The Effect of Dietary Patterns on Maternal Morbidity (Anaemia and Hypertensive Disorders of Pregnancy) in Ethiopia

Kelemu Tilahun Kibret

BSc (Public Health), MPH (Epidemiology)

A thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

(Clinical Epidemiology and Medical Statistics)

School of Medicine and Public Health

The University of Newcastle

December 2020

Newcastle, Australia

Statement of originality

I hereby certify that the work embodied in the thesis is my own work, conducted under normal supervision. The thesis contains no material that has been accepted, or is being examined, for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the *Copyright Act 1968* and any approved embargo.

Thesis by publication

I hereby certify that this thesis is in the form of a series of papers. I have included as part of the thesis a written declaration from each co-author, endorsed in writing by the Faculty Assistant Dean (Research Training), attesting to my contribution to any jointly authored papers.

Signed: ___________________________________

Date: 03 July 2020

Kelemu Tilahun Kibret

The University of Newcastle

Co-Author Statement

By signing below I confirm that Research Higher Degree candidate Kelemu Tilahun Kibret contributed each study's conception and design, developing analyses plans, designing research tools and collecting data; performing data analysis, interpreting the data and leading the writing of the manuscripts to the papers/publications included in this thesis by publication.

List of publications

1. Kibret KT, Chojenta C, Gresham E, Teketo TK, Loxton D. Maternal dietary patterns and risk of adverse pregnancy (hypertensive disorders of pregnancy and gestational diabetes mellitus) and birth (preterm birth and low birth weight) outcomes: a systematic review and meta-analysis. Public Health Nutr. 2019 Mar;22(3);506–520. Epub 2018 Oct 15. doi:10.1017/S1368980018002616.
2. Kibret KT, Chojenta C, D'Arcy E, Loxton D. The spatial distribution and determinant factors of anaemia among women of reproductive age in Ethiopia: a multilevel and spatial analysis. BMJ Open. 2019;9(1):e027276.
3. Kibret KT, Chojenta C, D'Arcy E, Loxton D. Population attributable fraction estimates for factors associated with different types of anaemia among women in Ethiopia: multilevel multinomial analysis. Public Health Nutrition,2020: doi:10.1017/S1368980020003109.
4. Kibret KT, Chojenta C, D'Arcy E, Loxton D. The effect of dietary patterns on hypertensive disorders of pregnancy in North Shewa, Ethiopia: A propensity score-matched case-control study Pregnancy hypertension, 2020; 22: 24-29; doi.org/10.1016/j.preghy.2020.07.002.

List of papers under review

5. Kibret KT, Chojenta C, D'Arcy E, Loxton D. The effect of dietary patterns on maternal anaemia in North Shewa, Ethiopia: a case-control study with propensity score analysis. Submitted to BMJ Open, under review.

Co-authors	Papers/publications	Signature	Date
Catherine Chojenta	1,2,3,4,5		
Deborah Loxton	1,2,3,4,5		
Ellie D'Arcy	1,2,3,4,5		
Teketo Kassaw Tegene	1		

Endorsed by Faculty of Health and Medicine Assistant Dean Research Training

Signed: Associate Professor Lesley MacDonald-Wicks Date: 6/7/2020

The University of Newcastle

Conference Presentations

- Spatial distribution and factors of anaemia among women: multilevel and spatial analysis. Rapid fair poster presentation at: Annual Scientific Meeting of the Australasian Epidemiological Association; 2019 October 23–25; Brisbane, Australia.
- Dietary patterns and risk of pregnancy outcomes: systematic review and meta-analysis. Rapid fair poster presentation at: Annual Scientific Meeting of the Australasian Epidemiological Association; 2019 October 23–25; Brisbane, Australia.
- Effect of Dietary Patterns on Maternal Anaemia in Ethiopia: A case-control study Poster presentation at: Virtual World Public Health Nutrition Congress 2020; 1 May to 12 June 2020; Brisbane, Queensland, Australia.

Training/workshops

- Propensity score methods for estimating causal effects in non-experimental settings [Workshop]. 2019 October 23; Australasian Epidemiological Association; Brisbane, Australia.
- Multilevel modelling course [Online]. 2017/2018; Centre for Multilevel Modelling, University of Bristol: UK.
- Nutrition and lifestyle during pregnancy [Online]. May–June 2017; Ludwig-Maximilians University (Coursera).
- Meta-analysis: concepts and applications. 13–15 February 2017; Biostat Inc.; Sydney, Australia.
- Introduction to systematic review and meta-analysis [Online]. November–December 2016; John Hopkins Bloomberg School of Public Health (Coursera).

Awards

- A 2019 $500 Australasia Epidemiological Association student conference award at the Australasian Epidemiological Association annual scientific meeting, 23–25 October 2019, Brisbane, Australia.

Dedications

I am privileged, and it is my pleasure, to dedicate this thesis to my beloved father, Tilahun Kibret Antenyistegn, and my late mother, Yelfe Degefe Mingude.

Copyright Permission

I warrant that I have obtained, where necessary, permission from the copyright owners to use any of my own published work (i.e. journal publications) in which the copyright is held by another party.

……………………….

Kelemu Tilahun Kibret

Acknowledgements

First and foremost, my deepest gratitude and appreciation go to my supervisors, Dr Catherine Chojenta, Professor Deborah Loxton and Dr Ellie D'Arcy, for your wholehearted and unreserved support, guidance and encouragement throughout my PhD candidature. You are not only inspirational and supportive but also genuine, kind, thoughtful and compassionate people. Thank you all so much for sharing your knowledge and skills, and for your continuous guidance, encouragement, kindness and patience. Dr Cath, you are very special and not only a supervisor or mentor, but you are also a sister and mam. You are dedicated to creating a conducive research environment, which has been inspiring and motivating. Your ability to solve problems and make things simple is exemplary and very helpful. I am very pleased with your sympathy, understanding and all-rounded help for my PhD study. Prof. Deb, your dedication, insight, skill and experience are very helpful in developing research skills. Thank you so much for your unreserved help in reviewing my work in your tight schedule. Dr Ellie, the way you see things in-depth and from different perspectives was important in making the work much better. Your commitment and dedication when you were pregnant and on maternity leave has been inspirational for me. Thank you so much for your continuous help while you were in such a very difficult period.

It is my pleasure to thank the University of Newcastle for providing me with a scholarship opportunity for my PhD study. I would like to extend my gratitude to all the staff members of the Research Centre for Generational Health and Ageing, and the School of Medicine and Public Health, as well as the Hunter Medical Research Institute, for creating such a supportive research environment and for their extensive support and facilitation in all aspects of my PhD study. I had an unforgettable stay during my PhD study. I am very grateful to Dr Ryan O'Neill and Ms Natalia Soeters for their help in improving my English language and in editing my papers and thesis. I also thank Debbie Booth for her substantial help concerning literature searches and EndNote issues. I would like to thank all my fellow PhD colleagues and friends. You were with me, and your emotional, psychological and motivational support helped me a lot in many aspects of my PhD journey. I wish you all the best of luck in your PhD studies and future career endeavours.

I would like to thank the North Shewa Zone Health Department, district-level health offices, and leaders and staff of the health facilities for their unreserved facilitation and cooperation during the data collection process. I am very grateful to the study participants and data collectors for participating in this case-control study. I would like to thank the women who participated in 2016 Ethiopian Demographic and Health Survey for their devotion to providing invaluable information.

I would like to thank my family: you are always with me. Your continuous spiritual, emotional and psychological support and encouragement helped me to be successful in a long and rocky academic journey and to reach the terminal degree, a PhD. My Dad, your continuous all-rounded advice, support and encouragement helped me to be successful not only in the academic journey but also in all aspects of life. To my brother, Getacher, and sister, Marye, you are two of my guides that helped me to grow and be successful in my academic life. To my sister-in-law Belaynesh Mamo, you are both a sister and mam, and your patience, respect, advice and encouragement are unforgettable and have been very helpful.

I would like to give special thanks to my nephews, Workshet Nigussie and Ayalew Getacher, and my niece, Marie Melese, who are not only prodigious friends but who also often fed me delicious meals and treats while I was doing my fieldwork for my PhD. Ayalew, you are exceptional and very mature for your age. Your unreserved care and support during my PhD fieldwork made it less stressful and easier. Worku, you are an obedient and a punctual person, and you did a great job during my PhD fieldwork, giving me the drive to reach each health facility on time and to achieve my desired goals. Thank you for your all-rounded and unreserved help. Both of you have made my PhD fieldwork smooth, less stressful and successful.

Last but not least, I would like to present my deepest acknowledgements to my beloved wife, Nitsuh Melese, and our son, Kidanemariam, for your courage, understanding, support and encouragement. I really appreciate your heartfelt empathy, encouragement and understanding. I know how very tough and difficult being pregnant and taking care of a child alone was, but you did it, and this helped me to concentrate on my PhD study. Thank you so much for your dedication, understanding and carrying the responsibility of being both a mother and father.

Contents

Statement of originality ... **i**

Thesis by publication ... **i**

Co-Author Statement ... **ii**
List of publications ... ii
List of papers under review ... ii

Conference Presentations ... **iv**

Training/workshops ... **iv**

Awards ... **iv**

Dedications ... **v**

Copyright Permission ... **vi**

Acknowledgements ... **vii**

Contents ... **ix**

List of figures ... **xv**

List of tables ... **xvi**

List of abbreviations ... **xvii**

Abstract ... **xviii**

Chapter 1: Introduction ... **1**
1.1 Background ... 1
1.2 Background on Ethiopia ... 3
1.2.1 Location/ecology, governance and population ... 3
1.2.2 Healthcare system ... 4
1.2.3 Dietary intake ... 5
1.3 Thesis structure/overview ... 5

Chapter 2: Literature review ... **7**
2.1 Literature search strategy ... 7
2.2 Maternal anaemia ... 7
2.2.1 Definition and burden ... 7
2.2.2 Determinant factors of anaemia ... 8
2.2.2.1 Biological factors ... 8
2.2.2.2 Disease/infection factors ... 10
2.2.2.3 Socioeconomic and environmental factors ... 10
2.2.2.4 Dietary factors ... 11
2.2.3 Consequences of anaemia ... 14
2.2.3.1 Maternal morbidity ... 14
2.2.3.2 Poor birth outcomes ... 15
2.2.4 Prevention of anaemia ... 15
2.3 HDPs ... 16
2.3.1 Definition and burden of HDPs ... 16
2.3.2 Predictors of HDPs ... 17
2.3.3 Consequences of HDPs ... 17
2.3.4 Prevention of HDPs ... 18
2.4 Dietary requirements and dietary intake during pregnancy ... 18

2.4.1 Dietary requirements during pregnancy 19
2.4.1.1 Requirements of energy and macronutrients 19
2.4.1.2 Micronutrient requirements 20
2.4.2 Dietary intake and diversity during pregnancy 21
2.4.3 Dietary patterns 22
2.5 Gap analysis and significance 24
2.6 Aims of the thesis 26
Chapter 3: Research methods 27
3.1 Systematic review and meta-analysis 27
3.1.1 Search strategy 27
3.1.2 Study selection and data extraction 28
3.1.2.1 Study selection 28
3.1.2.2 Data extraction 28
3.1.3 Quality assessments 28
3.1.4 Statistical analysis 29
3.2 Spatial and multilevel studies 30
3.2.1 Study design and setting 30
3.2.2 Sampling and measurements 31
3.2.2.1 Sampling 31
3.2.2.2 Measurements 31
3.2.2.2.1 Dependent variables 31
3.2.2.2.2 Explanatory variables (determinant factors) 32
3.2.3 Data analysis 35
3.2.3.1 Spatial analysis (to assess the spatial distribution and determinant factors of anaemia among women in Ethiopia) 35
3.2.3.2 Statistical analysis 36
3.2.3.2.1 Aim 2, Objective 2 (to identify the determinant factors for anaemia among women in Ethiopia) 36
3.2.3.2.2 Aim 2, Objective 3 (to assess the PAF estimates for factors associated with different types of anaemia among women in Ethiopia) 38
3.2.4 Ethics considerations 40
3.3 Case-control studies 40
3.3.1 Study area and periods 40
3.3.2 Study design 41
3.3.3 Source and study population 41
3.3.4 Sampling method and sample size determination 41
3.3.5 Data collection procedures and measurements 43
3.3.5.1 Data collection procedures 43
3.3.5.2 Data measurements 44
3.3.6 Data processing and analysis 44
3.3.6.1 Descriptive analysis 44
3.3.6.2 Propensity score analysis 45
3.3.7 Ethics considerations 46
Chapter 4: Maternal dietary patterns and risk of adverse pregnancy (hypertensive disorder of pregnancy and gestational diabetes mellitus) and birth (preterm birth and low birth weight) outcomes—a systematic review and meta-analysis 48
Abstract 48
4.1 Introduction 50
4.2 Methods 52

4.2.1 Search strategy 52
4.2.2 Study selection 52
4.2.3 Data extraction 53
4.2.4 Quality assessments 53
4.2.5 Statistical analysis 54
4.3 Results 55
4.3.1 Identified studies 55
4.3.2 Study characteristics 56
4.3.3 The effect of dietary patterns on adverse pregnancy outcomes (HDPs and GDM) 63
4.3.3.1 Dietary patterns and HDPs 63
4.3.3.1.1 Healthy dietary pattern 63
4.3.3.1.2 Western dietary pattern 64
4.3.3.2 Dietary patterns and GDM 64
4.3.3.2.1 Healthy dietary pattern 64
4.3.3.2.2 Western dietary pattern 64
4.3.4 The effect of dietary patterns on adverse birth outcomes (PTB and LBW) 67
4.3.4.1 Dietary patterns and PTB 67
4.3.4.2 Dietary patterns and LBW 69
4.4 Discussion 70
4.5 Conclusion 73

Chapter 5: The spatial distribution and determinant factors of anaemia among women of reproductive age in Ethiopia—a multilevel and spatial analysis 75
Abstract 75
5.1 Introduction 77
5.2 Methods 78
5.2.1 Patient and public involvement 78
5.2.2 Study design and setting 78
5.2.3 Sampling and data measurements 79
5.2.4 Explanatory variables (determinant factors) 80
5.2.5 Data analysis 81
5.2.5.1 Spatial analysis 81
5.2.5.2 Statistical analysis 82
5.2.6 Ethics considerations 83
5.3 Results 84
5.3.1 Sociodemographic characteristics 84
5.3.2 Prevalence rate of anaemia among women 87
5.3.3 Determinant factors of anaemia among women of reproductive age 89
5.3.3.1 Multilevel Analysis (fixed-effects analysis) 89
5.3.3.1.1 Individual-level factors 90
5.3.3.1.2 Community-level factors 91
5.3.3.2 Multilevel analysis (random-effects analysis) 91
5.3.4 Spatial data analysis 96
5.4 Discussion 99
5.5 Strengths and limitations 102
5.6 Conclusion 102

Chapter 6: Population attributable fraction estimates for factors associated with different types of anaemia among women in Ethiopia—multilevel multinomial analysis 104

Abstract 104
6.1 Introduction 106
6.2 Methods 107
6.2.1 Study design and setting 107
6.2.2 Sampling and sample size 107
6.2.3 Measurements 107
6.2.4 Statistical analysis of the data 108
6.2.5 Ethics approval 110
6.3 Results 110
6.3.1 Sociodemographic characteristics and prevalence of anaemia 110
6.3.2 Multivariable analysis 115
6.3.2.1 Factors for any anaemia among women 115
6.3.2.2 Factors associated with mild anaemia and moderate-severe anaemia 119
6.3.3 Random-effects analysis 123
6.4 Discussion 123
6.5 Conclusion 126
Chapter 7: The effect of dietary patterns on maternal anaemia in North Shewa, Ethiopia—a case-control study with propensity score analysis 128
Abstract 128
7.1 Introduction 129
7.2 Methods 130
7.2.1 Study settings and periods 130
7.2.2 Study design 130
7.2.3 Source and study population 131
7.2.4 Sampling method and sample size determination 131
7.2.5 Data collection procedures and measurements 131
7.2.5.1 Anthropometric and laboratory measurements 132
7.2.6 Data processing and analysis 132
7.2.6.1 Propensity score analysis 133
7.2.7 Ethics approval and consent to participate 134
7.3 Results 134
7.3.1 Sociodemographic, maternal and family characteristics 134
7.3.2 Maternal eating habits/practices 137
7.3.3 Propensity score analysis 138
7.3.4 Factors for the occurrence of maternal anaemia among pregnant women 140
7.3.4.1 Bivariate analysis 140
7.3.4.2 Multivariable analysis 140
7.4 Discussion 142
7.5 Conclusion 144
Chapter 8: The effect of dietary patterns on HDPs in North Shewa, Ethiopia: A propensity score-matched case-control study 146
Abstract 146
8.1 Introduction 147
8.2 Methods 148
8.2.1 Study settings, design and population 148
8.2.2 Sampling method and sample size determination 148
8.2.3 Data collection procedures and measurements 148
8.2.4 Anthropometric and laboratory measurements 149
8.2.5 Data analysis 149

8.2.5.1 Descriptive analysis 149
8.2.5.2 Propensity score analysis.. 149
8.2.6 Ethics approvals and consent to participate 151
8.3 Results 152
8.3.1 Sociodemographic characteristics of study participants.................................... 152
8.3.2 Maternal feeding habits/practices of study participants 154
8.3.3 Factors associated with pregnancy-induced hypertension................................. 155
8.4 Discussion 156
8.5 Conclusion.. 158

Chapter 9: General discussion and recommendations 159
9.1 Discussion 159
9.1.1 Overview.. 159
9.1.2 The effect of dietary pattern on adverse pregnancy and birth outcomes............. 159
9.1.3 Spatial distribution and determinant factors of anaemia among women 161
9.1.4 The effect of dietary patterns on maternal anaemia 164
9.2 Strengths and limitations... 164
9.3 Recommendations.. 165
9.4 Conclusions 167

References.. 169

Appendix 1: Ethics approval letter for EDHS data from the National Research Ethics Review Committee of Ethiopia 187

Appendix 2: Ethics approval letter for EDHS data from ICF Macro International.... 188

Appendix 3: Ethics approval for secondary data from the University of Newcastle Human Research Ethics Committee.. 189

Appendix 4: Questionnaire (English) 192

Appendix 5: Questionnaire (Amharic) 201

Appendix 6: Ethics approval for primary data from the University of Newcastle Human Research Ethics Committee.. 208

Appendix 7: Ethics approval from Amhara Public Health Institute 209

Appendix 8: Support letter from the Amhara Public Health Institute for Zonal Health office 210

Appendix 9: Letters for district health offices from the zonal health office 211

Appendix 10: Letters from district health offices to health facilities 213

Appendix 11: Information statement for health facilities (English)............................. 216

Appendix 12: Information statement for health facilities (Amharic)........................... 217

Appendix 13: Consent form for health facilities (English) 218

Appendix 14: Consent form for health facilities (Amharic) 219

Appendix 15: Information statement for participants (English).................................. 220

Appendix 16: Information statement for participants (Amharic)................................ 222

Appendix 17: Consent form for participants (English) 224

Appendix 18: Consent form for participants (Amharic) 225

Appendix 19: [Published manuscript] Maternal dietary patterns and risk of adverse pregnancy outcomes—a systematic review and meta-analysis...................................... 226

Appendix 20: [Published manuscript] The spatial distribution and determinant factors of anaemia among women—a multilevel and spatial analysis 241

List of figures

Figure 1-1 Map of Ethiopia (source: https://www.diva-gis.org/) 4

Figure 4-1 Flow chart of the study selection process. 55

Figure 4-2 Pooled *OR* of the association between a healthy dietary pattern and pre-eclampsia. 63

Figure 4-3 Pooled *OR* of associations between GDM and different dietary patterns—a) healthy and b) Western—with sub-group analysis regarding period of dietary assessment. 66

Figure 4-4 Pooled *OR* of association between PTB and different dietary patterns a) healthy, with sub-group analysis of assessment methods (MDS vs DDS vs PCA), b) healthy, with sub-group analysis of dietary assessment periods (second trimester vs both second and third trimesters vs all trimesters), and c) Western, with sub-group analysis of dietary assessment periods (second trimester vs both second and third trimesters). 69

Figure 5-1 Selection of sample in the 2016 EDHS. 80

Figure 5-2 Average Hgb value, with 95% CI, for women of reproductive age in different age groups, Ethiopia, 2016. 91

Figure 5-3 Spatial empirical Bayesian smoothed percentage of anaemia among women of reproductive age across regions, 2016 EDHS. 97

Figure 5-4 Standardised prevalence ratio for anaemia among women of reproductive age across the regions in Ethiopia (standardised to national prevalence of 23.6%), 2016 EDHS. 97

Figure 5-5 Spatial empirical Bayesian smoothed proportion of anaemia among women of reproductive age at zonal level, 2016 EDHS. 98

Figure 5-6 Standardised prevalence ratios for anaemia among women of reproductive age across zones in Ethiopia (standardised to national prevalence of 23.6%), 2016 EDHS. 98

Figure 5-7 Spatial pattern of hotspots and cold spots of anaemia rates among women of reproductive age at the cluster level in Ethiopia, 2016 EDHS. 99

Figure 7-1 Standardised mean differences before and after propensity score matching comparing covariate values for study subjects having high and low DDS 139

List of tables

Table 3.1 Variables identified for this study with coding. 32
Table 3.2 Sample size determination using different exposure variables. 42
Table 4.1 Inclusion and exclusion criteria for the systematic review. 53
Table 4.2 Characteristics of the articles included in the systematic review. 57
Table 5.1 Sociodemographic and other health-related characteristics of study participants included in the analysis, 2016 EDHS. 84
Table 5.2 The variation of anaemia prevalence rates across different regions and different sociodemographic characteristics of women in Ethiopia, 2016. 87
Table 5.3 Hgb levels among pregnant women in Ethiopia, 2016. 89
Table 5.4 Adjusted odds ration from multivariable multilevel logistic regression analysis for determinant factors associated with anaemia among Ethiopian women, 2016. 92
Table 6.1 Characteristics of the study population and prevalence of various levels of anaemia in Ethiopian women aged 15–49 years, 2016 EDHS. 111
Table 6.2 AORs from multilevel logistics regression and PAFs for factors associated with any anaemia among women in Ethiopia, 2016. 116
Table 6.3 AORs from multilevel multinomial logistics regression and PAFs for factors associated with mild and moderate-severe anaemia among women in Ethiopia, 2016. 120
Table 6.4. Measure of variation for different anaemia types at the cluster level (effect of variation from the random intercept model). 123
Table 7.1 Sociodemographic, maternal and family characteristics of study participants, North Shewa, 2019. 135
Table 7.2 Maternal feeding habits/practices of study participants, North Shewa, 2019. 137
Table 7.3 Determinant factors of anaemia among pregnant women in the selected public health facilities of North Shewa Zone, Ethiopia: Conditional logistic regression analysis, 2019. 140
Table 8.1 Standardised mean differences before and after propensity score matching, comparing covariate values for study subjects having high vs low DDSs. 150
Table 8.2 Sociodemographic characteristics of study participants, 2018/2019. 152
Table 8.3 Maternal feeding habits/practices of study participants, 2018/2019. 154
Table 8.4 Determinant factors for the occurrence of HDPs: comparison of cases and controls by bivariate and multivariable logistic regression analyses, 2018/2019. 155

List of abbreviations

ANC	antenatal care
ANOVA	analysis of variance
AOR	adjusted odds ratio
BMI	body mass index
CINAHL	Cumulative Index to Nursing and Allied Health Literature
COR	crude odds ratio
DASH	Dietary Approaches to Stop Hypertension
DBP	diastolic blood pressure
DDS	dietary diversity score
DHS	Demographic and Health Surveys (2)
EA	enumeration area
EDHS	Ethiopian Demographic Health Survey
FAO	Food and Agriculture Organization of the United Nations
FFQ	food frequency questionnaire
GDM	gestational diabetes mellitus
GPS	global positioning system
GSEM	generalised structural equation model
HDPs	hypertensive disorders of pregnancy
Hgb	haemoglobin
ICC	intra-cluster correlation coefficient
LBW	low birth weight
LMIC	lower and middle-income country
MDS	Mediterranean diet score
MEASURE DHS	Monitoring and Evaluation to Assess and Use Results Demographic and Health Surveys
MOR	median odds ratio
MUAC	mid-upper arm circumference
PAF	population-attributable fraction
PCA	principal component analysis
PCV	percentage change in variance
PTB	preterm birth
RCOG	Royal College of Obstetricians and Gynaecologists
SBP	systolic blood pressure
SNNP	Southern Nations, Nationalities and Peoples' (Regional State)
UK	United Kingdom
US	United States
VIF	variance inflation factor
WHO	World Health Organization

Abstract

Anaemia and hypertensive disorders of pregnancy (HDPs) are significant health problems in pregnant women, accounting for substantial morbidity and poor pregnancy outcomes. Evidence has shown that dietary patterns during pregnancy have an effect on anaemia and HDPs. However, the findings are inconsistent and inconclusive, and most studies have occurred in high-resource settings. Therefore, this thesis aims to assess the effect of dietary patterns on maternal morbidity (anaemia and HDPs) in the resource-limited setting of Ethiopia.

This thesis generated evidence using a combination of data sources, including a review of global literature, a detailed secondary analysis of large population-based national data and a regionally-based case-control study. A combination of advanced statistical methods, including systematic review with meta-analysis, spatial analysis, multilevel analysis and propensity score analysis, were employed. The effects of dietary patterns on risks in pregnancy (HDPs, gestational diabetes) and birth (preterm birth and low birth weight) outcomes were assessed through a systematic review with meta-analysis, using literature from across the globe. The effect of dietary patterns on maternal morbidity (anaemia and HDPs) was assessed in the low-resource setting of Ethiopia through a propensity score analysis and applying conditional logistics regression model. The spatial analysis and mixed effect multilevel models were applied to assess the spatial distribution and determinant factors of anaemia among women of reproductive age in Ethiopia.

The results of the systematic review suggest that healthy dietary patterns (high intake of fruits, vegetables, wholegrain foods, fish and poultry) have a positive effect on pregnancy outcomes (pre-eclampsia, preterm birth, gestational diabetes). The spatial analysis results showed that the prevalence of anaemia among women in Ethiopia was high and that there were spatial disparities across the country. The results revealed that anaemia is a moderate public health problem among women (> 20%) at the national level and a serious public health problem (> 40%) in five of the 11 regional states, based on World Health Organization criteria. The multilevel analysis demonstrated that sociodemographic factors (low educational status, low wealth index, rural residence and unimproved latrine facilities) and reproductive/biological factors (younger age, pregnancy, breastfeeding, and high gravidity) are associated with the occurrence of anaemia. The effect of dietary patterns on maternal morbidity (anaemia and HDPs) in the low-resource setting of Ethiopia was assessed through case-control studies. The

results indicated that having a more diversified food intake is associated with lower odds of anaemia and HDPs.

Dietary intake should be included as a core component for the prevention of adverse pregnancy outcomes through strengthening existing antenatal care programs. The prevention of anaemia among women could require context-specific and multifaceted intervention approaches, such as improving the economic and educational status of women or improving the availability of clean water and toilet facilities in limited-resource settings.

Chapter 1: Introduction

This chapter provides a brief overview of the relationship between dietary intake and maternal morbidity, particularly anaemia and hypertensive disorders of pregnancy (HDPs). This chapter summarises the study area, Ethiopia, including its agro-ecological condition and healthcare system. This chapter ends with a brief description of the structure of the thesis.

1.1 Background

Anaemia (3, 4) and HDPs (5, 6) are significant health problems for pregnant women and account for substantial morbidity and poor pregnancy outcomes. Anaemia increases the risk of severe maternal morbidity (7), low birth weight (LBW) and preterm birth (PTB) (8, 9). Anaemia is a common health problem in resource-limited settings, where up to 56% of pregnant women are affected in certain regions, including South Asia, and East, West and Central Africa (3). In Ethiopia, anaemia is one of the major contributing factors to maternal mortality and severe morbidity (10). Likewise, HDPs are leading causes of maternal morbidity and mortality both globally and regionally (5, 11), including in Ethiopia (12). Recent research in Ethiopia has shown that HDPs were responsible for a significant proportion (19%) of maternal deaths and were the third most common cause of maternal mortality after haemorrhages (22%) and obstructed labour/uterine ruptures (36%) (12).

The personal behaviour components of pregnancy, such as intake of an adequate and diverse diet, are becoming important areas of concern for the prevention and control of poor pregnancy outcomes (13, 14). Dietary intake is an important factor affecting pregnancy outcomes (15). The requirement of almost all nutrients (macro and micronutrients) is increased during pregnancy due to physiological and metabolic changes, maternal tissue deposition and fetus growth (16). Nutrients (e.g., thiamine, niacin, zinc, vitamin B6, iodine, iron, folate and protein) and energy requirements increase by 27%–54% during pregnancy (17, 18). Adequate nutritional intake helps pregnant women to have suitable gestational weight gain (19), which is essential for good pregnancy and birth outcomes (20). Excessive weight gain could increase rates of macrosomic infants, caesarean section, PTB and pre-eclampsia (21, 22), whereas low weight gain increases the risk of LBW (22). Therefore, a balanced energy intake along with specific nutrients is essential for optimum weight gain and a greater likelihood of healthy pregnancy outcomes (23).

Dietary intake is a modifiable factor that may have an effect on maternal morbidity, including anaemia (24, 25) and HDPs (26, 27), and is one potential area to target during pregnancy. The whole diet (i.e., dietary patterns) may have a greater influence on the occurrence of health outcomes than single nutrients or food (28). The effect of the whole diet can be examined through a more inclusive method of dietary pattern analysis. Dietary pattern analysis evaluates the usual diet as one complete dietary exposure (29, 30), which assists in the design and implementation of appropriate prevention strategies. Results of research on dietary patterns are more likely to be translated into policy and public health applications, and dietary recommendations could be more achievable, understandable and easily adoptable by community members (31). However, dietary patterns can be affected by sociocultural, sociodemographic and economic factors, with dietary patterns varying across different populations (32-36). Hence, studies needs to be conducted in specific localities to understand the direct impact of localised dietary patterns and their effects on maternal health.

Worldwide, the findings of epidemiological studies have indicated that dietary patterns have an influence on maternal morbidity and birth outcomes (37-40). However, these findings are inconsistent and inconclusive, with most studies occurring in high-resource settings (37-41). In an Australian longitudinal study, a pre-pregnancy Mediterranean diet (including vegetables, nuts, tofu, pasta, legumes, rice, rye bread, red wine and fish) was associated with a reduced risk of HDPs (37). Similarly, research findings from Norway (42) showed that adherence to healthy dietary patterns resulted in lower odds of PTB. In contrast, a study in Holland found that low adherence to a Mediterranean diet (vegetables, legumes, pasta, fish and rice) (40) did not have an effect on gestational hypertension or pre-eclampsia. Likewise, a study from the United States (US) revealed that being large or small for gestational age, having a LBW or poor fetal growth were not associated with any maternal dietary patterns (39). Previous research has also shown that dietary patterns during pregnancy have an effect on anaemia (24, 25, 43). However, inconsistent results have been reported (44-46), highlighting the need for further well-designed observational studies in this area. The inconsistency in effect may be due to several factors, including geographical variations, variation in methods and population differences in terms of food habits and intakes. For example, the Australian study focused on a pre-pregnancy diet(37), while the other studies assessed dietary intake during pregnancy (40, 42); the US study (39) and other studies (44, 45) assessed dietary patterns using diet scores. Furthermore, not only are the study results inconsistent and inconclusive, but there is also a lack of well-designed studies on the effect of dietary patterns on maternal morbidity in resource-limited settings. Ethiopia is one of these resource-limited countries and has an unacceptably high burden of maternal morbidity, particularly from anaemia and HDPs. Hence, this thesis assesses the spatial distribution and determinants of anaemia among women in Ethiopia and the effect of dietary patterns on anaemia and HDPs in a resource-limited setting of Ethiopia. A brief background to Ethiopia is presented in the next sub-section.

1.2 Background on Ethiopia

This section briefly describes the study area, Ethiopia, in terms of location/ecology, governance, population composition, health policy and dietary intake.

1.2.1 Location/ecology, governance and population

Ethiopia is a sovereign country in East Africa, covering 1,104,300 square kilometres and is the second most populous country in Africa. The country is bordered in the north by Eritrea, the north-east by Djibouti, the east by Somalia, the west by Sudan and South Sudan, and the south by Kenya. According to the Central Statistical Agency of Ethiopia's population projection, as of 2019, Ethiopia has a population of 98,665,000 (49,500,000 males and 49,164,000 females) (47) with a total fertility rate of 4.6 (48).

Ethiopia has a federal government system with two city administrations (Addis Ababa and Dire Dawa) and nine regional states (Amhara, Afar, Benishangul-Gumuz, Gambella, Harari, Oromia, Somali, Tigray, and Southern Nations, Nationalities and Peoples' [SNNP]). The states are further subdivided into zones, *woreda*s and *kebele*s (49). In Ethiopia, there are more than 80 ethnic groups, with the majority of the population identifying their ethnicity as Oromo (37%) or Amhara (23%). Concerning religion, Christianity accounts for nearly 60% of the population, followed by Islam (35%); about half of the population are Orthodox Christians, one-third are Muslims and nearly 18% are Protestants. More than 80 languages are spoken, but the official language is Amharic. Ethiopia has its own calendar, which is nearly 7 years and 3 months behind the Gregorian one, and the new year starts on the 11th of September (49).

The country is home to a diversity of life and landscapes, containing large fertile lands, jungles, various indigenous plants and animals, and many lakes and rivers (50). Topographically, the highest peak (Ras Dashen) is 4550 m above sea level, and the lowest point (Danakil Depression) is 110 m below sea level and is where the hottest place (Dallol) is located (50). Ethiopia has a tropical monsoon climate, which is classified as *Kolla* (hot lowlands; < 1500 m above sea level), *Woina Dega* (moderate temperatures; 1500–2300 m above sea level) and *Dega* (cold temperatures; > 2300 m above sea level) (51). In Africa, Ethiopia has the highest number of UNESCO World Heritage Sites. Additionally, Ethiopia is a founding member of the United Nations and the African Union, formerly the Organization of African Unity. Addis Ababa is the capital city of the country as well as the headquarters of the African Union, the United Nations Economic Commission for Africa, the Pan African Chamber of Commerce and Industry, and other non-governmental organisations (52).

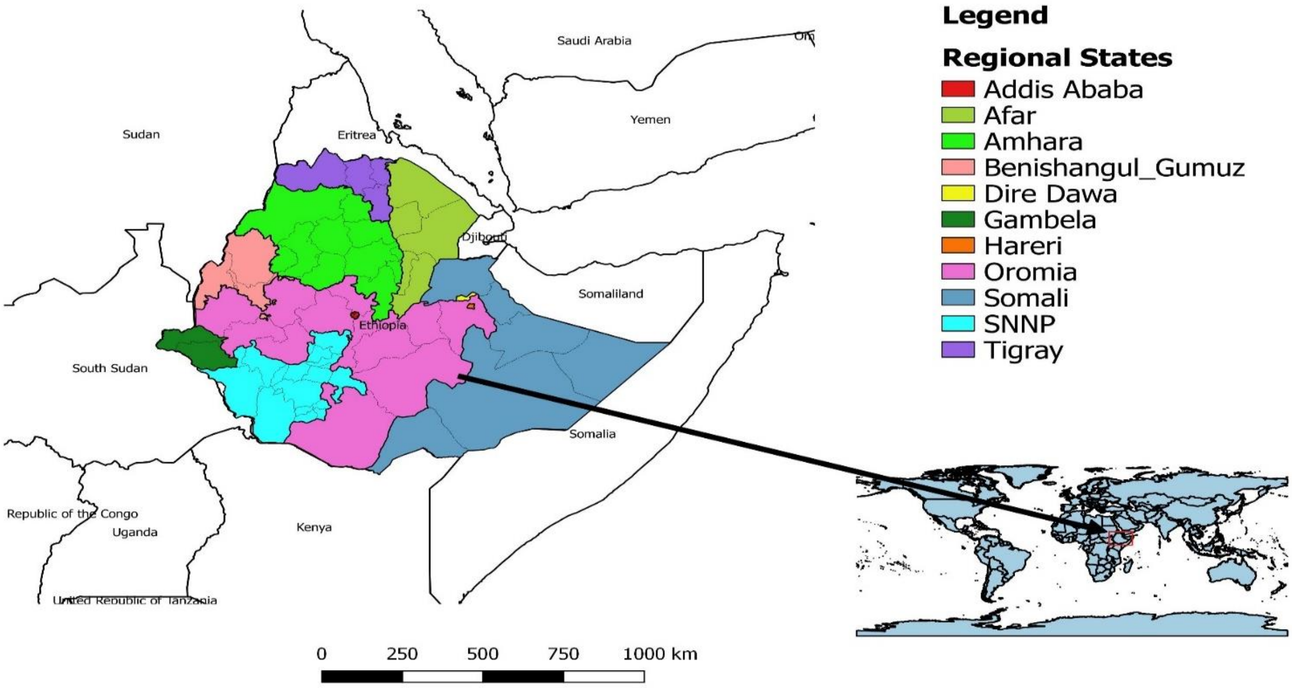


Figure 1-1 Map of Ethiopia (source: https://www.diva-gis.org/)

1.2.2 Healthcare system

The country's health policy focuses on promotive, preventive and curative health services. The healthcare system is organised into a three-tier system. Primary level health care comprises primary hospitals (one for every 60,000–100,000 people), health centres (one for every 15,000–25,000 people) and health posts (one for every 3000–5000 people). A secondary level of health care consists of a general hospital intended for every 1–1.5 million people, and tertiary level health care consists of specialised hospitals for every 3.5–5 million people (53). Communicable diseases account for the main health problems of the country and are responsible for the top 10 causes of morbidity and mortality (54). According to the most recent demographic health survey, conducted in 2016, the infant mortality rate and maternal mortality ratio are 48 per 1000 live births and 412 per 100,000 live births, respectively (48). In Ethiopia, the utilisation of maternal healthcare services is low, with 62% of women receiving antenatal care (ANC) from skilled providers at least once and only 32% of them having four or more ANC visits for their most recent live birth (48). Similarly, skilled providers attend 28% of births, 26% of births occur in health facilities and only 17% of women receive postnatal care within 2 days after birth (48). There are also differences in access and utilization of healthcare services between rural and urban areas (48). Anaemia is a common health problem for women and children; nearly a quarter of women of reproductive age (24%), 29% of pregnant women and more than half of children aged under five years (56%) suffer from some form of anaemia (48). HDPs are the third most common cause of maternal mortality in Ethiopia, being responsible for about 19% of maternal deaths (12).

1.2.3 Dietary intake

In Ethiopia, a variety of cereals, grains and legumes are harvested in different parts of the country. Due to differences in agroecological, sociocultural and socioeconomic status, there is considerable variation in dietary intake across the nation (55). Cereals/grains (eff, barley, maize, sorghum, oats, millet and wheat) constitute the major part of the diet; less than 10% of the population consume any food other than cereals/grains (55, 56). Fish, fruits and vegetables are consumed less frequently and inadequate micronutrient intakes have been observed in both females and males (57). Even though there are no national dietary guidelines in the country, Ethiopians usually eat three meals a day (breakfast, lunch and dinner) and snacks in between (58). Moreover, pregnant women have poor dietary practices: epidemiological studies have indicated that pregnant women do not eat diversified food, and some might even avoid some food types and/or others reduce their intake (59, 60). In the northern part of Ethiopia, 60% of pregnant women had poor dietary practices (i.e., did not consume vegetables, fruit, eggs), and 40% of them avoided certain foods during their pregnancy (58) due to physical discomfort, fear of having a big baby and food shortages (60).

1.3 Thesis structure/overview

This thesis is organised into nine chapters. The first chapter provides a brief introduction to the relationship between dietary intake and maternal morbidity (anaemia and HDPs) and an overview of the study area (Ethiopia). A detailed review of the literature on anaemia and HDPs is presented in Chapter 2, focusing on epidemiology, burden, effect/consequence, prevention strategies and possible determinant factors. Chapter 3 provides a detailed description of the methods used in each study presented in this thesis. The results of each study are presented in Chapters 4 to 8 as a series of published and submitted papers. Each result chapter is independent and includes a brief introduction, methods, results, discussion and conclusion. Chapter 4 is the first results chapter, assessing the effect of maternal dietary patterns on the risk of adverse pregnancy (HDPs and gestational diabetes mellitus [GDM]) and birth (PTB and LBW) outcomes through a systematic review and meta-analysis. Chapter 5 gives a detailed analysis of the geographical distribution of anaemia among women across the country using a recently conducted large population-based survey (the Ethiopian Demographic Health Survey [EDHS]) and spatial analysis. The chapter also identifies possible predictors of anaemia among women through a multilevel analysis, taking into consideration the hierarchical nature of the data. Chapter 6 provides population-attributable fraction (61) estimates for factors associated with different types of anaemia among women. Chapter 7 assesses the effect of dietary patterns on maternal anaemia in the low-resource setting of Ethiopia through a case-control study. Chapter 8 examines the effect of dietary patterns on HDPs in North Shewa, Ethiopia, using a case-control study design. Finally, Chapter 9 provides a brief discussion of the main findings of this thesis along with the strengths and limitations of this body of work. The thesis ends with conclusions and recommendations based on the main findings of the thesis.

Chapter 2: Literature review

The previous chapter provided a brief overview of the relationship between dietary intake and maternal morbidity, particularly anaemia and HDPs. Chapter 1 also gave an overview of the study area (Ethiopia). The following chapter highlights maternal anaemia, HDPs and dietary intake during pregnancy. Specifically, it addresses the burden, consequences, determinant factors and prevention mechanisms of anaemia and HDPs. It also provides an overview of dietary patterns, nutrient requirements and dietary intake and diversity during pregnancy.

2.1 Literature search strategy

The literature used throughout this thesis was sourced from several different databases. A broad search strategy was applied first in Google Scholar followed by PubMed/MEDLINE, Web of Science and Scopus databases to obtain articles on anaemia (using the key terms: anaemia/anaemia AND women/pregnant women/pregnancy), HDPs (key terms: hypertensive disorders of pregnancy/gestational hypertension/pregnancy-induced hypertension AND factors/determinants/risk factors/predictors/prevention strategy), and dietary intake/patterns/diversity and nutrient requirements. All searched literature was imported to and managed by EndNote version X8 (crandon.com.au/endnote). The literature search began in 2016 and was updated recurrently throughout the candidature. The literature was reviewed with a particular focus on the study area, Ethiopia, and provided evidence from other low- and middle-income countries (LMICs) to supplement necessary information.

2.2 Maternal anaemia

This section briefly describes the definition and burden of anaemia, possible determinants/predictors of anaemia, potential consequences of anaemia and strategies designed to prevent anaemia.

2.2.1 Definition and burden

Anaemia refers to a low blood haemoglobin (Hgb) level (< 11 g/dL and < 12 g/dL in pregnant and non-pregnant women at sea level, respectively) (62). If the Hgb level in the blood is low, the red blood cells are unable to carry adequate oxygen for the body's physiological needs (62). Women, particularly pregnant women, are at a higher risk of developing anaemia. This is due to the several bodily changes occurring during pregnancy, one of which is increased blood volume (by about 48%) (63), and the increment of red blood cell mass (by about 18%). A sufficient amount of iron, folate and B12 is required to make Hgb. Nevertheless, iron absorption is difficult, creating difficulties for producing Hgb, which can then lead to anaemia (63). Iron absorption can be inhibited by some chemicals like phytates, polyphenols and tannins which found in some food items such as tea and coffee such (64).

