.22 g/kg bw/day during the early stages (~16 weeks) of pregnancy and 1.52 g/kg bw/day during late stages (~36 weeks).

**1.3. Dietary methods:** dietary method of nutritional assessment includes looking at past or current intakes of nutrients and dietary diversity from food by individuals or a group to determine their nutritional status.

**1.3.1. Dietary intake assessment** includes dietary intake (frequency, quantity and diversity), eating habits (dieting, craving, food myths & taboos), food intolerance and dislikes, fatigue and physical activity, nausea, vomiting, availability of clean and safe water, and sanitation and hygiene practices in food preparation and handling (personal hygiene, food preparation and handling)

**1.3.2. Dietary diversity** assessment is a measure of the number of food groups consumed over a reference period, usually 24 hours using dietary recall (24-h dietary recall to determine the adequacy of dietary intake), and food frequency questionnaire. Dietary diversity score is an indicator of both the nutrient consumption and the level of food security in the household. The higher the dietary diversity score, the more diversified and the more food-secured the household and balanced the diet is.

It is a qualitative measure of food consumption that reflects household access to a variety of foods, and is also a proxy for nutrient adequacy of the diet of individuals. It includes all foods consumed and quality of the individual's diet; micronutrient adequacy of the diet, the frequency of meals consumed in the home or outside the home based on the Ethiopian nutritional recommendations such as: - Eat a variety of foods every day including fruits, vegetables, legumes and animal foods, eat legumes such as beans, chickpeas, peas and lentils every day, eat a variety of fruits and vegetables of different colors such as banana, papaya, kale, carrot and tomato every day, diversify your diet with nuts and oilseeds such as Niger seeds, add animal-

source foods such as eggs, milk and meat to your everyday meals, drink a minimum of 8–10 glasses of clean water daily, stay healthy by doing daily physical activity for at least 30 minutes daily, use fats and oils sparingly, limit the use of sugar, sweets and sugary soft drinks, salt and alcoholic beverages.

In addition, the food guide pyramid containing six food groups that our body needs to have every day will be used. The pyramid has the base or widest part and the tip or the narrowest part of the pyramid. The widest part indicates the need for higher quantities of consumption of carbohydrate source foods, while the tip is narrow, indicating the need for eating only small amounts of fats and sweet things. If a person consumes any examples of the food type from each of the six groups in 24 hours, we can say that their dietary diversity score is six.

## **2. Intervention model description**

**Intervention group:** will receive an audio-based nutrition education and egg based dietary intervention for six months starting from second trimester until the date of delivery.

**Comparator group:** will receive the standard health education package and iron and folic acid supplementation for six months until the date of delivery as per the Ethiopian guidelines.

**2.1. Nutrition education topics:** At the end of the session women should be expected to improve the knowledge/practice and skill about:

- Knowledge and practice of optimal diet during pregnancy
- Knowledge and practice of minimum dietary diversity
- Knowledge and practice of minimum meal frequency
- Practice of diet preparation and use optimum diet

**2.2. Egg based diet intervention:** The intervention group will receive nutrition education and feeding assistance with two boiled egg-based diets (diet containing two eggs or 100 mg/d per day) as a reference daily allowance three times a week over six months (February to July 2024) at each cluster. In comparison, the control group will receive standard/routine health education along with iron and folic acid supplements as part of the prevention and promotion of healthy prenatal feeding program of the Ethiopian Ministry of Health.

**End line nutritional assessment:** End line nutritional assessment will be conducted during second and third trimesters of pregnancy and at birth. It includes anthropometric assessment (gestational weight gain), nutrient adequacy (micronutrient and macronutrient) and birth outcomes (birth weight height and head circumferences). Healthy, well-nourished women should

gain 10 to 14 kg during pregnancy, with an average of 12 kg in order to increase the probability of delivering full-term infants with an average birth weight of 3.3 kg, and to reduce the risk of fetal and maternal complications.

**Anthropometric assessment:** The core elements of anthropometric data are height, weight, head circumference, body mass index (BMI) and MUAC. MUAC is defined as adequate between 25.75–28.10 cm (19–21 weeks), 25.75–28.70 cm (27–29 weeks) and 25.75–29.45 cm (37–39 weeks). For infant’s weight, length, and head circumference are indicated anthropometric data that will be collected at birth/ within 24 hours of age.