Anaemia is a major public health problem in pregnant women and children aged under 5 years (3). According to the World Health Organization (WHO) classification (62), anaemia is a moderate-severe public health problem (> 20%) among women and children under 5 years of age in the majority of WHO member states (3, 65). Globally, in 2011, 38% of pregnant women and 43% of children under 5 years of age were anaemic (3). The recent estimates from 2016 show that 33% of women are anaemic worldwide, and, notably, the occurrence is over 35% in Asia and Africa (2). It especially affects pregnant women, particularly in LMICs, where the highest prevalence rates are reported in Central and West Africa (56%), South Asia (52%) and East Africa (36%) (3). Similarly, a large proportion of non-pregnant women are reportedly anaemic in West and Central Africa (48%), South Asia (47%), and East Africa (28%) (3). A systematic review of 26 articles from low-income countries found that around 37% to 48% of pregnant women had experienced anaemia (4).

Anaemia is also a common problem in Ethiopia: the most recent EDHS (in 2016) reported a 29% prevalence of anaemia among pregnant women and a 24% prevalence among women of reproductive age, ranging from 16% to 59% in different parts of the country (48). Similarly, a number of small-scale studies from different parts of the country found various prevalence rates of anaemia among pregnant women, ranging from as low as 17% in the north (66), 32% in the south (25) and up to 44% (46) and 57% (67) in the east. This variation might be due to the occurrence of communicable diseases(54), differences in availability of healthcare facilities (68) and methodological or population variation.

2.2.2 Determinant factors of anaemia

Anaemia is a multifaceted disease and the role of various factors may differ from setting to setting (country to country or rural to urban areas). That is, the causes of anaemia are complex and setting-specific (69). The occurrence of anaemia can be affected by a wide variety of factors, such as biological or nutrient deficiencies, and socioeconomic, behavioural, contextual and environmental factors.

2.2.2.1 Biological factors

Biological factors such as nutrient deficiencies, menstruation and gravidity have a significant role in the occurrence of anaemia. Deficiency of different nutrients that are essential for the synthesis of Hgb and erythrocytes can lead to anaemia. Iron deficiency is the main nutritional cause of anaemia. However, deficiencies of other micronutrients (e.g., vitamins A, B6, B12 and folate) could also cause anaemia (70). Anaemia due to iron deficiency is thought to account for approximately 50% of all cases of anaemia among women globally (3, 65). The results of a large-scale population-based study conducted in Ethiopia indicated that folic acid and iron deficiencies constitute major nutrient deficiencies in Ethiopia and the odds of anaemia were higher in women who were also deficient in iron or folic acid (71). However, based upon the geographical location and disease situation in LMICs, about half of anaemia cases are attributable to diseases like parasitic infections, malaria and human immunodeficiency virus (HIV) infections (70). A recent systematic review of 25 surveys studies indicated that the proportion of anaemia due to iron deficiency was under 50% in LMICs, especially in rural populations, with some regional variation (72). This indicated that the prevalence of anaemia due to iron deficiency might be lower than previously thought in LMICs (72). This could be due to other causes of anaemia, such as vitamin B deficiencies and poor sanitary conditions that often occur with an increased occurrence of infections (72).

Deficiencies of B vitamins could also play a role in the occurrence of anaemia. Both vitamin B12 and folate deficiency could result in anaemia through its effect on erythrocyte production/synthesis (73). However, the evidence has indicated that B12 or folate deficiency might not necessarily relate to a high rate of anaemia among women when a vegetarian diet is taken into account (74). Vitamin C is important for the absorption of non-haem iron. A deficit of vitamin C can lead to haemolysis, through oxidative damage to erythrocytes, leading to blood loss (75). Iron absorption can be inhibited by some chemicals found in tea and coffee such as phytates, polyphenols and tannins (64).

Women's menstruation and fertility results in blood loss, which could also lead to anaemia. Menstruation increases iron losses, thus increasing the risk of anaemia in women throughout their reproductive years. Studies have documented an association between high menstrual blood loss and increased odds of anaemia among women of reproductive age (76, 77). Having a higher number of births has also been associated with increased odds of anaemia. Findings of studies from Ethiopia (77), Pakistan (78), Myanmar (79) and India (80) have shown that higher gravidity is associated with an increased odds of anaemia among women of reproductive age. Study results from Pakistan (78, 81), Timor-Leste (82) and Iran (83) have indicated that women with gravidity of four or more were at increased risk of anaemia compared to women with lower gravidity. Similarly, moderate-severe anaemia (Hgb value < 9.9 g/dl) was higher in women who had a greater number of births (84). This could be due to the fact that the more a woman gives birth, the more blood loss they experience, which in turn results in low Hgb levels in the blood (85). Similarly, prior births may deplete maternal iron stores due to the increased nutritional demands of pregnancy and puerperal blood loss (86).

2.2.2.2 Disease/infection factors

Different chronic or acute infections, such as parasitic or helminthic infections (hookworm and malaria) and HIV infections, can cause anaemia (77, 87-89). Helminthic infections, including hookworm, ascariasis and trichuriasis are associated with an increased risk of anaemia (90) due to their effect on blood (iron) loss (91). Hookworm infection has been documented as a risk factor for anaemia in women (89, 90). Particularly, in pregnant women, the intensity of hookworm infection negatively affects iron status (88). Other parasitic infections, such as malaria (88, 91) and schistosomiasis (70), can cause iron loss and lead to anaemia.

Anaemia is one of the main haematological anomalies in HIV-infected persons (92). HIV has an effect on anaemia both directly and indirectly. Its direct effect is by affecting haematopoietic progenitor cells and reducing responsiveness to erythropoietin (a hormone important for red blood cell production) (92, 93). Indirect effects of HIV infection on anaemia can be through opportunistic infections (e.g., malaria, hookworm) and nutritional problems (92). A cross-sectional study in Ethiopia revealed that patients with HIV who were infected with malaria and opportunistic infections were more likely to be anaemic (94). The prevalence of HIV in Ethiopia is estimated to be 0.9% in the general population and 1.2% among women of reproductive age (48).

2.2.2.3 Socioeconomic and environmental factors

A wide range of socioeconomic and environmental factors make certain groups of people more susceptible to anaemia. Such factors include low income, low educational status, unhealthy living conditions (poor dietary practices, tobacco smoking, unimproved water sources and unimproved latrine facilities) (70). Socioeconomic status is strongly related to anaemia and affects the occurrence of anaemia in different ways. Research has recognised low socioeconomic status as a predictor of a higher odds of anaemia among women (77, 80, 95). Poverty is a key predictor of poor health and is associated with poor living conditions (poor water, sanitation, hygiene and dietary habits, and limited access to animal-based foods and healthcare services), which can affect Hgb level. Studies conducted in developing countries like Pakistan (70), Benin (96) and India (97, 98) reported that the lowest wealth index, compared to the highest, was associated with a higher odds of anaemia among women. Similarly, a higher odds of moderate-severe anaemia cases was associated with the poorest wealth quantile (99, 100).

Another key socioeconomic risk factor related to anaemia is education. Lack of formal education or low educational attainment (primary education status or less) is associated with a high likelihood of anaemia occurrence. A review of studies of LMICs found that women who did not have formal education had higher odds of anaemia than those with a higher education (70). Studies conducted in developing countries (70), including Ethiopia (77), Timor-Leste (82), Benin (96) and India (76, 97), revealed that a low level of education was associated with higher odds of anaemia among women of reproductive age. Evidence has also shown that low educational status is associated with higher odds of moderate-severe anaemia among women (100, 101). Formal education might assist women in obtaining knowledge that in turn helps them to have better personal behaviours, like intake of diversified diet, better health-seeking habits (health literacy) and hygiene practices that can prevent anaemia (100).

Being of rural residence is also an important predictor for the occurrence of anaemia (102). The likelihood of anaemia is higher in rural residents compared to urban residents, particularly in resource-limited settings (70). Similarly, evidence has suggested that moderate-severe anaemia is more prevalent in individuals of rural residence (84, 103). Rural residents may have limited access to services (health care, water and sanitation), increased exposure to infectious agents, like soil-transmitted infections, and a less varied diet than urban inhabitants, all of which can increase the risk and likelihood of anaemia. Furthermore, research has revealed that women from households with unimproved latrine facilities were more likely to be anaemic than those with improved latrine facilities (96, 104). This might be due to the fact that unimproved latrine facilities can expose women to helminthic infections (105), which in turn may result in anaemia (106). Studies of low-income countries like Tanzania (100) and India (76) reported that unimproved latrine facilities were associated with higher odds of moderate-severe anaemia.

2.2.2.4 Dietary factors

Dietary intake is a factor that may influence the occurrence of anaemia (70). Dietary patterns may affect iron intake or bioavailability due to cultural or religious practices. For instance, the consumption of coffee or tea during meals affects the absorption of iron in a woman’s diet. Similarly, due to cultural beliefs, some food mixtures or domestic food distributions might affect iron consumption (107, 108). Besides, the intake of a diversified diet could be affected by socioeconomic conditions, and cross-sectional studies in Ethiopia have indicated that low dietary diversity was higher among women with no education and who were in the low wealth quantile (109, 110).

The effect of dietary patterns during pregnancy on anaemia has been reported in previous research (24, 25, 43, 111). Although some research findings did not show the association between a diversified dietary score and anaemia (44, 46, 112), a number of studies demonstrated an association between dietary pattern and anaemia. For instance, two community-based cross-sectional studies in the Southern part of Ethiopia have shown that pregnant women with a low dietary diversity score were more likely to have increased odds of anaemia (24, 25). Another cross-sectional study in Ethiopia (111) and a cross-sectional study from Ghana (43) showed that a low dietary diversity score was associated with higher odds of anaemia among pregnant women. However, other studies have reported inconsistent results (44, 46, 112). The cross-sectional studies from Ethiopia showed that dietary diversity did not relate to maternal anaemia (46, 112). Similarly, a cross-sectional study in Northern Ghana did not demonstrate the association between a diversified dietary score and anaemia (44). The inconsistencies in studies along with cross-sectional study design highlight the need for well-designed research in this area, whereby a better understanding of the effects of dietary patterns on maternal anaemia may help to tailor local strategies and dietary recommendations for the prevention of maternal anaemia.

In Ethiopia, in addition to disparities in prevalence rates, studies have different and inconsistent results when assessing factors associated with anaemia during pregnancy. For example, large family size, no education, rural residence, hookworm infestation and HIV infection were identified as factors contributing to anaemia in cross-sectional studies in Northern Ethiopia (66, 113), while cross-sectional studies from the eastern area reported that the chewing of khat (a stimulant leaf), restrictive dietary behaviours, multigravidas, third trimester of pregnancy and intestinal infestation were factors associated with anaemia during pregnancy (46, 114). A majority of these previous studies were cross-sectional and unable to allow for the determination of risk factors. Besides, some studies did not control for potentially confounding factors such as sanitation, water source and dietary intake (66, 113, 114); others lack representativeness (66, 114) as they were conducted in tertiary- or high-level health facilities/hospitals that are not accessible for the majority of women in Ethiopia. Furthermore, the impact of different determinant factors on maternal anaemia has not been evaluated. Use of the PAF approach could resolve some of these issues. We, therefore, performed this type of analysis to fill this gap in the literature as presented in Chapter 6.

PAF is an important tool for measuring the impact of factors in the population because it takes into consideration the relationship between potential risk factors and anaemia, and the prevalence of these factors in the population (115). PAF is useful for understanding the public health impact of factors in the population and can help in prioritising public health intervention strategies (116). The variation in rates of anaemia in Ethiopia could be due to diverse contextual and geographical variables. Some factors, like diet and communicable diseases, could result in environmental variances in the causes of anaemia (117). Malaria, nutritional iron deficiency and anaemia-causing soil-transmitted helminthic infections are related to ecological factors (e.g., temperature, rainfall and altitude) (118). Similarly, factors such as food insecurity, helminthic infections, clean water and sanitation are interconnected, contextual, differ in location and are linked with an increased risk of anaemia among women (69).

Nevertheless, no spatial analysis has, to date, been conducted to identify hotspot areas for maternal anaemia. Moreover, previous research has used traditional logistic models to identify determinant factors of anaemia in women, which may not address geographical clustering and factors at different levels (e.g., community and individual levels) (46, 66, 67, 114). Thus, assessing the geographic distributions of anaemia is important for the provision and application of practical prevention programs. Mapping the geographical distribution of anaemia can also be beneficial for the prevention and control of parasitic infections, including soil-transmitted helminthiasis, schistosomiasis and malaria. This is because the control programs of malaria and soil-transmitted helminthiasis have been evaluated using the burden of anaemia as a quantifiable indicator (119).

In this regard, the EDHS, which is a large-scale population-based study, can be used to assess geographical aggregation and the burden of maternal anaemia in Ethiopia via spatial analysis coupled with analysis of the determinant factors. Recognising specific regions or localities in Ethiopia is important for designing targeted prevention and control programs for maternal anaemia. In addition, it may help to correctly identify which factors (at the individual and community levels) are related to maternal anaemia. Thus, this thesis assesses the geographical patterns of anaemia among women by using spatial analysis and aims to identify the individual- and community-level factors through multilevel analysis using population-based national datasets (see Chapter 5).

2.2.3 Consequences of anaemia

2.2.3.1 Maternal morbidity

Anaemia has substantial effects on human health, socioeconomic status and progress. In 2019, anaemia was responsible for 58.6 million years of life lived with disability (range 40.14 - 81.1 million) (120). Evidence has linked anaemia with considerable maternal morbidity and poor birth outcomes (PTB and LBW) (4, 121). The WHO multi-country study (29 countries in Africa, Asia, Latin America and the Middle East) revealed that anaemia accounted for nearly half of the indirect causes of maternal mortality and severe morbidity worldwide (7). In a recent facility-based cross-sectional study in Ethiopia, anaemia was reported as a major contributing cause of maternal near-miss cases (40%)(10). Two multicounty studies in three regions (Africa, Latin America and Asia) have also reported that a low Hgb level was related to a higher risk of HDPs, especially pre-eclampsia (6, 122). Another retrospective cohort study from Turkey showed that a low Hgb level increases the risk of pre-eclampsia/eclampsia (123). A cohort study in Iran (124) and a case-control study in Sudan indicated that a low Hgb level increased the risk of pre-eclampsia (125). A cohort study in Poland indicated that women with low serum iron had a twofold increase in pregnancy-induced hypertension risk compared to women with high serum iron (126). On the other hand, study findings from Iran (127) and Pakistan (128) have reported that a higher Hgb concentration during gestation increased the odds of gestational hypertension. A cohort study in the Netherlands showed that an elevated Hgb level was associated with increased systolic blood pressure (SBP) and diastolic blood pressure (DBP) during pregnancy (129).

Evidence have also revealed that a higher risk of postnatal depression among women who were anaemic during pregnancy (130, 131). In a cross-sectional study in Turkey, a higher depression score was observed among anaemic women, compared to non-anaemic women, in the third trimester (132). Similarly, a cohort study in Iran revealed that the odds of postpartum depression was four times higher in pregnancies with a Hgb level < 11 g/dL at delivery (133). Furthermore, anaemia has an adverse effect on women's physical capabilities due to low oxygen supply to tissues and a disturbance of tissues' oxidative ability, which results in decreases in work productivity and performance (134) and leads to a decrease in household income and food security (70).

2.2.3.2 Poor birth outcomes

Studies have also shown that anaemia increases the risk of adverse birth outcomes, including LBW and PTB (8, 9). A systematic review of studies of LMICs revealed higher odds of LBW, PTB, perinatal mortality and neonatal mortality among anaemic women (4). A meta-analysis of clinical trials of both high- and low-income countries (135), a cohort study in Israel (8) and two studies from China (9, 136) have also shown that maternal anaemia is associated with a higher risk of PTB and LBW. In a recent systematic review, anaemia in the first trimester was found to increase the odds of LBW by 26% despite no association being found in the second and third trimesters (137). Anaemia may also increase the risk of perinatal mortality; however, these findings have been inconsistent and inconclusive (138, 139).

In brief, research has consistently demonstrated that maternal morbidity and poor birth outcomes (PTB and LBW) is linked with anaemia, but the evidence has been inconclusive on the effect of anaemia on prenatal mortality.

2.2.4 Prevention of anaemia

In various countries across the globe, several strategies are in place for the prevention of anaemia, including food fortification and diversification, bio-fortification, iron or other micronutrient supplementations, recommendations regarding the spacing of pregnancies, infectious disease control and parasitic disease control (70, 140). The WHO has recommended universal iron/folate supplementation and the treatment of women with anaemia during pregnancy with elemental iron (141). However, the coverage of supplements is low in developing countries, including Ethiopia (142, 143). A low rate of supplement compliance has also been reported in resource-limited settings (144-146). Studies have shown that a low proportion of pregnant women are compliant with recommended iron/folate supplementation in Ethiopia (38%–55%) (146-148), Kenya (33%) (149) and Saudi Arabia (50%) (150). A universal iron/folate supplementation approach can overlook other untreated diseases in resource-limited settings where anaemia is prevalent. Conversely, iron supplementation may have harmful effects, such as the risk of hypertension (151), and side effects, including diarrhoea, constipation, gastric irritation, nausea and vomiting (144, 145), with only 50% of anaemic women responsive to iron supplementation (3). Moreover, a recent systematic review of 27 trials from 21 countries showed that intermittent iron supplementation did not prevent anaemia among pregnant women (152). Similarly, another review of trials indicated that the provision of folic acid only, or with other micronutrients (153), and the provision of multiple micronutrients plus iron and folic acid (154) during gestation failed to improve maternal anaemia. A study from Ethiopia showed that iron/folate supplementation and compliance is low, with only 3.5% of pregnant women supplementing for the recommended 91 days (143). This puts the practicality of iron/folate supplementation into question and thus anaemia continues to be an issue worldwide.

2.3 HDPs

Both anaemia (6, 122) and the strategies that might prevent anaemia (e.g., dietary intake) (26, 27, 155) have been implicated as risk factors for hypertension during pregnancy. HDPs are a key health problem among pregnant women and are ranked in the top five major causes of maternal death in the world (5). HDPs are subject to many of the same risk factors as anaemia, including diet (26, 27, 155, 156) and low educational status (122, 157). This section presents the definition, burden and potential consequences of HDPs. It also briefly presents possible determinants/predictors of HDPs and available strategies for preventing HDPs.

2.3.1 Definition and burden of HDPs

HDPs include gestational hypertension, pre-eclampsia/eclampsia chronic hypertension, and pre-eclampsia superimposed on chronic hypertension (158). Gestational hypertension refers to the presence of two raised blood pressure (≥ 140/90 mmHg) readings, 4 hours apart, after 20 weeks gestation in women previously normotensive (159). Pre-eclampsia refers to a blood pressure ≥ 140/90 mmHg with ≥ +1 proteinuria on dipstick readings in women previously normotensive (159). Eclampsia includes pre-eclampsia plus a new event of seizure or convulsion (159). Chronic (pre-existing) hypertension refers to a blood pressure of ≥ 140/90 mmHg preceding pregnancy or before the 20th week of gestation and up to 12 weeks after birth. Pre-eclampsia superimposed on chronic hypertension is chronic hypertension with new or worsening proteinuria (158, 159).

According to a WHO multicountry survey, the incidence of pre-eclampsia and eclampsia varies within and across different regions; the highest pre-eclampsia in the US (4%), closely followed by Africa (2%). Pre-eclampsia incidence also differs according to a country’s income level: low (1%), lower-middle (2%), upper-middle (3%) and high income (3%) (122). Similarly, observational studies in Ethiopia reported that HDPs ranged from 4% (160) to 8.5% (161), of which the majority of cases were a result of severe pre-eclampsia (52%) (161) and eclampsia (8.4%) (162).

2.3.2 Predictors of HDPs

HDPs, caused by multiple risk factors (both modifiable and non-modifiable), are one of the most serious health problems for pregnant women (163); however, their exact causes are not known (164). Non-modifiable factors, such as being over 35 years of age (122, 165, 166), primiparity (122, 165-167), having had multiple pregnancies (122, 165, 166, 168), having a family history of hypertension (169-171), previously having pre-eclampsia or hypertension during pregnancy (157, 170, 172), having gestational diabetes (165, 167, 173, 174) and having pre-existing diabetes (171, 175), are associated with a higher odds of having HDPs.

Evidence has shown that modifiable risk factors, such as a body mass index (BMI) of 25 kg/m^2 or more (175, 176), low education attainment (122, 157), poor diet, anaemia and a high number of previous births (6, 122) are risk factors of HDPs. Additionally, epidemiological studies (167, 174) and systematic reviews (177-179) have revealed an inverse association between cigarette smoking and pre-eclampsia, although other studies have reported no such association (172, 180). Several studies have also reported that dietary intake during pregnancy plays an important role in the occurrence of HDPs (26, 27, 155). However, the findings remain varied and further research is necessary to clarify the effects of dietary intake on the occurrence of HDPs, particularly in resource-limited settings, including Ethiopia (37).

2.3.3 Consequences of HDPs

Hypertensive disorders can complicate pregnancy and are responsible for a significant proportion of maternal and neonatal deaths (6). HDPs complicate nearly 10% of pregnancies and cause an estimated 30,000 maternal deaths annually, with most deaths occurring in less-developed countries (11). According to a WHO systematic review published in 2014, hypertensive disorders were responsible for about 14% (11%–17%) of direct maternal deaths in the world between 2003 and 2009, second only to haemorrhages (27%) (5). In sub-Saharan and Northern Africa, hypertensive disorders accountable for nearly 16% and 17% of maternal deaths, respectively, whereas the figure was around 22% in Latin America and the Caribbean (5). A cohort study in Uganda reported that about 780 per 100,000 live births of maternal mortality were due to HDPs (181). HDPs also increase the risk of stillbirth (182-184), neonatal mortality (184, 185), LBW (6, 185) and caesarean delivery (185).

Recent research in Ethiopia has shown that HDPs were responsible for a significant proportion (19%) of maternal deaths and were the third most common cause of maternal mortality after haemorrhages (22%) and obstructed labour/uterine ruptures (36%) (12). Likewise, a recent facility-based cross-sectional study in Addis Ababa reported that hypertensive disorders were the main underlying cause for maternal near-miss cases (severe maternal morbidity; 53%) (10). Unfortunately, maternal deaths due to HDPs have shown to be an increasing trend (12, 186) from 4%–6% in 1980–1999 to 11%–29% in 2007–2012 (12).

2.3.4 Prevention of HDPs

Prevention strategies emphasise personal behaviour modification, nutritional supplementation and pharmacological therapy (187, 188). The WHO has recommended calcium supplementation and low-dose aspirin during pregnancy for the prevention of pre-eclampsia in women at high risk of developing the condition (189). The findings of studies have indicated that the prevention methods for pre-eclampsia/eclampsia have not been satisfactory, although aspirin and calcium might have an effect in some sub-populations (190), such as people who have low dietary calcium intake and those at higher risk of pre-eclampsia/eclampsia (191, 192). A meta-analysis of 10 trials revealed that supplementation of calcium during gestation resulted in a 59% reduction of pre-eclampsia and a 45% reduction of gestational hypertension in women in developing countries (193). Similarly, two meta-analyses of clinical trials revealed that supplementation of calcium during gestation reduced the odds of having pre-eclampsia (194, 195). Furthermore, a systematic review of clinical trials (196) and a meta-analysis of 31 clinical trials (197) showed that aspirin reduced pre-eclampsia and its complications.

In contrast, a large multicentre study by the WHO revealed that a 1.5 g/day calcium supplementation for women with low dietary calcium intake did not prevent gestational hypertension or pre-eclampsia, even though it reduced the severity of pre-eclampsia (198). Similarly, a prospective cohort study on primigravid women in China reported that low-dose calcium supplementation did not reduce the incidence of pregnancy-induced hypertension in high-risk women (199). The standard treatment guideline in Ethiopia recommends a low-dose of aspirin for high-risk women to prevent HDPs (200).

2.4 Dietary requirements and dietary intake during pregnancy

Dietary intake is one important factor that may have an effect on the occurrence of anaemia (24, 25) and HDPs (26, 27) and is one potential area to target during pregnancy. In this section, a detailed description of nutrient requirements, including macro and micronutrients during pregnancy, is presented. Besides, this section presents evidence on actual dietary intake during pregnancy, particularly in resource-limited settings.

2.4.1 Dietary requirements during pregnancy

During pregnancy, the requirements of most macro and micronutrients increase due to maternal tissue deposition and fetus growth, particularly during the third trimester (16).

2.4.1.1 Requirements of energy and macronutrients

Energy requirements rise throughout gestation due to the increase in tissue mass (201). During pregnancy, additional energy is necessary to build and maintain active tissues of the fetus, placenta, mother, and in response to the high metabolic burden of gestation. Basal metabolism increases in response to various changes, such as increasing circulatory, pulmonary and renal functions (202). The Food and Agriculture Organization of the United Nations (203) and the WHO have developed recommendations for energy intake during pregnancy. According to these recommendations, pregnant women should increase their energy intake by 85, 285 and 475 kcal per day in the first, second and third trimesters, respectively (202). The US Institute of Medicine has recommended that pregnant women (in the US) add 340 and 452 kcal per day in the second and third trimesters, respectively, with no additional calories needed for the first trimester (204). The Royal College of Obstetricians and Gynaecologists (RCOG), in the UK, has recommended increasing calorie intake by around 10% (200 kcal/day) in the third trimester relative to the recommended intake for a non-pregnant woman (205). The discrepancy between these recommendations is due to their target population differences: the FAO and WHO recommendations (202) target a global population, the Institute of Medicine recommendations (204) were established for US and Canadian populations, and the RCOG's recommendations are for the UK (205). This is due to the need for country-specific dietary recommendations.

In a typical diet, the main source of energy is macronutrients (carbohydrates, fat, protein), which can be utilised interchangeably (202). Carbohydrates, the body's main source of energy, contribute to about 35%–70% of the total energy intake, fat contributes 20%–45% and protein constitutes a smaller energy intake (206). Plant-derived foods, including whole grains, starchy vegetables (e.g., potatoes, yams, green peas and corn), fruits, legumes/pulses (e.g., beans, lentils, peas) and low-fat dairy products, provide greater amounts of carbohydrates (18).

Protein is considered to be the main structural and functional element of human body cells. Protein is important for enzymes, membrane carriers, blood transport molecules, vitamins, serum albumin, collagen and many hormones (206). Protein is the building block of maternal and fetal tissues and an alternative source of energy if carbohydrate consumption is inadequate. Due to maternal and fetal tissue development in the second and third trimesters, protein requirements are increased in these periods (207). The requirement of protein during pregnancy is approximately 71 g/day, starting in the second trimester, which is approximately 25 g more than what is recommended for non-pregnant women (208). Legumes/pulses (e.g., lentils, beans, nuts), seeds, meat, poultry, seafood, eggs and dairy products are the main sources of protein, and pregnant women should eat a range of these foods to fulfil their protein requirements (207, 209).

Likewise, fats are basic sources of energy and provide essential fatty acids that cannot be produced in the body. Dietary fats facilitate the absorption of some vitamins (A, D, E and K) (209) and the metabolism of carbohydrates (206). It is advised that the dietary intake of fat be between 20% and 35% of total calorie intake, even if the recommended amount of fat intake has not been determined. Intake of omega-3 (*n*-3) and omega-6 (*n*-6) polyunsaturated fatty acids should be increased, but saturated and trans-fatty acid and intake need to be limited (18). Both animal and plant products are sources of dietary fat. Animal fats contain abundant saturated fatty acids, whereas plant fats have a high content of unsaturated fatty acid. Saturated and trans fatty acids and lead to high concentrations of low-density lipoprotein cholesterol, which increases the risk of cardiovascular disease (18).

Water is a vital nutrient for the body, and around 60% (45%–75%) of body mass is composed of water. Adequate intake of water is required for pregnant women to be hydrated. Additional water intake of 300 mL/day above an intake adequate for non-pregnant women is needed for pregnant women, which equates to approximately 3 L/day (206, 210). Some of the water needs of pregnant women can be met through the consumption of juice, milk and high moisture foods including fruits, vegetables and meat. For pregnant women, around 19%–25% of total water intake can be gained from food moisture (206).

2.4.1.2 Micronutrient requirements

Micronutrients are an important element of nutrition and comprise vitamins and minerals (211). These nutrients are essential for pregnant women and the fetus despite only being required in small amounts. Micronutrients enable the body to synthesise enzymes, hormones and other substances essential for growth and development (212).

Micronutrient requirements increase throughout gestation because of the higher metabolic needs of the mother and the growth of the placenta and fetus. The concentration of nutrient carrier proteins also decreases (213). The requirement for some nutrients, such as thiamine, niacin, zinc, vitamin B6, iodine, iron, folate and protein, and energy, increases by 27% to 54%.

However, the need for other micronutrients, for example, some vitamins (D, E, K), fluoride, calcium and phosphorus remains unchanged (17, 18).

The deficiency of some micronutrients, like iodine, vitamin A and iron, is a global public health issue, especially for pregnant women and children in LMICs (212). In LMICs, the mean/median intake of micronutrients except for vitamin A, vitamin C and niacin—among women is below estimated average requirements (214).

2.4.2 Dietary intake and diversity during pregnancy

During pregnancy, women are recommended to have additional types and amounts of food compared to non-pregnant women (14). The WHO recommends pregnant women have a balanced diet with adequate energy, protein, vitamins and minerals. This balanced diet could be achieved through the consumption of diversified foods, such as vegetables, fruits, meat, fish, beans, nuts and whole grains (215). However, many women in both developing and developed countries do not consume enough nutrients (both macro and micro) in their diet during pregnancy (216). Food consumption practices vary across different populations and is affected by food availability and sociocultural, sociodemographic and economic factors (32, 33). Many pregnant women in developing countries are unable to eat a diversified diet, and some might avoid specific types of food or reduce their food intake (216). In contrast, women living in developed countries have been known to consume foods that are low in micronutrients, like soft drinks, and fast and convenience foods (216). Moreover, unbalanced macronutrient intake, inadequate micronutrient intake and greater consumption of plant-based foods are the features of pregnant women's diets in LMICs (217). Likewise, energy and macronutrient intake by women in some parts of Africa and Asia are lower than that of women in Latin American countries (217).

In Ethiopia, food intake is diverse, and there is no single dominant grain at the national level (56). Various types of grains such as teff, wheat, barley, sorghum, maize and enset ('false banana')— are commonly consumed in different parts of the country (56). Due to the variation in agroecological, sociocultural and socioeconomic conditions, the use of these grains and staples differs broadly across the nation (56). There is also a considerable difference in macronutrient intake across regions (55). The typical Ethiopian food source is high in complex carbohydrates and low in fat, protein and micronutrients (218). In Ethiopia, calorie intake is low and cereals typically constitute a substantial portion of this intake (56). Cereals/grains constitute a major part of the diet: less than 10% of the population consume any food other than cereals/grains (55). Fish, fruits and vegetables are consumed less frequently, and inadequate micronutrient intakes have been observed in both females and males (57).

Epidemiological studies have shown that pregnant women in Ethiopia do not eat a diversified diet; some avoid certain foods and others reduce their intake because of physical discomfort, food shortage and personal dislikes (59, 60). Formative research conducted in Ethiopia identified that most pregnant women did not change the quantity of food eaten, and some even reduced their food intake due to fear of having a big baby (219). Another study in Southern Ethiopia revealed that the majority of pregnant women were deficient in energy, protein, calcium, folate and niacin (59). The study also reported that more than two-thirds of women did not increase their food intake during pregnancy, and approximately 48% reported reducing their dietary intake due to physical discomfort, fear of having a big baby and food shortage (59). Another study in this area showed that more than 75% of pregnant women did not eat an additional meal, and 69% of them skipped one or more of their regular meals during pregnancy due to the aforementioned reasons (60). In the northern part of Ethiopia, 60% of pregnant women had poor dietary practices (i.e., did not consume vegetables, fruits, eggs), and 40% of them avoided certain foods during pregnancy due to cultural reasons, fear of having a big baby and fear of a difficult delivery (58). A lack of nutrition information and a lack of dietary knowledge were reported as factors for poor dietary practices (58).

2.4.3 Dietary patterns

The analysis of dietary patterns is another approach to examining the impact of diet on health. Dietary patterns refer to the amounts, proportions, types or mixtures of various foods/meals and drinks in a person's diet and the number or frequency of which this food is regularly consumed (220). Dietary pattern analysis is used to assess the usual foods consumed as one overall dietary exposure (29, 221); it is difficult to isolate the influence of individual foods or nutrients, as they have been consumed as a mixture and combined with other foodstuffs (28). When individuals consume food, they consume a combination of nutrients, not single nutrients (28). The whole diet (dietary patterns), with its expected synergistic effects, may have a greater influence on the occurrence of health outcomes than single nutrients or foods (28). Thus, the dietary pattern approach, which measures overall diet consumption, has been applied to elucidate the relationship between diet and adverse health outcomes (221). It appears more complete to examine the effect of the whole diet by applying an all-inclusive method of dietary pattern analysis (29, 30). Having information on the effects of complete dietary exposure helps in the design and implementation of appropriate prevention strategies. Research findings on dietary patterns are more likely to be translated into policy applications and public health practices (guidelines and recommendations), which are more achievable, understandable and easier to adopt by community members (31).

Dietary patterns may be affected by sociocultural, sociodemographic and economic factors, and thus, patterns can vary across different populations, which means context-specific research is required (32, 33). In the UK, pregnant women who have a higher educational status, are older and non-white tended to consume a 'health-conscious' diet (e.g., fruit, salad, rice, cereals, pulses, fruit, pasta, fish, eggs and meat), whereas women who smoked, had increased parity, were single and not working were less likely to eat a 'health-conscious' diet (35). A cross-sectional study in Brazil reported that women's socioeconomic factors like age, income and educational status affected their dietary practices (36). In Ethiopia, women who had a good living status, including having an improved water source and a latrine facility, lived in an urban area and had a bank account and mobile phone were more likely to have a diversified diet (34). This further reinforces the need for studies to be conducted in specific localities to understand dietary patterns and their effects on maternal health. Investigating current dietary patterns—that is, what food individuals consume their and associations with health outcomes—is essential from a public health perspective.

There are two different methods for determining dietary patterns based on dietary intake. The first is an a priori approach, which constructs dietary indices, or scores, according to predefined recommendations or current knowledge (29, 221, 222). The second is an a posteriori approach, which identifies data-driven dietary patterns using statistical methods (e.g., principal component analysis [PCA], cluster analysis and reduced rank regression) (29, 221, 222).

Dietary diversity score (DDS) is a priori–determined dietary index that is used to measure a population's adherence to dietary guidelines or references and to evaluate the implications of dietary advice on diseases (223). Dietary diversity refers to the number of various food groups or items eaten over a certain time. It measures food consumption patterns and reflects the food availability/accessibility of households or the quality of an individual's diet (224). It can be measured using food groups: most often, 8–12 food groups are considered. As an indicator of a healthy diet, dietary diversity may comprise a minimum of the following food groups: energy (e.g., cereals, tubers, roots), protein (e.g., pulses, solid foods of animal origin), minerals (e.g., pulses, other legumes, vegetables, solid foods of animal origin, milk) and vitamins (e.g., vegetables, green vegetables, fruits, solid food of animal origin) (224).

A guideline has been developed by the FAO to measure an individual's and household's dietary diversity through a standardised questionnaire, which is a quick, easily administered and low-cost assessment tool (224). These dietary diversity indicators are recognised to reflect micronutrient adequacy for mothers (225) and infants (226). These indicators have also been related to average household nutrient adequacy (226). More significantly, it is effective for studying nutritional quality at the population level (227). Moreover, the evidence has shown that DDS is a good indicator of food access at a household level (228), of micronutrient adequacy of women's diets (225, 229) and nutritional status (230, 231). Researchers have also reported a relationship between dietary diversity and maternal health in resource-limited settings, though the findings are inconsistent. For instance, a cross-sectional study in Tanzania (156) reported that, compared to a lower DDS, a high or medium DDS was associated with increased odds of gestational hypertension. In a cross-sectional study in Northern Ghana, DDS was not associated with anaemia among pregnant women (44). Similarly, another small-scale cross-sectional study also reported that a good DDS does not have a relationship with Hgb levels (45). This indicates that further research is needed clarify the effect of DDS on maternal morbidity in resource-limited settings. Therefore, in this thesis, DDS was used to assess maternal dietary intakes and their association with maternal morbidity (anaemia and HDPs).

2.5 Gap analysis and significance

Anaemia (3) and HDPs (5) are significant health problems, mainly in LMICs, that dietary patterns can influence, although research to date is inconclusive. Epidemiological studies have indicated that dietary patterns have an effect on maternal morbidity and birth outcomes (37-40), including anaemia (24, 25, 43, 46, 98, 232) and HDPs (233, 234). However, the findings are inconsistent concerning the effect of dietary patterns on anaemia. Some have shown that dietary patterns during pregnancy affect anaemia (24, 25, 43, 111), but others have not shown this association (44, 46, 112). Similarly, epidemiological studies have shown that dietary intake during pregnancy plays an important role in the occurrence of HDPs (26, 27, 155, 156), though the findings remain varied and inconclusive. This could be because dietary intake can be influenced by sociocultural, sociodemographic and economic factors, or because dietary patterns vary across different populations (32-35). This reinforces the need for studies in specific localities to understand the direct impact of localised dietary patterns and their effects on maternal health.

Furthermore, there is not yet enough research on the effect of dietary patterns on anaemia and HDPs in resource-limited settings specifically (particularly in Ethiopia). Thus, there is a need to identify which dietary patterns could have health benefits for pregnant women through prevention of morbidity and adverse pregnancy outcomes in these settings. A better understanding of the effects of dietary patterns on maternal morbidity may help to tailor local strategies and dietary recommendations for the prevention and control of maternal health problems, especially anaemia and HDPs. Thus, this thesis assesses the effect of dietary patterns on anaemia and HDPs in the resource-limited setting of Ethiopia.

In Ethiopia, varied prevalence rates of anaemia among women have been observed with different factors across different parts of the country (66, 67). The variation in rates of anaemia in Ethiopia could be due to the presence of diverse contextual and geographically variables, including diet and the incidence of communicable diseases (117). Even though anaemia is impacted by a range of social and geographical issues, there are not enough studies conducted using spatial analysis to identify hotspot areas of maternal anaemia. Previous studies have applied the traditional logistic models to assess the predictors of anaemia (46, 66, 67, 114), which might not correctly address geographical clustering and factors at different community and individual levels. In addition, the impact of these factors on anaemia has not been assessed through impact measures, like PAF, at the population level. PAF is an important tool for determining the impact of different factors on the occurrence of anaemia in the population (115).

Assessing the geographical distributions of anaemia and the impact of risk factors on disease prevalence and progression is important for prioritising and designing targeted prevention and control programs for maternal anaemia (116). Mapping the geographical distribution of anaemia can also be beneficial for the prevention and control of parasitic infections like soil-transmitted helminthiasis, schistosomiasis and malaria. This is because the control programs for soil-transmitted helminthiasis and malaria have been evaluated using the burden of anaemia as a quantifiable indicator (119).

The WHO has set a global target of a 50% reduction of anaemia prevalence among women of reproductive age between 2012 and 2025 (235). The latest global estimates indicate that no county is on track to achieve this reduction (236). According to these estimates, Ethiopia did not show any reduction in the prevalence of anaemia among women between 2012 and 2016 (236). There is a need to explore the country-specific determinants of anaemia in women of reproductive age (237) to achieve the WHO goal of a 50% reduction of anaemia by 2025. A more thorough assessment of anaemia in particular settings is necessary to successfully address anaemia at the national or regional levels. Each location will need to identify the most important determinant factors and choose the best prevention methods accordingly. Thus, this thesis intends to identify contextual and individual predictors of anaemia among women in Ethiopia and provide evidence for the proper action and setting of local intervention programs. In this thesis, various methods are used: systematic reviews of literature, in-depth analysis of large-scale population-based datasets and a case–control study using primary data.

2.6 Aims of the thesis

The general aim of the thesis was to assess the effect of dietary patterns on maternal morbidity (anaemia and HDPs) in the resource-limited setting of Ethiopia. Specific aims were:

Aim 1: To assess the effect of dietary patterns on adverse pregnancy (HDPs and GDM) and birth (PTB and LBW) outcomes at a global level (Chapter 4)

Aim 2: To assess the spatial distribution and determinant factors of anaemia among women in Ethiopia (Chapters 5 & 6)

> *Objective 1*: To assess the spatial distribution of anaemia among women in Ethiopia
>
> *Objective 2*: To identify the determinant factors of anaemia among women in Ethiopia
>
> *Objective 3:* To estimate the PAF for factors associated with different types of anaemia among women in Ethiopia.

Aim 3: To assess the effect of dietary patterns on the risk of maternal anaemia and HDPs in the low-resource setting of Ethiopia (Chapters 7 & 8)

> *Objective 1*: To determine the effects of dietary patterns on maternal anaemia in North Shewa, Ethiopia
>
> *Objective 2*: To assess the effect of dietary patterns on HDPs in North Shewa, Ethiopia.

Chapter 3: Research methods

In this chapter, a detailed description of the methods used in this thesis is presented in three sections. The first section starts with a description of the methods used in Chapter 4 to meet Aim 1 (a systematic review and meta-analysis). The second section describes the methods used in Chapters 5 and 6 to address Aim 2 (spatial and multilevel analysis). Finally, the third section describes the methods used in Chapters 7 and 8 to address Aim 3 (case-control studies). The methods described for each section include the study design, study population, sampling method and size determination, data collection procedures, analytical methods and ethical considerations.

3.1 Systematic review and meta-analysis

A systematic review with meta-analysis was conducted to assess the effects of dietary patterns on adverse pregnancy (HDPs and GDM) and birth (PTB and LBW) outcomes using global evidence (Chapter 4). The primary research aim was to assess the effect of dietary patterns on pregnancy outcomes. A detailed description of this systematic review method is presented below.

3.1.1 Search strategy

Seven databases were searched, including MEDLINE, Embase, CINAHL (Cumulative Index to Nursing and Allied Health Literature), Scopus, the Cochrane Library, Web of Science, and Maternity and Infant Care. The reference lists of relevant articles were then individually searched.

The following query was used to search the databases:

> diet OR nutrition OR “food pattern” OR “meal pattern” OR “eating practice” OR “food intake” OR “food habits” OR “eating behaviour” OR “dietary pattern” OR “dietary diversity score” AND “pregnancy” OR “pregnant women” OR “gravid” OR “gestation” OR “prenatal care” OR “antenatal care” AND “gestational hypertension” OR “pregnancy-induced hypertension” OR “preeclampsia” OR “pre-eclampsia” OR “LBW” OR “premature infant” OR “premature birth” OR “PTB” OR “pregnancy in diabetics” OR “gestational diabetes mellitus”.

The search comprised a free-text word search; a search for terms in the title and Medical Subject Headings for outcomes, exposure and participants; limited to English language and human subjects.

3.1.2 Study selection and data extraction

3.1.2.1 Study selection

The studies were screened by title and abstract by two reviewers. The full texts of all selected studies were critically reviewed based on the following inclusion criteria: pregnant women, original articles (randomised trials and observational studies (case-control, cohort and cross-sectional studies)) and dietary pattern as the exposure variable. There were no date restrictions, and they also needed to include one or more of the following outcome variables: HDPs, GDM, LBW and PTB. Animal studies, qualitative studies, brief communications, case series, editorials, review studies and studies focusing on single nutrients were excluded.