**Nutrient adequacy:** the level of energy protein and omega 3 fatty acid, and the 11 micronutrient during pregnancy (vitamin C, calcium, iron, zinc, B1, B2, B3, B6, folate, vitamin A and B<sub>12</sub>) based on the recommended daily allowance (RDA) for the nutrients.

Nutrient	Biochemical test	Normal range in serum	RDA during pregnancy
Vitamin A	Serum vitamin	< 20 mcg/dl	770 µg
Calcium	Serum calcium	8.5 and 10.2 (mg/dL	950 mg/dL
Iron	Serum Iron	110g/l to < 60 mcg/dl	27mg/day
Zinc	Serum zinc	80 and 120 mcg/dL	11.3 mcg/dL
B <sub>1</sub>	Whole blood	2.5-7.5 µg/dL	0.1 µg/dL
B <sub>2</sub>	Urine level B <sub>2</sub>	120 mcg/day	1.9 mcg/day
B <sub>3</sub>	Serum level	0.50–8.45 ug/mL	1.6 ug/mL
B <sub>6</sub>	Serum level	5-50 mcg/L	1.9 mcg/L
B <sub>9</sub>	Serum folate	< 600 ng/ml	600 micrograms/day
B <sub>12</sub>	Serum level	300 pg/mL	4.5 pg/mL
Vitamin C	Serum vitamin C	0.2 - 1.1 mg/dL	105 mg/dL
Protein	Serum albumin	< 3.5 g/ dl	0.8 g/kg bw/day to 1.1 g/kg bw/day

## **Annex V: Curriculum Vitea**

### **1. General:**

1.1 Name: Kaleb Mayisso Rodamo

1.2 Date of Birth: December 4, 1974 G.C.

1.3 Place of Birth: Sidama National Regional State, Derara

1.4 Nationality: Ethiopian

1.5 Marital Status: Married, have two sons and two daughters

1.6 Language: Can write, read and speak: Sidamifa, Amharic, and English

1.7 Address: Tel. +25-07-0436-1408 +25-09-1953-2392

Email: [kalebm@hu.edu.et](mailto:kalebm@hu.edu.et)

: [kalebmayisso@gmail.com](mailto:kalebmayisso@gmail.com)

## **2. EDUCATION:**

2.1. 2022 until now: PhD fellow in Human Nutrition with completion of first year and second year first semester course works with cumulative GPA 3.71

2.2. 2014 Jimma University: Graduated from Jimma University with Mph degree in public health -with CGPA 3.46.

(Thesis title: The magnitude and determinants of utilization of skilled birth attendances in Sidama south east Ethiopia)

A. 2013-2014 Jimma University: Studied at Jimma University School of public health Mph program

B. 2010 Hawassa University: Graduated from Hawassa University School of public health BSc program in public health (public health officer) – with CGPA 2.97

C. 2007 – 2010 Hawassa University: Studied at Hawassa University School of public health with Bsc degree in public health (public health officer)

D. 2002- Hawassa College of health sciences: Graduated from Hawassa College of health sciences diploma program in clinical nursing - CGPA 3.56

E. 2001-2002 Hawassa College of health Sciences: Studied at Hawassa College of health sciences diploma program in clinical nursing

F. 1998. Yirgalem Comprehensive Senior Secondary School: Ethiopian Schools Leaving Certificate Examination (ESLCE) with (2.8 point) 1

G. 1995 – 1998 Senior Secondary: Studied at Yirgalem Comprehensive Senior secondary school Grade 9 – 12

H. 1993-1994 Junior Secondary School: Studied at Yekatit 25 Junior Secondary school (Yirgalem) Grade 7 & 8 I. 1987- 1992 Elementary school: Studied at Gorbe sala elementary school Grade 1- 6 1.

## **3. WORK EXPERIENCE AND OTHER SKILLS**

3.1. Assistant professor, offering various public health courses at Hawassa University, Faculty of Health Sciences Department of Public Health as of May1, 2020 till present.

3.2. Hospital Manager, Hawassa university comprehensive specialized hospital, Hawassa

University College of Medicine and Health Sciences, January 2016 May 2019.