3.1.2.2 Data extraction

The following variables were extracted: authors, publication year, study period, study design, settings/country, population sample, dietary pattern with food details, dietary assessment methods and periods, main outcomes (HDPs, GDM, LBW and PTB) and adjustment for confounders. Theses variables were extracted by two independent reviewers and disagreement was solved through discussion.

3.1.3 Quality assessments

The quality of the selected full-text articles was assessed by two reviewers independently using the Academy of Nutrition and Dietetics' quality appraisal tool (238). This tool has four relevance questions and 10 validity questions. The validity questions appraise the selection, comparability of groups, assessment of exposures or outcomes, and the statistical analysis for each study separately (238). The validity of a study is only assessed if the responses to all four relevance questions were 'Yes'. The response for validity questions was 'Yes' if the criterion was fulfilled, 'No' if not fulfilled, 'Unclear' if not precisely stated and 'N/A' (not applicable) if the criterion did not apply to the article (238). The rating scores of studies were positive (+) if the responses to the validity questions were 'Yes' for six or more responses (including all four relevance questions). If an article did not fulfil the relevance criterion of selection, comparability of groups, or measurement of exposures or outcomes, then the rating score was neutral (ϕ). If the responses for the validity questions were ' No' or 'Unclear' for six or more responses, then a negative (–) rating score was given (238).

3.1.4 Statistical analysis

The data were entered into a spreadsheet in Microsoft Excel (version 16) and exported to Stata (version 13) for analysis. The odds ratio (*OR*) was used as a measure of the effect estimate. If an incidence of the outcome variable was less than or equal to 20%, the risk ratio (*RR*) and odds ratio were pooled together in the meta-analysis; otherwise, the risk ratio was converted to an odds ratio using the proposed methods of Zhang and Yu (239) and Cochrane (240). If the studies did not report odds/risk ratios but reported the coefficient (β) of the regression, they were converted into odds/risk ratios by exponentiation of coefficients (i.e., $OR = \exp[\beta]$) (241).

Some articles reported odds/risk ratios based on different reference groups. Some used lower adherence to dietary patterns, and some used good adherence. To make this consistent and unify all results using either the higher or lower group as reference, the new odds/risk ratio was calculated by taking the reciprocal of the reported odds/risk ratio. The lower limit of the new odds/risk ratio is the reciprocal of the upper limit of the old odds/risk ratio and the upper limit of the new odds/risk ratio is the reciprocal of the lower limit of the old odds/risk ratio (242).

The random-effects model was used for calculating pooled estimates. Statistical heterogeneity was evaluated by Cochran's Q test (I^2), which shows the amount of heterogeneity between studies. An I^2 value reflects between-study variation (values of 25%, 50% and 75% refer to low, medium and high variation, respectively) (243).

A sub-group analysis was conducted to detect a potential source of heterogeneity. The possible effects of the between-study variance of dietary assessment methods (DDS, Mediterranean diet score [MDS] and PCA) and dietary assessment period/trimesters (first trimester [1st–12th week], second trimester [13th–27th week] or third trimester [28th–40th week]) were assessed.

Dietary patterns detected in each study differed regarding the country of origin and the approaches used for identifying dietary patterns; however, they had similarities among commonly consumed food items. For instance, most articles identified the 'prudent', traditional, Mediterranean or healthy dietary pattern, which commonly consists of whole grains, nuts, legumes/pulses, vegetables/fruits and fish. These studies were grouped together and analysed by labelling them as 'healthy dietary pattern'.

Similarly, the patterns that were mostly composed of refined grains, processed meats or snacks, high-sugar and high-fat dairy products, eggs and white potatoes were grouped together, labelled as the 'Western dietary pattern' and then analysed.

Using the available articles, pooled estimates were determined for the effect of the healthy pattern on HDPs, GDM, PTB and LBW. Likewise, a meta-analysis was performed for the Western dietary pattern and HDPs, GDM and PTB.

3.2 Spatial and multilevel studies

Spatial and multilevel analysis was used to meet Aim 2, which focuses on assessing the spatial distribution and determinant factors of anaemia among women in Ethiopia and has the following three objectives:

Objective 1: To assess the spatial distribution of anaemia among women in Ethiopia

Objective 2: To identify the determinant factors of anaemia among women in Ethiopia

Objective 3: To assess the PAF estimates for factors associated with different types of anaemia among women in Ethiopia.

3.2.1 Study design and setting

To address Aim 2, an in-depth analysis of the 2016 EDHS data was conducted. EDHS 2016 was a large-scale population-based cross-sectional study conducted across Ethiopia. It was the fourth national survey conducted in all parts of Ethiopia: in nine regional states (Tigray; Afar; Amhara; Oromia; Somali; Benishangul-Gumuz; SNNP's Region; Gambella; and Harari) and two city administrations (Addis Ababa and Dire Dawa) (48). The EDHS was collected through interviewer-administered questionnaires, which were prepared in English and then translated into local languages (Amharic, Tigrigna and Oromifa). The EDHS aimed to produce up-to-date information on key demographic and health indicators and provide a wide-ranging overview of population, maternal and child health issues in Ethiopia. The survey target groups were women aged 15–49 years and men aged 15–59 years in randomly selected households across Ethiopia. Comprehensive information was collected from the participants, such as background characteristics (age, educational status, marital status and occupation), fertility, family planning, pregnancy care, child feeding practices, nutritional status, and adult and childhood mortality. The EDHS was executed by the Central Statistical Agency in cooperation with the Ministry of Health and the Ethiopian Public Health Institute with technical support from ICF International.

3.2.2 Sampling and measurements

3.2.2.1 Sampling

In the 2016 EDHS, stratified and cluster multistage sampling was used, and it was intended to be representative at the regional and national level in terms of appropriate demographic and health indicators. Each region was stratified into rural and urban areas, resulting in 21 strata. Samples of EAs were selected independently in each stratum in two stages. In the first stage, 645 clusters of enumeration areas (EAs; 202 urban and 443 rural) were identified using probability proportional to the size of EAs. In the second stage, all households from September to December 2015 within each EA were listed and then 28 households from each cluster or EA were selected, which resulted in a random sample of 18,008 households. Of this, 16,650 were successfully interviewed, reflecting a response rate of 98%. In the interviewed households, 16,583 eligible women were identified for individual interviews. A total of 15,683 women aged 15–49 years were interviewed, and Hgb levels were measured for 14,923 of them (48). Data collection took place from 18 January to 27 June 2016. The data was collected by trained data collectors. Detailed training was given for data collectors on interviewing techniques and field procedures, questionnaire content, mock interviews between participants in the classroom, and practice interviews with real respondents in areas outside the survey sample.

The sample size for the EDHS was determined based on the multistage sampling procedure and took into consideration sampling variation. Standard errors were computed using the Taylor linearization method. The design effect, which is the ratio between the standard error with the given sample design and the standard error that would result if a simple random sample had been used, was determined. The value of the design effect, averaged over all variables, was 1.99. This meant that, because of multistage clustering of the sample, the average standard error was increased by a factor of 1.99 beyond that of an equivalent simple random sample (48).

3.2.2.2 Measurements

3.2.2.2.1 Dependent variables

Hgb levels of the women were measured using HemoCue, which is suitable for resource-poor settings (244) and was used as the standard test in the 2016 EDHS (48). All Hgb values were adjusted for both altitude and smoking status (48). Pregnant women with a Hgb value < 11 g/dL and non-pregnant women with a Hgb value < 12 g/dL were considered anaemic (62). Furthermore, anaemia was classified according to its severity as severe (Hgb < 7 g/dL), moderate (Hgb 7.0–9.9 g/dL) and mild (Hgb 10.0–10.9 g/dL in pregnant women and 10.0–11.9 g/dL in non-pregnant women) (62).

3.2.2.2.2 Explanatory variables (determinant factors)

Different variables were extracted from the EDHS dataset for this study. These included factors relating to sociodemographic, health services and reproduction. Wealth index measures the economic status and was computed using variables related to household assets, size of agricultural land and the quantity of livestock and housing construction materials. PCA was used to compute wealth index and was categorised into quintiles (poorest, poorer, middle, richer and richest). For this analysis, the independent factors were grouped into individual- and community-level factors. The individual- and community-level factors included in this study are presented in Table 3.1 with their definition and category. The variables were selected based on the literature review for factors affecting anaemia (46, 66, 113, 114); sociodemographic, maternal and community-level factors were identified as important factors for the occurrence of anaemia. Therefore, the variables available in the dataset were included in the analysis. Individual factors included age, religion, marital status, educational status, birth interval, use of contraceptives, wealth index, family size, iron/folate intake and gravidity of women. Community-level factors were residence (urban, rural), region, water source and latrine facility type. Community-level measures could also be derived by aggregating individual-level variables: for example, the proportion of women in the community who were in the top quintile of wealth index and the proportion of women in the community who had clean water access. Community-level factors describe the group of populations living in similar settings.

The assumption of independence of observation was taken as a basis to determine which variables were analysed at the individual and community levels. If the observations at the individual level were independent, variables were treated as individual-level factors. However, if the observations were clustered into higher levels of units, and if several women had shared features (such as place of residence, types of water source, latrine facility and region) that could have the same effect on anaemia among women in the locality, then variables were analysed at the community level.

Table 3.1 Variables identified for this study with coding.

Variable	Categories	Recoding
Age		1 = 15–19; 2 = 20–29; 3 = 30–39; 4 = 40–49

Variable	Categories	Recoding
Region	1 = Tigray; 2 = Afar; 3 = Amhara; 4 = Oromia; 5 = Somali; 6 = Benishangul-Gumuz; 7 = SNNP; 8 = Gambella; 9 = Harari; 10 = Addis Ababa; 11 = Dire Dawa	Same as EDHS dataset
Area of residence	1 = Urban; 2 = Rural	Same as EDHS dataset
Education level	1 = No education; 2 = Primary; 3 = Secondary; 4 = Higher	Same as EDHS dataset
Source of drinking water	10 = Piped water; 11 = Piped into dwelling; 12 = Piped to yard/plot; 13 = Piped to neighbour; 14 = Public tap/standpipe; 20 = Tube well water; 21 = Tube well or borehole; 30 = Dug well (open/protected); 31 = Protected well; 32 = Unprotected well; 40 = Surface water; 41 = Protected spring; 42 = Unprotected spring; 43 = River/dam/lake/pond/stream/canal/irrigation channel; 51 = Rainwater; 61 = Tanker truck; 62 = cart with small tank; 71 = Bottled water; 96 = Other; 97 = Not dejure resident.	1 = Piped water; 2 = Other improved (public taps, standpipes, tube wells, boreholes, protected dug wells and springs, rainwater, bottled water); 3 = Unimproved (river, pond, unprotected spring and well)
Type of toilet facility	10 = Flush toilet; 11 = Flush to piped sewer system; 12 = Flush to septic tank; 13 = Flush to pit latrine; 14 = Flush to somewhere else; 15 = Flush, don't know where; 20 = Pit toilet latrine; 21 = Ventilated improved pit latrine; 22 = Pit latrine with slab; 23 = Pit latrine without slab/open pit; 30 = No facility 31 = No facility/bush/field; 41 = Composting toilet; 42 = Bucket toilet; 43 = Hanging toilet/latrine; 96 = Other; 97 = Not dejure resident	1 = Improved (flush/pour flush toilets to piped sewer systems, septic tanks, and pit latrines; ventilated improved pit latrines; pit latrines with slabs; and composting toilets); 2 = Unimproved; 3 = Open defecation; 4 = Others
Religion	1 = Orthodox; 2 = Catholic; 3 = Protestant 4 = Muslim; 5 = Traditional; 96 = Other	1 = Orthodox; 2 = Protestant; 3 = Muslim; 4 = Others (Catholic, Traditional, Other)
Ethnicity	1 = Amhara; 2 = Oromo; 3 = Tigray; 4 = Somali; 5 = Sidama; 6 = Gurage; 7 = Welayta; 8 = Hadya; 9 = Other	1 = Amhara; 2 = Oromo; 3 = Tigray; 4 = Somali; 5 = Sidama; 6 = Gurage; 7 = Welayta; 8 = Hadya; 9 = Other

Variable	Categories	Recoding
Wealth index	1 = Poorest; 2 = Poorer; 3 = Middle; 4 = Richer; 5 = Richest	Same as EDHS dataset
Preceding birth interval (for youngest child - for youngest child), no interval for a first birth		1 = <24 months; 2 = ≥24 months
Total children ever born		1 = 0; 2 = 1–3; 3 = 4+
Births in the past year (number of births in the past 12 months [0 to 11] prior to the month of interview)		1 = 0; 2 = 1–2
Currently pregnant	0 = No or unsure; 1 = Yes	Same as EDHS dataset
Ever had a terminated pregnancy (miscarriage, abortion or stillbirth)	1 = Yes; 2 = No	Same as EDHS dataset
Births in the last three years (0 to 35 months prior to the month of interview)	1 = Yes; 2 = No	1 = Yes; 2 = No
Current contraceptive use	1 = Yes; 2 = No	1 = Yes; 2 = No
Haemoglobin level adjusted for altitude and smoking		(g/dL to one decimal)
Anaemia	1 = Severe; 2 = Moderate; 3 = Mild; 4 = Non-anaemic	1 = Anaemic (<11.9 g/dL]); 2 = Non-Anaemic
BMI		1 = <18.5; 2 = 18.5–24.9; 3 = ≥25
Smoking	1 = Yes; 2 = No	Same as EDHS dataset
Current marital status	0 = Never in union; 1 = Married ; 2 = Living with partner; 3 = Widowed ; 4 = Divorced; 5 = Separated	1 = Single; 2 = Married/Living with partner; 3 = Divorced/Widowed/Separated
During pregnancy, given or bought iron tablets/syrup for most recent pregnancy	0 = No; 1 = Yes; 3 = I don't know	Same as EDHS dataset
Drugs for intestinal parasites during pregnancy	0 = No; 1 = Yes; 3 = I don't know	Same as EDHS dataset 0 = No; 1 = Yes; 3 = I don't know
Currently breastfeeding	0 = No; 1 = Yes	Same as EDHS dataset
Respondent's occupation (grouped)	0 = No; 1 = Yes	1 = Working; 2 = Not working
Have you ever chewed khat	0 = No; 1 = Yes	Same as EDHS dataset

Variable	Categories	Recoding
Have you ever taken a drink that contains alcohol	0 = No; 1 = Yes	Same as EDHS dataset
HIV test	1 = Positive; 2 = Negative	Same as EDHS dataset

Note. SNNP = Southern Nations, Nationalities and People; BMI = body mass index; HIV = human immunodeficiency virus.

3.2.3 Data analysis

3.2.3.1 Spatial analysis (to assess the spatial distribution and determinant factors of anaemia among women in Ethiopia)

For Aim 2, Objective 1, a spatial analysis was performed to identify the clustering of anaemia in women or hotspot areas (the areas that have higher anaemia prevalence rates compared to the national average) in different regions of Ethiopia. Spatial analysis is an epidemiological method useful for specifying geographical areas with high or low rates of disease occurrence and its variability over the region or country (245). Spatial analyses were performed using GeoDa version 1.8.10 (geodacenter.github.io), QGIS version 2.18.0 (qgis.org) and ArcGIS version 10.1 (arcgis.com) with base files of the administrative regions for Ethiopia obtained from DIVA-GIS (diva-gis.org). The spatial analysis was conducted by joining the occurrence of anaemia in each cluster (as a proportion) to the corresponding geospatial location (survey cluster values). The values of the EDHS dataset were merged with the GPS (global positioning system) dataset in GeoDa using the cluster-ID, which is common in both EDHS and GPS datasets. The values were then imported into QGIS and anaemia proportions were computed at lower (cluster), zonal and regional levels.

The spatial pattern of the rate of anaemia among women of reproductive age was visualised and a spatially smoothed proportion was obtained through empirical Bayes estimation methods (246). The smoothed proportions presented clearer patterns: that is, where the problem was most severe. The spatial empirical Bayes 'smooth' estimates technique was able to deal with spatial heterogeneity. The estimation technique guarantees that estimates of neighbouring states are more alike than estimates of states that are further away (247).

A standardised prevalence rate, or the ratio of the observed prevalence rate to a national prevalence rate, was determined using GeoDa (247). GeoDa implements this in the form of an excess risk estimate as part of the map. The excess risk rate is the ratio of the observed rate to the average rate computed for all the data (247).

Furthermore, a spatial analysis was performed to identify the clustering of anaemia in women or hotspot areas (the areas that have higher anaemia prevalence rates compared to the national average) in different regions of Ethiopia. Spatial analysis is an epidemiological method useful for identifying geographic areas with high or low rates of disease occurrence and variability over the region or country (245). The Getis-Ord Gi* statistic was used for this spatial analysis. Local Getis-Ord Gi* statistics (248) were important for identifying the hot and cold spot areas for anaemia in women of reproductive age using GPS latitude and longitude coordinate readings, which were taken at the nearest community centre for EAs or 2016 EDHS clusters (48). An anaemia hotspot refers to the occurrence of high prevalence rates of anaemia clustered together on the map, whereas cold spot refers to the occurrence of low prevalence rates of anaemia clustered together on the map (248).

A local Getis-Ord Gi* statistic tool in ArcGIS was used to calculate the spatial variability of high and low prevalence rates of anaemia among women of reproductive age. Autocorrelation can be classified into positive and negative correlation through local Getis-Ord Gi* statistics (248). Positive autocorrelation occurs when similar values are clustered together on a map (high rates surrounded by nearby high rates or low rates surrounded by nearby low rates). Negative autocorrelation indicates different values are clustered together on a map: that is, high values surrounded by nearby low values or low values surrounded by nearby high values. Statistical significance of autocorrelation was determined by *z* scores and *p* values with a 95% level of confidence. The distribution of and variations in anaemia prevalence rates among women across the country were displayed on the map.

3.2.3.2 Statistical analysis

3.2.3.2.1 Aim 2, Objective 2 (to identify the determinant factors for anaemia among women in Ethiopia)

For Aim 2, Objective 2 a multilevel logistics regression model was used to determine the effect of different factors on anaemia in women. The descriptive statistical analysis was performed using SPSS version 24.0 (spss.com) and complex sample analysis. Frequencies, percentages and standard deviations were used for the descriptive analysis. Since some regions with small populations were over-sampled, while others with large populations were under-represented, the weighted frequencies and percentages (based on the population sizes of each region) were computed as a correction. The detailed weighting procedure is described in the 2016 EDHS report (48). The mean and standard deviation were computed for blood Hgb level. The mean

Hgb value was also compared across different independent categorical variables using one-way analysis of variance (ANOVA).

The multivariable multilevel logistic regression model was used to determine the effects of different factors on anaemia among women. The analysis was performed using SAS version 9.4 (SAS, North Carolina State University, sas.com) using PROC GLIMMIX with Laplace's method. For this multilevel analysis, four models were constructed. The first model was constructed without independent variables to assess the effect of community variation on anaemia among women. The second model incorporated individual-level factors. The third model included community-level factors. Finally, the fourth model included both individual- and community-level factors.

The results of fixed effects analysis were presented as odds ratios with 95% confidence intervals. An adjusted odds ratio (AOR) with 95% confidence intervals was computed to identify the independent factors of anaemia among women and a $p < 0.05$ was used as a measure of statistical significance. A multicollinearity test was performed to rule out a significant correlation between variables. If values of the variance inflation factor (VIF) were lower than 10, then the collinearity problem was considered less likely. Random effects (variation of effects) were measured with the intra-cluster correlation coefficient (ICC; variance partition coefficient) (249), the percentage change in variance (PCV) (250) and median odds ratio (MOR) (249, 251), which measured the variability between clusters in multilevel models. The ICC explains the cluster variability, while the MOR can quantify unexplained cluster variability (heterogeneity). The MOR translates cluster variance into an odds ratio scale. In the multilevel model, the PCV can measure the total variation due to factors at the community and individual levels (250). The ICC, PCV and MOR were determined using the estimated variance of clusters utilising the following formulas (249, 250):

$$ICC = \frac{V}{(V + \frac{\pi^2}{3})} \text{ and}$$

$$MOR = \exp\sqrt{2 \times V \times 0.6745} \sim \exp(0.95\sqrt{V}),$$

where V is the estimated variance of clusters, and

$$PCV = \frac{(V_A - V_B)}{V_B} \times 100,$$

where V_A is the variance of the initial model and V_B is the variance of the model with more terms.

The multilevel analysis model was one of the analysis methods that could correctly handle the correlated data (252). A multilevel logistic model has the following advantages over standard logistics regression models (252). First, a multilevel model evaluates how factors at different levels affect the dependent variable. Second, it provides accurate parameter estimates by correcting the biases introduced from clustering. It is more likely to have correlated observations within clusters; ignoring clustering would result in incorrect parameter estimates. The multilevel model gives correct standard errors and therefore correct confidence intervals and significance values.

In traditional binary logistic regression models, the assumption of independence of observation is violated if the observations are clustered into higher levels of units. The clustering of data should be taken into consideration in the analysis of the EDHS data, due to the fact that, in a single household, several women could be selected for the survey, and these women may have similar characteristics. Similarly, households in the same environment locality have shared features—like sociocultural factors, types of harvests, types of water sources, and socioeconomic and housing factors—which could have the same effects on maternal anaemia in the locality. In clustered data, basic assumptions like the same variance through clusters and independent observation among individuals within the same locality/cluster are violated. Thus, such problems should be handled by applying appropriate statistical analysis methods. The multilevel analysis model was one such analytical method that could correctly handle the aforementioned problems by taking into consideration the correlated data.

3.2.3.2.2 Aim 2, Objective 3 (to assess the PAF estimates for factors associated with different types of anaemia among women in Ethiopia)

The distribution of respondents' characteristics was analysed using Stata version 14 (stata.com). The complex sample analysis method was used for this analysis (253, 254), which takes into consideration the Demographic and Health Surveys (255) complex sampling design by incorporating sampling frame information (primary sampling units and strata) and weights in all analyses presented as percentages with 95% confidence intervals. Individual weights were used for descriptive statistics in this study. The prevalence rate of anaemia (any, mild and moderate-severe) was analysed by different factors such as residence, educational status, age, wealth index and gravidity.

Given the hierarchical structure of the sample, a multivariable multilevel logistic modelling approach was used to assess the association between different factors and anaemia among women in Ethiopia. Similarly, to identify independent predictors associated with different levels of anaemia (mild and moderate-severe), multilevel multinomial logistic regression models were used. The AOR with 95% confidence intervals were computed to identify the independent factors for different levels of anaemia, using a multilevel generalised structural equation model (GSEM) (256). GSEM allows for the fit of complex models and takes into consideration the hierarchical structure of the data (257). Many regression models are a special case of GSEM (257).

A $p < 0.05$ was used as a measure of statistical significance in the final model. The analysis was performed by using Stata version 14 (Stata Corp, College Station, TX, USA, stata.com).

PAFs were estimated to assess the contribution of each factor to the occurrence of anaemia (any, mild, moderate-severe) among women. PAFs were estimated by using AORs from the multivariable logistic regression for each variable that was significantly associated with anaemia (any, mild, moderate-severe). The idea of estimating attributable fractions using logistic regression analysis was initiated by Bruzzi et al. (258), developed by Eide and Gefeller (259) and was practically operationalised by Rückinger and colleagues (260). Ideally, the risk ratio would be used for PAFs; however, the odds ratio calculated from cross-sectional and case-control studies can also be used to compute PAFs (261). Thus, in this study, *the* odds ratio was used to estimate the PAFs because the EDHS was a cross-sectional study and the odds ratio was calculated using logistic regression.

The PAFs were calculated using the following formula (262):

$$PAF = \frac{p(AOR - 1)}{AOR},$$

where p is the proportion of women with factors among cases (i.e., ratio of exposed cases relative to a total number of cases) and AOR, the adjusted odds ratio, is the association between factors and anaemia.

PAF is an important tool for measuring the impact of factors in the population. PAFs offer estimates of the proportion of anaemia cases that could be prevented if a particular factor were eliminated or at least reduced in the population. The PAF takes into consideration the strength of the association between factors and the outcome of interest, and the prevalence of the factors in the population (115). Thus, a high association between a disease and a factor might have a low population impact if the factor is rare. Conversely, a low association between a disease and a factor may have a high impact on public health if the factor is common (263). In this sense, the PAF is important for understanding the public health impact of factors in the population and can assist in prioritising public health intervention strategies (116). PAFs are useful for indicating where preventive efforts should be focused to achieve the greatest potential reductions in anaemia cases (261).

3.2.4 Ethics considerations

Publicly available 2016 EDHS data were used for this study. The 2016 EDHS was approved by the National Research Ethics Review Committee of Ethiopia (Ref. No. 310/114/2016; see Appendix 1) and ICF Macro International (see Appendix 2). Informed consent was given by each participant and all identifiers were removed. Monitoring and Evaluation to Assess and Use Results Demographic and Health Surveys (MEASURE DHS) approval was obtained to use the 2016 EDHS for this analysis. This study was also approved by the University of Newcastle Human Research Ethics Committee (Ref. No. H-2018-0045; see Appendix 3).

3.3 Case-control studies

The cases control studies were conducted to address Aim 3: To assess the effect of dietary patterns on the risk of maternal anaemia and HDPs in the low-resource setting of Ethiopia, and has the following objectives

> *Objective 1*: To determine the association between dietary patterns and maternal anaemia in North Shewa, Ethiopia.
>
> *Objective 2*: To assess the association between dietary patterns and HDPs in North Shewa, Ethiopia.

3.3.1 Study area and periods

A case-control study was conducted in five selected health facilities in North Shewa, Ethiopia, from November 2018 to March 2019. North Shewa Zone is one of the administrative areas of the Amhara region. According to the 2007 census, this zone has a population of 1,837,490, of whom 51% ($n = 928{,}694$) are men and 49% ($n = 908{,}796$) are women. It has an area of 15,936.13 square kilometres, and around 12% of the population are urban inhabitants. In this zone, the Amhara are the largest ethnic group (96%); 97% of people speak Amharic as a first language and 95% of the population are Ethiopian Orthodox Christians. This zone is subdivided into districts and each district has more than 10 *kebele*s (the lowest administrative unit). The zone has six district primary hospitals, one zonal referral hospital and 95 health centres. In each district, there is at least one health centre, each of which is expected to provide services to more than 25,000 people.

3.3.2 Study design

A case-control study was used to assess the effect of dietary patterns on maternal morbidity (HDPs and anaemia) in five selected health facilities in North Shewa Zone, Ethiopia. Participants were recruited for approximately four months during their ANC visits from each selected health facility. ANC services are universal across Ethiopia and available at the lower level health services. In Ethiopia, pregnant women expect to receive four or more ANC visits, with 62% of women receiving at least one ANC visit in 2016 (48). For Aim 3, Objective 1, the cases were all pregnant women with a Hgb level < 11 g/dL, and the controls were women with a Hgb value ≥ 11.0 g/dL. For Aim 3, Objective 2, the cases were pregnant women who had gestational hypertension (blood pressure ≥ 140/90 mmHg), and the controls were pregnant women who were normotensive during their pregnancy. In both studies, for each identified case, three healthy controls were selected from each health facility and there may have been overlaps.

3.3.3 Source and study population

The study population included all pregnant women who had attended ANC follow-up in one of the five selected health facilities, had laboratory measurements and had provided informed consent during the study period (November 2018 to March 2019). Women who were unable to hear or speak, with multiple pregnancies, who were lactating, had a mental illness, were severely ill with medical problems like cardiovascular or renal diseases, or unwilling to participate were not included in the study.

3.3.4 Sampling method and sample size determination

Five health facilities were purposely selected for this study. A sample size quota was allocated to each health facility proportional to the average number of ANC visits for the preceding 3 months (August–October 2018). Participants were recruited from each health facility until the allotted quota was filled. The participants who fulfilled the inclusion criteria from each health facility were invited to take part in the study. Participants were invited and given an information statement while they were in the waiting room/area. At the conclusion of their ANC appointment, they were provided with an opportunity to ask questions of the data collector to clarify any questions about the project. At this time, if their queries had been satisfied, they were asked if they would consent to take part in the project. Participants only consented to the project after they had been provided with the information statement, been able to ask questions to clarify their role in the project, and the data collector was sure they had fully understood their involvement in the study. Participation was completely voluntary and no incentives were not provided to the participants.

The sample size was calculated using different factors of anaemia and HDPs obtained from previous studies. We then selected the factors (intestinal parasite and age>35) that produced a maximum sample size. To determine the optimal sample size, studies were selected by taking into consideration the following points: recently conducted studies, comparable population and study setting, and well-conducted studies (adequate sample size with low non-responses rates and appropriate statistical analysis with control for confounders) (see Table 3.2). For Objective 1, the sample size was calculated using the following parameters: intestinal parasite as the exposure variable, 5% significance level, a power level of 80%, a 1:3 ratio of cases to controls and using the double proportion formula (264). Using a 5% contingency level, the final sample size was 418 women (105 cases and 313 controls). For Objective 2, the sample size was calculated using the following parameters: age > 35 years as the exposure variable, 5% significance level, a power level of 80%, a 1:3 ratio of cases to controls applying the double proportion formula (264) and using OpenEpi version 3.01 (openepi.com). Using a 5% contingency level for non-response, the final sample size was 314 women (79 cases and 235 controls).

Table 3.2 Sample size determination using different exposure variables.

	Proportion of exposure (%)		**Sample size (*n*)**		
Exposure variable (references)	**Cases**	**Controls**	**Cases**	**Controls**	**Total**
	Anaemia as cases				
Intestinal parasite detected* (114)	42	58	100	298	398
No education (113)	44	27	82	246	328
Rural residence (113)	42	58	100	298	398
No iron supplementation (113)	40	59	75	224	299
HIV	39	61	64	162	216
	HDPs as cases				
Anaemia (125)	13	2.3	44	132	176
Age > 35 years$ (162)	10	2.4	75	224	299
Multigravida (265)	31	69	18	52	70

Note. HIV = human immunodeficiency virus; HDPs = hypertensive disorders of pregnancy.

*Sample size for Objective 2.

$Sample size for Objective 1.

3.3.5 Data collection procedures and measurements

3.3.5.1 Data collection procedures

The data were collected using an interviewer-administered questionnaire, anthropometry and a record review of laboratory measurements. Five data collectors were involved in the study. Data collectors had at least a diploma or bachelor's degree in health sciences (public health, nursing and midwifery) and at least one year of work experience at healthcare facilities. The training was provided to the data collectors about the research project and the specific details of the methods to conduct the research and data collection procedures, including participants' enrolment and obtaining consent. Detailed training was also provided to the data collectors on the method related to the questionnaires of the study. The principal investigator (KT), continuously supervised and assisted the data collectors, including giving directions on how to handle participants, giving clarifications and ensuring that all activities of the data collection process were followed.

The questionnaire was adapted from the FAO/WHO survey, the 2016 EDHS (48, 224) and by reviewing relevant literature (58-60). The questionnaire comprised five sections (see Appendix 4). The first section assessed the respondents' sociodemographic characteristics: age, religion, occupation, ethnicity, educational status, marital status, place of residence, income, main water source and toilet facilities available in their household. The second section evaluated maternal characteristics, including gravidity/parity, birth interval, stillbirths, ANC visits, nausea/vomiting and alcohol intake. The third section addressed maternal feeding habits/practices, including varying food intake, avoidance of foods, pica practices (ingestion of non-nutritive substances), meal frequency, eating patterns and use of supplements including iron/folate or consumption of de-worming tablets. The fourth section of the questionnaire was designed to examine the dietary intake of study participants. Dietary intake of participants was assessed through the administration of a 24-hour recall food questionnaire, adapted from the FAO and 2016 EDHS (48, 224). Participants were requested to recall all the foods they had consumed in the preceding 24 hours. This was done initially and spontaneously by the participant and then through probing questions from the interviewer regarding all foods consumed. The final section of the questionnaire included measurements of maternal anthropometry (height, mid-upper arm circumference [MUAC], weight, gestational age and blood pressure) and a record review of laboratory measurements (Hgb level, urine protein and stool examination).

The questionnaire was prepared in English (see Appendix 4) and translated into Amharic, the local language (see Appendix 5) and then re-translated back to English to ensure consistency. Pre-testing was then undertaken to ensure the face validity of the questionnaire. The training was provided to all data collectors, and the overall activity of the study was closely monitored at each health facility. Data quality was assured through continuous supervision and by using data collection tools adapted from validated measures/sources. All completed questionnaires were examined for completeness and consistency during data collection, and the data were cleaned before analysis.

3.3.5.2 Data measurements

The Hgb levels of participants, which were routinely measured during ANC follow-ups to determine the anaemia status of pregnant women, were taken from ANC registries. A Hgb level below 11 g/dL was classified as anaemia (62). The MUAC was measured by using non-stretchable measuring tapes: two measurements were taken from the relaxed left arm and rounded to the nearest 0.1 cm and the average was taken. The MUAC reflects the past and current nutritional status of a pregnant woman. MUAC cut-off values below 23 cm (wasting) and greater than or equal to 23 cm (normal) were used to classify nutritional status (266). Women were instructed to wear light clothing and were weighed without shoes (to the nearest 100 g) using a mechanical weight scale. The heights of each study participant were also measured with shoes off. Height was measured using a Stadiometer to the nearest 0.1cm while the participant stood bare-foot. Midwives estimated the gestational age of each participant using the last menstrual period method at the ANC visit in the health facility.

The blood pressures of participants were measured to the nearest 0.5 mmHg by using an arm sphygmomanometer after a 10-minute rest. A blood pressure measurement ≤ 140/90 mmHg was taken as normal (140 and 90 refer to SBP and DBP, respectively). The urine protein level values were taken from the ANC registries.

3.3.6 Data processing and analysis

3.3.6.1 Descriptive analysis

The completeness and consistency of each filled questionnaire was checked in the field. Similarly, after the data were entered in the computer, the completeness and consistency of the data were checked by running the frequencies procedure in SPSS. After the data were cleaned, the analysis was conducted using Stata version 14 (stata.com). Descriptive statistics were calculated, and the mean Hgb level was computed. The DDS was computed using data from

24-hour dietary recall, based on the recommendations of the Food and Nutrition Technical Assistance Project (220). Food items and liquids reported in the 24-hour dietary recall were categorised into 10 food groups based on WHO/FAO guidelines (220). These food groups were the following: 1) Starchy staples (grains, white roots, tubers); 2) Legumes/pulses (beans, peas and lentils); 3) Nuts and seeds; 4) Dairy; 5) Meat, poultry and fish; 6) Eggs; 7) Dark green leafy vegetables; 8) Vitamin A-rich fruits and vegetables; 9) Other vegetables (tomatoes, onions); and 10) Other fruits. Women who ate a single food item from any of these food groups earned 1 point. If the participant did not consume a food item within the food group, they would receive 0 points for that category. The minimum and maximum DDSs were 0 and 10 points, respectively (220). Consumption of at least 5 (minimum threshold) out 10 defined food groups by women of reproductive age over the previous 24 hours was calculated which is associated with a higher probability of adequacy for 11 micronutrients (220).

3.3.6.2 Propensity score analysis

Propensity score analysis was performed to adjust for significant differences in baseline covariates and to have unbiased estimates. The propensity score (267, 268) is the conditional probability of assigning a variable to a particular group (exposed or unexposed) given a set of observed covariates. A propensity score is an essential tool for causal inference in non-experimental studies in which randomisation is impossible and symmetry of treatment/exposure groups is unlikely. Propensity score analysis avoids selection or confounder bias (269). The propensity score analysis was performed as follows. First, a propensity score for each patient was estimated using the logistic regression model, with dietary diversity during pregnancy as the endpoint (high coded as 1; low, as 0). The following variables were used to estimate the propensity score: age, residence, educational status, marital status, occupation, first pregnancy, ANC, nausea and vomiting, gestational age, eating before pregnancy, change in food after pregnancy, food avoided, started new food types, meal patterns, fasting and craving. The propensity score model was assessed by using the *c* statistic (270) and Hosmer–Lemeshow statistics (271).

Second, the study subjects were grouped into 10 strata based on the quantiles of population propensity scores (272). In propensity score analysis, the sub-classification method uses all individuals in the dataset, and it is recommended for settings where the outcome data is already available (269). Third, the main concern with propensity score analysis is the balance of the covariates in the resulting matched data (269). Thus in this study, the covariate balance between two groups (women with low DDS and women with high DDS) was checked using the standardised mean difference (standardised bias) with the 'pbalchk' command in Stata (273). It is recommended that the absolute standardised differences of means should be less than 0.25 (274).

Finally, using the propensity score-matched data, a conditional logistic regression model was used to assess the association between maternal DDSs and the outcomes of interest (anaemia and HDPs), with adjustment for covariates (275) to control for the remaining minor differences in the matched sample (276).

Bivariate analysis was undertaken to determine the effect of dietary intake and other factors on anaemia and HDPs. Crude odds ratios (CORs) with 95% confidence intervals were estimated.

Multivariable conditional logistic regression was used to identify the independent predictors of anaemia. The predictors that had a $p < 0.25$ in the bivariate logistic regression model were entered into a multivariable logistic regression model. The p-value cut off <0.25 was used to identify important variables based on the Hosmer–Lemeshow recommendation (271). This multivariable logistic regression can help to adjust for confounders and a $p < 0.05$ was taken as significant. The Hosmer–Lemeshow test was used to check the goodness of model fit, and it was non-significant ($p = 0.18$; $p > 0.05$ is considered as the best model fit) (271).

3.3.7 Ethics considerations

This study was approved by the University of Newcastle Human Research Ethics Committee (Ref. No. H-2018-0017; see Appendix 6). Ethics approval was also obtained from Amhara Public Health Institute Research Ethics Committee (Ref. No. HRTT 03/163/2018; see Appendix 7), and a support letter for the zonal health office (see Appendix 8). The zonal health office wrote a support letter to the district health offices (see Appendix 9), who then sent a letter of cooperation to health facilities (see Appendix 10). The information statement sheets (see Appendices 11 and 12 for English and Amharic, respectively) and consent forms (see Appendices 13 and 14 for English and Amharic, respectively) were prepared for health facilities, and permission was obtained from each health facility.

Detailed information (the information statement) was given to each participant containing information on the risk/benefits, safety/privacy and confidentiality (see Appendices 15 and 16 for English and Amharic, respectively). Written consent was then obtained from each participant (see Appendices 17 and 18 for English and Amharic, respectively).

To protect against undue influence, the recruitment of participants was performed in an exit interview by data collectors after they had finished their ANC visit. Confidentiality was assured for all the information provided by respondents. To preserve confidentiality, no personal identifiers were used in the data collection tool. All recorded data were recognisable only by medical record number, and an identification number was used for each participant to avoid over-surveying and to correctly track in case of inconsistencies. The data were not used for purposes other than this study and have been kept confidential. The results of this thesis presented in the next consecutive chapters (4-8). The results of the systematic review were presented in chapter 4. Chapter 5 and 6 contain the result of spatial and multilevel analysis. The results of case-control studies were addressed in chapter 7 and 8.

Chapter 4: Maternal dietary patterns and risk of adverse pregnancy (hypertensive disorder of pregnancy and gestational diabetes mellitus) and birth (preterm birth and low birth weight) outcomes—a systematic review and meta-analysis

This study was designed to answer Aim 1 through a detailed analysis of the global literature to assess the effect of maternal dietary patterns on the risks of adverse pregnancy (HDPs and GDM) and birth (PTB and LBW) outcomes. This chapter was published as an article in *Public Health Nutrition* in October 2018 (see Appendix 19), and it has currently been cited in 20 publications as of 8 December 2020.

> Kibret KT, Chojenta C, Gresham E, Teketo TK, Loxton D. Maternal dietary patterns and risk of adverse pregnancy (hypertensive disorders of pregnancy and gestational diabetes mellitus) and birth (preterm birth and low birth weight) outcomes: a systematic review and meta-analysis. Public Health Nutr. 2019 Mar;22(3);506–520. Epub 2018 Oct 15. doi:10.1017/S1368980018002616.

Abstract

Introduction: Epidemiological studies have indicated that dietary patterns during pregnancy have been associated with adverse pregnancy and birth outcomes such as HDPs, GDM, PTB and LBW. However, the results of these studies are varied and inconsistent.

Objective: This study aimed to assess the association between dietary patterns and the risk of adverse pregnancy and birth outcomes.

Design: This study is a systematic review and meta-analysis. Seven databases were searched for articles. Two reviewers performed the study selection and data extraction. A random-effects model was used to estimate the pooled effect sizes of eligible studies.

Settings: Articles conducted all over the world were incorporated.

Subjects: This study focused on pregnant women.

Results: A total of 21 studies were identified. Adherence to a healthy dietary pattern (intake of vegetables, fruits, legumes, wholegrains) was significantly associated with lower odds of pre-eclampsia (OR = 0.78; 95% CI: 0.70, 0.86; I^2 = 39.0%; p = 0.178), GDM (OR = 0.78; 95% CI:

0.56, 0.99; I^2 = 68.6%; p = 0.013) and PTB (*OR* = 0.75; 95% CI: 0.57, 0.93; I^2 = 89.6%; p = 0.0001).

Conclusion: This review suggests that dietary pattern with a higher intake of fruits, vegetables, legumes, whole grains and fish is associated with a decreased likelihood of adverse pregnancy and birth outcomes including preeclampsia, GDM and PTB. Further research should be conducted in low-income countries to understand the impact of limited resources on dietary intake and adverse pregnancy and birth outcomes.

Keywords: Dietary patterns, dietary intake, pregnancy, pregnant women.

4.1 Introduction

HDPs are a group of conditions related to high blood pressure during pregnancy, proteinuria and, in some cases, convulsions (158). HDPs are responsible for increased morbidity and mortality in mothers and newborns, accounting for approximately 14% of maternal deaths globally between 2003 and 2009 (5). According to an analysis of international cohorts from six countries (Australia/New Zealand, Canada, Israel, Japan, Spain and Sweden), the incidence rate of HDPs was 13% (ranging from 10.3%–16.4%) (277).

PTB is the premature delivery of a neonate before 37 weeks of gestation (278). PTB is most common in LMICs and is one of the leading causes of direct neonatal deaths and complications (278), responsible for more than 50% of neonatal mortality in 2010 (279). According to a systematic analysis and estimation of PTB, the global rate of PTB was 11% in 2010, ranging from 5% in European countries to 18% in some African countries (280). Similarly, LBW, which refers to a newborn's birth weight being less than 2.5 kg, is common (15%). High rates of LBW are reported in many developing countries, especially within South Asia (25%) and sub-Saharan Africa (12%) (281), and in Pakistan (35%), Nepal (30%) and Jordan (22%) (282).

Evidence has shown that dietary patterns have an influence on adverse pregnancy and birth outcomes (42, 233). When individuals consume food, they consume a combination of nutrients, not single nutrients (28). The whole diet, with its expected synergistic effects, may have a greater influence on the occurrence of health outcomes than single nutrients (28). Hence, it appears more comprehensive to examine the effect of the whole diet by applying a more inclusive method of dietary pattern analysis because dietary patterns evaluate the usual diet as one complete dietary exposure (29, 30).

Dietary pattern analysis aims to assess the usual foods consumed as one overall dietary exposure (29, 221). Dietary patterns are defined as the quantities, proportions, variety or combinations of different foods and beverages in diets, and the frequency with which they are regularly consumed (220). Dietary patterns can be determined by one of three approaches. The first is an a priori approach, which constructs dietary indices, or scores, according to predefined recommendations or current knowledge (29, 221, 222). The second is an a posteriori approach, which identifies data-driven dietary patterns using statistical methods (e.g., cluster analysis and PCA) (29, 221, 222). The third approach consists of hybrid methods such as reduced rank regression, which combines aspects of the a priori and a posteriori approaches (222).

Previous studies have indicated that dietary patterns during pregnancy have varied effects on maternal health and pregnancy outcomes such as HDPs (233, 234), GDM (283, 284), PTB (42, 285, 286) and LBW (287). For HDPs, an intake of vegetables, legumes, nuts, tofu, rice, pasta, rye bread, fish, milk, green leafy vegetables and pulses/beans were associated with a lower odds of pre-eclampsia/eclampsia (26, 233). The consumption of meat, potatoes, processed meat, sweet drinks and salty snacks increased the likelihood of pre-eclampsia (40, 233, 288). Other studies have reported contradictory findings. A cohort study in the US (234) reported that a higher Alternate Healthy Eating Index score—comprising vegetables, fruit, fibre, trans fats, a high ratio of polyunsaturated to saturated fatty acids, folate, calcium and iron from foods—was not associated with pre-eclampsia. For GDM, a Western dietary pattern (high intake of red meat, processed meat, refined grain products, sweets, French fries and pizza) among pregnant women in the US (289), a pasta-cheese-processed-meat pattern (283) in a Singaporean population, and a sweet and seafood pattern in China (284) have been associated with an increased odds of GDM.

With regard to the birth outcomes, a ‘prudent’ dietary pattern with a high intake of vegetables, fruits, oils, water (beverage), wholegrain cereals and fibre-rich bread is associated with a reduced occurrence of PTB (42). In contrast, a Western pattern (salty and sweet snacks, white bread, desserts and processed meat products) (42) and a Mediterranean diet (with a high intake of fish, fruit, vegetables, olive/canola oil and a low intake of red meat and coffee) had no effect on PTB (285). Contrary to this, in a Danish birth cohort study, the odds of PTB increased in women who adhered to a Western pattern (high in meat and fats and low in fruits and vegetables) (286). Additionally, a study from the US (39) revealed that birth weight and fetal growth were not associated with the maternal Alternate Healthy Eating Index score (high intakes of vegetables, fruit, whole grains, nuts and legumes, long-chain [*n*-3] fats, polyunsaturated fats, folate, calcium and iron).

Current epidemiological studies have shown some evidence for an association between dietary pattern and adverse pregnancy and birth outcomes. However, the findings are inconsistent and there is a need to identify which dietary patterns could have health benefits for pregnant women in preventing adverse pregnancy and birth outcomes. Therefore, we aimed to determine the association between dietary patterns during pregnancy and the risk of pregnancy (HDPs, GDM) and birth (PTB and LBW) outcomes through a systematic review and meta-analysis.

4.2 Methods

4.2.1 Search strategy

Seven databases were searched, including MEDLINE, Embase, CINAHL (Cumulative Index to Nursing and Allied Health Literature), Scopus, the Cochrane Library, Web of Science, and Maternity and Infant Care. The reference lists of relevant articles were then individually searched.

The following query was used to search the databases:

> diet OR nutrition OR "food pattern" OR "meal pattern" OR "eating practice" OR "food intake" OR "food habits" OR "eating behaviour" OR "dietary pattern" OR "dietary diversity score" AND "pregnancy" OR "pregnant women" OR "gravid" OR "gestation" OR "prenatal care" OR "antenatal care" AND "gestational hypertension" OR "pregnancy-induced hypertension" OR "preeclampsia" OR "pre-eclampsia" OR "LBW" OR "premature infant" OR "premature birth" OR "PTB" OR "pregnancy in diabetics" OR "gestational diabetes mellitus".

The search comprised a free-text word search; a search for terms in the title and Medical Subject Headings for outcomes, exposure and participants; limited to English language and human subjects.

4.2.2 Study selection

The studies were screened by titles and then by abstracts by two reviewers. The full texts of all selected studies were critically reviewed based on the inclusion and exclusion criteria as shown in Table 4.1.

Table 4.1 Inclusion and exclusion criteria for the systematic review.

Inclusion Criteria • Pregnant women • No time restrictions • Original articles (randomised trials and observational studies) • Dietary pattern as the exposure variable • Included one or more of the following outcome variables: HDPs, GDM, LBW, PTB.
Exclusion criteria • High-risk populations: women with heart diseases, diabetes, pre-eclampsia or gestational hypertension at baseline • Unpublished papers • Animal studies • Brief communications, case series, editorials, review studies • Studies that focused on single nutrients.

Note. HDPs = hypertensive disorders of pregnancy (gestational hypertension, pre-eclampsia and eclampsia); GDM = gestational diabetes mellitus; LBW= low birth weight; PTB = preterm birth.

4.2.3 Data extraction

The following variables were extracted: authors, publication year, study period, study design, settings/country, population sample, dietary pattern with food details, dietary assessment methods and periods, main outcomes (HDPs, GDM, LBW and PTB) and adjustment for confounders.

4.2.4 Quality assessments

The quality of the selected full-text articles was assessed by two reviewers independently using the Academy of Nutrition and Dietetics' quality appraisal tool (238). This tool has four relevance questions and 10 validity questions. The validity questions appraise the selection, comparability of groups, assessment of exposures or outcomes, and the statistical analysis for each study separately (238). The validity of a study is only assessed if the responses to all four relevance questions were 'Yes'. The response for validity questions was 'Yes' if the criterion was fulfilled, 'No' if not fulfilled, 'Unclear' if not precisely stated and 'N/A' (not applicable) if the criterion did not apply to the article (238). The rating scores of studies were positive (+) if the responses to the validity questions were 'Yes' for six or more responses (including all four relevance questions). If an article did not fulfil the relevance criterion of selection, comparability of groups, or measurement of exposures or outcomes, then the rating score was neutral (ф). If the responses for the validity questions were ' No' or 'Unclear' for six or more responses, then a negative (–) rating score was given (238).

4.2.5 Statistical analysis

The data were entered into a spreadsheet in Microsoft Excel (version 16) and exported to Stata (version 13) for analysis. The odds ratio was used as a measure of the effect estimate. If an incidence of the outcome variable was less than or equal to 20%, the risk and odds ratios were pooled together in the meta-analysis; otherwise, the risk ratio was converted to an odds ratio using the proposed methods of Zhang and Yu (239) and Cochrane (240). If the studies did not report odds/risk ratios but reported the coefficient (β) of the regression, they were converted into odds/risk ratios by exponentiation of coefficients (i.e., $OR = \exp[\beta]$) (241).

Some articles reported odds/risk ratios based on different reference groups. Some used lower adherence to dietary patterns, and some used good adherence. To make this consistent and unify all results using either the higher or lower group as reference, the new odds/risk ratio was calculated by taking the reciprocal of the reported odds/risk ratio. The lower limit of the new odds/risk ratio is the reciprocal of the upper limit of the old odds/risk ratio and the upper limit of the new odds/risk ratio is the reciprocal of the lower limit of the old odds/risk ratio (242).

The random-effects model was used for calculating pooled estimates. Statistical heterogeneity was evaluated by Cochran's Q test (I^2), which shows the amount of heterogeneity between studies. An I^2 value reflects between-study variation (values of 25%, 50% and 75% refer to low, medium and high variation, respectively) (243).

A sub-group analysis was conducted to detect a potential source of heterogeneity. The possible effects of the between-study variance of dietary assessment methods (DDS, MDS and PCA) and dietary assessment period/trimesters (first trimester [1st–12th week], second trimester [13th–27th week] or third trimester [28th–40th week]) were assessed.

Dietary patterns detected in each study differed concerning the country of origin and the approaches used for identifying dietary patterns; however, they had similarities among commonly consumed food items. For instance, most articles identified the 'prudent', traditional, Mediterranean or healthy dietary pattern, which commonly consists of whole grains, nuts, legumes/pulses, vegetables/fruits and fish. These studies were grouped together and analysed by labelling them as 'healthy dietary pattern'.

Similarly, the patterns that were mostly composed of refined grains, processed meats or snacks, high-sugar and high-fat dairy products, eggs and white potatoes were grouped together, labelled as the 'Western dietary pattern' and then analysed.

Using the available articles, pooled estimates were determined for the effect of the healthy pattern on HDPs, GDM, PTB and LBW. Likewise, a meta-analysis was performed for the Western dietary pattern and HDPs, GDM and PTB.

4.3 Results

4.3.1 Identified studies

Our search identified 6291 records after removal of duplicates. Seventy-nine articles were excluded due to different reasons: reviews (n=6), outcomes (did not address the outcomes)(n=40) and exposures (focused on single nutrients)(n=33). One hundred articles were identified for full-text review, with 21 articles incorporated into the systematic review and meta-analysis (see Figure 4.1).

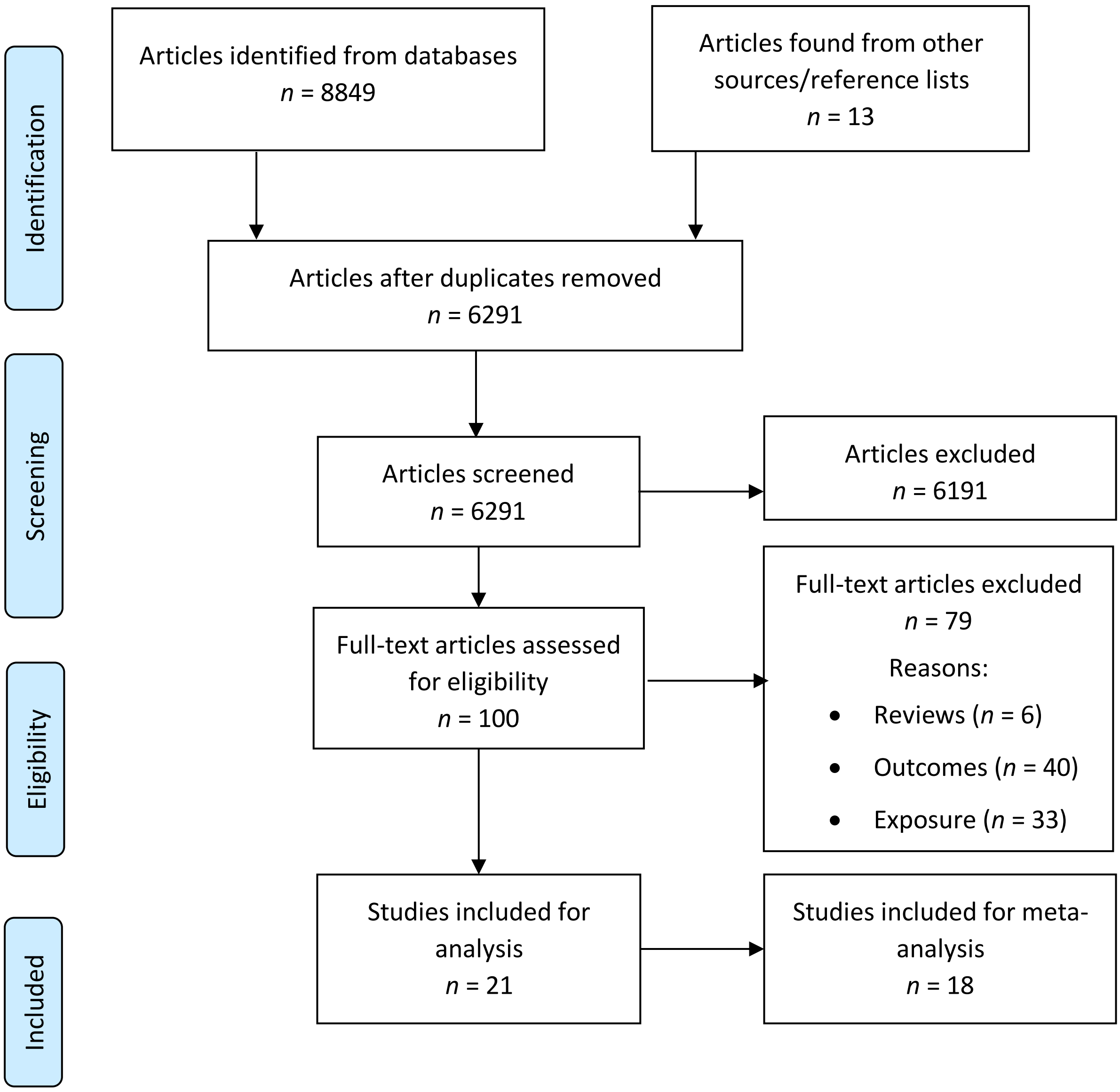


Figure 4-1 Flow chart of the study selection process.

4.3.2 Study characteristics

Of the 21 articles included, the majority (*n* = 15) were conducted in developed countries, with the remainder in developing countries. Out of all included articles, 18 were cohort studies and three were cross-sectional studies. The articles were published between 2008 and 2016. The samples in each study ranged from 168 (290) to 66,000 (42), with 302,450 pregnant women in total. In the included articles, six reported the effect of dietary patterns on HDPs (40, 156, 233, 291-293), six reported on GDM (283, 284, 290, 294-296), nine reported on PTB (42, 285, 286, 292, 297-301) and two reported on LBW (301, 302) (see Table 4.2).

Most of the articles (*n* = 15) used a food frequency questionnaire (FFQ) (40, 42, 233, 284-286, 291-293, 295, 296, 298-300, 302) as the method of dietary assessment method, five studies used 24-hour recall (156, 283, 294, 297, 301) and one used a 4-day food record (290) to assess dietary intake. Various types of approaches were used to identify dietary patterns. Most studies applied an a posteriori approach (i.e., PCA; *n* =13) (40, 42, 233, 283, 284, 286, 290, 291, 293, 296-298, 302), seven studies used an a priori method—DDS (156, 301), MDS (285, 295, 299, 300) or New Nordic Diet (292)—and one study used the reduced rank regression method (294) to identify the dietary patterns of women (see Table 4.2).

Table 4.2 Characteristics of the articles included in the systematic review.

First author, publication year	Study design; period; country	Sample (n)	Dietary assessment		Method of defining dietary pattern	Dietary patterns identified	Main findings*	Outcomes	Confounding factors
			Methods	Trimester/s (weeks)’					
Brantsaeter, 2009 (233)	Cohort; 2002–2006; Norway	23,423	255-item FFQ[a]	2nd (17–22)	PCA	Vegetables; potato and fish; cakes and sweets; processed foods	High tertile of vegetable (3 vs 1): *OR* = 0.72 [0.62, 0.85]; processed food (3 vs 1): *OR* = 1.21 [1.03, 1.42]; potato and fish (3 vs 1): *OR* = 1.00 [0.84, 1.18]	PE	BMI, education, age, smoking, height, educational status, hypertension prior to pregnancy, total energy intake and dietary supplement use
Eshriqui, 2016 (291)	Cohort; 2009–2012; Brazil	299	82-item FFQ[a]	3rd (28–38)	PCA	Healthy; processed; common Brazilian	Mixed-effects regression. SBP. Healthy: β = –0.199 [–1.28, 0.88], *OR* = 0.82 [0.28, 2.1]; processed: β= –0.268 [–1.67, 1.14], *OR* = 0.76 [0.188, 3.13] DBP. Healthy: β = −0.670 [–1.573, 0.232], *OR* = 0.51 [0.21, 1.26]; processed: β = −0.032 [–1.202, 1.138], *OR* = 0.97 [0.3, 3.12]	Blood pressure (SBP & DBP)	Age, BMI, education, parity and total energy intake
Mwanri, 2015 (156)	Cross-sectional; 2011–2012; Tanzania	910	16 food groups, 24 h recall[a]	2nd & 3rd (20–36)	DDS	16 food groups	Medium DDS: *OR* = 2.54 [1.04, 6.16]; high DDS: *OR* = 5.84 [2.11–16.15]	Hypertension during pregnancy	Residence, age, gestational age, MUAC, parity, GDM, education, physical activity
Timmermans, 2011 (40)	Prospective cohort; the Netherlands	3,187	293-item FFQ[a]	All (*Mdn* = 13.5)	PCA	MD; traditional	Low adherence to MD: *OR* = 1.2 [0.6, 2.3]; adhere to MD: *OR* = 0.83 [0.43, 1.6]; adhere to traditional: *OR* = 1.1 [0.6, 2.1]. For PE, low adherence to MD:	PE & GHT	Maternal BMI, maternal age, parity, educational level, smoking, vomiting and preconception folic acid use

First author, publication year	Study design; period; country	Sample (*n*)	Dietary assessment		Method of defining dietary pattern	Dietary patterns identified	Main findings*	Outcomes	Confounding factors
			Methods	Trimester/s (weeks)'					
							OR = 1.3 [0.9, 1.9]; adhere to MD: *OR* = 0.77 [0.53, 1.11]. For GHT, adhere to traditional: *OR* = 1.3 [0.9–1.9]		
Torjusen, 2014 (293)	Cohort; 2002–2008; Norway	28,192	6 food group–FFQ	2nd (17–22)	PCA	Healthy; organic vegetables	Healthy pattern tertile (3 vs 1): *OR* = 0.74 [0.64, 0.85]; organic vegetables: *OR* = 0.79 [0.62, 0.99]	PE	Hypertension prior to pregnancy, pre-pregnant BMI, height, age, education, household income, smoking during pregnancy, total energy intake and gestational weight gain
Hillesund, 2014 (292)	Cohort; Norway	72,072	255-item FFQ[a]	(25)	NNDs	NND	Risk of PE with high NNDs: *OR* = 0.86 [0.78, 0.95]; early PE: *OR* = 0.71 [0.52, 0.96]; PTB: *OR* = 0.91 [0.8, 1.3]	PE & PTB	Maternal age, height, pre-pregnancy BMI, parity, education, smoking status, exercise during pregnancy, chronic hypertension, diabetes, marital status and energy intake
Dayeon, 2015 (294)	Cross-sectional; US	253	8 food groups, 24 h recall	All (average 20)	Reduced rank regression	High refined grains; high nuts, seeds and low milk; high added-sugar and organ meats; low fruits,	High refined-grain pattern: *OR* = 4.9 [1.4, 17.0]; high nuts, seeds, fats and soybean, low milk pattern *OR* = 7.5 [1.8, 32.3]; high added-sugar and organ meat: *OR* = 22.3 [3.9–127.4]	GDM	Age, race/ethnicity, family poverty–income ratio, education, marital status, energy intake, pre-pregnancy BMI, gestational weight gain and log-transformed C-reactive protein

First author, publication year	Study design; period; country	Sample (*n*)	Dietary assessment		Method of defining dietary pattern	Dietary patterns identified	Main findings*	Outcomes	Confounding factors
			Methods	Trimester/s (weeks)'					
						vegetables and seafood			
DeSeymour, 2016 (283)	Multiethnic Asian cohort; Singapore	909	68 food groups, 24 h recall[a]	2nd & 3rd (26–28)	PCA	Vegetable-fruit-rice-based; a seafood-noodle-based; pasta-cheese-processed-meat-based	Vegetable-fruit-rice-based diet: *OR* = 1.10 [0.90, 1.35]; seafood-noodle-based diet: *OR* = 0.74 [0.59, 0.93]; pasta-cheese-processed-meat diet: *OR* = 0.96 [0.79, 1.17]	GDM	Energy intake, pregnancy BMI, birth order, smoking, alcohol intake, age, ethnicity, education, previous GDM, family history of diabetes, household monthly income and other dietary patterns
He, 2015 (284)	Prospective cohort; China	3,063	64-item FFQ[a]	2nd (24–27)	PCA	Vegetable; protein-rich; prudent; sweets and seafood	Vegetable pattern: *RR* = 0·79 [0·64, 0·97]; sweets and seafood pattern: *RR* = 1.23 [1.02, 1.49]; protein-rich pattern: *RR* = 0.95 [0.78, 1.16]; prudent pattern: *RR* = 1.0 [0.82, 1.22]	GDM	Maternal age, education level, monthly income, parity, pre-pregnancy BMI and family history of diabetes
Karamanos, 2014 (295)	Prospective cohort; Jan 2010 – Jul 2011; 10 Mediterranean countries	1,076	78-item FFQ[a]	2nd & 3rd (24–32)	MD score	MD index	MD: *OR* = 0.618 [0.401, 0.950]	GDM	Age, BMI, diabetes in the family, weight gain and energy intake
Nascimento, 2016 (296)	Prospective cohort; Nov 2011 – Feb 2014; Spain	841	81-item FFQ[a]	2nd (15–20)	PCA	Traditional; vegetable and Western; mixed	High tertile traditional pattern (3 vs 1): *RR* = 0.88 [0.49, 1.58]; mixed pattern: *RR* = 0.93 [0.51, 1.71]; Western pattern: *RR* = 0.78 [0.43, 1.43]	GDM	BMI, age, education, monthly income, family history of diabetes and parity
Tryggvadottir, 2016 (290)	Prospective Cohort; Apr	168	18 food groups,	2nd (19–24)	PCA	Prudent pattern	Adhering to the prudent pattern: *OR* = 0.44 [0.21, 0.90]	GDM	Age, parity, pre-pregnancy weight,

First author, publication year	Study design; period; country	Sample (*n*)	Dietary assessment		Method of defining dietary pattern	Dietary patterns identified	Main findings*	Outcomes	Confounding factors
			Methods	Trimester/ s (weeks)'					
	2012 – Oct 2013; Iceland		4-day weighed food record						energy intake, weekly weight gain and total metabolic equivalent of task
Chia, 2016 (297)	Cohort study; 2009–2010; Singapore	923	68 food groups, 24 h recalls, 3-day food diaries	2nd & 3rd (26–28)	PCA	Vegetable, fruit and white rice; seafood and noodle; pasta, cheese and processed meat	Vegetable, fruit and white rice pattern: *OR* = 0.67 [0.50, 0.91]; seafood and noodle pattern: *OR* = 1.27 [0.93, 1.74]; pasta, cheese and processed meat: *OR* = 0.79 [0.55, 1.12]	PTB	Sex of infant, birth order, maternal total energy intake, maternal age, ethnicity, pre-pregnancy BMI, weight gain until 26–28 weeks of gestation, height, GDM status, educational status, alcohol use, smoking during pregnancy and other dietary patterns
Englund-Ögge, 2014 (42)	Prospective cohort; 2002–2008; Norway	66,000	255-item FFQ[a]	2nd (17-22)	PCA	Prudent; Western; traditional	Prudent: *RR* = 0.88 [0.80, 0.97]; Western: *RR* = 1.02 [0.92, 1.13]; traditional: *RR* = 0.91 [0.83, 0.99]	PTB	Maternal age, pre-pregnancy BMI, height, parity, total energy intake, maternal education, marital status, smoking, previous preterm delivery, household income and other dietary patterns
Haugen, 2008 (285)	Cohort; Norway	569	255-item FFQ[a]	2nd (18–22)	MD score	MD criteria	MD criteria (5 vs none): *OR* = 0.73 [0.32, 1.68]	PTB	Parity, BMI, maternal height, socioeconomic status and cohabitant status

First author, publication year	Study design; period; country	Sample (*n*)	Dietary assessment		Method of defining dietary pattern	Dietary patterns identified	Main findings*	Outcomes	Confounding factors
			Methods	Trimester/s (weeks)’					
Martin, 2015 (298)	Prospective cohort; US	3,143	95-item FFQ	2nd & 3rd (26–29)	PCA and DASH	4 factors	Factor 1: *OR* = 0.87 [0.60, 1.27]; factor 2: *OR* = 1.53 [1.02, 2.30]; factor 3: *OR* = 1.55 [1.07, 2.24]; adherence to the DASH diet: *OR* = 0.59 [0.40, 0.85]	PTB	Maternal age, race, maternal pre-pregnancy BMI status, educational level, household income, parity, marital status, smoking status and energy intake
Rasmussen, 2014 (286)	Longitudinal cohort; Denmark	59,949	360-item FFQ[a]	2nd & 3rd (average 25)	PCA	Vegetable; prudent; Western; seafood	Western pattern *OR* = 1.30 [1.13, 1.49]; vegetable pattern: *OR* = 1.4 [0.8, 1.62]; seafood pattern: *OR* = 0.90 [0.72, 1.11]	PTB	Maternal age, maternal height, pre-pregnancy BMI, parity, civil status, socioeconomic status and smoking during pregnancy
Zerfu, 2016 (301)	Prospective cohort; Ethiopia	432	9 food groups, 24 h WDDS[a]	2nd & 3rd (24–28)	DDS	9 food groups	Low DDS: *RR* = 4.61 [2.31, 9.19]; high DDS: *RR* = 0.21 [0.11, 0.43]	PTB	Age, height, MUAC, education, Hgb level
Mikkelsen, 2008 (299)	Cohort; Denmark	35,530	360-item FFQ	2nd & 3rd (average 25)	MD score	MD[b]	MD criteria[c] (5 vs 0): *OR* = 0.61 [0.35, 1.05]; MD criteria (5 vs 1–4): *OR* = 0.92 [0.69, 1.24]	PTB	Parity, BMI, maternal height, socioeconomic status and cohabitant status
Saunders, 2014 (300)	Cohort; 2004–2007; French Caribbean island	728	214-item FFQ	Days following delivery	MD score	9 categories of the Mediterranean scale[d]	Adherence to MD: *OR* = 0.9 [0.8, 1.0]	PTB	Maternal place of birth, marital status, pre-pregnancy BMI, maternal education, enrolment site, weight gain during pregnancy, energy intake and maternal smoking during

First author, publication year	Study design; period; country	Sample (*n*)	Dietary assessment		Method of defining dietary pattern	Dietary patterns identified	Main findings*	Outcomes	Confounding factors
			Methods	Trimester/s (weeks)'					
									pregnancy (*n* = 710 with complete data)
Abubakari, 2016 (302)	Cross-sectional; Ghana	578	55-item FFQ[a]	2nd and 0–1 month post-birth	PCA	Non–health conscious; health-conscious	Health-conscious diet: *OR* = 0.23 [0.12, 0.45]; non–health conscious: *OR* = 1.04 [0.65, 1.67]; high DDS: *OR* = 0.10 [0.04–0.13]	LBW	Gestational age
Zerfu, 2016 (301)	Cohort; Ethiopia	432	9 food groups 24 h WDDS[a]	2nd & 3rd (24–28)	DDS	9 food groups	High DDS: *RR* = 2.06 [1.03, 4.11]	LBW	Education, age, height, MUAC and Hgb level

Note. BMI = body mass index; DASH = Dietary Approaches to Stop Hypertension; DBP = diastolic blood pressure; DDS = dietary diversity score; FFQ = food frequency questionnaire; GDM = gestational diabetes mellitus; GHT = gestational hypertension; HDPs = hypertensive disorders of pregnancy; Hgb = haemoglobin; LBW = low birth weight; MD = Mediterranean diet; MUAC = mid-upper arm circumference; NND = New Nordic Diet; PCA = principal component analysis; PE = pre-eclampsia; PTB = preterm birth; *RR* = risk ratio; SBP = systolic blood pressure; WDDS = women dietary diversity score.

[a]Validated FFQ.

[b]Criteria: consumption of fish twice a week, intake of olive or rape seed oil, high consumption of fruits/vegetables (5 a day or more), and meat (other than poultry and fish) at most twice a week.

[c]'5 vs 0' means ≥ 5 vs no fulfilled criteria.

[d]Vegetables, legumes, fruits and nuts, cereals, fish, meat and poultry, dairy products, alcohol and fat.

*Square brackets indicate 95% CIs.

4.3.3 The effect of dietary patterns on adverse pregnancy outcomes (HDPs and GDM)

4.3.3.1 Dietary patterns and HDPs

Six articles (40, 156, 233, 291-293) assessed the association between dietary patterns and HDPs. These articles identified a range of different dietary patterns—such as healthy, traditional, Mediterranean and Western patterns—and, therefore, the results could not be pooled in the meta-analysis, except those pertaining to the healthy dietary pattern.

4.3.3.1.1 Healthy dietary pattern

Four studies (40, 233, 292, 293) that reported the association between a healthy dietary pattern and a high intake of fruits, vegetables, wholegrain foods, fish and poultry were available for meta-analysis. Based on this pooled analysis, study participants who adhered to a healthy dietary pattern were shown to have significantly lower odds of pre-eclampsia (*OR* = 0.78; 95% CI: 0.70, 0.86; I^2 = 39.0%; *p* = 0.178; see Figure 4.2).

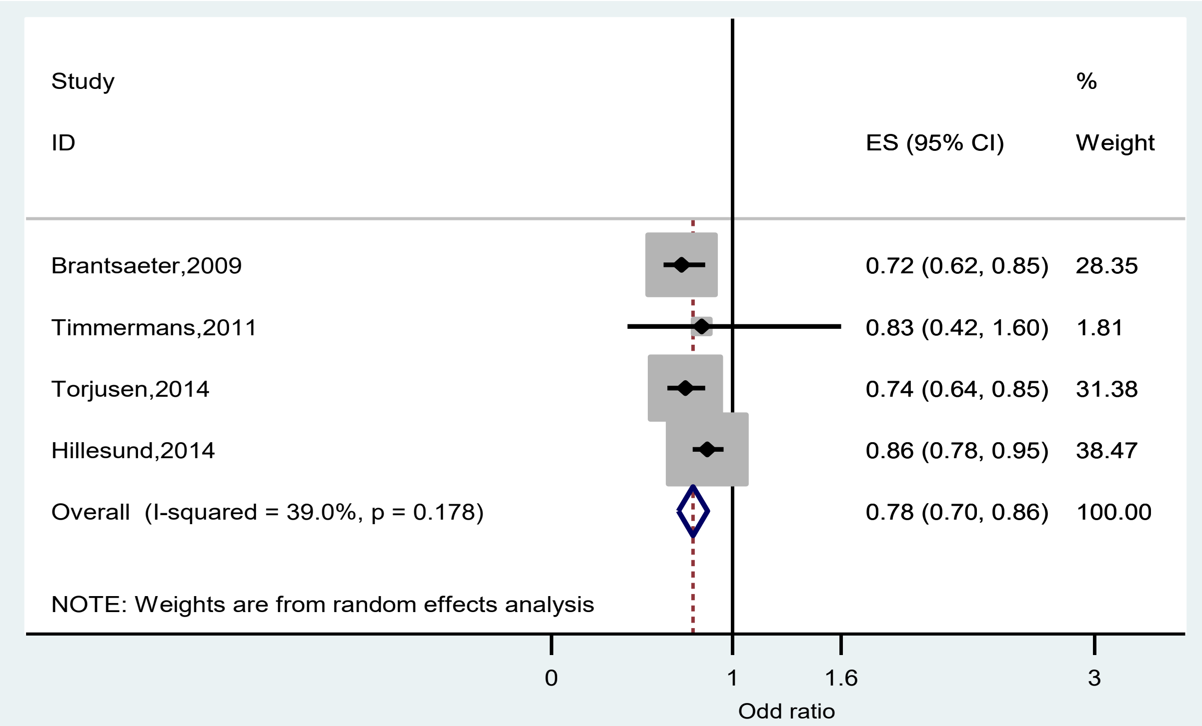


Figure 4-2 Pooled *OR* of the association between a healthy dietary pattern and pre-eclampsia.

Note. Weights are from a random-effects analysis; ES = effect size.

However, one cross-sectional study in Tanzania indicated that a high DDS (*OR* = 5.84; 95% CI: 2.11, 16.15) or a medium DDS (*OR* = 2.54; 95% CI: 1.04, 6.16) was associated with an increased odds of gestational hypertension (156). In contrast, in a cohort study, the association was not observed between gestational hypertension and adherence to a Mediterranean (*OR* = 0.77; 95% CI: 0.53, 1.11) or traditional dietary pattern (*OR* = 1.3; 95% CI: 0.9, 1.9) (40). Similarly, a cohort study from Brazil (303) revealed that adherence to a healthy dietary pattern did not have an effect on SBP (*OR* = 0.82; 95% CI: 0.28, 2.21) and DBP (*OR* = 0.94: 95% CI: 0.18, 1.28).

4.3.3.1.2 Western dietary pattern

In a cohort study in Norway (233), a potato and fish dietary pattern (lean fish, cooked potatoes, processed fish, fish burgers, margarine, fish soufflé, meat spread, lean fish and poultry) was not associated with pre-eclampsia (*OR* = 1.00; 95% CI: 0.84, 1.18). Similarly, a cohort study in Brazil (291) reported that adherence to a processed food pattern was not significantly associated with SBP (*OR* = 0.76; 95% CI: 0.19, 3.13) or DBP change (*OR* = 0.97; 95% CI: 0.30, 3.10) during pregnancy.

4.3.3.2 Dietary patterns and GDM

4.3.3.2.1 Healthy dietary pattern

Six studies (283, 284, 290, 294-296) assessed the effect of dietary patterns on GDM. A cohort study in Singapore (283) indicated that a seafood-noodle-based diet was related to lower odds of GDM (*OR* = 0.74; 95% CI: 0.59, 0.93). However, adherence to a higher compared to lower vegetable-fruit-rice-based diet (*OR* = 1.10; 95% CI: 0.90, 1.35) or a pasta-cheese-processed-meat-based diet (*OR* = 0.96; 95% CI: 0.79, 1.17) was not associated with GDM. Similarly, adherence to a traditional pattern (*RR* = 0.88; 95% CI: 0.49, 1.58), as well as to a mixed pattern (*RR* = 0.93; 95% CI: 0.51, 1.71) was not associated with the incidence of GDM among Brazilian women (296).

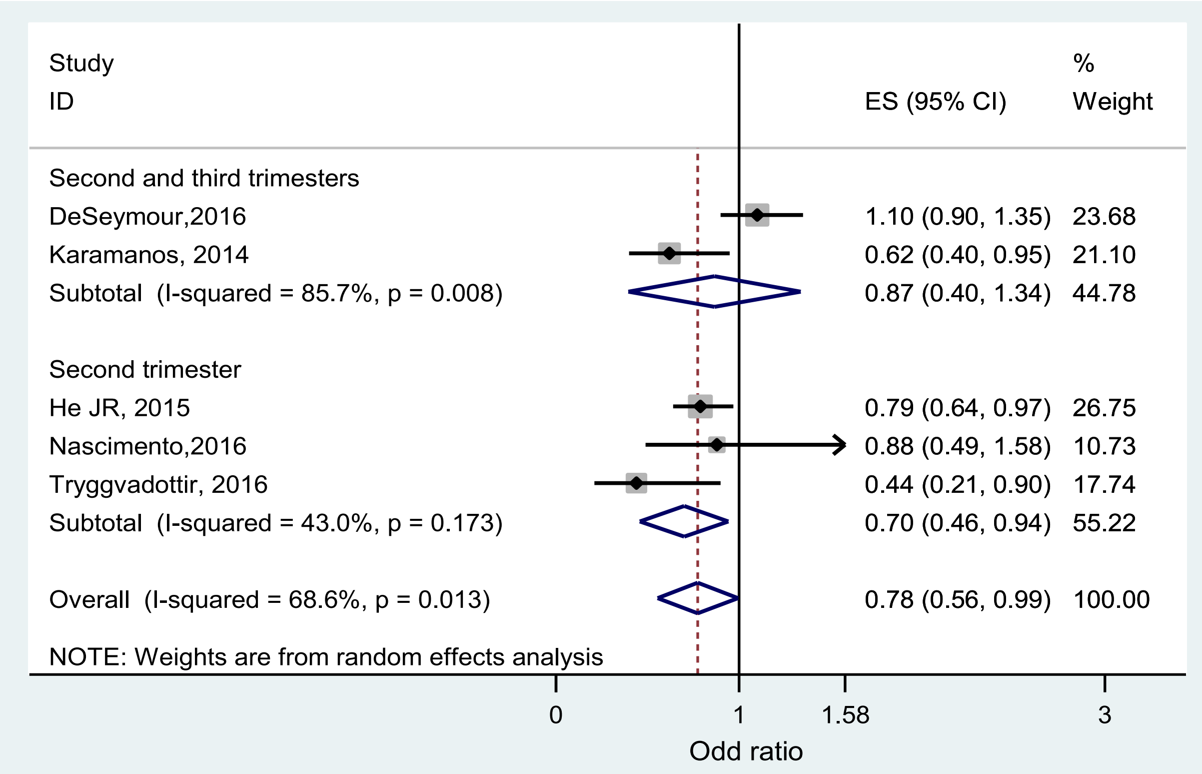
The pooled estimate of a healthy dietary pattern on GDM was determined by using five studies (283, 284, 290, 295, 296). Based on this estimate, women who had higher adherence to a healthy dietary pattern had lower odds of GDM (*OR* = 0.78; 95% CI: 0.56, 0.99) with significant heterogeneity detected between studies (I^2 = 68.6%; p = 0.013; see Figure 4.3a).

4.3.3.2.2 Western dietary pattern

Four studies (283, 284, 294, 296) were combined, showing no relationship between adherence to a Western dietary pattern and odds of GDM (*OR* = 0.94; 95% CI: 0.81, 1.07), and no heterogeneity between studies (I^2 = 0.0%; p = 0.825; see Figure 4.3b).

A cross-sectional survey in the US (294) and prospective cohort study in China (284) reported that adherence to dietary patterns of refined grains (*OR* = 4.9; 95% CI: 1.4, 17.0), high nuts, seeds, fat and soybeans (*OR* = 7.5; 95% CI: 1.8, 32.3), and sweets and seafood patterns (*RR* = 1.23; 95% CI: 1.02, 1.49) during pregnancy was associated with an increased likelihood of GDM.

a) Healthy dietary pattern and GDM



b) Western pattern and GDM

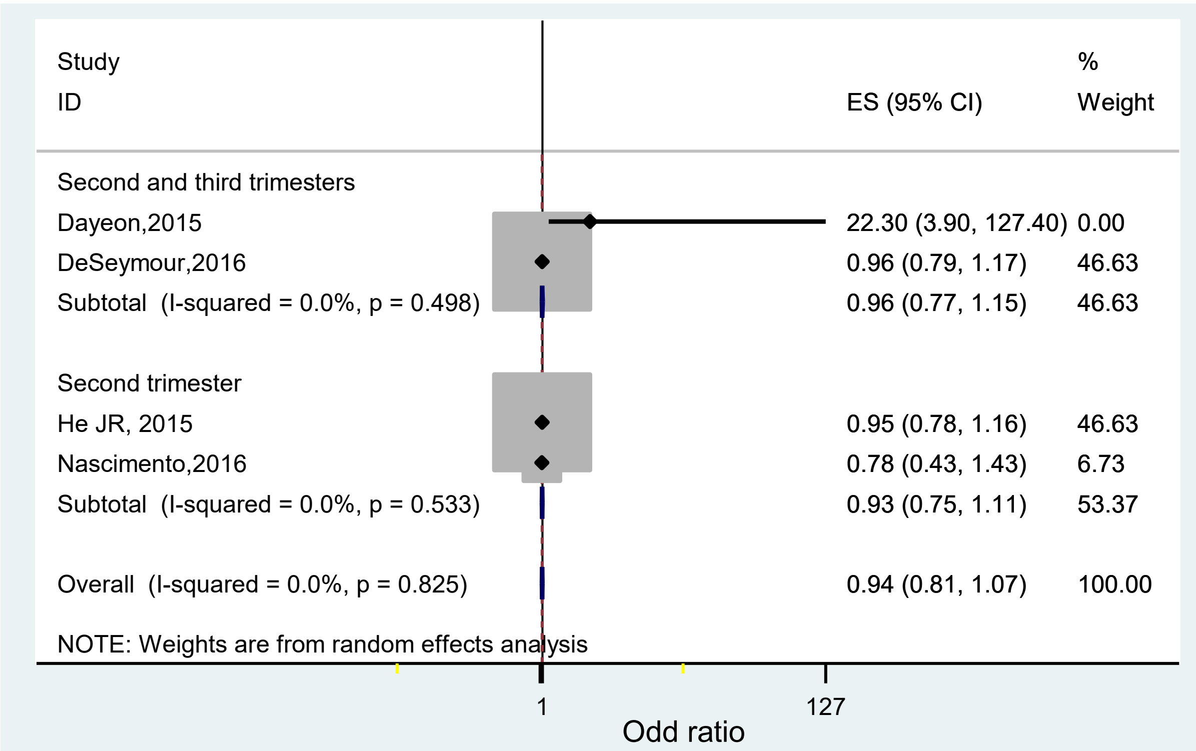


Figure 4-3 Pooled *OR* of associations between GDM and different dietary patterns—a) healthy and b) Western—with sub-group analysis regarding period of dietary assessment.

Note. Weights are from a random-effects analysis. ES = effect size.