3.3. Lecturer, offering various public health courses at Hawassa University, Faculty of Health Sciences Department of Public Health as of January 1, 2016 till June, 2020.

3.4. Neglected Tropical disease and Non communicable disease officer at South Ethiopia Nation Nationalities People Regional Government Health Bureau Disease Prevention and Health Promotion Core Process, July, 2014-December 30, 2016

3.5. Head of health office Iloka Abaya district Sidama zone South Ethiopia Nation Nationalities People Regional Government for Three years

3.6. Maternal and child health officer at Dale district health office disease prevention and health promotion core process, Sidama zone South Ethiopia Nation Nationalities People Regional Government for Two years

3.7. Head of Mesenkela health center Dale district Sidama zone South Ethiopia Nation Nationalities People Regional Government for Two years

#### **4. Trainings**

4.1. Certificate in Training of trainers on continuous quality improvement from Hawassa University College of medicine and health sciences

4.2. Higher Diploma in teaching methodology from Hawassa University

4.3. Certificate in Cervical cancer Screening and Management in women living with HIV from CDC/PEPFAR

4.4. Certificate in Integrated management of neonate and childhood illness from Plan Ethiopia 2

4.5. Certificate in Master TOT health information management system (HMIS)

4.6. Certificate in Training on supportive supervision from ESHEJSI

4.7. Certificate in Ethiopian contraceptive logistics (ECLS) from DELIVER

4.8. Certificate in Health Management information System from ESHEJSI

4.9. Certificate in Community Health Promoters Initiative from ESHEJSI

4.10. Certificate in Integrated refresher training from ESHEJSI

4.11. Certificate in Training of trainers on community based Health care on adult nutrition from GOAL ETHIOPIA

#### **5. MEMBERSHIP**

5.1. Ethiopian Public Health Association (EPHA)

## 6. PUBLICATIONS

### I – Peer reviewed Journal

6.1. Kaleb Mayisso Rodamo, Waju Beyene Salgado, Gebeyehu Tsega Nebeb. Magnitude and Determinants of Utilization of Skilled Birth Attendance among Women of Child Bearing Age in Sidama Zone, Southeast Ethiopia A community based cross sectional study. *Journal of Gynecology and Obstetrics*, Vol. 3, No. 4, 2015, pp. 69-76. Doi: 10.11648/j.jgo.20150304.11; Published: June 3, 2015 6.2.

6.2. Kaleb Mayisso Rodamo, Yonas Alemayehu Fiche, Fisseha Bonja Geleto, Rekiku Fikre Abebe, Desalegn Dabaro Dangiso. Magnitude and Associated Factors of Protein Energy Malnutrition among Children Aged 6-59 Months in Wondogenet District, Sidama Zone, Southern Ethiopia. *Journal of Gynecology and Obstetrics*, Vol. 6, No. 3, 2018, pp. 47-55. Doi: 10.11648/j.jgo.20180603.13 6.3.

6.3. Gorfu Geremew Gunsa, Kaleb Mayisso Rodamo, Desalegn Dabaro Dangiso. Determinants of Acute Diarrhea among Children Aged 6-59 Months in Chire District, Southern Ethiopia: Unmatched Case-Control Study. *Journal of Gynecology and Obstetrics*, Vol. 6, No. 2, 2018, pp. 15-25. Doi: 10.11648/j.jgo.20180602.11

6.4. Getahun H/meskel Alemu<sup>1\*</sup>, Keneni Gutema Negari<sup>2</sup>, Kaleb Mayisso Rodamo<sup>2</sup> and Agete Tadewos Hirigo<sup>3</sup> Factors associated with the length of stay in emergency departments in Southern-Ethiopia. *Journal of BMC Research Notes*, Alemu et al. *BMC Res Notes* (2019) 12:239 <https://doi.org/10.1186/s13104-019-4271-7> 3

6.5. Mulugeta Meles Dibabi, Alemu Tamiso Debiso and Kaleb Mayisso Rodamo\*. Adverse maternal outcomes associated with Cesarean deliveries and their determinants: hospital based cross sectional, mixed- methods study. <https://www.emerald.com/insight/2586-940X.htm> .*Journal of Health Research*, Emerald Publishing Limited e-ISSN: 2586-940Xp-ISSN: 0857 4421. DOI 10.1108/JHR-09-2020-0396