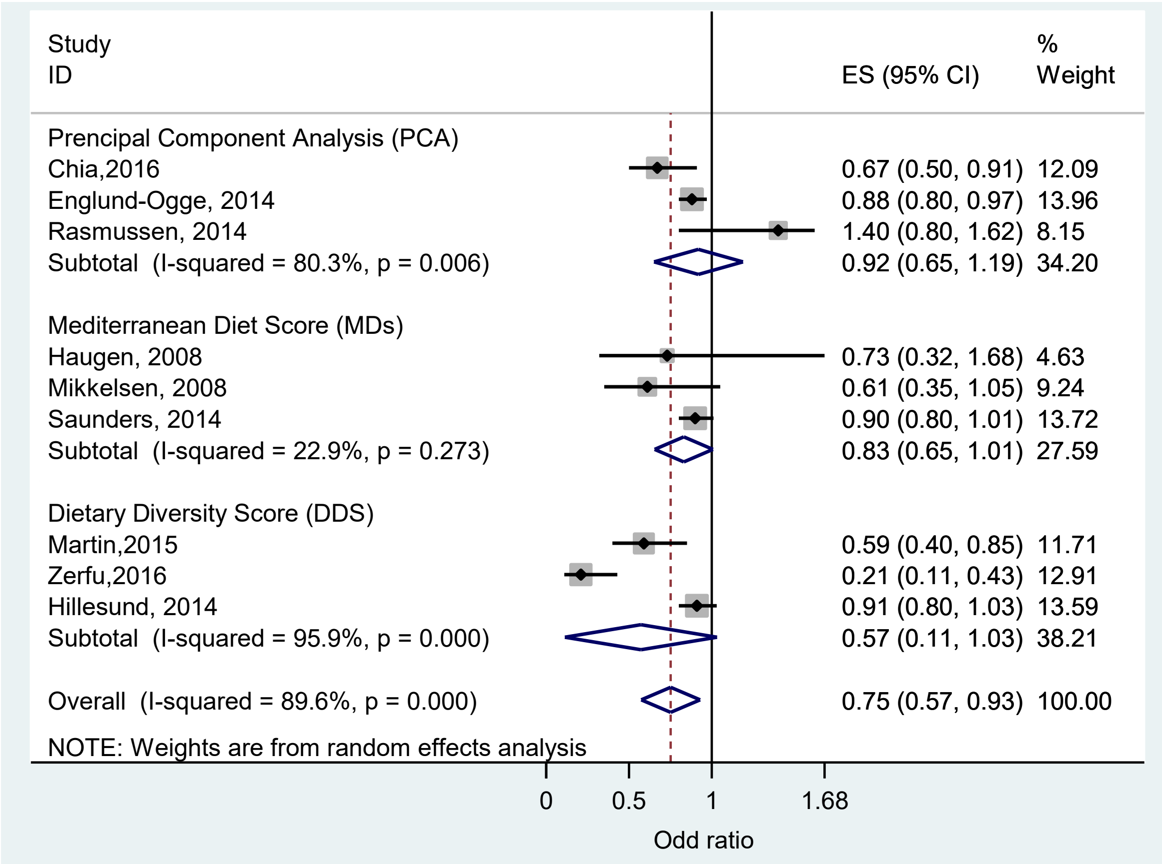
4.3.4 The effect of dietary patterns on adverse birth outcomes (PTB and LBW)

4.3.4.1 Dietary patterns and PTB

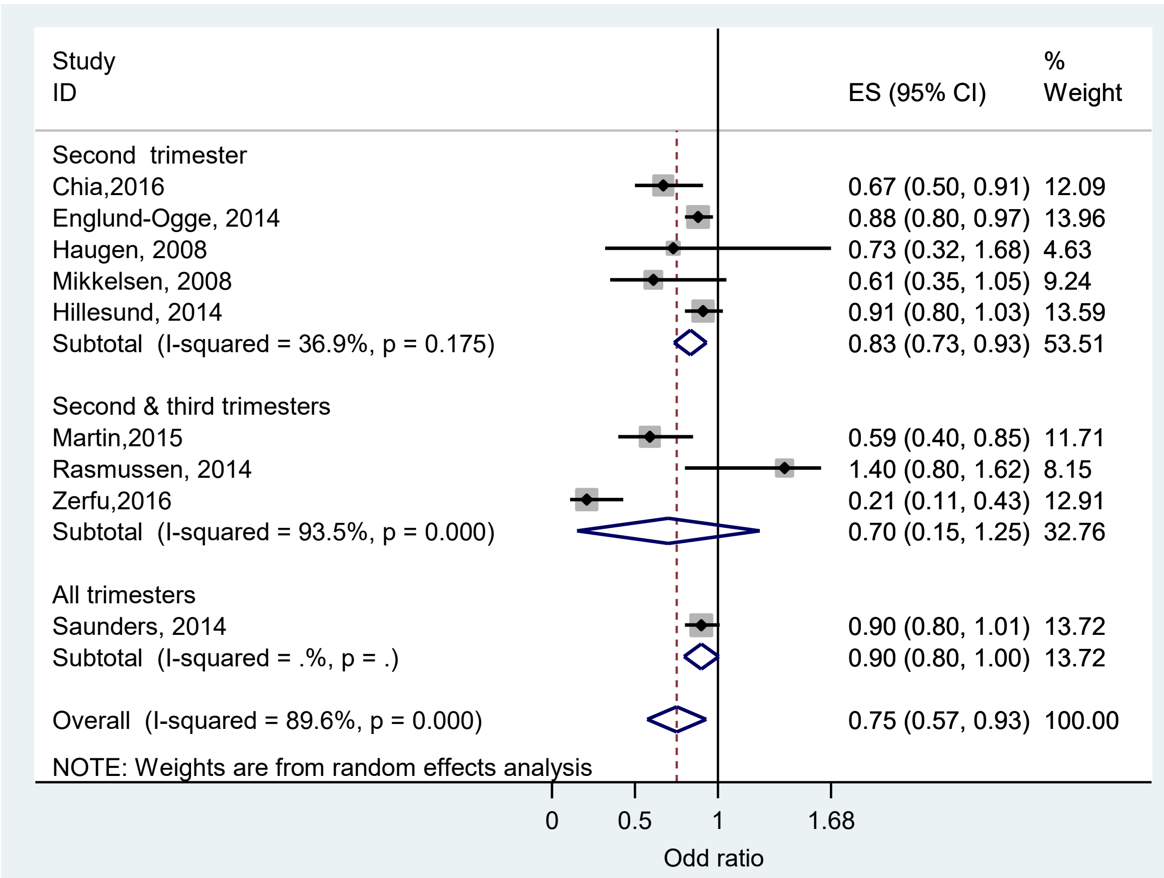
Based on a meta-analysis of nine studies (42, 285, 286, 292, 297-301), women who had good adherence to a healthy dietary pattern were shown to have reduced odds of PTB (*OR* = 0.75; 95% CI: 0.57, 0.93), although significant heterogeneity was observed (I^2 = 89.6%; p = 0.0001; see Figure 4.4a). Further sub-group analysis indicated a difference in relation to dietary pattern assessment methods (MDS, DDS or PCA; p = 0.001). There was also a significant sub-group difference regarding dietary assessment periods (second trimester and both second and third trimesters; p = 0.001; see Figure 4.4b).

Conversely, the pooled estimate of four studies (42, 286, 297, 298) showed that a Western dietary pattern did not increase the odds of PTB (*OR* = 1.11; 95% CI: 0.87, 1.34; I^2 = 78%; p = 0.004; see Figure 4.4c). There were sub-group differences between assessing diet in the second trimester and both the second and third trimesters with respect to risk of PTB (p = 0.001). We did not undertake a sub-group analysis with regard to study design, as all studies had the same design (i.e., cohort).

a) Healthy dietary pattern and PTB



b) Healthy dietary pattern and PTB



c) Western pattern and PTB

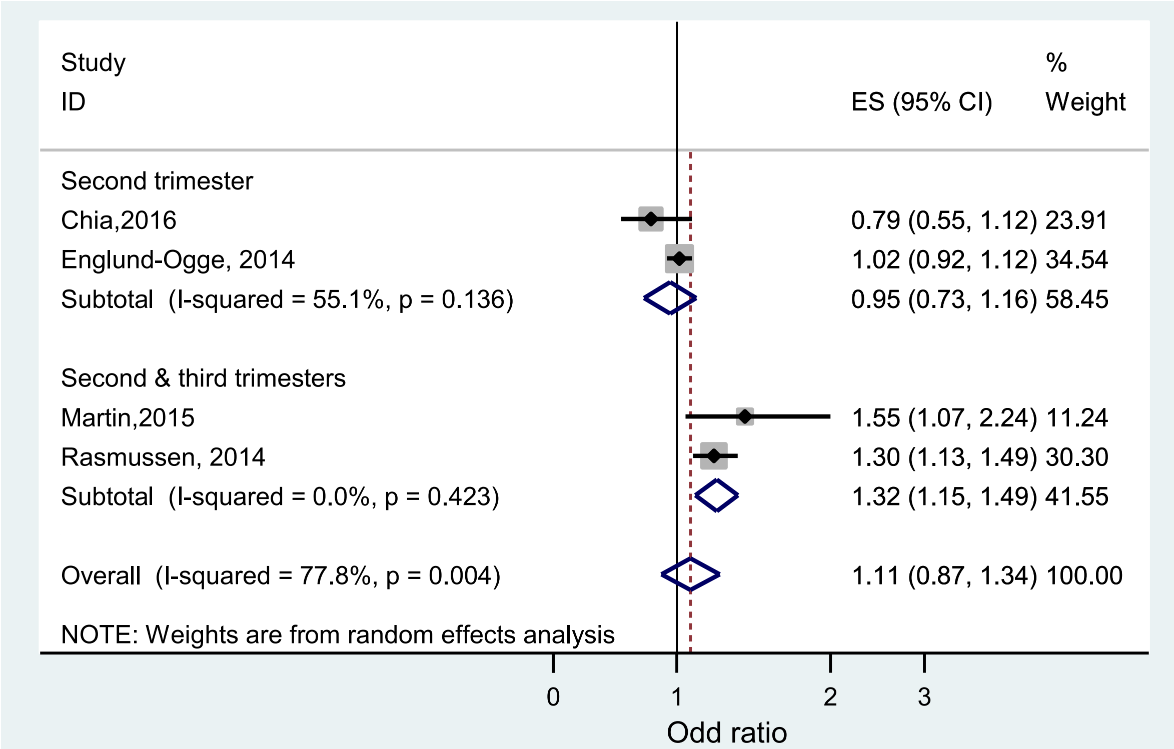


Figure 4-4 Pooled *OR* of association between PTB and different dietary patterns a) healthy, with sub-group analysis of assessment methods (MDS vs DDS vs PCA), b) healthy, with sub-group analysis of dietary assessment periods (second trimester vs both second and third trimesters vs all trimesters), and c) Western, with sub-group analysis of dietary assessment periods (second trimester vs both second and third trimesters).

Note. Weights are from a random-effects analysis. ES = effect size.

4.3.4.2 Dietary patterns and LBW

Two studies assessed the effect of dietary patterns during gestation on LBW. A study in Ghana (302) reported that a 'health-conscious' dietary pattern with a high intake of corn, rice, cassava, yam, fruits, vegetables (carrots, tomatoes, dark green leafy vegetables, cabbage, salad and cucumber), meat and eggs reduced the odds of LBW (*OR* = 0.23; 95% CI: 0.12, 0.45). Similarly, the study reported that women who had a higher DDS were less likely to deliver an LBW baby compared to those who had a lower DDS (*OR* = 0.10; 95% CI: 0.04, 0.13). However, high consumption of sweetened beverages, ice cream, chocolate, energy drinks, milk and local soft drinks, which was labelled as the 'non–health conscious' dietary pattern, was not significantly associated with LBW (*OR* = 1.04; 95% CI: 0.65, 1.67). Another study in Ethiopia

(301) showed that women who had adequate DDS were less likely to deliver an LBW baby (*OR* = 0.49; 95% CI: 0.24, 0.97).

4.4 Discussion

This systematic review and meta-analysis summarised evidence focusing on the effects of different dietary patterns during pregnancy on adverse pregnancy (HDPs and GDM) and birth (PTB and LBW) outcomes. Globally, adverse pregnancy outcomes and nutritional insufficiencies still remain public health problems (304). Sufficient consumption of energy, protein and micronutrients continues to be essential throughout pregnancy (305).

HDPs: The meta-analysis of four studies assessing the healthy dietary pattern resulted in pooled estimates suggesting decreased odds of pre-eclampsia. However, other studies reported inconsistent findings on the association between adherence to a healthy dietary pattern and the likelihood of HDP occurrence. A cohort study in the Netherlands (40) revealed that adherence to a Mediterranean dietary pattern (vegetables, vegetable oils, pasta, fish, legumes and rice) and a traditional pattern (meat and potatoes) was not associated with gestational hypertension. A cohort study in Brazil (291) revealed that adherence to healthy dietary patterns with high intakes of dairy products, fruit, green vegetables, legumes, fish, cakes, cookies/crackers and tea was not associated with a change in SBP or DBP. By contrast, a cross-sectional study in Tanzania (156) reported that, compared to a lower score, having a high or medium DDS was associated with increased odds of gestational hypertension.

These inconsistencies might be due to the differences in methods and population characteristics. The Tanzanian study was cross-sectional (156) and conducted in a resource-limited setting; however, the other studies were cohort studies conducted in well-resourced settings, except the Brazilian study (291). These studies also assessed dietary intake using a different number of food items and methods. The Tanzanian study applied a 24-hour recall method using 16 food groups, while the studies from Brazil (291) and the Netherlands (40) assessed dietary intake using an 82- and 293-item FFQ, respectively.

The healthy dietary pattern is in line with dietary guidelines, which recommend the consumption of whole grains, vegetables, fruits, potatoes, pasta, cereals, beans and lentils, and fish (306). Similarly, the beneficial influence of diets high in fibre, potassium, fruits, vegetables, cereals, dark bread and low-fat dairy products was reported as decreasing the odds of pre-eclampsia (307). It has also been reported that a lower likelihood of pregnancy-induced hypertension or pre-eclampsia has been observed with the intake of foodstuffs in plant-driven diets with vegetables (308). The risk of pregnancy complications, like pre-eclampsia and LBW, has been linked with maternal oxidative stress in the middle of pregnancy (309). Evidence indicates that oxidative stress during pregnancy could be reduced by antioxidant compounds from fruit and vegetables (310). The findings of a multicentre study indicate that oxidative stress could be reduced by a sufficient intake of fruit, vegetables and vitamin C (310). A combination of vitamins C and E might lower the risk of pre-eclampsia (311) through the removal of free radicals, which may cause oxidative stress during pregnancy (312). Therefore, it could be the cumulative effect of nutrients and their biochemical properties that influence pre-eclampsia risk.

GDM: The meta-analysis of five studies assessing the healthy dietary pattern resulted in pooled estimates that indicated reduced odds of GDM, but this was not statistically significant, most likely due to insufficient power since few articles were included. Additionally, there were inconsistent findings among included studies for meta-analysis regarding healthy dietary patterns and GDM: three studies showed decreased odds of GDM, while the remainder reported no association. This might be due to the effect of unmeasured factors, as the majority of studies did not control for all possible confounding factors. For instance, He et al. (284) could not control for parity, energy intake, blood pressure and family history of Type 2 diabetes mellitus. Similarly, parity, energy intake and blood pressure were not adjusted for in the other two studies (295, 296). There was also a difference in assessing dietary intake across these studies, with four studies (283, 284, 295, 296) using either validated FFQs or a non-validated FFQ (290). Dietary intake was assessed at different trimesters of pregnancy, even though there was no significant difference in sub-group analysis based on dietary intake assessment periods. This could be a possible explanation for the variations across different studies.

Evidence indicated that pre-pregnancy adherence to a Mediterranean dietary pattern—with an intake of fruit, vegetables, legumes, nuts, fish and cereals—and the DASH (Dietary Approaches to Stop Hypertension) diet decreased the odds of GDM (313, 314). Similarly, a clinical trial reported that adhering to the DASH diet, which is high in fruits, vegetables, whole grains and low-fat dairy products, and low in saturated fats, cholesterol and refined grains, reduced the need for insulin treatment (315). Intake of fibre, fruits and cereals reduced the odds of GDM (316).

A cohort study reported that higher odds of GDM were observed in adherence to a Western dietary pattern, which contains a higher intake of refined grain products, processed meat, red meat, French fries, pizza, sweets and desserts (289). However, our pooled estimate of four articles did not show a significant relationship between the Western pattern and occurrence of GDM. A possible explanation may be the difference in the dietary pattern investigation methods (two studies used FFQs (284, 296), and two studies used 24-hour recall methods (283, 294)) and population (one study was conducted in a Western population (294) and three studies were conducted in an Asian population (283, 284, 296)).

PTB: In this systematic review, a pooled estimate of nine studies indicated that, when compared to low adherence, higher adherence to a healthy dietary pattern significantly decreased the odds of PTB. Similarly, the pooled estimates of four studies on the vegetable pattern and three studies on the Mediterranean diet indicated decreased odds of PTB, but this was not statistically significant. However, the meta-analysis of four studies assessing the Western pattern and PTB showed that adherence to the Western pattern was not significantly associated with PTB. There were significant differences in sub-group analysis based on dietary intake assessment periods. In two articles, the dietary intake was assessed in the second (13–27 weeks) and third (28–40 weeks) trimesters, and it was reported that the Western dietary pattern significantly increased the odds of PTB. Nevertheless, the other two studies assessed the dietary intake in the second trimester (13–27 weeks), and the Western dietary pattern did not significantly increase the odds of PTB. A previous systematic review of clinical trial articles revealed that macronutrient dietary interventions reduced PTB (317).

LBW: Two articles assessed the effect of dietary patterns on LBW. Dietary patterns labelled as ‘health conscious’, characterised by an intake of local dishes made from corn flour, vegetables (carrot, tomatoes, dark green leafy vegetables, cabbage, salad and cucumber), rice, meat, a mixture of corn and cassava dough, yams, fruits, water and eggs were associated with reduced odds of LBW (302). Similarly, women who had higher DDS were less likely to deliver an LBW baby (301, 302). However, high consumption of sweetened beverages, ice cream, chocolate, energy drinks, milk and local soft drinks, which was labelled as a ‘non–health-conscious’ dietary pattern, showed a significant effect on the risk of LBW (302). This is in line with evidence that suggests the occurrence of LBW decreases through the consumption of fortified foodstuffs (318).

It is suggested that pregnant women should be advised to eat a diet rich in fruits and vegetables, whole grains, beans, lean meats and fish/seafood, and low in added sugar, red meat and processed foods (319). Intake of vegetables, fruits and legumes improve micronutrient and antioxidant intakes, which could improve pregnancy and birth outcomes (319), particularly in the second trimester, since oxidative stress has been shown to reach high levels mid-pregnancy (320). Pregnancy complications and adverse outcomes, like pre-eclampsia and PTB, have been related to oxidative stresses and associated inflammation (309). Antioxidant vitamins (C and E) and essential trace elements (copper and zinc), through the dietary intake of legumes and fruits, which are rich in these nutrients, could decrease this risk (321-323). Oxidative stress–linked adverse pregnancy outcomes could be reduced by antioxidants through an intake of vegetables and fruits (324).

The limitations of this systematic review must be acknowledged. To acquire complete dietary data, most of the articles in this review applied FFQs followed by diet scores. Nevertheless, there are unavoidable dietary intake misclassifications, which probably bias the degree of detecting real effects. Furthermore, problems of recall bias are also unavoidable because dietary information is dependent on memory. Including only articles written in the English language is another shortcoming of this systematic review. Due to the nature of nutritional research, it is difficult to make all dietary exposures similar to all study subjects. Heterogeneity among studies is a further issue in this review; however, meta-analysis permits the inconsistent findings among studies to be evaluated, even with heterogeneity (325). As all included studies were observational epidemiological studies, the effect of confounders may be a limitation of this review, despite controlling for some possible confounding factors. Additionally, publication bias is always a concern in any review: studies that had negative results might not have been submitted for publication and are thus less likely to have been published.

4.5 Conclusion

The evidence presented in this systematic review indicates the inconsistent associations between different dietary patterns, and pregnancy and birth outcomes. Some results in this systematic review show the importance of healthy dietary intake during gestation for improving pregnancy and birth outcomes for the mother and infant, even though inconsistencies have been observed among studies. Essentially, this review suggests that dietary patterns with a higher intake of whole grains, vegetables/fruits, legumes and fish are associated with a lower likelihood of adverse pregnancy and birth outcomes particularly HDPs, GDM, PTB and LBW. However, as the evidence presented in this study is inconsistent concerning the association between dietary intake and pregnancy and birth outcomes, caution should be given when advising pregnant women about diet. Since the majority of the included articles in the review were conducted in resource-rich settings, additional studies are needed in resource-limited settings to elucidate the impact of limited resources on dietary intake and adverse pregnancy and birth outcomes.

Chapter 5: The spatial distribution and determinant factors of anaemia among women of reproductive age in Ethiopia—a multilevel and spatial analysis

This study is a detailed analysis of data from a recent large population survey to assess the spatial distribution and determinant factors of anaemia among women through spatial and multilevel analysis. This chapter was published in BMJ Open in April 2019 (see Appendix 20), and it has currently been cited in five publications as of June 2020.

> Kibret KT, Chojenta C, D'Arcy E, Loxton D. The spatial distribution and determinant factors of anaemia among women of reproductive age in Ethiopia: a multilevel and spatial analysis. BMJ Open. 2019;9(1):e027276.

Abstract

Objective: This study aimed to assess the spatial distribution and determinant factors of anaemia among women of reproductive age in Ethiopia.

Methods: An in-depth analysis of the 2016 EDHS data was undertaken. Getis-Ord Gi* statistics were used to identify the hot and cold spot areas for anaemia among women of reproductive age. A multilevel logistic regression model was used to identify independent predictors of anaemia among women of reproductive age.

Results: Older age (AOR = 0.75; 95% CI: 0.64, 0.96), no education (AOR = 1.37; 95% CI: 1.102, 1.72), lowest wealth quantile (AOR = 1.29; 95 % CI: 1.014, 1.60), currently pregnant (AOR = 1.28; 95% CI: 1.10, 1.51), currently breastfeeding (AOR = 1.09; 95% CI: 1.025, 1.28), high gravidity (AOR = 1.39; 95% CI: 1.13, 1.69) and HIV-positive (AOR = 2.11; 95% CI: 1.59, 2.79) were individual factors associated with the occurrence of anaemia. Similarly, living in a rural area (AOR = 1.29; 95% CI: 1.02, 1.63) and availability of unimproved latrine facilities (AOR = 1.18; 95% CI: 1.01, 1.39) were community-level factors associated with higher odds of anaemia. The spatial analysis indicated that statistically high hotspots of anaemia in the eastern (Somali, Dire Dawa and Harari regions) and north-eastern (Afar) parts of the country.

Conclusion: The prevalence rate of anaemia among women of reproductive age varied across the country. Significant hotspots/high prevalence of anaemia was observed in the eastern and north-eastern parts of Ethiopia. Anaemia prevention strategies need to be targeted to rural

residents, women with limited to no education, women who are breastfeeding, areas with poor latrine facilities and women who are HIV-positive.

Keywords: Anaemia, spatial analysis, multilevel analysis, women of reproductive age, women.

5.1 Introduction

Anaemia refers to a low Hgb level (< 11 g/dL for pregnant women and < 12 g/dL for non-pregnant women) (62). If an individual's Hgb level is low, the red blood cells are unable to carry adequate oxygen for the body's physiological needs (62). Anaemia is a major public health problem in women and children under 5 years of age (3). Worldwide in 2011, 38% of pregnant women and 29% of non-pregnant women were anaemic (3). Pregnant women in LMICs experience high rates of anaemia, in which the highest prevalence rates are reported in Central and West Africa (56%), South Asia (52%) and East Africa (36%) (3). Similarly, a large proportion of non-pregnant women were reportedly anaemic in West and Central Africa (48%), South Asia (47%) and East Africa (28%) (3). Anaemia can have negative effects on a woman's health, including maternal mortality and severe morbidity (7), depression (130, 131), raised blood pressure (127, 128), as well as negative influences on the infant, including LBW and PTB (4). Thus, anaemia remains a health priority at the global level but particularly in resource-limited settings (117). Reducing anaemia is considered to be an essential part of improving the health of women, and the WHO has set a global target of achieving a 50% reduction of anaemia among women of reproductive age by 2025 (235).

Anaemia is also a common problem in Ethiopia; the most recent EDHS (in 2016) reported a 29% prevalence of anaemia among pregnant women and 24% among women of reproductive age; these prevalence statistics ranged from 16% to 59% across different parts of the country (48). Similarly, in several pocket studies from different parts of the country, researchers reported varied anaemia prevalence rates among pregnant women, which ranged from 17% in the north, (66), 32% in the south (25), and up to 44% (46) and 57% (67) in the eastern part of Ethiopia. Similarly, in different studies, there was reported to be a 16% (77) prevalence of anaemia among non-pregnant women, and 29% (326) and 30% (71, 327) among women of reproductive age.

There are a number of factors contributing to the burden of anaemia, with iron deficiency the main cause of the disease (328). Other micronutrients (vitamin A, vitamin B12 and folate), chronic bleeding, acute or chronic infections, and parasitic infections (hookworm and malaria) are also known to cause anaemia (77, 87-89). Based on the geographical distribution and disease burden in LMICs, about half of anaemia cases are attributable to a deficiency of iron, and the remainder may be due to diseases like parasitic infections, malaria and HIV (70). A recent systematic review revealed that the proportion of anaemia cases caused by iron deficiency was below 50% in LMICs (with regional variations); poor sanitary conditions and the subsequent increased occurrence of infections also contributed to anaemia (72).

In Ethiopia, varied prevalence rates of anaemia among women have been observed with different factors across different parts of the country (66, 67). For instance, large family size, low educational status, rural residence, hookworm infestation and HIV infection were identified as factors contributing to anaemia in Northern Ethiopia (66, 113). In studies from the eastern area, it was reported that multigravidas, third trimester of pregnancy and intestinal infestation were factors contributing to anaemia during pregnancy (46, 114). The variation in rates of anaemia among women in Ethiopia might be due to the presence of diverse contextual and geographically variable factors, including diet and the incidence of communicable diseases (117).

To date, spatial analyses have not been conducted to identify areas with hotspots (high prevalence rates) of anaemia among women of reproductive age in Ethiopia. Assessing the geographical distributions of anaemia and the impact of risk factors on disease prevalence by area is important for prioritising and designing targeted prevention and intervention programs to address anaemia in women (116). In addition, the burden of anaemia has been used as a measurable indicator of soil-transmitted helminthiasis, so understanding the geographical distribution of anaemia can help target prevention and control mechanisms for parasitic infections such as these (119).

Thus, this study aimed to assess the spatial distribution and determinant factors of anaemia among women of reproductive age in Ethiopia.

5.2 Methods

5.2.1 Patient and public involvement

This study used a publicly available dataset of the 2016 EDHS; therefore, there were no patients or members of the public involved.

5.2.2 Study design and setting

An in-depth analysis of the 2016 EDHS data was undertaken for this study. The 2016 EDHS was a population-based cross-sectional study conducted across the country. It was the fourth national survey conducted in all parts of Ethiopia in nine regional states (Tigray; Afar; Amhara; Oromia; Somali; Benishangul-Gumuz; SNNP's Region; Gambella; and Harari) and two city administrations (Addis Ababa and Dire Dawa) (48). In Ethiopia, the states are administratively further subdivided into zones, zones into *woreda* and *woreda* further into the lowest unit called *kebele.*

5.2.3 Sampling and data measurements

In the 2016 EDHS, stratified and cluster multistage sampling was used, and it was intended to be representative at the regional and national level in terms of appropriate demographic and health indicators. In the first stage, 645 clusters of EAs (202 urban and 443 rural) were identified using probability proportional to the size of EAs. In the second stage, a random sample of 18,008 households was selected from all the identified EAs. A total of 15,683 women aged 15–49 years were interviewed, and Hgb levels were measured for 14,923 of them (48) (see Figure 5.1). Data collection took place from 18 January 2016 to 27 June 2016.

The sample size for the EDHS was determined based on the multistage sampling procedure, taking into consideration the sampling variation. Standard errors were computed using the Taylor linearization method. The design effect, which is the ratio between the standard error with the given sample design and the standard error that would result if a simple random sample had been used, was determined (48).

Hgb levels of the women were measured using HemoCue, which is the standard test used in the 2016 EDHS, and all Hgb values were adjusted for both altitude and smoking status (48). Pregnant women with a Hgb value < 11 g/dL and non-pregnant women with a Hgb value < 12 g/dL were considered anaemic (62). Similarly, anaemia was classified according to its severity as severe (Hgb < 7 g/dL), moderate (Hgb 7.0–9.9 g/dL) and mild (Hgb 10.0–10.9 g/dL in pregnant women and 10.0–11.9 g/dL in non-pregnant women) (62).

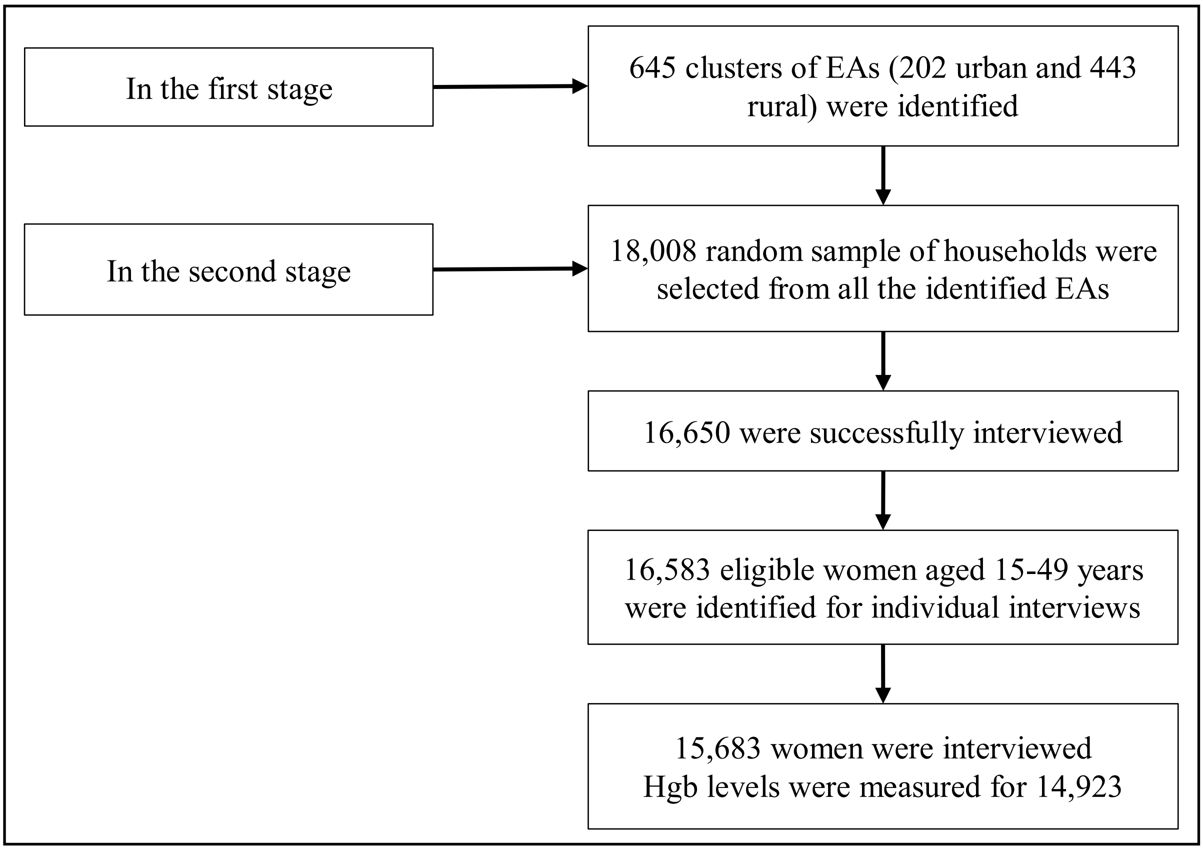


Figure 5-1 Selection of sample in the 2016 EDHS.

Note. EA = enumeration area; Hgb = haemoglobin.

5.2.4 Explanatory variables (determinant factors)

Both individual- and community-level factors were used. The individual- and community-level factors included in this study are presented in Table 3.1, with their definitions and coding. The variables were selected based on the literature review on factors affecting anaemia (46, 66, 113, 114), and sociodemographic, maternal, as well as community-level factors, were identified as important factors for the occurrence of anaemia. Therefore, all the available variables in the dataset were included in the analysis. Individual factors included age, religion, marital status, educational status, BMI, birth interval, use of contraceptives, wealth index, family size, iron/folate intake and gravidity of women. The community-level factors were residence (urban, rural), region, water source and latrine facility type. Community-level measures could also be derived by aggregating individual-level variables: for example, the proportion of women in the community who are in the top quantile of wealth index and the proportion of women in the community who have clean water access. Community-level factors describe the group of populations living in similar settings.

The assumption of independence of observation was taken as a basis to determine which variables were analysed at the individual and community levels. If the observations at the individual level were independent, variables were treated as individual-level factors. However, if the observations were clustered into higher levels of units, and if several women had shared features (such as place of residence, types of water source, latrine facility and region) that could have the same effect on anaemia among women in the locality, then variables were analysed at the community level.

5.2.5 Data analysis

5.2.5.1 Spatial analysis

Spatial analyses were performed using GeoDa version 1.8.10 (geodacenter.github.io), QGIS version 2.18.0 (qgis.org) and ArcGIS version 10.1 (arcgis.com) with base files of the administrative regions for Ethiopia obtained from DIVA-GIS (diva-gis.org). The spatial analysis was conducted by joining the occurrence of anaemia in each cluster (as a proportion) to the corresponding geospatial location (survey cluster values). The values of the EDHS data were merged with the GPS dataset in GeoDa, and these values were imported into QGIS. Anaemia proportions were then computed at lower (cluster), zonal and regional levels using QGIS.

The spatial pattern of the rate of anaemia among women of reproductive age was visualised and a spatially smoothed proportion was obtained through empirical Bayes estimation methods (246). The smoothed proportions presented clearer patterns: that is, where the problem was most severe. The spatial empirical Bayes 'smooth' estimates technique was able to deal with spatial heterogeneity. The estimation technique guarantees that estimates of neighbouring states are more alike than estimates of states that are further away (247).

A standardised prevalence rate, or the ratio of the observed prevalence rate to a national prevalence rate, was determined using GeoDa (247). GeoDa implements this in the form of an excess risk estimate as part of the map. The excess risk rate is the ratio of the observed rate to the average rate computed for all the data (247).

Furthermore, a spatial analysis was performed to identify the clustering of anaemia in women or hotspot areas (the areas that have higher anaemia prevalence rates compared to the national average) in different regions of Ethiopia. Spatial analysis is an epidemiological method useful for identifying geographic areas with high or low rates of disease occurrence and variability over the region or country (245). The Getis-Ord Gi* statistic was used for this spatial analysis.

Local Getis-Ord Gi* statistics (248) were important for identifying the hot and cold spot areas for anaemia in women of reproductive age using GPS latitude and longitude coordinate readings, which were taken at the nearest community centre for EAs or 2016 EDHS clusters (48). An anaemia hotspot refers to the occurrence of high prevalence rates of anaemia clustered together on the map, whereas cold spot refers to the occurrence of low prevalence rates of anaemia clustered together on the map (248).

A local Getis-Ord Gi* statistic tool in ArcGIS was used to calculate the spatial variability of high and low prevalence rates of anaemia among women of reproductive age. Autocorrelation can be classified into positive and negative correlation through local Getis-Ord Gi* statistics (248). Positive autocorrelation occurs when similar values are clustered together on a map (high rates surrounded by nearby high rates or low rates surrounded by nearby low rates). Negative autocorrelation indicates different values are clustered together on a map: that is, high values surrounded by nearby low values or low values surrounded by nearby high values. Statistical significance of autocorrelation was determined by *z* scores and *p* values with a 95% level of confidence. The distribution of and variations in anaemia prevalence rates among women across the country were displayed on the map.

5.2.5.2 Statistical analysis

The descriptive statistical analysis was performed using SPSS version 24.0 (spss.com) and complex sample analysis. Frequencies, percentages and standard deviations were used for the descriptive analysis. Since some regions with small populations were over-sampled, while others with large populations were under-represented, the weighted frequencies and percentages (based on the population sizes of each region) were computed as a correction. The detailed weighting procedure is described in the 2016 EDHS report (48). The mean and standard deviation were computed for blood Hgb level. The mean Hgb value was also compared across different independent categorical variables using one-way ANOVA.

The multivariable multilevel logistic regression model was used to determine the association between different factors and anaemia among women. The analysis was performed using SAS version 9.4 (SAS, North Carolina State University, sas.com) using PROC GLIMMIX with Laplace's method. For this multilevel analysis, four models were constructed. The first model was constructed without independent variables to assess the effect of community variation on anaemia among women. The second model incorporated individual-level factors. The third model included community-level factors. Finally, the fourth model included both individual- and community-level factors.

The results of fixed effects analysis were presented as odds ratios with 95% confidence intervals. An AOR with 95% confidence intervals was computed to identify the independent factors of anaemia among women and a $p < 0.05$ was used as a measure of statistical significance. A multicollinearity test was performed to rule out a significant correlation between variables. If the values of the VIF were lower than 10, then the collinearity problem was considered less likely. Random effects (variation of effects) were measured with the ICC (variance partition coefficient) (249), PCV (250) and MOR (249, 251), which measured the variability between clusters in multilevel models. The ICC explains the cluster variability, while the MOR can quantify unexplained cluster variability (heterogeneity). The MOR translates cluster variance into an odds ratio scale. In the multilevel model, the PCV can measure the total variation due to factors at the community and individual levels (250). The ICC, PCV and MOR were determined using the estimated variance of clusters utilising the following formulas (249, 250):

$$ICC = \frac{V}{(V + \frac{\pi^2}{3})} \text{ and}$$

$$MOR = \exp\sqrt{2 \times V \times 0.6745} \sim \exp(0.95\sqrt{V}),$$

where V is the estimated variance of clusters, and

$$PCV = \frac{(V_A - V_B)}{V_B} \times 100,$$

where V_A is the variance of the initial model and V_B is the variance of the model with more terms.

The multilevel analysis model is one of the analysis methods that could correctly handle the correlated data (252). A multilevel model evaluates how factors at different levels affect the dependent variable. A multilevel model provides correct parameter estimates by correcting the biases introduced from clustering and by producing correct standard errors, thus producing correct confidence intervals and significance values (252)

5.2.6 Ethics considerations

Publicly available 2016 EDHS data were used for this study. The 2016 EDHS was approved by the National Research Ethics Review Committee of Ethiopia (Ref. No. 310/114/2016; see Appendix 1) and ICF Macro International (see Appendix 2). Informed consent was taken from each participant and all identifiers were removed. Approval was obtained from MEASURE DHS to use the 2016 EDHS dataset. This analysis was approved by the University of Newcastle Human Research Ethics Committee (Ref. No. H-2018-0045; see Appendix 3).

5.3 Results

5.3.1 Sociodemographic characteristics

The data on 14,923 women were included in this analysis, including 642 clusters nested in 11 regions. The descriptive statistics of the study participants are presented in Table 5.1. The mean (±*SD*) age of the respondents was 28.2 years (±9.2 years). The majority of participants lived in a rural area (78%). Nearly two-thirds (66%) of participants were married or living with a partner. Almost half (48%) of the women had no formal education, and around 43% were of the Orthodox Tewahdo Christian religion. Only 18% of the households had access to a piped water source for drinking, and 15% had access to an improved latrine facility. Nearly one-third (*n* = 4657; 31.2%) of women were breastfeeding at the time of the survey (see Table 5.1). The average Hgb level among lactating mothers was 12.6 g/dL (±1.7 g/dL), and about 28.3% (95% CI: 25.7, 31.0%) of these women were anaemic.

Table 5.1 Sociodemographic and other health-related characteristics of study participants included in the analysis, 2016 EDHS.

Variables	Weighted frequency	Weighted %
Age (years)		
15–19	3,165	21.2
20–29	5,467	36.6
30–39	4,078	27.3
40–49	2,213	14.8
Place of residence		
Urban	3,169	21.2
Rural	11,754	78.8
Educational status		
No education	7,215	48.3
Primary	5,244	35.1
Secondary	1,676	11.2
Higher	789	5.3
Marital status		
Single	3,758	25.2

Variables	Weighted frequency	Weighted %
Married	9,800	65.7
Divorced/widowed/separated	1,365	9.1
Religion		
Orthodox	6,447	43.2
Protestant	3,514	23.5
Muslim	4,645	31.1
Other	317	2.1
Region		
Tigray	1,073	7.2
Afar	119	0.8
Amhara	3,645	24.4
Oromia	5,422	36.3
Somali	417	2.8
Benishangul-Gumuz	146	1.0
SNNPR	3,124	20.9
Gambella	42	0.3
Harari	32	0.2
Addis Ababa	825	5.5
Dire Dawa	77	0.5
Wealth index		
Poorest	2,519	16.9
Poorer	2,717	18.2
Middle	2,891	19.4
Richer	2,979	20.0
Richest	3,816	25.6
BMI		
< 18.5	3,060	22.1
18.5–24.9	9,740	70.5
≥ 25	1,018	7.4
Birth interval (months)		
< 24	1,415	18.3
≥ 24	6,305	81.7
Current use of contraceptives		
Yes	1,088	7.3
No	13,835	92.7
Iron/folate intake during pregnancy (n = 7328)		

Variables	Weighted frequency	Weighted %
Yes	3,108	42.4
No/don’t know	4,220	57.6
Gravidity of women (children ever born)		
0	4,745	31.8
1–3	4,715	31.6
4+	5,464	36.6
Children ever born in the preceding 5 years		
0	7,595	50.9
1	4,475	30.0
2+	2,852	19.1
Currently breastfeeding		
Yes	4,657	31.2
No	10,266	68.8
Currently pregnant		
Yes	1,088	7.3
No	13,835	92.7
Smoking		
Yes	96	0.6
No	14,827	99.4
Births in the last year		
0	12,474	83.6
1–2	2,449	16.4
HIV test		
Positive	187	1.3
Negative	1,4724	98.7
Water source		
Piped water	2,646	17.7
Other improved	6,926	46.4
Unimproved	5,351	35.9
Latrine facility type		
Improved toilet	2,231	14.9
Unimproved toilet	7,877	52.8
Open defecation	4,414	29.6
Other	401	2.7
Anaemia status		
Anaemic	3,527	23.6

Variables	Weighted frequency	Weighted %
Non-anaemic	11,396	76.4
Proportion of women in the community who have clean water source; *M* (*SE*)	64.1 (33.6)	
Proportion of women in the community who have unimproved latrine facility; *M* (*SE*)	85.1 (25.0)	
Proportion of women in the community who are in the lowest quantile of wealth index; *M* (*SE*)	35.1 (30.0)	
Percentage of unimproved water per cluster; *M* (*SE*)	35.9 (33.6)	

Note. *N* = 14,923. SNNPR = Southern Nations, Nationalities and Peoples' Region; BMI = body mass index; HIV = human immunodeficiency virus; M= mean; SE= Standard Error

5.3.2 Prevalence rate of anaemia among women

Among all respondents, the mean (±SD) blood Hgb level (adjusted for altitude) was 12.8 g/dL (±1.7 g/dL). The overall prevalence of anaemia among women of reproductive age across the country was 23.6% (95% CI: 22.0, 25.3). The prevalence of mild, moderate and severe anaemia among all women of reproductive age was 17.8% (95% CI: 16.7, 19), 5.0% (95% CI: 4.3, 5.8) and 0.8% (95% CI: 0.5, 1.2), respectively. There was regional variation in anaemia prevalence among women of reproductive age (p = 0.0001) and higher prevalence rates observed in the Afar, Somali, Gambella, Dire Dawa and Oromia regions. A lower prevalence of anaemia was observed in the Addis Ababa, Tigray and Amhara regions. Rural areas had a higher prevalence of anaemia in women (25.4%; 95% CI: 23.5, 27.4) than compared to urban areas (17.0%; 95% CI: 14.4, 20.0; p = 0.0001). The highest proportion of anaemia among women was found in the Somali Regional State, while the lowest proportions were found in Addis Ababa (see Table 5.2).

Table 5.2 The variation of anaemia prevalence rates across different regions and different sociodemographic characteristics of women in Ethiopia, 2016.

	Weighted frequency			
Region	Anaemic	Non-anaemic	Weighted proportion of anaemia (95% CI)	*p*
Place of residence				0.0001
Urban	538	2,630	17.0 (14.4, 20.0)	
Rural	2,989	8,766	25.4 (23.5, 27.4)	
Region				0.0001
Tigray	212	861	19.7 (16.8, 23.0)	

Region	Weighted frequency		Weighted proportion of anaemia (95% CI)	*p*
	Anaemic	Non-anaemic		
Afar	53	66	44.7 (39.9, 49.6)	
Amhara	627	3,019	17.2 (14.9, 19.7)	
Oromia	1,480	3,942	27.2 (23.8, 31.1)	
Somali	248	169	59.5 (55.2, 63.7)	
Benishangul-Gumuz	28	118	19.2 (16.1, 22.7)	
SNNP	704	2,420	22.5 (19.4, 26.0)	
Gambella	11	31	26.1 (21.3, 31.5)	
Harari	9	23	27.7 (23.7, 32.1)	
Addis Ababa	132	693	16.0 (13.5, 18.8)	
Dire Dawa	23	54	30.0 (25.8, 34.8)	
Educational status				0.0001
No education	2,002	5,212	27.8 (25.4, 30.2)	
Primary	1,136	4,108	21.7 (19.8, 23.7)	
Secondary	297	1,378	17.8 (14.9, 21.0)	
Higher	91	697	11.5 (8.2, 16.0)	
Wealth index				0.0001
Poorest	863	1,656	34.3 (29.7, 39.1)	
Poorer	688	2,028	25.3 (22.6, 28.3)	
Middle	686	2,205	23.7 (21.2, 26.5)	
Richer	625	2,354	21.0 (18.6, 23.6)	
Richest	664	3,152	17.4 (15.1, 19.9)	
Currently pregnant				0.003
Yes	317	771	29.1 (24.9, 33.7)	
No	3,210	10,625	23.2 (21.6, 24.9)	
Currently breastfeeding				0.0001
Yes	1,317	3,340	28.3 (25.7, 31.0)	
No	2,210	8,055	21.5 (20.0, 23.2)	
Total	**3,527**	**11,396**	**23.6 (22.0, 25.3)**	

Note. SNNP = Southern Nations, Nationalities and Peoples.