6.6. Temesgen Tafesse<sup>1\*</sup>, Amanuel Yoseph<sup>2</sup>, Kaleb Mayiso<sup>2</sup> and Taye Gari<sup>3</sup> factors associated with stunting among children aged 6–59months in Bensa District, Sidama Region, South Ethiopia: unmatched case-control study. Tafesse et al. *BMC Pediatrics* (2021) 21:551 <https://doi.org/10.1186/s12887-021-03029-9>

6.7. Tamrat Alemu Tegegn, Kaleb Mayisso Rodamo\*, Keneni Gutama Negeri, Breast self examination practice and the associated factors among Bule Hora University students, Oromia Regional State, Ethiopia. An institution based cross sectional study Hawassa University College of Medicine and Health Sciences, Hawassa, Ethiopia. Copyright: the Author(s), 2022 Licensee PAGE Press, Italy Healthcare in Low-resource Settings 2022; 10:9994 doi:10.4081/hls.2022.9994

6.8. Kefale Lelamo Legu, Alemu Tamiso Debiso, and Kaleb Mayisso Rodamo\* the magnitude of perinatal mortality rate and associated risk factors among deliveries at Dilla University Referral Hospital, Southern Ethiopia: A case-control study Hawassa University College of Medicine and Health Sciences, Hawassa. Copyright: the Author(s), 2022 Licensee PAGE Press, Italy Healthcare in Low-resource Settings 2022; 10:9994 doi:10.4081/hls.2022.9994

6.9. Bethel Tagesse<sup>1</sup>, Alemu Tamiso<sup>2</sup>, Kaleb Mayisso<sup>2</sup>, Andualem Zenebe<sup>1</sup>\* Prevalence and Associated Factors of Disrespectful and Abusive Care During Childbirth Among Women Who Gave Birth in Health Facilities in Hawassa City, Southern Ethiopia. Ethiop, J. Health Biomed Sci., Sept. 2021. Vol.11, No.1 67 Original Article

6.10. Meiraf Daniel Meshesha 1, Ayantu Melke<sup>2</sup>, Abraham Teka Ajema<sup>2</sup>, Kaleb Mayisso Evaluation of Red Blood Cell Indices for Prediction of Glycemic Control in People Living with Type 2 Diabetes. Diabetes, Metabolic Syndrome and Obesity, 2024; 17:619-632. <https://doi.org/10.2147/DMSO.S445331>. 6.11

6.11. Mayisso K, Bosha T and Tamiru D (2025). Validation of food variety and dietary diversity scores as indicators of micronutrient adequacy among pregnant women in the northern zone of Sidama, Ethiopia. Front. Public Health 13:1536419. Doi: 10.3389/fpubh.2025.1536419

6.12. Kaleb Mayisso<sup>1</sup>\*, Tafese Bosha<sup>1</sup> and Dessalegn Tamiru<sup>2</sup>. Effect of nutrition intervention coupled with healthy dietary advice on the nutritional status of pregnant women in the northern zone of the Sidama region, Ethiopia: a multilevel, cluster randomized controlled trial. Journal of Health, Population <https://doi.org/10.1186/s41043-025-00968-2>

## **7. MEDIA EVENTS**

7.1. South Radio and TV Agency FM 97.1 one hour live interview about Guan worms transmission and techniques of prevention and control with Tenachin Radio program on Oct.

2/2016

7.2. South Radio and TV Agency FM 97.1 one hour live interview about amoebiasis transmission and techniques of prevention and control with Tenachin Radio program on December 28/2017

## **8. CURRENT RESEARCH ON PROGRESS**

8.1. Effect of nutrition education on improving nutrient adequacy and serum levels of essential micronutrients in pregnant women

8.2. Maternal anthropometric deficits and low serum folate levels during pregnancy are linked to an increased risk of preterm birth

8.3. Association of maternal anthropometric deficits and low serum ferritin levels with the risk of low birth weight: a prospective cohort study

## **9. HOBBIES**

9.1. Spiritual Music

9.2. Reading books, journals

## **10. REFERENCES**

10.1. Dr. Keneni Gutema- Associate professor.

Tele. +25-1 9-1658-0266

Email: [kenenigut2000@yahoo.com](mailto:kenenigut2000@yahoo.com)

10.2. Gorfu Geremew - PhD candidate, Jimma University

Tele. +251927079266.

Email: [gorfu.geremew@ju.edu.et](mailto:gorfu.geremew@ju.edu.et),

A/Kiira/ቁጥር/Ref.No. DFE/JASS/1  
Barra/ቀን/Date 20/03

2016

**Sidama National Regional State Health Bureau Public Health Institute Health Research  
Ethical Clearance Form**

Name of the applying principal/s (PI/s) Kaleb Mayisso  
Name of the applying institution Personal  
Address of the applying PI(s) (Mobile) +251-919532392

**Title of the project: Effects of Nutrition Education and Egg-based Local Diet Interventions on Dietary- intake, Nutrient Adequacy, Weight Gain and Birth Weight Among Pregnant Women in Sidama Region, Ethiopia**

Dear/Sir/Madam,

The Sidama Public Health Institute Research Ethical Review Committee has reviewed the aforementioned project proposal with special emphasis on the following points;

- |  |                                     |                          |
|--|-------------------------------------|--------------------------|
| 1. Are all ethical principles considered?                | Yes                                 | No                       |
| 1.1 Respect for person:                                  | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 1.2 Beneficence:   | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 1.3 Justice:   | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 2. Are the objectives of the study ethically achievable? | <input checked="" type="checkbox"/> | <input type="checkbox"/> |
| 3. Are proposed research methods have ethical sound?     | <input checked="" type="checkbox"/> | <input type="checkbox"/> |

**Comments of the ethics committee:**

Based on the above mentioned ethical assessment, the regional Ethical clearance committee has

- A. Approved the proposal for implementation
- B. Conditionally approved
- C. Not approved

Reason if not approved \_\_\_\_\_

The study should comply with the standard international and national scientific and ethical guideline. Any change to the approved protocol, any adverse or unanticipated events should be reported within 48 hours to Regional Health Bureau. Be informed that the regional health bureau ethical review committee has right and responsibility to conduct surprise and/or informed supervision of your work during the study.

Chairman of REC  
ሰነድ ለመግቢያ ደብዳቤ

Signature

Date

Nov 30 / 2023

CC  
✓ Health Research and Technology Transfer Directorate  
Hawassa ኢ.ፌ.ዲ.ሪ. ጤና ስራዎች ክልል





Ref. No: IRB/098/16

Date: 12/03/2024

Name of Researcher(s): **Kaleb Mayisso Rodamo (MPH), Dessalegn Tamiru (PhD, Asso. Prof.), Tafese Bosha (PhD, Asst. Prof.)**

Topic of Proposal: *Effect of nutrition education and egg based diet interventions on dietary intake practice, nutrient adequacy and gestational weight gain among pregnant women, and newborn's birth weight in north Sidama zone, Ethiopia*

Dear researcher(s),

The Institutional Review Board (IRB) at the College of Medicine and Health Sciences of Hawassa University has reviewed the aforementioned research protocol with special emphasis on the following points:

- 1. Are all principles considered?
  - 1.1. Respect for persons: Yes  No
  - 1.2. Beneficence: Yes  No
  - 1.3. Justice: Yes  No
- 2. Are the objectives of the study ethically achievable? Yes  No
- 3. Are the proposed research methods ethically sound? Yes  No

Based on the aforementioned ethical assessment, the IRB has:

- A. Approved the proposal for implementation  Approval period -**12 MAR. 2024 to 11 MAR. 2025**
- B. Conditionally Approved  Element Approved: **Protocol Version No. 1**
- C. Not Approved  Follow up report expected in **6 months**

Obligation of the PI:

- 1. Should comply with the standard international and national scientific and ethical guidelines
- 2. All amendment and changes made in protocol and consent form needs IRB approval
- 3. The PI should report SAE within 3 days of the event
- 4. End of the study, including the manuscript should be reported to the IRB

Yours faithfully,

Embialle Mengistie Beyene  
(PhD, Asso. Professor)  
Institutional Review Board Chairperson