Around 1088 (7.3%; 95% CI: 6.6, 8.1) participants were pregnant at the time of the interview. The mean Hgb level among pregnant women was 11.7 g/dL (±1.8 g/dL) and 29.1% (95% CI: 24.9, 33.7) of these women were anaemic. The prevalence of anaemia was higher among pregnant women (29.1%; 95% CI: 24.9, 33.7) than non-pregnant women (23.2; 95% CI: 21.6, 24.9; p = 0.003; see Table 5.2). The mean Hgb value of women in their second and third trimesters was significantly lower compared to women in their first trimester (p = 0.001). The mean Hgb levels in pregnant women who had less than a 24-month birth interval (for their most recent birth) were significantly lower compared to women who had a birth interval of less than or equal to 24 months (p = 0.0001). Similarly, receiving iron/folate supplements during pregnancy improved the mean Hgb values in pregnant women (see Table 5.3).

Table 5.3 Hgb levels among pregnant women in Ethiopia, 2016.

Variables	**Number**	**Hgb level (g/dL)** ***M*** **(*SD*)**	***p****
Children ever born	1,088		0.0001
0	213	12.1 (1.7)	
1–3	484	11.7 (1.8)	
4+	390	11.5 (1.8)	
Pregnancy stage	1,088		0.0001
1st trimester	226	12.4 (1.7)	
2nd trimester	433	11.6 (1.6)	
3rd trimester	429	11.5 (1.9)	
CEB in last 5 years	1,088		0.0001
0	339	12.1 (1.7)	
1	484	11.7 (1.8)	
2+	265	11.4 (1.9)	
Fe-Fol supplementation	749		0.018
Yes	251	11.8 (1.5)	
No	498	11.5 (1.9)	
Birth interval	702		0.0001
< 24 months	206	11.2 (2.0)	
≥ 24 months	497	11.9 (1.5)	

Note. Hgb = haemoglobin; CEB = children ever born; Fe-Fol = iron–folate
*of ANOVA or independent t test.

5.3.3 Determinant factors of anaemia among women of reproductive age

5.3.3.1 Multilevel Analysis (fixed-effects analysis)

The results of multilevel logistic regression for the individual- and community-level variables are presented in Table 5.4. In the full model, in which all individual- and community-level factors are included, residence, education, religion, wealth index, pregnancy, breastfeeding status, gravidity and lack of availability of an improved latrine were factors significantly associated with anaemia in women. The results of the multicollinearity test indicated that no collinearity problem existed, since the VIF of all variables was lower than 10.

5.3.3.1.1 Individual-level factors

The average Hgb value was significantly different across age groups (p = 0.0001). The highest mean Hgb level (13 g/dL) was observed in the youngest (15–19 years) age group, while the lowest mean Hgb level (12.71 g/dL) was observed in the 30–34 years age group. The general pattern indicated a roughly linear decline among women aged 15–34 years (see Figure 5.2). Women aged 40–49 years were 25% less likely to be anaemic compared to women in the youngest age group (15–19 years old; AOR = 0.75; 95% CI: 0.64, 0.96). Women with limited education were 1.37 times more likely to be anaemic than women who had completed higher education (AOR = 1.37; 95% CI: 1.102, 1.72). The odds of anaemia increased by 29% (AOR = 1.29; 95% CI: 1.014, 1.60) when comparing the poorest women to the richest women. The odds of anaemia were higher in women who were pregnant (AOR = 1.28; 95% CI: 1.10, 1.51) compared to those who were not pregnant. Women who were currently breastfeeding were 9% (AOR = 1.09; 95% CI: 1.025, 1.28) more likely to be anaemic. The odds of anaemia were 39% higher among mothers who had given birth to four or more children (AOR = 1.39; 95% CI: 1.13, 1.69). Women who had given birth to two or more children in the five years preceding the survey were at higher risk of having anaemia (AOR = 1.31; 95% CI: 1.09, 1.57). In this study, women who were HIV-positive had twofold increased odds of having anaemia compared to women classified as HIV-negative (AOR = 2.11; 95% CI: 1.59, 2.79; see Table 5.4).

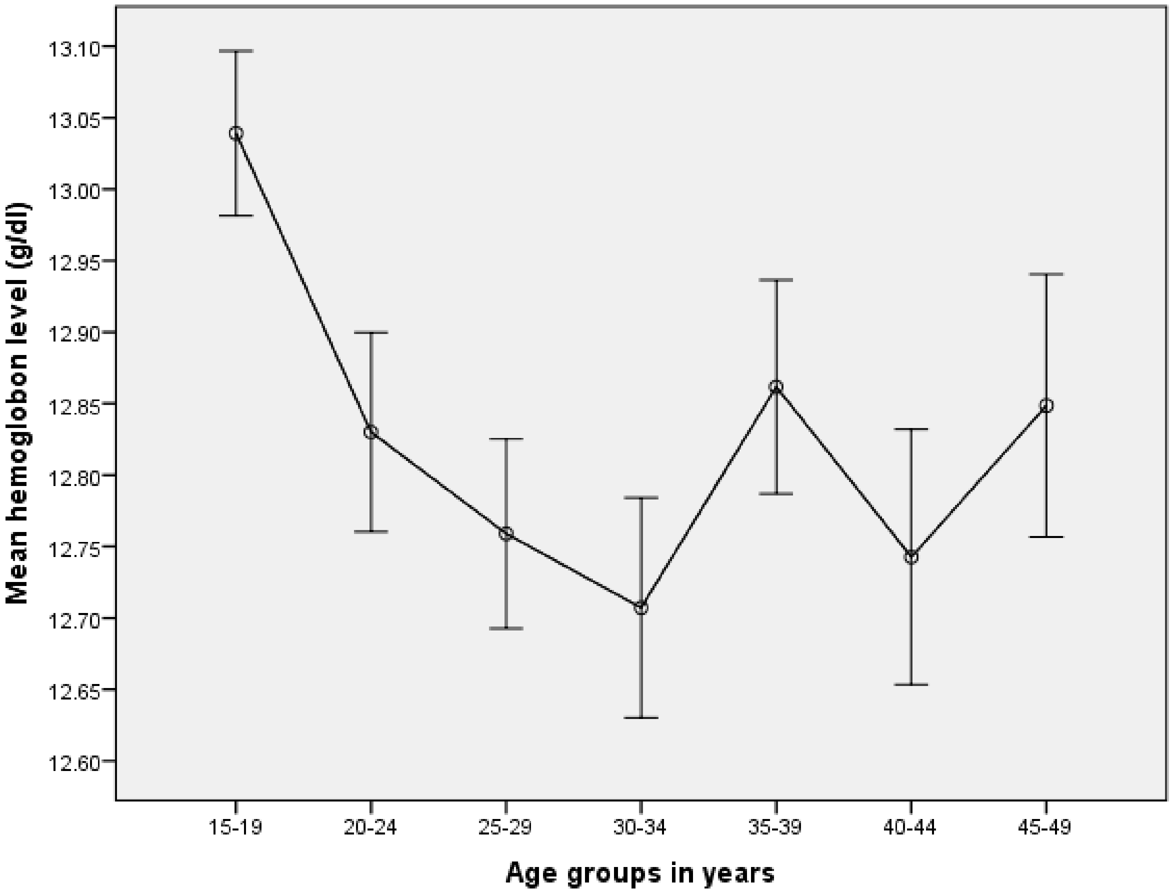


Figure 5-2 Average Hgb value, with 95% CI, for women of reproductive age in different age groups, Ethiopia, 2016.

5.3.3.1.2 Community-level factors

Living in a rural area was associated with 29% higher odds of anaemia among women of reproductive age than women who were urban residents (AOR = 1.29; 95% CI: 1.02, 1.63). Women from households without access to a latrine had 18% higher odds of anaemia compared to women from households that had an improved latrine facility (AOR = 1.18; 95% CI: 1.01, 1.39). Higher odds of anaemia were observed in Somali Regional State (AOR = 2.16; 95 % CI: 1.58, 2.90) compared to Dire Dawa. However, the odds of anaemia among women were lower in Gambella, Addis Ababa, Amhara and Oromia regions compared to Dire Dawa (see Table 5.4).

5.3.3.2 Multilevel analysis (random-effects analysis)

The results of the random-effects model are shown in Table 5.4. Prevalence rates of anaemia varied across communities ($t^2 = 0.88$, $p \leq 0.0001$). In other words, the anaemia prevalence rate was not similarly distributed across the communities. About 21% of the variance in the odds of anaemia in women could be attributed to community-level factors, as calculated by the ICC based on estimated intercept component variance. After adjusting for the individual and community-level factors, the variation in anaemia across communities remained statistically significant. About 16% of the odds of anaemia variation across communities was observed in the full model (Model 4; see Table 5.4).

Moreover, the MOR indicated that anaemia was attributed to community-level factors. The MOR for anaemia was 2.44 in the empty model (Model 1); this shows that there was variation between communities (clustering) since MOR was 2.4 times higher than the reference (MOR = 1). The unexplained community variation in anaemia decreased to a MOR of 2.1 when all factors were added to the null model (empty model). This indicates that, when all factors are included, the effect of clustering is still statistically significant in the full model (see Table 5.4).

Table 5.4 Adjusted odds ration from multivariable multilevel logistic regression analysis for determinant factors associated with anaemia among Ethiopian women, 2016.

Variables	AOR(95%CI) Model 1	AOR(95%CI) Model 2	AOR(95%CI) Model 3	AOR(95%CI) Model 4
Individual-level factors				
Age (years)				
15–19		1		1
20–29		0.93 (0.81, 1.07)		0.96 (0.82, 1.19)
30–39		0.89 (0.75, 1.10)		0.92 (0.78, 1.11)
40–49		0.76 (0.61, 0.92)		0.75 (0.64, 0.96)
Educational status				
No education		1.41 (1.13, 1.76)		1.37 (1.10, 1.72)
Primary		1.22 (0.99, 1.51)		1.24 (1.00, 1.53)
Secondary		1.22 (0.98, 1.5)		1.23 (0.98, 1.52)
Higher		1		1
Marital status				
Single		0.99 (0.80, 1.22)		0.97 (0.81, 1.22)
Married		1.07 (0.92, 1.23)		1.09 (0.91, 1.23)
Divorced/widowed/separated		1		1
Religion				
Orthodox		1		
Protestant		1.36 (1.16, 1.58)		1.37 (1.15, 1.63)

Variables	AOR(95%CI) Model 1	AOR(95%CI) Model 2	AOR(95%CI) Model 3	AOR(95%CI) Model 4
Muslim		2.04 (1.79, 2.33)		1.36 (1.16, 1.58)
Other		1.49 (1.05, 2.12)		1.52 (1.06, 2.13)
Wealth index				
Poorest		1.73 (1.48, 2.03)		1.29 (1.01, 1.60)
Poorer		1.31 (1.10, 1.54)		1.21 (0.96, 1.45)
Middle		1.28 (1.08, 1.51)		1.22 (0.98, 1.50)
Richer		1.04 (0.88, 1.24)		1.01 (0.82, 1.24)
Richest		1		1
Currently using contraceptives				
Yes		0.99 (0.90, 1.10)		1.0 (0.91, 1.11)
No		1		1
Currently pregnant				
Yes		1.30 (1.11, 1.52)		1.28 (1.10, 1.51)
No		1		1
Currently breastfeeding				
Yes		1.12 (1.00, 1.24)		1.09 (1.03, 1.28)
No		1		1
Gravidity of women (total children ever born)				
0		1		1
1–3		1.23 (1.03, 1.46)		1.22 (1.02, 1.44)
4+		1.40 (1.15, 1.72)		1.39 (1.13, 1.69)
Smoking				
Yes		0.98 (0.64, 1.50)		1.05 (0.69, 1.61)
No		1		1
Birth in the last 1 year				
0		1		1
1–2		1.20 (1.05, 1.37)		1.15 (1.01, 1.32)
Children ever born in preceding 5 years				
0		1		1
1		1.12 (0.96, 1.29)		1.10 (0.95, 1.27)
2+		1.39 (1.16, 1.66)		1.31 (1.09, 1.57)
HIV test				
Positive		2.19 (1.65, 2.91)		2.11 (1.59, 2.79)
Negative		1		1
Community-level factors				
Place of residence				

Variables	**AOR(95%CI) Model 1**	**AOR(95%CI) Model 2**	**AOR(95%CI) Model 3**	**AOR(95%CI) Model 4**
Urban			1	1
Rural			1.67 (1.35, 2.05)	1.29 (1.02, 1.63)
Region				
Tigray			0.39 (0.28, 0.53)	0.52 (0.38, 0.72)
Afar			1.25 (0.91, 1.70)	1.14 (0.83, 1.56)
Amhara			0.30 (0.22, 0.41)	0.39 (0.28, 0.54)
Oromia			0.55 (0.41, 0.75)	0.57 (0.42, 0.78)
Somali			2.40 (1.78, 3.27)	2.16 (1.58, 2.90)
Benishangul-Gumuz			0.36 (0.25, 0.50)	0.37 (0.26, 0.52)
SNNPR			0.40 (0.29, 0.54)	0.41 (0.29, 0.57)
Gambella			0.63 (0.45, 0.87)	0.63 (0.45, 0.89)
Harari			0.74 (0.53, 1.04)	0.76 (0.54, 1.04)
Addis Ababa			0.54 (0.39, 0.73)	0.67 (0.49, 0.91)
Dire Dawa			1	1
Water source				
Piped water			1	1
Other improved			1.15 (0.95, 1.39)	1.04 (0.86, 1.26)
Unimproved			1.18 (0.95, 1.44)	1.03 (0.83, 1.27)
Latrine facility type				
Improved toilet			1	1
Unimproved toilet			1.12 (0.97, 1.29)	1.08 (0.94, 1.25)
Open defecation			1.33 (1.15, 1.55)	1.18 (1.00, 1.39)
Other			0.86 (0.64, 1.17)	0.94 (0.69, 1.27)
Random effects (effect of variation/measure of variation for anaemia)				
Community-level variance (*SE*)	0.888 (0.07)	0.46 (0.05)	0.32 (0.04)	0.31 (0.035)
p	0.001	0.001	0.001	0.001
DIC (–2 log-likelihood)	7926.056	7749.25	7720.74	7613.56
ICC (%)	21.25	16.10	18.30	15.86
Explained variation: PCV (%)	Reference	40.95	21.00	43.10
MOR	2.44	2.13	2.30	2.10

Note. Model 1 = empty model (without predictors); Model 2 = adjusted for individual factors; Model 3 = adjusted for community-level factors; Model 4 = adjusted for both community- and individual-level factors. HIV = human immunodeficiency virus; SNNPR = Southern Nations, Nationalities and Peoples' Region; DIC = deviance information criterion; ICC = intra-cluster correlation coefficient; PCV = percentage change in variance; MOR = median odds ratio.

5.3.4 Spatial data analysis

Figure 5.3 displays the empirical Bayes smoothed proportion estimate of anaemia among women across regions in Ethiopia. A severe anaemia prevalence rate (≥ 40%) among women of reproductive age was observed in Afar and Somali regional states. Likewise, a moderate anaemia prevalence rate (20%–40%) was observed for Oromia, Gambella, SNNP's, Harari and Dire Dawa regional states. Conversely, a mild anaemia prevalence rate (< 20%) was observed in Tigray and Amhara regional states and Addis Ababa.

Similarly, the standardised prevalence ratio by region (standardised to the national average prevalence of 23.6%), ranging from 0.63 to 2.39, is displayed in Figure 5.4. A higher prevalence ratio of anaemia was observed in Somali (2.39), Afar (1.8) Oromia (1.17), Dire Dawa (1.15) and Gambella (1.12) regional states (see Figure 5.4). A lower prevalence ratio of anaemia occurred in other regional states: Addis Ababa (0.64), Amhara (0.76), Benishangul-Gumuz (0.79), SNNP's Region (0.96) and Tigray (0.85).

Figure 5.5 displays the smoothed anaemia prevalence rates at the zonal level, where higher anaemia rates were observed in all zones in Afar and Somali regions as well as in some zones in Oromia. Similarly, the higher standardised ratios of anaemia were observed in all zones in Afar and Somali regions as well as in some zones in Oromia (see Figure 5.6).

The spatial distributions of anaemia among women at the lower level (cluster level) is displayed in Figure 5.7. The spatial investigation at the cluster level indicated statistically high hotspots of anaemia in the eastern (Somali, Dire Dawa and Harari regions) and in north-eastern (Afar) parts of the country, while cold spots of anaemia were observed in the northern (Tigray, Amhara), central (Addis Ababa and Oromia) and western (Benishangul-Gumuz and Gambella) parts of the country (see Figure 5.7).

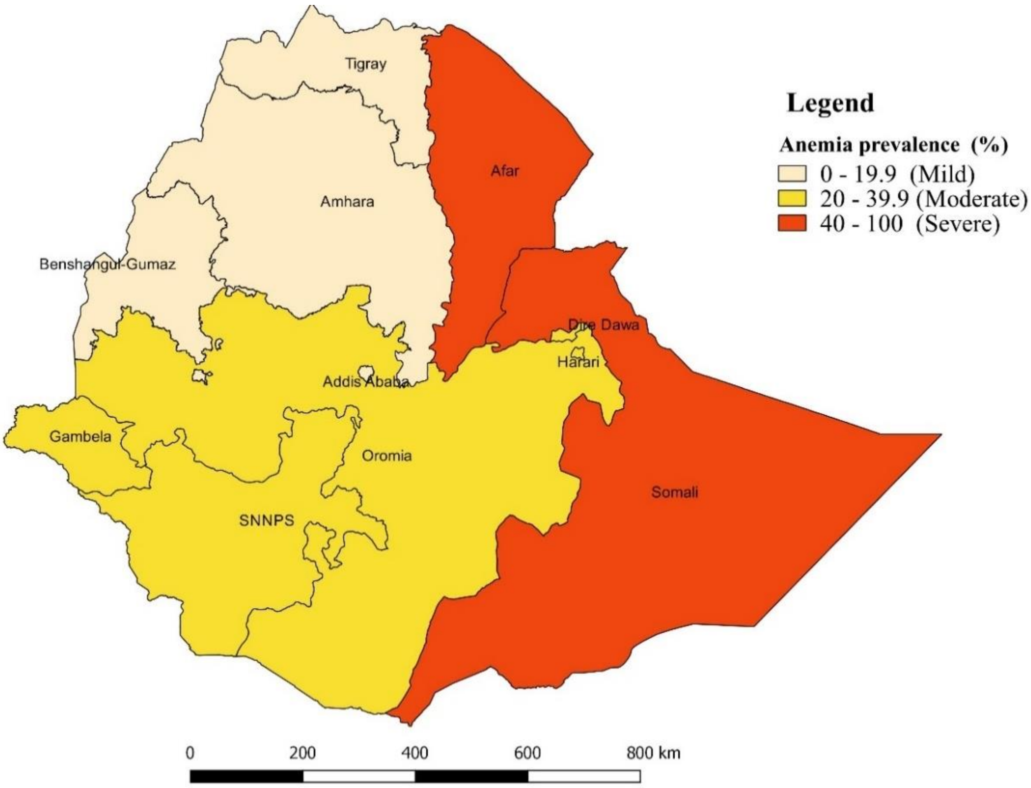


Figure 5-3 Spatial empirical Bayesian smoothed percentage of anaemia among women of reproductive age across regions, 2016 EDHS.

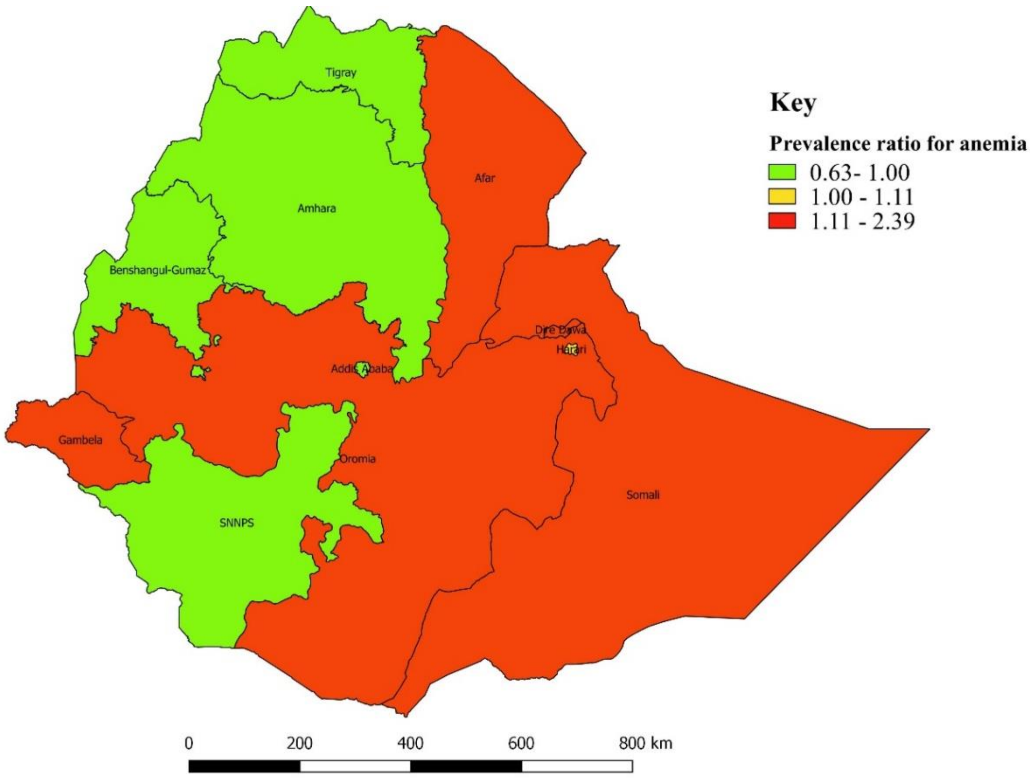


Figure 5-4 Standardised prevalence ratio for anaemia among women of reproductive age across the regions in Ethiopia (standardised to national prevalence of 23.6%), 2016 EDHS.

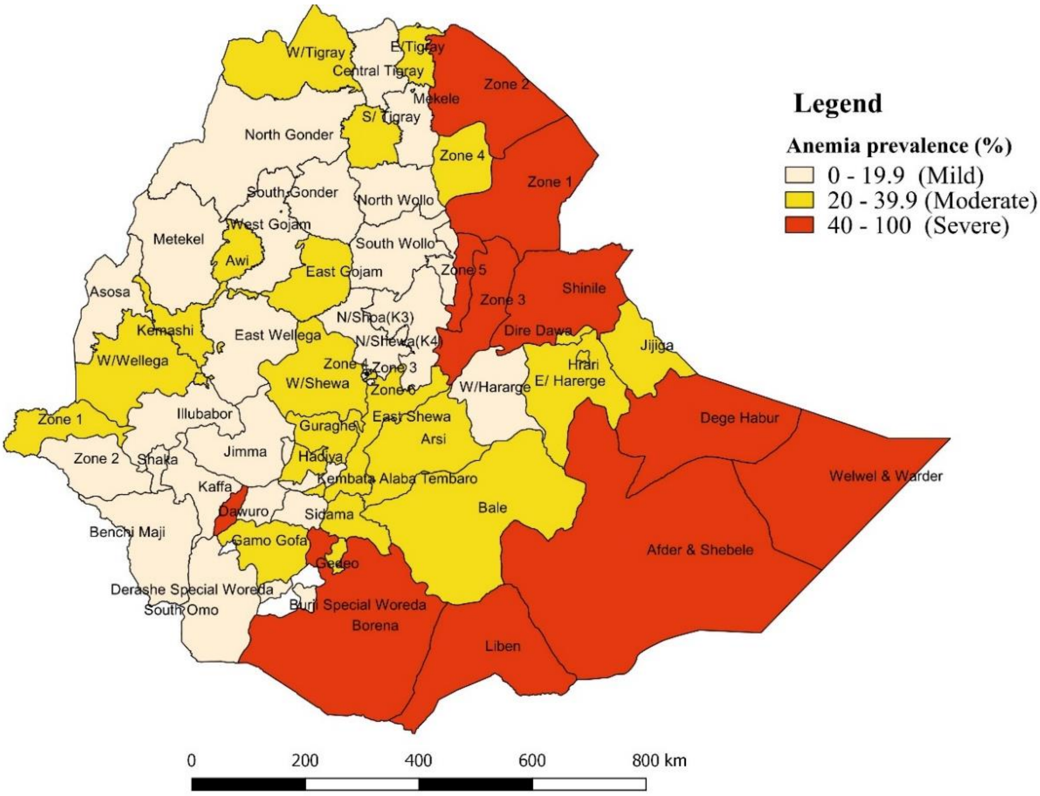


Figure 5-5 Spatial empirical Bayesian smoothed proportion of anaemia among women of reproductive age at zonal level, 2016 EDHS.

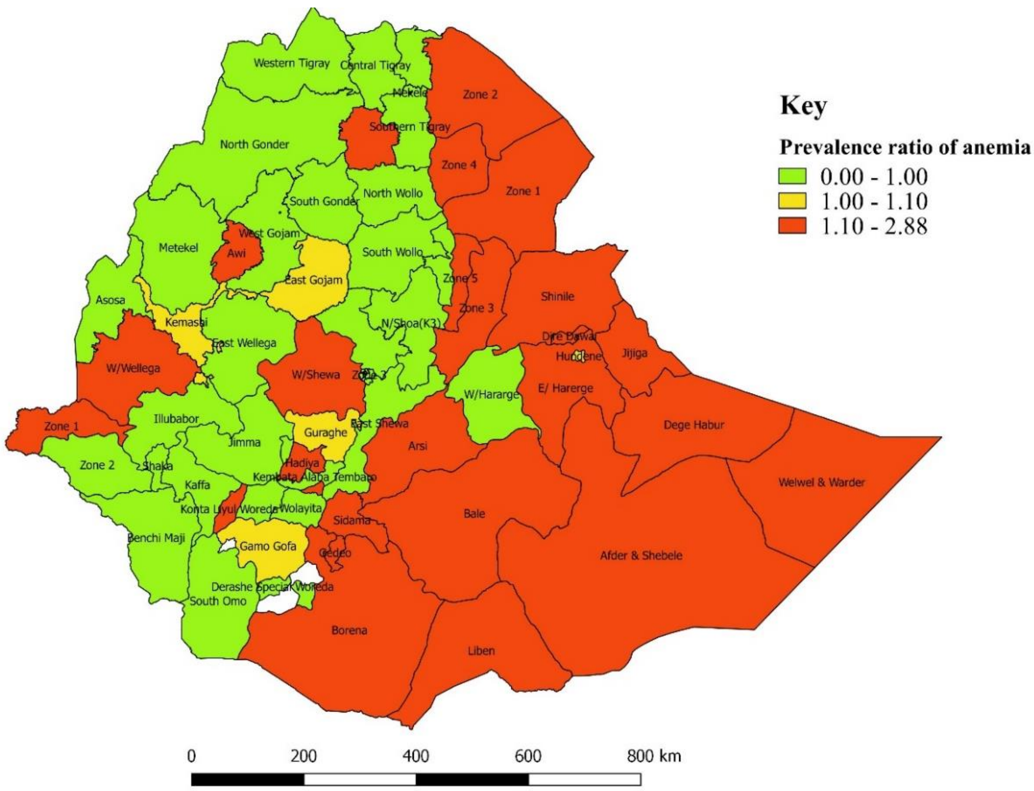


Figure 5-6 Standardised prevalence ratios for anaemia among women of reproductive age across zones in Ethiopia (standardised to national prevalence of 23.6%), 2016 EDHS.

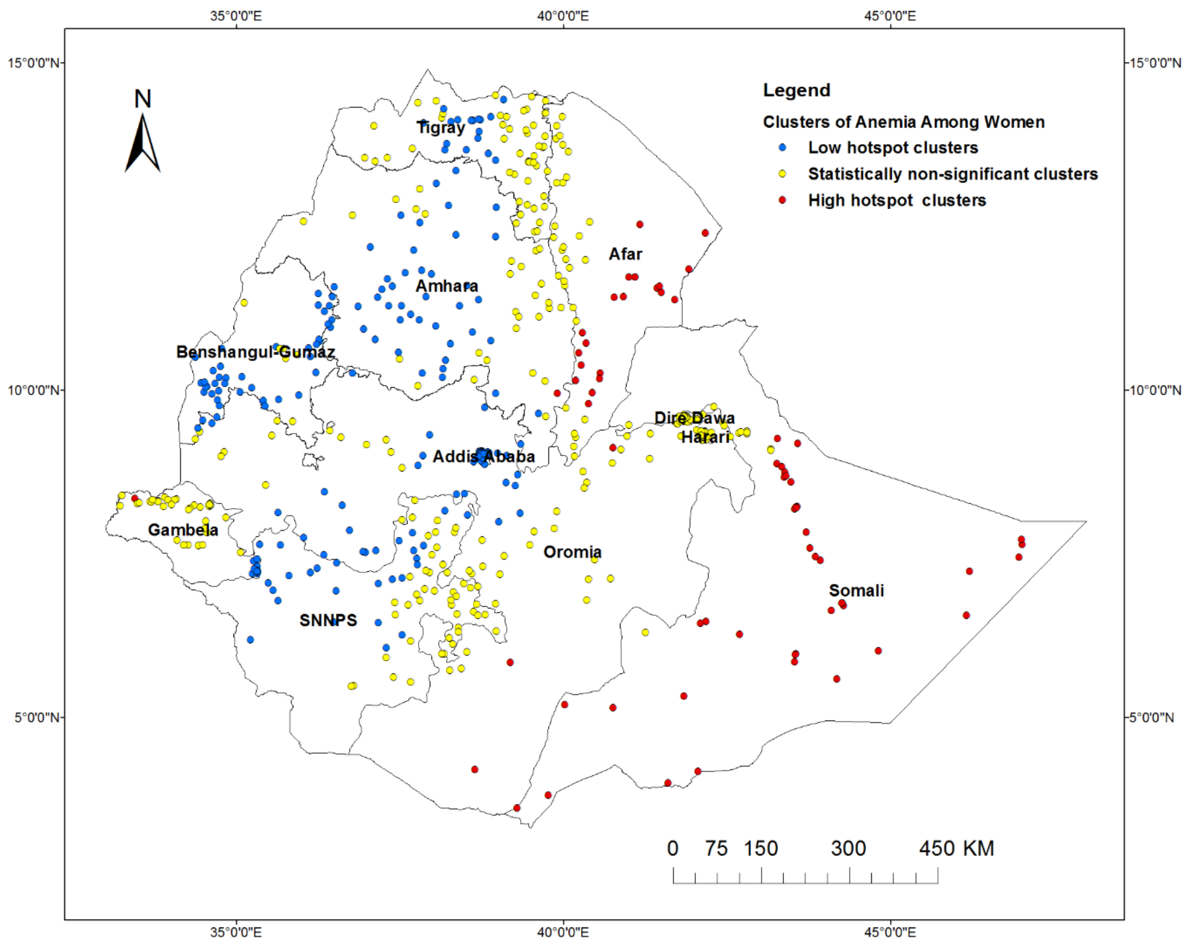


Figure 5-7 Spatial pattern of hotspots and cold spots of anaemia rates among women of reproductive age at the cluster level in Ethiopia, 2016 EDHS.

5.4 Discussion

Approximately a quarter of women of reproductive age were anaemic in the current study, indicating that anaemia is a moderate public health problem at the national level in Ethiopia (62). However, geographic differences demonstrated that anaemia is a serious public health problem in five of the 11 Ethiopian states. A higher proportion of anaemia cases was observed in the eastern and north-eastern parts of the country, which are less developed compared to other Ethiopian states in terms of economy, gender equality, healthcare facilities and food availability (51). The geographical differences of anaemia across the regional states might be attributable to the regional variation of food consumption preferences (55, 56), the occurrence of communicable diseases such as helminths (54) and malaria (329) and differences in availability of healthcare facilities (68). In addition, the lack of clean water and unimproved latrine facilities would increase the occurrence of soil-transmitted infections (105), which in turn could lead to anaemia (106). This might explain some of the observed geographical differences.

According to the final model, both individual- and community-level factors were responsible for about 43% of the disparity of anaemia prevalence rates among women of reproductive age in Ethiopia. After adjusting for all factors in the model, the likelihood of having anaemia was higher among those of younger age, with lower levels of education, living in rural areas, in the lowest wealth quantile, who were currently pregnant or breastfeeding, with high gravidity, who had given birth in the year prior to the survey and who were without access to an improved latrine facility.

Women aged 40–49 years had a lower likelihood of being anaemic compared to women aged 15–19 years. This finding is in line with other study findings from Ethiopia (77, 327) and Benin (96). This could be due to the fact that low fertility rates occurred in this age group (40–49 years) (48). However, in Iran (83), it has been reported that women aged 20–24 years were less likely to be anaemic compared to those aged 45–49 years; this might be a result of Iran having targeted interventions for younger women or women of reproductive age (83).

In this study, it was found that there was a variation of the anaemia rate in terms of the educational status of women. A higher proportion of anaemic cases were observed among women with no education. It was found that women who did not have formal education had higher odds of being anaemic than those with a higher education. This is consistent with other studies conducted in developing countries (70), including in Ethiopia (77), Timor-Leste (82), Benin (96) and India (76, 97), in which it was reported that a low level of education was associated with higher odds of anaemia among women of reproductive age. Formal education might assist women in obtaining knowledge that in turn helps them to follow better personal behaviours, like diversified diet intake, and to form better health-seeking habits and hygiene practices that can prevent anaemia among women.

A higher proportion of anaemic cases was observed among women in the poorest wealth quantile. The lowest wealth quantile, compared to the highest quantile, was associated with a higher risk of anaemia. Results of this study show that women who were in the poorest wealth quintile were 30% more likely to be anaemic than women who belonged to the richest quintile; this is in line with the results of other studies conducted in other developing countries (70) like Benin (96) and India (97, 98). This might be due to the fact that having a low income would mean having less money to buy nutritious foods or to have a balanced diet and less likely to afford quality healthcare (36, 219), which in turn leads to inadequate nutrient intake and nutritional status (330). More than 38% of the Ethiopian population belongs to the poor and poorest wealth quintiles, which indicates a large percentage of women are at risk for anaemia because of a low socioeconomic position (48).

Lactating mothers were 9% more likely to have anaemia than non-lactating mothers. Lactating may predispose women to low Hgb, which results in anaemia. In a study conducted in India (80), a similar finding was reported: lactating mothers were more likely to be anaemic than non-lactating women.

The findings of our study clearly show the role of women's fertility in anaemia. Increased odds of anaemia were associated with high gravidity, births in the five years prior to the survey and having a birth in the past year. Similar studies in Ethiopia (77), Iran (83) and Timor-Leste (82) have also documented this association between parity and risk of anaemia. The results of studies from Pakistan (78, 81) and Iran (83) have indicated that women with a parity of four or more were found to be at increased risk of anaemia than women with lower parity. This might be explained by that fact that, the more the women give birth, the more they are exposed to blood loss, which in turn results in low Hgb levels in the blood (85). Similarly, prior births may deplete maternal iron stores due to the increased nutritional demands of pregnancy and puerperal blood loss (86). Consequently, emphasis needs to be placed on family planning services. Increased odds of anaemia were observed in HIV-positive women. In this study, women who were HIV-positive had a twofold increased odds of having anaemia. This could be due to the direct effects of the HIV infection on the bone marrow and depletion of Hgb levels in the blood (93). Many of the opportunistic infections to which patients with HIV are susceptible might also lead to anaemia (93).

This study revealed that there is a significant difference in the proportion of anaemia cases according to the place of residence (i.e., urban or rural). The likelihood of having anaemia was higher for rural residents compared to urban residents. This is in agreement with a study conducted in low-income countries, in which it was revealed that living in a rural area was a determinant factor for anaemia (70). A recent report also illustrated that more than half of the Ethiopian population only had access to unimproved toilet facilities (331). Our study findings revealed that women from households with unimproved latrine facilities were more likely to be anaemic than women from households with improved latrine facilities. This is in agreement with other research findings (96, 104). The possible explanation might be that an unimproved latrine facility exposes women to helminthic infections (105), which in turn results in them developing anaemia (106).

5.5 Strengths and limitations

This study used large population-based data with a large sample size, which was representative of all regions of Ethiopia. Furthermore, a combination of statistical methods (spatial analysis and multilevel logistics analysis) were applied to this study, which allowed for the understanding of the role of contextual and geographical factors in the occurrence of anaemia among women of reproductive age. Due to the cross-sectional nature of the EDHS data, the cause/effect and the temporal relationship could not be established based on these study findings. Similarly, essential factors such as dietary intake and behavioural factors were not available in the EDHS survey, so it was not possible to incorporate these variables in the analysis. Furthermore, EDHS was a questionnaire-based survey and relied on the memory of respondents, and, as such, recall bias in the results might be a weakness of this study.

5.6 Conclusion

This study indicates that considerable geographic disparities in anaemia prevalence rates exist within Ethiopia. The results of this study revealed that anaemia among women varied across the country; significant anaemia hotspots were observed in the eastern and north-eastern parts of the country, while anaemia cold spots were observed in the northern and western parts of the country. About 43% of the disparity in anaemia occurrence across communities was attributable to both individual- and community-level factors. The increased occurrence of anaemia among women was associated with an individual and community-level factors. For women, being of rural residence, having no formal education, being in the poorest wealth index, either currently pregnant or breastfeeding, and higher gravidity were factors that increased the odds of anaemia at the individual level, whereas lack of a clean water source and access to an unimproved toilet facility were factors significantly associated with anaemia among women.

Accordingly, the prevention of anaemia among women requires multifaceted intervention approaches—for instance, improving the economic and educational status of women and improving the availability of clean water and toilet facilities. Anaemia prevention strategies must be targeted at these identified factors. Priority should be given to those states or areas that have anaemia hotspots. In particular, any intervention programs need to be prioritised for pregnant women, women recently giving birth, those with lower levels of education and women living in rural areas. The regions with the greatest numbers of anaemic women (Afar and Somali) should be prioritised, as the burden of anaemia is higher in these areas with more than 50% of women being anaemic.

Acknowledgements

We would like to thank the DHS Program for allowing the use of EDHS data for this study. We are also very grateful to Dr Ryan O'Neill for his help in language editing.

Authors' contributions

Formulating the research question(s): KTK, CC, DL and EG; designing the study: KTK, CC, DL, EG; analysing the data: KTK; interpreting the results: KTK, CC, DL and EG; drafting, writing, reviewing and approving the final manuscript: KTK, CC, DL and EG.

Financial support

This research received no specific grant from any funding agency or the commercial or not-for-profit sectors.

Conflicts of interest

The authors declare that they have no conflicting interests.

Data sharing statement

This study was an in-depth analysis of a publicly available dataset from the DHS Program. The dataset is available at the DHS Program website (measuredhs.com).

Chapter 6: Population attributable fraction estimates for factors associated with different types of anaemia among women in Ethiopia—multilevel multinomial analysis

This study aimed to estimate the PAFs for factors associated with different types of anaemia among women in Ethiopia. This chapter was published in Public Health Nutrition in September 2020.

Kibret KT, Chojenta C, D'Arcy E, Loxton D. Population attributable fraction estimates for factors associated with different types of anaemia among women in Ethiopia: multilevel multinomial analysis. Public Health Nutrition, 2020: doi:10.1017/S1368980020003109.

Abstract

Background: Anaemia is one indicator of poor health in women. There is limited evidence assessing the predictors for anaemia severity levels (mild, moderate-severe) among women of reproductive age in Ethiopia. This study aimed to estimate the PAFs for factors associated with different types of anaemia among women in Ethiopia.

Design: This study was a detailed analysis of the data of the 2016 EDHS, which was a large-scale population-based cross-sectional study. AORs with 95% confidence intervals were computed to identify the independent factors for different levels of anaemia using multilevel multinomial regression models, and the PAFs were estimated using these AORs.

Setting: This study was conducted in Ethiopia.

Subject: This study focused on women of reproductive age.

Results: The PAFs showed that the proportion of mild anaemia cases attributable to having no formal education was 14.6% (95% CI: 3.4, 24.5), high gravidity (≥ 4) was 11.2% (95% CI: 1.2, 19.9) and currently breastfeeding was 5.2% (95% CI: 0.0, 10.7). Similarly, the proportion of moderate-severe anaemia cases attributable to being in a rural residence was 38.1% (95% CI: 15.9, 54.8); poorest wealth quantile, 12.6% (95% CI: 2.9, 24.6); giving birth in the last five years, 10.5% (95% CI: 2.9, 18.2); and unimproved latrine facilities, 17% (95% CI: 0, 32.5).

Conclusions: The PAFs suggest that rural residency, low education, low wealth status, high parity, pregnancy and breastfeeding contribute to the occurrence of anaemia among women in Ethiopia. Mild anaemia could be reduced by setting intervention strategies targeting women with low education, multigravida women and breastfeeding women, while preventing moderate-severe anaemia may require increasing income and improving living environments through the accessibility of hygienic latrines.

Key terms: Population-attributable fractions, anaemia, women, multinomial model.

6.1 Introduction

Anaemia is a major public health concern among women in several low-income countries (332). In 2011, the WHO estimated that nearly 528.7 million women globally were anaemic, mainly in South-East Asian (42%) and African regions (39%) (65). Similarly, about 20.2 million women were severely anaemic, including 0.8 million pregnant women and 19.4 million non-pregnant women (65). The prevalence of moderate-severe anaemia is high in African countries (332).

Evidence suggests that specifying anaemia severity levels is important for appropriate intervention, particularly in settings that require strengthened control efforts to change the burden of anaemia to lower severity levels (70, 117). Findings from the 2016 EDHS indicate that anaemia is a moderate public health problem, and all anaemia levels have increased from 2011 to 2016 (48). Anaemia is a key indicator of poor health among women (119), and several health problems among women have been linked to anaemia, including the risk of maternal morbidity and mortality (7), PTB (8), LBW (8) and perinatal death (138). Moderate–severe anaemia could lead to high blood loss during delivery and the postpartum period (333), which can be prevented by targeting the main factors of moderate-severe anaemia before and during pregnancy. Thus, preventing anaemia in women of reproductive age can improve maternal and perinatal health conditions (70) and subsequent pregnancy and birth outcomes.

Worldwide, the main contributing factors for anaemia are dietary deficiencies, high parity and infections (e.g., geohelminths) (70, 82). Moreover, the risk factors of anaemia among women in low-income countries are varied, contextual and multifaceted. In sub-Saharan Africa, iron deficiency, malaria, low economic status, illiteracy, multiparity and having an intestinal parasitic infection were the main predictors of anaemia in women of reproductive age (77). In Ethiopia, the analysis of previous EDHS data has indicated that wealth index, use of family planning, ANC use and breastfeeding for two years were factors associated with lower odds of having anaemia in lactating mothers (334), and most other studies have focused on pregnant women (46, 66, 113, 114). However, there is limited evidence assessing predictors for anaemia severity levels (mild, moderate or severe) among women of reproductive age in Ethiopia (71, 77).

Additionally, the impact of different factors of anaemia among women of reproductive age has not been evaluated using PAF. PAF is an important tool to measure the impact of factors in the population. PAFs offer estimates of the proportion of anaemia cases that could be prevented if a particular factor were eliminated or at least reduced in the population. PAF takes into consideration the strength of the association between factors, the outcome of interest and the prevalence of the factors in the population (115). Thus, a high association between a disease and a factor might have a low population impact if the factor is rare. Conversely, a low association between a disease and a factor may have a high impact on public health if the factor is common (263). In this sense, the PAF is important for understanding the public health impact of factors in the population and can assist in prioritising public health intervention strategies (116). PAFs are useful for indicating where preventive efforts should be focused to achieve the greatest potential reductions in anaemia cases (261).

This study aimed to identify independent factors for different severity levels of anaemia among Ethiopian women through a multivariable multinomial logistic regression model. This study also aimed to quantify the PAFs to understand the relative contribution of different factors to the occurrence of anaemia using a large-scale, population-based cross-sectional study.

6.2 Methods

6.2.1 Study design and setting

This study used data collected in the 2016 EDHS, which was a population-based cross-sectional study (48) conducted to provide the latest estimates of key demographic and health indicators. The 2016 EDHS datasets are publicly available from MEASURE DHS (measuredhs.com).

6.2.2 Sampling and sample size

The 2016 EDHS used a two-stage cluster sampling technique. The first stage involved selecting 645 clusters (primary sampling units) with probability proportional to the size (the number of households in the cluster). The second stage involved the systematic sampling of households from the selected clusters. A sample of 18,008 households was then selected from the clusters. Of this, 16,650 households were successfully interviewed, with 16,583 eligible women identified for individual interviews. A total of 15,683 women aged 15–49 years were interviewed, and Hgb levels were measured for 14,923 of them (48). Data collection took place from 18 January to 27 June 2016 (~5 months).

6.2.3 Measurements

HemoCue was used to measure Hgb levels of women and all Hgb values were adjusted for altitude and smoking status. Different anaemia levels were defined using WHO cut-off points

(62). Pregnant women with a Hgb value < 11 g/dL and non-pregnant women with a Hgb level < 12 g/dL were considered to have anaemia. Similarly, anaemia was classified according to its severity levels as severe (Hgb < 7 g/dL) and moderate (7.0–9.9 g/dL) in all women. Mild anaemia was classified as a Hgb level of 10.0–10.9 g/dL in pregnant women and a Hgb level of 10.0–11.9 g/dL in non-pregnant women based on WHO recommendations (62). For this study, anaemia was grouped into three categories: 1) non-anaemic, 2) mild anaemia and 3) moderate–severe anaemia. Due to the small number of severe anaemia cases, moderate and severe anaemia cases were merged into a single category for analysis purposes.

The determinant (exposure) variables included for analysis were age (15–24, 25–34, 35–49 years), educational status (no formal education, primary, secondary, tertiary), marital status (single, married/living together, divorced/widowed), place of residence (urban, rural), wealth index (poorest, poorer, middle, richer, richest), number of children ever born (0, 1–3, ≥ 4), births in the last 5 years (0, 1–2), currently pregnant (at the time of the survey: pregnant, not sure/non-pregnant), currently breastfeeding (breastfeeding, non-breastfeeding), current contraceptive use (yes, no), toilet facility (improved, unimproved) and water source (improved, unimproved).

6.2.4 Statistical analysis of the data

All analyses were conducted using Stata version 14 (Stata Corp, College Station, TX, USA, stata.com). Complex sample analysis methods were used (26, 27), which took into consideration the DHS sampling design by incorporating the sampling frame information (primary sampling units and strata) and weights in all analyses, presented as percentages with 95% confidence intervals. Using Stata, the survey analysis module commands ('[SVY]') were used to account for the complex sampling design, including the sampling weight. The prevalence rate of anaemia (any, mild and moderate-severe) was estimated in terms of different factors such as residence, education status, age, wealth index and gravidity.

The independent predictors of mild and moderate-severe anaemia were identified using a multinomial logistic regression model, with non-anaemia used as the reference. A multinomial regression model was selected for the analysis when it was determined that the assumption of proportional odds was not satisfied for an ordinal logistical model, as recommended by Hosmer and Lemeshow (28). Moreover, we wanted to estimate a separate coefficient for each category (mild, moderate-severe) of the outcome, using one category (non-anaemia) as the reference. In this regard, the multinomial model was suitable for estimating the coefficient for each category of the outcome variable. Thus, multinomial logistic regression could enable the extraction of more information from the data and prevent the loss of information due to the collapsing of categories. In addition, the multinomial logistic regression had further advantages: 1) it does not assume a linear relationship between the dependent variable and independent variables, and 2) normally distributed error terms are not assumed (28).

Given the hierarchical structure of the sample, a multivariable multilevel logistic model was initially applied to assess the associations between different factors and any anaemia (yes, no) among women in Ethiopia. Subsequently, multilevel multinomial logistic regression models were used to identify independent predictors for different levels of anaemia (mild and moderate-severe compared to no anaemia). The AORs with 95% confidence intervals were computed using GSEMs (Stata command 'GSEM') (29, 30), which allow for the fitting of complex models and take into consideration the hierarchical structure of the data (31). A $p < 0.05$ was used as a measure of statistical significance in the final model. The random effects (variation of effects) were measured by a variance partition coefficient (32), which measures the cluster variability in the multilevel models.

PAFs were estimated to assess the contribution of each factor to the occurrence of anaemia (any, mild, moderate-severe) among women. PAFs were estimated by using AORs from the multivariable logistic regression model for each variable that was significantly associated with anaemia (any, mild, moderate-severe). Estimating attributable fractions using logistic regression analysis was initiated by Bruzzi et al. (33), developed by Eide and Gefeller (34), and was operationalised by Rückinger and colleagues (35). Ideally, risk ratios would be used to estimate PAFs. However, the odds ratio calculated from cross-sectional and case-control studies can also be used to compute PAFs (24) when risk ratios are not appropriate or available. Thus, in this study, the odds ratio was used to estimate the PAFs because EDHS was a cross-sectional study and odds ratio was calculated through logistic regression.

The PAFs were calculated using the following formula (24), which has been used in different studies (36–38), all of which estimated PAFs using AORs from a cross-sectional or case-control study:

$$PAF = \frac{p(AOR - 1)}{AOR},$$

where p is the proportion of women with factors among cases (i.e., ratio of exposed cases relative to a total number of cases) and AOR, the adjusted odds ratio, is the association between factors and anaemia.

6.2.5 Ethics approval

Publicly available 2016 EDHS data were used for this study. The study has also been approved by the University of Newcastle Human Research Ethics Committee (Ref. No. H-2018-0045; see Appendix 3).

6.3 Results

6.3.1 Sociodemographic characteristics and prevalence of anaemia

The proportion of mild and moderate-severe anaemia among women was estimated to be 17.8% (95% CI: 16.7, 19.0) and 5.8% (95% CI: 4.9, 6.8), respectively (see Table 6.1). A higher prevalence rate of any anaemia was observed among women who had higher gravidity (≥ 4; 28.8%; 95% CI: 26.7, 30.9) compared to women who had no previous births (18.2%; 95% CI: 16.4, 20.1). The prevalence of any anaemia was significantly greater in pregnant women (29.1%; 95% CI: 24.9, 33.7) than non-pregnant women (23.2%; 95% CI: 21.6, 24.9). Similarly, a higher prevalence of moderate-severe anaemia was observed in pregnant women (12.6%; 95% CI: 10.0%, 15.8%) compared to non-pregnant women (5.3%; 95% CI: 4.4, 6.3; see Table 6.1).

Table 6.1 Characteristics of the study population and prevalence of various levels of anaemia in Ethiopian women aged 15–49 years, 2016 EDHS.

	Study population	Any anaemia		Mild anaemia		Moderate–severe anaemia	
Variables	***n* (%)**	***n***	**Weighted % (95% CI)**	***n***	**Weighted % (95% CI)**	***n***	**Weighted % (95% CI)**
Total	14,923 (100)	3,527	23.6 (22.0, 25.3)	2,661	17.8 (16.7, 19.0)	866	5.8 (4.9, 6.8)
Educational status							
No education	7,215 (48.3)	2,002	27.8 (25.4, 30.2)	1,466	20.3 (18.8, 21.9)	537	7.4 (6.0, 9.2)
Primary	5,244 (35.1)	1,136	21.7 (19.8, 23.7)	883	16.8 (15.2, 18.6)	253	4.8 (4.0, 5.7)
Secondary	1,676 (11.2)	297	17.8 (14.9, 21.0)	240	14.3 (11.8, 17.2)	57	3.4 (2.4, 4.9)
Higher	789 (5.3)	91	11.5 (8.2, 16.0)	72	9.2 (6.2, 13.3)	19	2.4 (1.3, 4.4)
Wealth index							
Poorest	2,519 (16.9)	863	34.3 (29.7, 39.1)	580	23.0 (20.3, 26.0)	283	11.2 (7.8, 15.8)
Poorer	2,717 (18.2)	688	25.3 (22.6, 28.3)	509	18.7 (16.4, 21.4)	180	6.6 (5.3, 8.3)
Middle	2,891 (19.4)	686	23.7 (21.2, 26.5)	538	18.6 (16.4, 21.0)	149	5.1 (4.0, 6.6)
Richer	2,979 (20.0)	625	21.0 (18.6, 23.6)	493	16.6 (14.5, 18.8)	132	4.4 (3.4, 5.7)
Richest	3,816 (25.6)	664	17.4 (15.1, 19.9)	541	14.2 (12.3, 16.3)	123	3.2 (2.4, 4.3)
Residence							
Urban	3,169 (21.2)	538	17.0 (14.4, 20.0)	441	13.9 (11.7, 16.4)	97	3.1 (2.2, 4.2)
Rural	11,754 (78.8)	2,989	25.4 (23.5, 27.4)	2,220	18.9 (17.6, 20.3)	768	6.5 (5.5, 7.8)
Region							
Tigray	1,073 (7.2)	212	19.7 (16.8, 23.0)	171	15.9 (13.7, 18.4)	41	3.8 (2.6, 5.6)
Afar	119 (0.8)	53	44.7 (39.9, 49.6)	34	28.8 (25.7, 32.0)	19	15.9 (12.6, 20.0)
Amhara	3,645 (24.4)	627	17.2 (14.9, 19.7)	534	14.6 (12.8, 16.7)	93	2.5 (1.8, 3.6)

Variables	Study population	Any anaemia		Mild anaemia		Moderate–severe anaemia	
	n (%)	*n*	Weighted % (95% CI)	*n*	Weighted % (95% CI)	*n*	Weighted % (95% CI)
Oromia	5,422 (36.3)	1,480	27.2 (23.8, 31.1)	1,095	20.2 (17.8, 22.8)	386	7.1 (5.1, 9.8)
Somali	417 (2.8)	248	59.5 (55.2, 63.7)	125	30.0 (27.2, 33.0)	123	29.5 (25.8, 33.6)
Benishangul-Gumuz	146 (1.0)	28	19.2 (16.1, 22.7)	23	15.8 (13.1, 19.0)	5	3.4 (2.3, 5.0)
SNNP	3,124 (20.9)	704	22.5 (19.4, 26.0)	545	17.4 (14.9, 20.2)	160	5.1 (3.8, 6.9)
Gambella	42 (0.3)	11	26.1 (21.3, 31.5)	9	20.6 (16.8, 25.0)	2	5.5 (3.8, 7.9)
Harari	32 (0.21)	9	27.7 (23.7, 32.1)	6	18.9 (15.5, 22.9)	3	8.7 (6.7, 11.4)
Addis Ababa	825 (5.5)	132	16.0 (13.5, 18.8)	105	12.7 (10.7, 15.1)	27	3.2 (2.4, 4.3)
Dire Dawa	77 (0.5)	23	30.0 (25.8, 34.8)	16	21.0 (17.6, 24.7)	7	9.2 (6.8, 12.1)
Age (years)							
15–19	3,165 (21.2)	631	19.9 (17.9, 22.2)	492	15.6 (13.8, 17.4)	139	4.4 (3.3, 5.7)
20–29	547 (36.6)	1,320	24.2 (21.7, 26.8)	947	17.3 (15.6, 19.2)	373	6.8 (5.6, 8.3)
30–39	4,078 (27.3)	1,039	25.5 (23.3, 27.8)	783	19.2 (17.3, 21.3)	256	6.3 (5.0, 7.9)
40–49	2,213 (14.8)	537	24.3 (21.6, 27.1)	440	19.9 (17.4, 22.6)	98	4.4 (3.4, 5.8)
Marital status							
Single	3,757 (25.2)	667	17.7 (15.9, 19.8)	538	14.3 (12.7, 16.2)	129	3.4 (2.6, 4.4)
Married	9,800 (65.7)	2572	26.2 (24.3, 28.3)	1896	19.3 (18.0, 20.8)	676	6.9 (5.8, 8.2)
Divorced/widowed/ separated	1,365 (9.1)	288	21.1 (18.1, 24.5)	227	16.6 (14.0, 19.7)	61	4.5 (2.9, 6.7)
Religion							
Orthodox	6,447 (43.2)	1166	18.1 (16.4, 19.9)	961	14.9 (13.6, 16.3)	206	3.2 (2.6, 4.0)
Protestant	3,514 (23.5)	851	24.2 (21.2, 27.5)	672	19.1 (16.7, 21.8)	179	5.1 (3.8, 6.7)
Muslim	4,645 (31.1)	1,391	30.0 (27.2, 32.8)	969	20.9 (18.7, 23.2)	422	9.1 (7.8, 10.6)

Variables	Study population n (%)	Any anaemia n	Any anaemia Weighted % (95% CI)	Mild anaemia n	Mild anaemia Weighted % (95% CI)	Moderate–severe anaemia n	Moderate–severe anaemia Weighted % (95% CI)
Other	317 (2.1)	118	37.4 (16.6, 64.2)	60	18.9 (13.8, 25.4)	59	18.5 (5.3, 47.7)
Birth interval							
< 24 months	1,621 (19.2)	519	32.0 (28.4, 35.8)	356	22.0 (19.0, 25.3)	162	10.0 (8.0, 12.4)
≥ 24 months	6,801 (80.9)	1,749	25.7 (23.7, 27.9)	1,338	19.7 (18.1, 21.3)	412	6.1 (4.9, 7.4)
Gravidity (number of children ever born)							
0	4,745 (31.8)	862	18.2 (16.4, 20.1)	670	14.1 (12.6, 15.8)	192	4.0 (3.3, 5.0)
1–3	4,715 (31.6)	1,092	23.2 (20.7, 25.9)	793	16.8 (15.2, 18.6)	299	6.3 (4.7, 8.5)
4+	5,464 (36.6)	1,573	28.8 (26.7, 30.9)	1,198	21.9 (20.2, 23.8)	375	6.9 (5.8, 8.1)
CEB in the preceding 5 years							
0	7,595 (50.9)	1,484	19.5 (17.9, 21.3)	1,178	15.5 (14.2, 16.9)	306	4.0 (3.4, 4.8)
1	4,475 (30.0)	1,069	23.9 (21.7, 26.2)	689	17.5 (15.6, 19.4)	287	6.4 (4.9, 8.4)
+2	2,852 (19.1)	974	34.2 (31.0, 37.5)	702	24.6 (22.2, 27.2)	272	9.5 (7.9, 11.5)
HIV test							
Positive	251 (1.7)	65	25.7 (18.7, 34.3)	33	17.5 (11.7, 25.3)	12	4.7 (2.4, 9.2)
Negative	14,672 (98.3)	3,462	23.6 (22.0, 25.3)	2,625	17.8 (16.7, 19.0)	854	5.8 (4.9, 6.9)
Water source							
Piped water	2,646 (17.7)	460	17.4 (14.8, 20.3)	354	13.4 (11.4, 15.6)	106	4.0 (2.9, 5.5)
Other improved	6,926 (46.4)	1,599	23.1 (21.3, 25.0)	1,270	18.3 (16.8, 20.0)	329	4.8 (4.0, 5.6)
Unimproved	5,351 (35.9)	1,468	27.4 (24.5, 30.5)	1,038	19.4 (17.4, 21.5)	430	8.0 (6.4, 10.1)
Latrine facility type							
Improved toilet	2,231 (14.9)	455	20.4 (18.0, 23.1)	346	15.5 (13.4, 17.9)	109	4.9 (3.8, 6.2)
Unimproved toilet	7,877 (52.8)	1,729	21.9 (20.2, 23.8)	1,360	17.3 (15.8, 18.8)	369	4.7 (3.9, 5.6)

Variables	Study population	Any anaemia		Mild anaemia		Moderate–severe anaemia	
	***n* (%)**	***n***	**Weighted % (95% CI)**	***n***	**Weighted % (95% CI)**	***n***	**Weighted % (95% CI)**
Open defecation	4,414 (29.6)	1,267	28.7 (25.3, 32.4)	903	20.5 (18.4, 22.6)	364	8.2 (6.0, 11.1)
Other	401 (2.7)	76	19.0 (14.1, 25.0)	52	13.1 (9.4, 17.9)	24	5.9 (3.0, 11.2)
Currently pregnant							
Yes	1,087 (7.3)	317	29.1 (24.9, 33.7)	179	16.5 (13.4, 20.2)	137	12.6 (10.0, 15.8)
No	13,835 (92.7)	3,210	23.2 (21.6, 24.9)	2,482	17.9 (16.8, 19.2)	728	5.3 (4.4, 6.3)
Currently breastfeeding							
Yes	4,657 (31.2)	1,317	28.3 (25.7, 31.0)	1,007	21.6 (19.7, 23.7)	309	6.6 (5.2, 8.5)
No	10,266 (68.8)	2,210	21.5 (20.0, 23.2)	1,654	16.1 (14.9, 17.4)	556	5.4 (4.6, 6.4)
Currently using contraception							
Yes	3,070 (20.6)	717	23.3 (20.8, 26.1)	522	17.0 (15.1, 19.1)	194	6.3 (4.9, 8.1)
No	11,853 (79.4)	2,567	23.7 (22.0, 25.5)	2,139	18.0 (16.8, 19.4)	671	5.7 (4.8, 6.7)
Birth in the past 1 year							
0	12,474 (83.6)	2,797	22.4 (20.9, 24.0)	2,156	17.3 (16.1, 18.6)	641	5.1 (4.3, 6.1)
1–2	2,449 (16.4)	730	29.8 (26.6, 33.2)	505	20.6 (18.2, 23.2)	225	9.2 (7.4, 11.3)

Note. SNNP = Southern Nations, Nationalities and Peoples; CEB = children ever born; HIV = human immunodeficiency virus.

6.3.2 Multivariable analysis

6.3.2.1 Factors for any anaemia among women

The multilevel logistic regression results show that having no formal education (AOR = 1.37; 95% CI: 1.10, 1.72), having only a primary education (AOR = 1.24; 95% CI: 1.00, 1.53), living at a rural residence (AOR = 1.29; 95% CI: 1.02, 1.63), being in the poorest wealth quantile (AOR =1.29; 95% CI: 1.01, 1.60), having higher gravidity (≥ 4 births; AOR = 1.39; 95% CI: 1.13, 1.69), being HIV-positive (AOR = 2.11; 95% CI: 1.59, 2.79), currently breastfeeding (AOR = 1.09; 95% CI: 1.03, 1.28), having menstruated in the last 6 weeks (AOR = 1.1; 95% CI: 1.01, 1.23) and open defecation (AOR = 1.18; 95% CI: 1.00, 1.39) were all significantly associated with the occurrence of any anaemia among women of reproductive age after adjusting for all other variables in the model. Current contraceptive use (AOR = 1.01; 95% CI: 0.91, 1.11) and unimproved water source (AOR = 1.03; 95% CI: 0.83, 1.27) were not significantly associated with any anaemia (see Table 6.2).

Population-attributable fractions/proportions: Around 15.4% (95% CI: 4.8, 25.1) of anaemia in women from the study population is attributable to having no formal education. About 19% (95% CI: 1.61, 33.6) of anaemia cases among women of reproductive age might be attributable to being of rural residence. Around 6% (95% CI: 0.20, 10.9) of anaemia cases could be attributable to being in the poorest wealth quantile. Furthermore, the proportion of anaemic cases in the study population that could be attributed to having access to an unimproved latrine facility was estimated to be 8% (95% CI: –3.5, 18.4). Similarly, an estimated 3% (95% CI: 0.99, 9.9) of cases of anaemia among women could be attributed to being currently breastfeeding. Around 13% (95% CI: 4.8, 19.6) of anaemia cases were attributable to having higher gravidity (≥ 4; see Table 6.2).

Table 6.2 AORs from multilevel logistics regression and PAFs for factors associated with any anaemia among women in Ethiopia, 2016.

Variables	**Anaemia cases (*n*)**	**Proportion of anaemia cases[a] (CI)**	**AOR (CI)**	**PAF% (CI)**
Educational status				
No education	2,002	0.57 (0.53, 0.60)	**1.37 (1.10, 1.72)**	15.4 (4.8, 25.1)
Primary	1,136	0.32 (0.29, 0.35)	**1.24 (1.00, 1.53)**	6.2 (0.0, 12.1)
Secondary	298	0.08 (0.07, 0.10)	1.23 (0.98, 1.52)	1.5 (–0.14, 3.4)
Higher	91	0.03 (0.02, 0.04)	1	1
Wealth index				
Poorest	863	0.25 (0.20, 0.29)	**1.29 (1.01, 1.60)**	6.1 (0.20, 10.9)
Poorer	689	0.20 (0.17, 0.22)	1.21 (0.96, 1.45)	3.5 (–1.24, 6.8)
Middle	686	0.20 (0.17, 0.22)	1.22 (0.98, 1.50)	3.6 (–0.35, 7.3)
Richer	625	0.18 (0.15, 0.21)	1.01 (0.82, 1.24)	0.18 (–3.3, 4.1)
Richest	664	0.19 (0.16, 0.22)	1	1
Residence				
Urban	539	0.15 (0.13, 0.18)	1	1
Rural	2,989	0.85 (0.82, 0.87)	**1.29 (1.02, 1.63)**	19.1 (1.61, 33.6)
Age (years)				
15–19	631	0.18 (0.16, 0.20)	1	1
20–29	1,320	0.37 (0.35, 0.40)	0.96 (0.82, 1.19)	–1.54 (–7.7, 6.4)
30–39	1,039	0.29 (0.27, 0.32)	0.92 (0.78, 1.11)	–2.5 (–7.6, 3.2)
40–49	537	0.15 (0.13, 0.17)	**0.75 (0.64, 0.96)**	–5.0 (–7.3, –0.71)
Marital status				
Single	667	0.19 (0.17, 0.21)	0.97 (0.81, 1.22)	–0.59 (–4.0, 3.8)

Variables	**Anaemia cases (*n*)**	**Proportion of anaemia cases[a] (CI)**	**AOR (CI)**	**PAF% (CI)**
Married	2,572	0.73 (0.71, 0.75)	1.09 (0.91, 1.23)	6.0 (–7.0, 14.0)
Divorced/widowed/separated	288	0.08 (0.07, 0.10)	1	1
Gravidity of women				
0	862	0.24 (0.22, 0.27)	1	1
1–3	1,092	0.31 (0.28, 0.34)	**1.22 (1.02, 1.44)**	5.6 (0.55, 10.4)
4+	1,573	0.45 (0.42, 0.48)	**1.39 (1.13, 1.69)**	12.6 (4.8, 19.6)
CEB in the preceding 5 years				
0	1,484	0.42 (0.39, 0.45)	1	
1	1,069	0.30 (0.28, 0.33)	1.10 (0.95, 1.27)	2.7 (–1.47, 7.0)
2+	974	0.28 (0.25, 0.31)	**1.31 (1.09, 1.57)**	6.6 (2.1, 17.7)
HIV test				
Positive	65	0.02 (0.01, 0.03)	2.11 (1.59, 2.79)	1.05 (0.48, 1.90)
Negative	3,462	0.98 (0.97, 0.99)	1	1
Water source				
Improved	2,059	0.58 (0.53, 0.63)	1	1
Unimproved	1,468	0.42 (0.37, 0.47)	1.03 (0.83, 1.27)	1.2 (–7.6, 9.99)
Latrine facility type				
Improved toilet	455	0.13 (0.11, 0.15)	1	1
Unimproved toilet	3,072	0.87 (0.85, 0.89)	1.10 (0.96, 1.26)	7.9 (–3.5, 18.4)
Currently pregnant				
Yes	317	0.09 (0.08, 0.11)	**1.28 (1.10, 1.51)**	2.0 (0.73, 3.7)
No	3,210	0.91 (0.89, 0.92)	1	

Variables	Anaemia cases (*n*)	Proportion of anaemia cases[a] (CI)	AOR (CI)	PAF% (CI)
Currently breastfeeding				
Yes	1,317	0.37 (0.34, 0.40)	**1.09 (1.03, 1.28)**	3.1 (1.0, 8.8)
No	2,210	0.63 (0.60, 0.67)	1	1
Currently using contraception				
Yes	717	0.20 (0.18, 0.23)	1.01 (0.91, 1.11)	0.20 (-1.8, 2.3)
No	2,810	0.80 (0.77, 0.82)	1	1
Birth in last 1 year CEB				
0	2,797	0.79 (0.77, 0.82)	1	1
1–2	730	0.21 (0.18, 0.23)	**1.15 (1.01, 1.32)**	2.7 (0.18, 5.6)
Menstruated in last 6 weeks				
Yes	1,795	0.51 (0.48, 0.54)	**1.10 (1.01, 1.23)**	4.6 (0.47, 10.1)
No	1,732	0.49 (0.46, 0.52)	1	

Note. AOR = adjusted odds ratio; PAF = population-attributable fraction; CEB = children ever born; HIV = human immunodeficiency virus.

[a]Proportion of anaemic women exposed to a factor (ratio of exposed cases to total cases).

6.3.2.2 Factors associated with mild anaemia and moderate-severe anaemia

The results of the multilevel multinomial logistic regression analyses of factors for mild anaemia and moderate-severe anaemia are presented in Table 6.3.

Multivariable multinomial analysis shows that having no formal education (AOR = 1.36; 95% CI: 1.07, 1.74), breastfeeding (AOR = 1.16; 95% CI: 1.0, 1.35), higher gravidity of women (≥ 4 births; AOR = 1.33; 95% CI: 1.03, 1.71), HIV infection (AOR = 1.89; 95% CI: 1.39, 2.57) and menstruation in the last six weeks (AOR = 1.13; 95% CI: 1.02, 1.26) were factors independently associated with mild anaemia. Similarly, rural residence (AOR = 1.75; 95% CI: 1.23, 2.48), birth in the last year (AOR = 1.60; 95% CI: 1.28, 2.0), birth in the last 5 years (AOR = 1.50; 95% CI: 1.12, 2.0), currently pregnant (AOR = 2.35; 95% CI: 1.83, 3.01), unimproved latrine facility (AOR = 1.24; 95% CI: 1.0, 1.56) and poorest wealth index (AOR = 1.63; 95% CI: 1.14, 2.34) were independently associated with moderate–severe anaemia (see Table 6.3).

PAFs: The proportions of mild and moderate-severe anaemia attributable to having no formal education were estimated to be 14.6% and 18% among women, respectively. Proportions of moderate-severe anaemia attributable to current pregnancy were 9.1% (Table 6.3). Being a rural resident was attributable to 38.1% of moderate-severe anaemia cases among women. In addition, 12.6% of moderate-severe anaemia cases might be attributable to household wealth being rated in the poorest wealth quantile. The proportion of mild anaemia cases attributable to high gravidity of women (≥ 4) and currently breastfeeding were 11.2% and 5.2%, respectively. Similarly, 16.9% and 10.5% of moderate-severe anaemia cases among women were due to unimproved latrine facilities, birth in the last 5 years preceding the survey, respectively (Table 6.3).

Table 6.3 AORs from multilevel multinomial logistics regression and PAFs for factors associated with mild and moderate-severe anaemia among women in Ethiopia, 2016.

	Mild anaemia			Moderate–severe anaemia		
Variables	**Proportion of cases[a] (CI)**	**AOR (CI)**	**PAF**	**Proportion of cases[a] (CI)**	**AOR (CI)**	**PAF**
Educational status						
No education	55.1 (51.7, 58.4)	**1.36 (1.07, 1.74)**	14.6 (3.4, 24.8)	62.0 (55.6, 68.1)	1.41 (0.94, 2.11)	18.0 (–3.5, 35.8)
Primary	33.2 (30.3, 36.3)	**1.28 (1.01, 1.61)**	7.3 (0.3, 13.8)	29.2 (24.4, 34.5)	1.08 (0.73, 1.60)	2.2 (–9.0, 12.9)
Secondary	9.0 (7.4, 10.9)	1.27 (0.99, 1.62)	1.9 (–0.1, 4.2)	6.6 (4.5, 9.7)	1.00 (0.66, 1.53)	0.0 (–2.3, 3.4)
Higher	2.7 (1.9, 3.8)	1	1	2.2 (1.2, 4.0)	1	1
Wealth index						
Poorest	21.8 (18.3, 25.8)	**1.23 (0.97, 1.54)**	4.1 (–0.6, 9.0)	32.7 (23.8, 42.9)	**1.63 (1.14, 2.34)**	**12.6 (2.9, 24.6)**
Poorer	19.1 (16.3, 22.2)	1.17 (0.92, 1.46)	2.8 (–1.4, 7.0)	20.7 (16.3, 26.0)	**1.39 (0.96, 2.01)**	5.8 (–0.7, 13.1)
Middle	20.2 (17.6, 23.1)	1.18 (0.94, 1.49)	3.1 (–1.1, 7.6)	17.2 (13.0, 22.4)	1.34 (0.93, 1.94)	4.4 (–0.98, 10.9)
Richer	18.5 (15.7, 21.7)	0.95 (0.76, 1.19)	–1.0 (–5.0, 3.5)	15.2 (11.3, 20.1)	1.17 (0.81, 1.67)	2.2 (–2.7, 8.1)
Richest	20.3 (17.3, 23.7)	1	1	14.2 (10.3, 19.2)	1	1
Residence						
Urban	16.6 (14.0, 19.6)	1	1	11.2 (8.2, 15.2)	1	1
Rural	83.4 (80.4, 86.0)	1.22 (0.95, 1.56)	15.0 (–4.2, 30.9)	88.8 (84.8, 91.8)	**1.75 (1.23, 2.48)**	**38.1 (15.9, 54.8)**
Age (years)						
15–19	18.5 (16.4, 20.8)	1	1	16.0 (12.8, 19.8)	1	1
20–29	35.6 (32.7, 38.6)	0.87 (0.74, 1.02)	–5.3 (–11.5, 0.8)	43.1 (38.9, 47.4)	1.12 (0.88, 1.44)	4.6 (–5.3, 14.5)
30–39	29.4 (26.9, 32.0)	0.86 (0.70, 1.05)	–4.8 (–11.5, 1.5)	29.6 (25.6, 34.0)	1.14 (0.85, 1.54)	3.6 (–4.5, 11.9)
40–49	16.5 (14.4, 18.9)	0.82 (0.65, 1.04)	–3.6 (–7.8, 0.7)	11.3 (8.4, 15.0)	0.88 (0.61, 1.27)	–1.5 (–5.4, 3.2)

Variables	Mild anaemia			Moderate–severe anaemia		
	Proportion of cases[a] (CI)	AOR (CI)	PAF	Proportion of cases[a] (CI)	AOR (CI)	PAF
Marital status						
Single	20.2 (17.9, 22.8)	0.95 (0.76, 1.20)	–1.1 (–5.7, 3.8)	14.8 (11.5, 18.9)	1.18 (0.81, 1.72)	2.3 (–2.7, 7.0)
Married	71.3 (68.5, 73.9)	1.05 (0.89, 1.23)	3.4 (–8.5, 13.8)	78.1 (73.9, 81.8)	1.19 (0.91, 1.56)	12.5 (–7.3, 29.4)
Divorced/widowed/separated	8.5 (7.1, 10.1)	1	1	7.0 (5.0, 9.9)	1	1
Gravidity						
0	25.2 (22.7, 27.8)	1	1	22.2 (17.9, 27.1)	1	1
1–3	29.8 (27.2, 32.5)	1.15 (0.93, 1.43)	3.9 (–2.0, 9.8)	34.5 (28.7, 40.9)	1.02 (0.72, 1.43)	0.7 (–11.2, 12.3)
4+	45.0 (42.0, 48.0)	**1.33 (1.03, 1.71)**	**11.2 (1.2, 19.9)**	43.3 (37.9, 48.9)	1.02 (0.70, 1.51)	0.9 (–16.2, 16.5)
CEB in 5 years						
0	44.3 (41.0, 47.6)	1	1	35.4 (30.2, 40.9)	1	1
1	29.4 (26.6, 32.3)	1.00 (0.85, 1.18)	0.0 (–4.7, 5.8)	33.2 (28.0, 38.8)	1.33 (1.04, 1.71)	8.2 (1.1, 16.1)
2+	26.4 (23.5, 29.5)	**1.22 (1.00, 1.49)**	4.8 (0.0, 9.7)	31.5 (27.0, 36.3)	**1.50 (1.12, 2.00)**	**10.5 (2.9, 18.2)**
HIV test						
Positive	1.2 (0.8, 1.9)	**1.89 (1.39, 2.57)**	0.6 (0.2, 1.2)	1.4 (0.7, 2.9)	3.04 (1.92, 4.80)	0.9 (0.34, 2.3)
Negative	98.8 (98.1, 99.2)	1	1	98.6 (97.1, 99.3)	1	1
Water source						
Improved	13.3 (11.0, 16.0)	1	1	12.3 (8.7, 17.0)	1	1
Unimproved	86.7 (84.0, 89.0)	1.09 (0.89, 1.34)	7.2 (–10.4, 22.6)	87.7 (83.0, 91.3)	0.83 (0.61, 1.14)	–18.0 (–53,11.2)
Latrine facility						
Improved toilet	13.0 (11.0, 15.4)	1	1	12.6 (9.4, 16.7)	1	1
Unimproved toilet	87 (84.6, 89.1)	1.04 (0.89, 1.21)	3.4 (–10.5, 15.5)	87.2 (83, 90.6)	**1.24 (1.00, 1.56)**	16.9 (0.0, 32.5)

Variables	Mild anaemia			Moderate–severe anaemia		
	Proportion of cases[a] (CI)	AOR (CI)	PAF	Proportion of cases[a] (CI)	AOR (CI)	PAF
Currently pregnant						
Yes	6.7 (5.5, 8.2)	0.95 (0.77, 1.18)	–0.4 (–1.6, 1.3)	15.9 (12.5, 19.9)	**2.35 (1.83, 3.01)**	**9.1 (5.7, 13.3)**
No	93.3 (91.8, 94.5)	1	1	84.2 (80.1, 87.5)	1	1
Currently breastfeeding						
Yes	37.9 (34.7, 41.1)	**1.16 (1.00, 1.35)**	5.2 (0.0, 10.7)	35.7 (30.5, 41.3)	0.76 (0.61, 0.95)	–11.3 (–19.5, –2.2)
No	62.2 (58.9, 65.3)	1	1	64.3 (58.7, 69.5)	1	1
Currently using contraception						
Yes	19.6 (17.2, 22.3)	0.99 (0.88, 1.10)	–0.2 (–2.3, 2.0)	22.4 (18.6, 26.8)	1.04 (0.88, 1.22)	0.9 (–2.5, 4.8)
No	80.4 (77.7, 82.8)	1	1	77.6 (73.2, 81.4)	1	1
CEB in last 1 year						
Zero	81.0 (78.3, 83.5)	1	1	74.1 (69.4, 78.2)	1	1
1–2	19.0 (16.5, 21.7)	1.00 (0.85, 1.16)	0.0 (–2.9, 3.0)	25.9 (21.8, 30.6)	**1.60 (1.28, 2.00)**	**9.7 (4.8, 15.3)**
Menstruated in last 6 weeks						
Yes	53.0 (49.8, 56.1)	**1.13 (1.02, 1.26)**	6.1 (1.0, 11.6)	44.5 (39.1, 49.9)	**1.05 (0.88, 1.24)**	**2.1 (–4.5, 9.7)**
No	47.0 (43.9, 50.2)	1	1	55.5 (50.1, 60.9)	1	1

Note. AOR = adjusted odds ratio; PAF = population-attributable fraction; CEB = children ever born; HIV = human immunodeficiency virus.

[a]Proportion of anaemic women exposed to factors (ratio exposed cases to total cases).

6.3.3 Random-effects analysis

The results of the random-effects analysis showed that there was variation in log odds of different types of anaemia across communities ($\tau^2 = 0.907$). According to the variance partition coefficient, about 21.6% of the variance in the odds of different anaemia types in women could be attributed to community-level factors. The variation in odds of different anaemia types across communities remained statistically significant even after adjusting for the individual and community-level factors. About 9% of the odds of anaemia variation across communities was observed in the full model (Model 2; see Table 6.4).

Table 6.4. Measure of variation for different anaemia types at the cluster level (effect of variation from the random intercept model).

Variation	**Model 1[€]**	**Model 2[¥]**
Variance (*SE*)	0.907 (0.074)	0.313 (0.036)
ICC%	21.6	8.7
DIC (–2 log-likelihood ratio)	20562.4	19512.2

Note. ICC = intra-cluster correlation coefficient; DIC = deviance information criterion.

[€]Empty model (without the predictors).

[¥]Adjusted for predictors

6.4 Discussion

This study assessed the impact of predictors on all levels of anaemia among women using large-scale population data. The findings indicate that having no formal education, currently breastfeeding, having higher (≥ 4) gravidity, having HIV infection and having menstruated in the past 6 weeks preceding the survey were factors independently associated with higher odds of mild anaemia. Similarly, living in a rural area, having an unimproved latrine facility, giving birth in the past year, being currently pregnant, being of the poorest wealth status and having an HIV infection was independently associated with moderate-severe anaemia. Moreover, having rural residency, no formal education, high gravidity, being in the poorest wealth quantile and having unimproved latrine facilities were positively associated with the occurrence of any anaemia among women. These results are consistent with other study findings from low-income countries, which reported associations between socioeconomic status and all anaemia levels (84, 101, 335).

A relevant question to ask is how much of the burden of anaemia could be avoided if these factors were addressed, or reduced, in the population. PAF is a measure of the overall effect of a factor on the problem/outcome of interest at the population level (116). The PAF estimates of this study showed that the proportion of mild anaemia cases attributable to high gravidity (≥ 4), currently breastfeeding and menstruation in the last six weeks was 11.2%, 5.2% and 6.1%, respectively, and could potentially be reduced if intervention approaches targeted on women with these factors in the population. Similarly, the proportion of moderate-severe anaemia attributable to living in a rural area, having no formal education, being in the poorest wealth quantile and giving birth in the last 5 years was 38.1%, 18%, 12.6% and 10.5%, respectively. The higher proportion of any anaemia cases could be attributed to rural residency (19%), having no formal education (15%), high gravidity (13%), poorest wealth quantile (6%) and having unimproved latrine facilities (8%). These are theoretical calculations, but they illustrate the important role these factors play in determining the occurrence of anaemia among women in this population. Thus, rural residence, illiteracy and being in a low wealth quantile would be predicted to have a substantial effect on the occurrence of anaemia among women in Ethiopia. Similar findings have been reported in other studies from developing countries, in that high proportions of anaemia cases were observed in women of rural residence, with low education and being in a low wealth quantile (76, 97). Education and poverty reduction are also a target in the Sustainable Development Goals (336).

Research has recognised low socioeconomic status as a predictor of higher odds of anaemia among women of reproductive age (77, 80, 95). A higher prevalence of anaemia was observed in women with low socioeconomic status compared to women with high socioeconomic status (83, 337). Our results are in line with these findings and indicated that women from households in the poorest wealth quantile were at higher risk of having moderate-severe anaemia. About 13% of moderate-severe anaemia cases among women could be attributed to being in the poorest wealth quantile; this is consistent with a previous finding that showed that higher odds of moderate-severe anaemia cases were associated with the poorest wealth quantile (100). Moreover, the current study revealed that the odds of any anaemia among women was higher among the poorest compared to the richest women, which aligns with study findings in Bangladesh (95, 103) and Ethiopia (77). A possible explanation is that, as the income level of women is lower, women may not be able to purchase adequate or varied foodstuffs and subsequently do not consume a diversified nutritious diet or could have limited access to fortification or supplementation (36). As a result, women are unable to obtain adequate nutrients and are subsequently exposed to anaemia. Furthermore, women with no formal education are at higher odds of anaemia compared to women with tertiary education. The proportion of any anaemia attributable to having no education was nearly 15%. This result is consistent with previous study results conducted in Ethiopia (77), Timor-Leste (82), India (76, 97), Bangladesh (95, 103) and Senegal (338), which reported that low educational status was associated with an increased odds of anaemia among women. Evidence has also shown that low educational status is associated with higher odds of moderate-severe anaemia among women (100, 101). The effect of low education on the odds of anaemia could be due to a reduced capacity to pursue health care and limited awareness about diversified food intake or health risks. Low education would also impact on health literacy, high number of pregnancies or birth spacing.

The odds of any anaemia and moderate-severe anaemia were higher in rural compared to urban women, but the odds of mild anaemia were not statistically different between urban and rural women. The odds of any anaemia and moderate-severe anaemia attributable to a rural residence are 19% and 38%, respectively, which is consistent with evidence suggesting that higher moderate-severe anaemia prevalence was more noticeable in individuals of rural residence (84, 103). A higher prevalence of moderate-severe anaemia and any anaemia in rural areas could be attributed to differences in availability and utilisation of health care, diversified foods, infection risk and fertility preferences (70, 335). Moreover, having unimproved latrine facilities was associated with an increased odds of any anaemia and moderate-severe anaemia among women. This result is in line with other study findings from low-income settings (76, 100, 338). This may be partially explained by the fact that unimproved toilet facilities could decrease sanitation standards and increase the risk of intestinal infections (104), which are risk factors for anaemia (339).

The results of this study also revealed that higher gravidity of women was associated with increased odds of any anaemia and mild anaemia. Similarly, a higher number of births in the previous 5 years, as well as in the past year, was associated with an increased odds of moderate-severe anaemia among women. A similar finding was reported that moderate-severe anaemia was higher in women who had more births in the last 5 years (84) and who had given birth in the previous year (82). Similarly, studies from Ethiopia (77), Myanmar (79), Iran (83) and India (80) have reported that higher gravidity was associated with an increased odds of anaemia among women of reproductive age. This could be the fact that repeated pregnancies/higher gravidity reduces iron stores, which leads to anaemia (79, 83, 84).

Menstruation in the 6 weeks preceding the survey was associated with increased odds of anaemia among women. Similar results have been documented in other studies, in which high menstruation blood loss was associated with an increased odds of anaemia among women of reproductive age (76, 77). This could be the fact that excessive blood loss is linked directly to a depletion of iron stores and leads to anaemia (340). The infection by HIV might also increase the risk of anaemia due to its effects on the bone marrow and the reduction of Hgb levels in the blood (93). However, our results indicate that HIV prevalence in women of reproductive age in Ethiopia is estimated to be about 1.7% and was not the main contributor to anaemia (77).

Strengths and limitations of the study: One of the main strengths of this study is the large representative population-based survey data. The other strength of this study is the identification of predictors for different levels of anaemia among women of reproductive age using multilevel multinomial models. Furthermore, in this study, the relative contribution of each factor for the occurrence of anaemia among women was quantified through PAFs, which will help to prioritise any intervention programs. The PAFs were estimated using AORs to obtain unbiased estimates (341).

This study sets a benchmark for assessing the impact of the predictors at the population level, using large population-based cross-sectional data. However, the analyses and estimates of PAFs for assessing the impact of factors depend on assumptions that cannot be addressed, including the potential for unincorporated factors and remaining confounding or non-causal relations. Since this study is observational, temporal and cause-effect relationships cannot be established. Recall bias might also be an issue for this study as the DHS data relied on the memory of study participants. This error could inflate/deflate some of the estimates reported in this study. Another limitation of this study was the lack of data on some important factors in anaemia, such as dietary intake and helminthic infections.

6.5 Conclusion

The current study indicated that having no formal education, currently breastfeeding and higher (≥ 4) gravidity were factors associated with increased odds of mild anaemia among women. Furthermore, higher odds of moderate-severe anaemia were observed among women who were rural residents, had an unimproved latrine facility, gave birth in the past year, were currently pregnant, were in the poorest wealth quantile or were infected with HIV.

The PAFs suggest that rural residency, low education, low wealth status, pregnancy and high gravidity contribute substantially to the occurrence of anaemia among women. The burden of different levels of anaemia among women in the population could potentially be reduced by employing a large range of approaches targeting these maternal and sociodemographic factors. Therefore, pregnant women, women with high gravidity and those with recent births, women with low education, low wealth status and women living in rural areas should be prioritised in any intervention program targeting anaemia. Different approaches would be needed when targeting mild and moderate-severe anaemia. Mild anaemia could be reduced by setting intervention strategies targeting multigravida and breastfeeding women, while preventing moderate-severe anaemia may require working on improving income, educating women and improving living conditions through the accessibility of hygienic latrines. Further research needs to be conducted to identify potential factors associated with mild anaemia by incorporating data on dietary intake and infections (malaria and helminths).

Chapter 7: The effect of dietary patterns on maternal anaemia in North Shewa, Ethiopia—a case-control study with propensity score analysis

The findings of Chapter 5 indicated that higher odds of anaemia were observed among pregnant women compared to non-pregnant women. Thus, in this chapter further assessment was conducted to identify potential predictors of anaemia among pregnant women. This chapter has been submitted for publication in the *BMJ Open* and is currently under review.

> Kibret KT, Chojenta C, D'Arcy E, Loxton D. The effect of dietary patterns on maternal anaemia in North Shewa, Ethiopia: a case-control study with propensity score analysis.

Abstract

Introduction: Dietary patterns are a modifiable factor that can influence the occurrence of anaemia. Current evidence is inconsistent, and resource-limited settings have not been well researched. This study aimed to assess the effect of dietary patterns during pregnancy on anaemia in Ethiopia.

Methods: A case-control study with propensity score analysis was conducted among pregnant women in North Shewa, Ethiopia, from November 2018 to March 2019. Four hundred and seventeen pregnant women were included (105 cases and 312 controls) with a 1:3 case to control ratio. Cases were pregnant women with a Hgb level < 11 g/dL, and controls were pregnant women with a Hgb level ≥ 11.0 g/dL. Data were collected through an interviewer-administered questionnaire and record review of laboratory measurements. A multivariable conditional logistic regression model was applied after propensity score matching to assess the effect of dietary patterns on anaemia and a $p < 0.05$ was taken as significant.

Results: A low DDS (< 5) (AOR = 2.14; 95% CI: 1.24, 3.69) comparted to high DDS, reducing food intake (AOR = 6.89; 95% CI: 3.23, 14.70) compared to increasing food intake and having no formal education (AOR = 3.13; 95% CI: 1.18, 8.32) were independent predictors of maternal anaemia.

Conclusion: During pregnancy, intake of a low diversified diet, reduced food intake and low educational status were associated with higher odds of anaemia. Diversified dietary counselling should be emphasised and strengthened in the existing prenatal health service program, with women strongly encouraged to increase their food intake instead of reducing it during pregnancy.

Key terms: Anaemia, dietary patterns, dietary diversity, pregnant women, case-control study.

7.1 Introduction

Anaemia in pregnant women is defined as a Hgb level < 11 g/dL at sea level (62). Pregnant women are at higher risk of anaemia due to several bodily changes during pregnancy, such as increased blood volume with a low increment of red blood cell mass (63). Thus, a sufficient amount of iron, folate and vitamin B12 is required to make Hgb. Iron absorption during pregnancy is difficult, creating difficulties for producing Hgb, which can then lead to anaemia (63).

Anaemia is a major public health problem in pregnant women globally (3), with greater rates in LMICs (5). Worldwide, in 2011, approximately 38% of pregnant women and 43% of children aged 5 years and under were classified as anaemic. The highest prevalence rates in LMICs are reported in Central and West Africa (56%), South Asia (52%) and East Africa (36%) (3). Similarly, a recent systematic review of 26 articles from developing countries found that around 37% to 48% of pregnant women had experienced anaemia (4).

Anaemia is a common problem in Ethiopia: the current 2016 EDHS reported a 29% prevalence rate of anaemia among pregnant women (48). Similarly, a number of small-scale studies from different parts of the country reported that prevalence rates of anaemia among pregnant women ranged from as low as 17% in the north (66), 32% in the south (25) and up to 44% (46) and 57% (67) in the east.

Studies have linked anaemia to substantial maternal morbidity, poor pregnancy outcomes (PTB and LBW), perinatal mortality and neonatal mortality (4, 8, 9, 121). Anaemia increases the risk of severe maternal morbidity and accounted for nearly half of the indirect causes of maternal mortality and severe morbidity in resource-limited settings (7, 10). Furthermore, a higher risk of postnatal depression has been observed among woman who was anaemic during pregnancy (130, 131).

The main cause of anaemia is thought to be iron deficiency (328); however, deficiencies of other micronutrients (vitamin A, vitamin B12 and folate), chronic bleeding, chronic or acute infections and parasitic infections (hookworm and malaria) have also been shown to cause anaemia (77, 87-89). Sociodemographic and maternal factors have also been shown to affect the occurrence of maternal anaemia. Being a rural residence, low education and being in the lowest wealth quantile increase the odds of anaemia due to the fact low socioeconomic status may limit the capability to access diversified diet (70, 113). By contrast, employment and a higher wealth quantile have been shown to reduce the odds of anaemia among pregnant women

(98). In Ethiopia, studies have reported different and inconsistent sociodemographic factors of anaemia during pregnancy. For example, large family size, no education, rural residence, hookworm infestation and HIV infection were identified as factors of anaemia in Northern Ethiopia (66, 113). Studies from the eastern area have reported that a reduced dietary intake, multigravidas, being in the second or third trimester of pregnancy and intestinal infestation were factors of anaemia during pregnancy (46, 114).

Dietary intake is considered to be a modifiable risk factor that may influence the occurrence of anaemia and one potential area to target for the prevention of anaemia during pregnancy. Previous research has shown that dietary patterns during pregnancy have an effect on anaemia in resource-limited settings (24, 25, 43, 46, 98, 232). However, inconsistent results have been reported in other studies (44, 45), and most of the studies were cross-sectional studies and could not control for all possible confounder factors like sanitation, water source and gravidity. Moreover, the association between dietary intake and anaemia may be context-dependent and, hence, well-designed research is necessary for this area to properly assess the effect of dietary patterns on maternal anaemia. Understanding the effects of dietary patterns on maternal anaemia may help to tailor local strategies and dietary recommendations for the prevention of maternal anaemia. Thus, this study aims to assess the effects of dietary patterns on maternal anaemia in North Shewa, Ethiopia.

7.2 Methods

7.2.1 Study settings and periods

This study was conducted across five health facilities in North Shewa, Ethiopia, from November 2018 to March 2019. The North Shewa Zone is one of the administrative areas of Amhara Regional State. This zone is subdivided into districts and each district has more than 10 *kebele*s (the lowest administrative unit). The zone has six district primary hospitals, one zonal referral hospital and 95 health centres. In each district, there is at least one health centre, each of which is expected to provide services to more than 25,000 people.

7.2.2 Study design

A case-control study was used to assess the effect of dietary patterns on maternal anaemia. Cases were all pregnant women with a Hgb level < 11 g/dL and controls were women with a Hgb level ≥ 11.0 g/dL. For each identified case, three healthy controls were selected from each health facility. Participants were recruited consecutively for approximately 4 months during their ANC visits from each selected health facility.

7.2.3 Source and study population

The study population included all pregnant women who had attended at least one ANC follow-up in one of the five selected health facilities and had provided informed consent during the study period (November 2018 to March 2019). Women who were unable to hear or speak, temporary residents, severely ill with medical problems like cardiovascular or renal diseases, or unwilling to participate were not included in the study.

7.2.4 Sampling method and sample size determination

Five health facilities were purposely selected for this study. A sample size quota was allocated to each health facility proportional to the average number of ANC visits for the preceding 3 months (August–October 2018). Participants were recruited from each health facility until the allotted quota was filled.

The sample size was calculated using different factors of anaemia (intestinal parasite, no education, iron supplementation) and selecting those that produced a maximum sample. To determine the optimum sample size, studies were selected taking into consideration the following points: recently well-conducted studies, with a comparable population and study setting, and well-conducted studies (adequate sample size with low non-responses rates and appropriate statistical analysis with control for confounders). The sample size was then calculated using OpenEpi version 3.01 (openepi.com) using the following parameters: intestinal parasite as the exposure variable, 5% significance level, a power level of 80%, a 1:3 ratio of cases to controls and the double proportion formula (264). Therefore, using a 5% contingency level, the final sample size was 417 (105 cases and 312 controls).

7.2.5 Data collection procedures and measurements

The data were collected using an interviewer-administered questionnaire, anthropometry and a record review of laboratory measurements. The questionnaire was adapted from the FAO and 2016 EDHS surveys (48, 224) and by reviewing other relevant literature (58-60). The questionnaire comprised five sections. The first section assessed the respondents' sociodemographic characteristics: age, religion, occupation, ethnicity, educational status, marital status, place of residence, family size, income, main water source and toilet facilities available in their household. The second section evaluated maternal characteristics, including gravidity/parity, birth interval, stillbirths, ANC visit, nausea/vomiting and alcohol intake. The third section addressed maternal eating habits/practices, including varying food intake, avoidance of foods, pica practices (ingestion of non-nutritive substances), meal frequency, eating patterns and use of supplements including iron/folate or consumption of de-worming tablets. The fourth section of the questionnaire was designed to examine the dietary intake of study participants. Dietary intake of participants was assessed through the administration of a 24-hour recall food questionnaire, adapted from the FAO and 2016 EDHS. Participants were requested to recall all the foods they had consumed in the preceding 24 hours. This was done initially and spontaneously by the participant and then through probing questions from the interviewer regarding all foods consumed. The final section of the questionnaire included measurements of maternal anthropometry (height, MUAC, weight, gestational age and blood pressure) and a record review of laboratory measurements (Hgb level, urine protein and stool examination).

7.2.5.1 Anthropometric and laboratory measurements

The Hgb levels of participants, which were routinely measured during ANC follow-ups to determine the anaemia status of pregnant women, were taken from ANC registries. A Hgb level below 11 g/dL was classified as anaemia (62). The MUAC was measured by using non-stretchable measuring tapes: the measurement was taken from the relaxed left arm and rounded to the nearest 0.1 cm. The MUAC reflects the past and current nutritional status of a pregnant woman. MUAC cut-off values below 23 cm and greater than or equal to 23 cm were used to classify women as ‘wasting’ or ‘normal’, respectively (266). Women were instructed to wear light clothing and were weighed without shoes (to the nearest 100 g) using a mechanical weight scale. The heights of each study participant were also measured with shoes off. Midwives estimated the gestational age of each participant using the last menstrual period method at the ANC visit in the health facility. The stool examination values were taken from the antenatal logbook kept at the clinic by the data collectors.

The questionnaire was prepared in English and translated into Amharic. The training was provided to all data collectors, and the overall activity of the study was closely monitored at each health facility. Data quality was assured through continuous supervision and by using the data collection tools adapted from validated measures/sources. All completed questionnaires were examined for completeness and consistency during data collection, and the data were cleaned before analysis.

7.2.6 Data processing and analysis

After the data had been cleaned, the analysis was conducted using Stata version 14 (stata.com). Descriptive statistics were calculated. The DDS was computed using data from 24-hour dietary recall, based on the recommendations of the Food and Nutrition Technical Assistance Project (220). Food items and liquids reported in the 24-hour dietary recall were categorised into 10 food groups. These food groups were the following: 1) Starchy staples (grains, white roots, tubers); 2) Legumes/pulses (beans, peas and lentils); 3) Nuts and seeds; 4) Dairy; 5) Meat, poultry and fish; 6) Eggs; 7) Dark green leafy vegetables; 8) Vitamin A-rich fruits and vegetables; 9) Other vegetables (tomatoes, onions); and 10) Other fruits. Women who ate a single food item from any of these food groups earned 1 point. If the participant did not consume a food item within the food group, they would receive 0 points for that category. The minimum and maximum DDSs were 0 and 10 points, respectively (220). The DDSs grouped in to low (< 5) and high DDS (≥5).

7.2.6.1 Propensity score analysis

Propensity score analysis was performed to adjust for significant differences in baseline covariates and to have unbiased estimates. The propensity score (267, 268) is the conditional probability of assigning a variable to a particular group (exposed or unexposed) given a set of observed covariates. A propensity score is an essential tool for causal inference in non-experimental studies in which randomisation is impossible and symmetry of treatment/exposure groups is unlikely. Propensity score analysis avoids selection or confounder bias (269). The propensity score analysis was performed as follows. First, a propensity score for each patient was estimated using the logistic regression model, with dietary diversity during pregnancy as the endpoint (high coded as 1; low, as 0). The following variables were used to estimate the propensity score: age, residence, educational status, marital status, occupation, first pregnancy, ANC, nausea and vomiting, gestational age, eating before pregnancy, change in food after pregnancy, food avoided, started new food types, meal patterns, fasting and craving. The propensity score model was assessed by using the *c* statistic (270) and Hosmer–Lemeshow statistics (271).

Second, the study subjects were grouped into 10 strata based on the quantiles of population propensity scores (272). In propensity score analysis, the sub-classification method uses all individuals in the dataset, and it is recommended for settings where the outcome data is already available (269). Third, the main concern with propensity score analysis is the balance of the covariates in the resulting matched data (269). Thus in this study, the covariate balance between two groups (women with low DDS and women with high DDS) was checked using standardised mean difference (standardised bias) with the 'pbalchk' command in Stata (273).

It is recommended that the absolute standardised differences of means should be less than 0.25 (274).

Finally using the propensity score-matched data, a conditional logistic regression model was used to assess the association between maternal DDS and anaemia, with adjustment for covariates (275) to control for the remaining minor differences in the matched sample (276).

Bivariate analysis was undertaken to determine the effect of dietary intake and other factors on anaemia (age, occupation, educational status, place of residence, main water source and toilet facility, gravidity/parity, ANC visits, nausea/vomiting, changing food intake, meal frequency and pattern, intake of iron/folate or de-worming tablets, MUAC and gestational age). CORs with 95% confidence intervals were also calculated.

Multivariable conditional logistic regression was used to identify the independent predictors of anaemia. The predictors that had a $p < 0.25$ in the bivariate logistic regression model were entered into a multivariable logistic regression model. Multivariable logistic regression can help to adjust for confounders and $p < 0.05$ was taken as significant.

7.2.7 Ethics approval and consent to participate

Ethics approval was obtained from the University of Newcastle Human Research Ethics Committee (Ref. No. H-2018-0017; see Appendix 6. This study was also approved by the Amhara Public Health Institute Research Ethics Committee (Ref. No. HRTT03/163/2018; see Appendix 7. Written permission was obtained from the zonal health department office and each health facility administration. Data collectors explained the study to the participants and written informed consent was obtained from each study participant. To protect against undue influence, the recruitment of participants was performed in an exit interview after they had finished their ANC visit. The data were not used for purposes other than this study and have been kept confidential.

7.3 Results

7.3.1 Sociodemographic, maternal and family characteristics

A total of 417 pregnant women participated in the study (n = 105 [25%] cases; n = 312 [75%] controls). The mean (±*SD*) age of cases was 26.2 (±4.5) years and of controls was 26.3 (±5.0) years. Around 58% of cases and 55% of controls were aged 25–34 years, respectively. The proportion of rural participants in both cases and controls was similar: 42% in cases and 44% in controls. Nearly two-fifths of the cases (41%) and 21% of controls did not attend formal education. A majority of cases (57%) and controls (51%) were pregnant for the first time. A large proportion of cases (71%) and controls (70%) had experienced nausea/vomiting during pregnancy. Similar proportions of cases (65%) and controls (65%) were in the third trimester of pregnancy. About 39% of women in the case group and 29% of women in the control group had low MUAC measurements (< 23 cm). The mean (±*SD*) weight in cases was 58.5 (±6.5) kg and in controls was 58.8 (±7.4) kg (see Table 7.1).

Table 7.1 Sociodemographic, maternal and family characteristics of study participants, North Shewa, 2019.

Variables	**Cases** ***n*** **(%)**	**Controls** ***n*** **(%)**	**Total** ***n*** **(%)**
Age (years), *M* (*SD*, IQR)	26.2 (4.5, 22–29)	26.3 (5.0, 23–29)	26.3 (4.9, 22–29)
Age group (years)			
15–24	37 (35.2)	115 (36.9)	152 (36.5)
25–34	61 (58.1)	170 (54.5)	231 (55.4)
≥ 35	7 (6.7)	27 (8.7)	34 (8.2)
Place of residence			
Urban	61 (58.0)	175 (56.0)	236 (56.6)
Rural	44 (42.0)	137 (44.0)	181 (43.4)
Religion			
Orthodox	97 (92.4)	300 (96.0)	397 (95.2)
Other	8 (7.6)	12 (3.9)	20 (4.8)
Ethnicity			
Amhara	98 (93.3)	306 (98.1)	404 (96.9)
Other	7 (9.7)	6 (1.9)	13 (3.1)
Educational status			
No education	43 (41.0)	66 (21.2)	109 (26.1)
Primary	23 (22.0)	120 (38.4)	143 (34.3)
Secondary	24 (23.0)	81 (26.0)	105 (25.2)
Tertiary	15 (14)	45 (14.4)	60 (14.4)
Marital status			
Single	6 (5.7)	13 (4.2)	19 (4.6)
Married	97 (92.4)	290 (93.0)	387 (92.8)
Divorced/widowed	2 (1.9)	9 (2.9)	11 (2.7)
Occupation			
Farmer	21 (20.0)	68 (21.8)	89 (21.3)
Merchant	23 (21.9)	66 (21.2)	89 (21.3)
Government employee	21 (20.0)	46 (14.7)	67 (16.1)

Variables	Cases *n* (%)	Controls *n* (%)	Total *n* (%)
Housewife	29 (27.6)	103 (33.0)	132 (31.7)
Other*	11 (10.5)	29 (9.3)	40 (9.6)
Drinking water source			
Improved	86 (81.9)	272 (87.2)	358 (85.9)
Unimproved	19 (18.1)	40 (12.8)	59 (14.1)
Latrine facility			
Improved	60 (57.1)	201 (64.42)	261 (62.6)
Unimproved	45 (42.9)	111 (35.6)	156 (37.4)
Monthly income (ETB), *M* (*SD*)	3558.6 (2466)	2916.06 (1891.8)	3078.0 (2065)
First pregnancy			
Yes	60 (57.1)	160 (51.3)	220 (52.8)
No	45 (42.9)	152 (48.7)	197 (47.2)
Previous antenatal care visits			
Yes	38 (36.2)	136 (43.6)	174 (41.7)
No	67 (63.8)	176 (56.4)	243 (58.3)
Nausea/vomiting			
Yes	75 (71.4)	220 (70.5)	295 (70.7)
No	30 (28.6)	92 (29.5)	122 (29.3)
Alcohol consumed during pregnancy			
Yes	17 (16.2)	40 (12.8)	57 (13.7)
No	88 (83.8)	272 (87.2)	360 (86.3)
Trimester			
First	2 (1.9)	19 (6.1)	21 (5.0)
Second	35 (33.3)	89 (28.5)	124 (29.7)
Third	68 (64.8)	204 (65.4)	272 (65.2)
Weight (14) , *M* (*SD*)	58.5 (6.5)	58.8 (7.4)	58.8 (7.2)
Height (cm), *M* (*SD*)	159.7 (6.5)	159.9 (6.3)	159.9 (6.3)
MUAC (cm), *M* (*SD*)	23.37 (2.3)	23.8 (2.2)	23.7 (2.3)
< 23	41 (39.1)	90 (28.9)	131 (31.4)
≥ 23	64 (61.0)	222 (71.2)	286 (68.6)
SBP (mmHg), *M* (*SD*)	109.14 (15.3)	114.98 (18.1)	113.5 (17.6)
DBP (mmHg), *M* (*SD*)	69.51 (10.9)	73.5 (13.2)	72.5 (12.8)

Note. IQR = interquartile range; MUAC = mid-upper arm circumference; SBP = systolic blood pressure; DBP = diastolic blood pressure; ETB=Ethiopian birr

*E.g., daily labourer, private employee or self-employed.

7.3.2 Maternal eating habits/practices

Both cases and controls had similar eating practices before pregnancy; 72% of cases and controls ate three times a day before pregnancy. On becoming pregnant, 35% of cases and 49% of controls did not change their food intake. Around one-fifth, (21%) of cases and a quarter (26%) of controls reported avoiding certain foods once they became pregnant. A further 33% of cases and 10% of controls reported reducing their food intake (size and/or frequency) once they were pregnant. A majority of cases (45%) and controls (40%) consumed two main meals and two snacks daily during pregnancy, with a majority of participants having a low DDS (53% of cases and 40% of controls) (Table 7.2).

Table 7.2 Maternal feeding habits/practices of study participants, North Shewa, 2019.

Variables	**Cases** *n* **(%)**	**Controls** *n* **(%)**	**Total** *n* **(%)**
Eating patterns before pregnancy per day			
Once/twice	2 (1.9)	16 (5.1)	18 (4.3)
Three times	76 (72.4)	226 (72.4)	302 (72.4)
Four or more times	27 (25.7)	70 (22.4)	97 (23.3)
Changed food intake this pregnancy			
No change	37 (35.2)	154 (49.4)	191 (45.8)
Increased size and number	33 (31.4)	128 (41.0)	161 (38.6)
Decreased size and number	35 (33.3)	30 (9.6)	65 (15.6)
Changed snack intake this pregnancy			
No change	56 (53.3)	173 (55.5)	229 (54.9)
Increased size and number	35 (33.3)	114 (36.5)	149 (35.7)
Decreased size and number	14 (13.3)	25 (8.01)	39 (9.35)
Avoidance of food this pregnancy			
Yes	22 (21.0)	82 (26.3)	104 (24.9)
No	83 (79.1)	230 (73.7)	313 (75.1)
Additional foods consumed this pregnancy			
Yes	53 (50.5)	142 (45.5)	195 (46.8)
No	52 (49.5)	170 (54.5)	222 (53.2)
Typical meal pattern this pregnancy			
2 main & 1 small	45 (42.9)	141 (45.2)	186 (44.6)
2 main & 2 main	47 (44.8)	124 (39.7)	171 (41.0)
2 main & 3+ small	13 (12.3)	47 (15.1)	60 (14.4)
Fasting during this pregnancy			
Yes	35 (33.3)	80 (25.7)	115 (27.6)

No	70 (66.7)	231 (74.3)	301 (72.4)
Craving food this pregnancy			
Yes	46 (43.8)	128 (41.0)	174 (41.7)
No	59 (56.2)	184 (59.0)	243 (58.3)
Taking supplements this pregnancy			
Yes	37 (35.2)	121 (38.8)	158 (37.9)
No	68 (64.8)	191 (61.2)	259 (62.1)
De-worming			
Yes	26 (25.2)	88 (28.2)	114 (27.5)
No	77 (74.8)	224 (71.8)	301 (72.5)
Dietary diversity score			
≥ 5 (good)	49 (46.7)	187 (59.9)	237 (56.8)
< 5 **(342)**	56 (53.3)	125 (40.1)	180 (43.2)

7.3.3 Propensity score analysis

The propensity score model was assessed using the *c* statistic and Hosmer–Lemeshow statistics. The Hosmer–Lemeshow goodness-of-fit test (p = 0.177) and the *c* statistic (0.72) indicated good calibration and discrimination ability of the propensity score model.

The covariate balance check indicated that all of the variables had less than 0.25 absolute mean standardised difference (see Figure 7.1), which is in the range of the recommended cut-off values (< 0.25) (274).

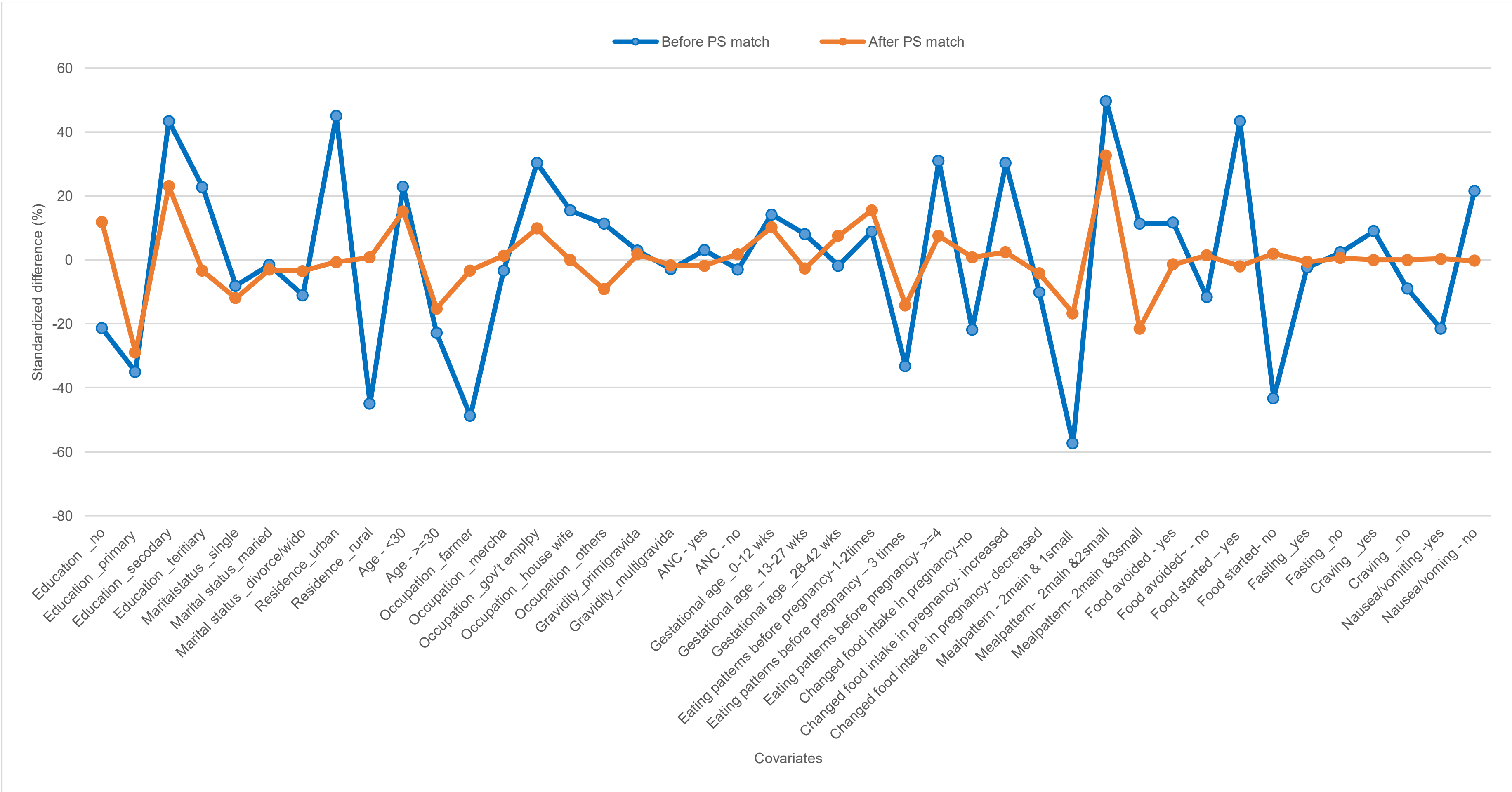


Figure 7-1 Standardised mean differences before and after propensity score matching comparing covariate values for study subjects having high and low DDS

7.3.4 Factors for the occurrence of maternal anaemia among pregnant women

7.3.4.1 Bivariate analysis

The association between predictor variables and maternal anaemia was assessed using a bivariate logistic regression model. Low educational status, a MUAC < 23 cm, decreasing portion size and frequency of food intake after becoming pregnant, and low DDS were significantly associated with higher odds of anaemia among pregnant women.

The bivariate analysis indicated that the odds of anaemia in women with no education was 2.53 times higher than women with tertiary education (COR = 2.53; 95% CI: 1.07, 5.95). Similarly, those who had decreased the portion size and frequency of food intake after becoming pregnant were at higher odds of anaemia compared to participants who had increased the size and frequency of food intake after becoming pregnant (COR = 4.51; 95% CI: 2.39, 8.89). However, there was no significant difference with regard to MUAC, gestational age, water source, latrine facility, alcohol consumption or ANC visits and odds of anaemia (Table 7.3).

7.3.4.2 Multivariable analysis

The multivariable logistic regression analysis showed that a low DDS (AOR = 2.14; 95% CI: 1.24, 3.69), reducing food intake (AOR = 6.89; 95% CI: 3.23, 14.70) and having no formal education (AOR = 3.13; 95% CI: 1.18, 8.32) were associated with an increased odds of anaemia. Similarly, some variables, such access to an unimproved latrine facility (AOR = 1.37; 95% CI: 0.72, 2.62), primigravidity (AOR = 1.29; 95% CI: 0.77, 2.18), a MUAC < 23 cm (AOR = 1.33; 95% CI: 0.75, 2.38), fasting (AOR = 1.52; 95% CI: 0.87, 2.65) and previous ANC visit (AOR = 0.75; 95% CI: 0.43, 1.31), were positively associated with an increased odds of anaemia, though these were not statistically significant (see Table 7.3).

Table 7.3 Determinant factors of anaemia among pregnant women in the selected public health facilities of North Shewa Zone, Ethiopia: Conditional logistic regression analysis, 2019.

Variables	COR	95% CI	*p*	AOR (95% CI)
Age (years)				
15–24	1			
25–34	1.08	0.68, 1.74	0.74	
≥ 35	0.75	0.30, 1.88	0.55	

Variables	COR	95% CI	*p*	AOR (95% CI)
Place of residence				
Urban				
Rural	0.77	0.44, 1.37	0.38	
Educational status				
No education	**2.53**	**1.07, 5.95**	0.03	**3.13 (1.18, 8.32)**
Primary	0.69	0.31, 1.53	0.37	0.55 (0.23, 1.29)
Secondary	0.99	0.47, 2.12	0.99	0.77 (0.34, 1.78)
Tertiary	1			1
Occupation				
Farmer	0.42	0.16, 1.11	0.08	
Merchant	0.64	0.30, 1.38	0.03	
Housewife	0.56	0.28, 1.12	0.10	
Other*	0.85	0.35, 2.05	0.72	
Government employee	1			
Water source				
Unimproved	1.53	0.78, 3.02	0.22	0.97 (0.42, 2.25)
Improved	1			1
Latrine facility				
Unimproved	1.37	0.84, 2.25	0.21	1.37 (0.72, 2.62)
Improved	1			1
Parity				
Primigravida	1.29	0.83, 2.02	0.25	1.29 (0.77, 2.18)
Multigravida	1			1
Antenatal care visit so far				
Yes	0.74	0.47, 1.16	0.19	0.75 (0.43, 1.31)
No				1
Experienced nausea/vomiting				
Yes	0.98	0.59, 1.63	0.93	
No				
Alcohol consumed during pregnancy				
Yes	1.33	0.72, 2.47	0.37	
No	1			
Gestational age				
First	1	1		1

Variables	COR	95% CI	*p*	AOR (95% CI)
Second	3.37	0.75, 15.25	0.11	3.91 (0.82, 18.68)
Third	2.84	0.64, 12.58	0.17	4.12 (0.87, 19.46)
MUAC				
< 23 cm	1.53	0.95, 2.47	0.08	1.33 (0.75, 2.38)
≥ 23 cm	1	1		1
Changed food intake in this pregnancy				
No change	0.97	0 .56, 1.73	0.96	0.79 (0.42, 1.46)
Decreased size and number	**4.51**	**2.39, 8.89**	0.01	**6.89 (3.23, 14.70)**
Increased size and number	1	1		1
Typical meal pattern				
2 main & 1 small	1.02	0.43, 2.41	0.97	
2 main & 2 main	1.37	0.64, 2.91	0.42	
2 main & 3+ small	1	1		
Fasting during pregnancy				
Yes	1.52	0.93, 2.47	0.09	1.52 (0.87, 2.65)
No	1			1
Craving food				
Yes	1.14	0.73, 1.79	0.56	
No	1			
Taking supplements				
Yes	0.86	0.54, 1.36	0.51	
No	1		1	
De-worming				
Yes	0.85	0.51, 1.42	0.55	
No				
Dietary diversity score				
< 5 (342)	**1.82**	**1.13, 2.94**	0.014	**2.14 (1.24, 3.69)**
≥ 5 (good)	1			**1**

Note. COR = crude odds ratio; AOR = adjusted odds ratio; MUAC = mid-upper arm circumference; *E.g., daily labourer, private employee or self-employed

7.4 Discussion

The findings of this study indicated that a low DDS, reducing food intake and having no formal education were significant predictors of anaemia among pregnant women in North Shewa, Ethiopia. This study revealed that women who had low DDS were two times more likely to have anaemia compared to women with a higher DDS. This finding is in line with previous studies conducted in Eastern Ethiopia (46, 343), which have reported higher odds of anaemia in women with a low DDS. Similarly, the results of studies conducted in north-west Ethiopia (232), Southern Ethiopia (24, 25) and Ghana (43) have also indicated that a low DDS is associated with an increased odds of anaemia. Conflicting results have been reported in studies from Pakistan (45) and Ghana (44), possibly due to the measurement of dietary intake differences. Our results showed that women who reduced their dietary intake were more likely to be anaemic compared to those who did not change their dietary intake. Similar results have been reported in studies conducted in Ethiopia (46) and Mali (344).

The association of a high DDS with the lower occurrence of anaemia might be due to sufficient and diversified food intake during pregnancy, which helps to meet required nutrient recommendations, (including for iron) and prevents unintended consequences such as anaemia (345). Furthermore, this might also be due to the fact that an increase in a woman's DDS is a good proxy indicator of micronutrient adequacy in her diet (225, 229) as well as a positive indicator of nutritional status (230, 231). Reducing dietary intake during pregnancy might lead to insufficient food intake, which could result in low iron intake (346) and a subsequent lack of macro and micronutrients. Thus, it is important to provide dietary counselling to women during pregnancy.

In agreement with other studies conducted in Ethiopia (113), the present study showed that having no formal education was associated with a higher odds of anaemia among pregnant women compared with those who had completed tertiary education. However, the findings of previous studies did not demonstrate an association between maternal education and the risk of anaemia (46, 66, 77, 114, 347). The discrepancy of study results might be due to the differences in population and methodology, as the present study was a case-control study, whereas previous studies were cross-sectional study.

Furthermore, living in a rural area has been associated with a greater occurrence of anaemia during pregnancy (113, 114). However, other studies have reported that the odds of anaemia were not significantly different between rural and urban residents (347, 348), which is in line with our study results. The gravidity of women was identified as a predictor in several studies conducted in Ethiopia (24, 25, 46, 77, 343). Our study and a cross-sectional study from Ethiopia have indicated that gravidity was not associated with increased odds of anaemia (114). This might be due to methodological differences, as the present study was a case-control study, but the previous studies were cross-sectional.

Different observational studies report that iron/folate supplementation was associated with lower odds of anaemia during pregnancy (24, 67, 113, 349). In contrast, the present study and another study conducted in north-west Ethiopia (232) have indicated that the odds of anaemia were not significantly different between those who had supplemented with iron/folate and those who did not. Similarly, evidence has shown that intermittent iron supplementation (152), supplementation with folic acid only or with other micronutrients (153) and the provision of multiple micronutrients plus an iron and folic acid supplement (154) during gestation failed to improve maternal anaemia. A possible explanation could be due to different side effects, women might not adhere to supplementation guidelines, which may dilute the effect of iron supplementation on anaemia towards the null.

The strength of this study is the use of the case-control study design, which is an analytical design and important for identifying potential factors of anaemia. Case-control designs are especially suitable for studying diseases with a long latency period and to assess multiple exposures. Another strength of this study is the application of an advanced statistical analysis (propensity score analysis), which can help to reduce selection and confounder bias. However, the possible limitations of this study are social desirability and recall biases, as this study relied on self-reporting and the memories of participants. The use of one 24 hour recall might not be representative of the usual dietary intake of women so that there could be inflation or deflation of DDS scores. Further, a case-control study can only identify an association; it does not establish a temporal or cause-effect relationship. Due to resource constraints, it was impossible to measure and incorporate all potential predictors of maternal anaemia. As a result, there could be an under-or over-inflation of reported effect sizes, and the interpretation of the study's results should consider these limitations.

7.5 Conclusion

This study demonstrated that intake of a less diversified diet, reducing food intake and having no formal education were associated with higher odds of anaemia. Interventions focused on dietary counselling should be considered to strengthen existing prenatal health service programs. Women who are pregnant or considering pregnancy should be strongly encouraged to increase, rather than decrease, both the diversity and amount of food intake during pregnancy to ensure they meet macro-and micronutrient requirements.

Chapter 8: The effect of dietary patterns on HDPs in North Shewa, Ethiopia: A propensity score-matched case-control study

This chapter was published in the *Journal of Pregnancy Hypertension in October 2020*.

Kibret KT, Chojenta C, D'Arcy E, Loxton D. The effect of dietary patterns on hypertensive disorders of pregnancy in North Shewa, Ethiopia: A propensity score-matched case-control study Pregnancy hypertension, 2020; 22: 24-29; doi.org/10.1016/j.preghy.2020.07.002.

Abstract

Objective: This study aimed to assess the effect of dietary patterns during pregnancy on HDPs. A propensity score-matched case-control study was conducted with 340 pregnant women (71 cases and 269 controls) in North Shewa Zone, Ethiopia. Data were collected through an interviewer-administered questionnaire and maternal anthropometry measurements. After propensity score matching, a conditional logistic regression model was used to identify the independent predictors of HDPs by adjusting for confounders. $P < 0.05$ was statistically significant.

Results: A high DDS (AOR = 0.45; 95% CI: 0.21, 0.93) was associated with lower odds of HDPs. Being a merchant (AOR = 3.71; 95% CI: 1.16, 11.89), having a previous history of HDPs (AOR = 27.58; 95% CI: 4.53, 168.06) and a high Hgb level (AOR= 2.26; 95% CI: 1.66, 3.09) were associated with increased odds of HDPs. Diet is an amendable factor, and the promotion of a diversified diet is an important approach for preventing the occurrence of HDPs. Women should be counselled to diversify their dietary intake to include a large number of vegetables, legumes and fruit.

Key terms: Hypertensive disorders of pregnancy, gestational hypertension, dietary intake, pregnant women, case-control study.

8.1 Introduction

HDPs are a group of disorders that include chronic hypertension, gestational hypertension, pre-eclampsia/eclampsia and pre-eclampsia superimposed on chronic hypertension (158). Gestational hypertension refers to the presence of raised blood pressure (≥ 140/90 mmHg) in two measurements, 4 hours apart, after 20 weeks of gestation in women previously normotensive (159). Pre-eclampsia refers to blood pressure ≥ 140/90 mmHg with ≥ +1 proteinuria in women previously normotensive (159). Eclampsia includes pre-eclampsia plus a new event of seizure or convulsion (159). Chronic (pre-existing) hypertension refers to a blood pressure ≥ 140/90 mmHg preceding pregnancy or before the 20th week of gestation (158, 159).

HDPs are among the leading causes of maternal morbidity and mortality globally and regionally (5, 11), including in Ethiopia (12). HDPs are a health problem among pregnant women and ranked in the top five major causes of maternal death worldwide (5). HDPs complicate nearly 10% of pregnancies and cause an estimated 30,000 maternal deaths annually, with most deaths occurring in less-developed countries (11). In sub-Saharan and Northern Africa, hypertensive disorders accounted for nearly 16% and 17% of maternal deaths, respectively (5). In Ethiopia, it is the third most common cause of maternal mortality (19%) next to haemorrhages (22%) and obstructed labour/uterine ruptures (36%) (12). Unfortunately, maternal deaths due to HDPs have shown to be an increasing trend (12, 186).

The exact causes of HDPs are not known (164), although it is proposed that there are multiple risk factors (modifiable and non-modifiable) (163). Evidence has shown that modifiable risk factors, including a BMI of 25 kg/m^2 or more (175, 176), low education attainment (122, 157), poor diet, anaemia and the number of previous births (6, 122) are risk factors of HDPs. Moreover, non-modifiable factors, such as being over 35 years of age, (122, 165, 166) primiparity (122, 165-167), multiple pregnancies (122, 165, 166, 168), family history of hypertension (169-171), previous pre-eclampsia or hypertension during pregnancy (157, 170, 172), GDM (165, 167, 173, 174) and pre-existing diabetes (171, 175) are also associated with a higher odds of HDPs.

Several studies have also reported that dietary intake during pregnancy plays an important role in the occurrence of HDPs (26, 27, 155, 156). However, the findings remain varied, and further research is necessary to clarify the effects of dietary intake on the occurrence of HDPs, particularly in resource-limited settings, including in Ethiopia (37). Further research is needed to properly clarify the effect of DDSs on HDPs in resource-limited settings. Therefore, this study aims to assess the effect of dietary patterns on the risk of HDPs in North Shewa, Ethiopia.

8.2 Methods

8.2.1 Study settings, design and population

A case-control study was conducted in five selected health facilities in North Shewa Zone, Ethiopia, from November 2018 to March 2019. The cases were pregnant women who had a blood pressure ≥ 140/90 mmHg. Controls were pregnant women who were normotensive during their pregnancy. For each case, three healthy controls were identified.

The study population was all pregnant women who attended the ANC clinics in the selected health facilities. Any pregnant woman who had an ANC follow-up in that specific health facility during the study period between November 2018 and March 2019, and provided consent was included in this study. Pregnant women who could not hear or speak were temporary residents, had severe medical problems (cardiovascular or renal diseases) or were not willing to participate were excluded.

8.2.2 Sampling method and sample size determination

A sample size quota was allocated for each selected health facility proportional to the average number of ANC visits for the preceding three months. Participants were recruited from each health facility until the allotted sample size was fulfilled. The sample size was calculated using significant factors of HDPs and selected to produce a maximum sample. The optimum sample size was calculated using the following parameters: age > 35 years as the exposure variable, 5% significance level, a power level of 80%, a 1:3 ratio of cases to controls, and a double proportion formula (264). Therefore, using a 5% contingency level for non-response, the final sample size was 314 women (79 cases and 235 controls).

8.2.3 Data collection procedures and measurements

Data were collected using an interviewer-administered questionnaire, anthropometry measurements and a record review of laboratory measurements. The questionnaire assessed sociodemographic characteristics: maternal and family characteristics, maternal feeding habits/practices and maternal dietary intake (24-hour recall). The dietary intake of participants was assessed through the administration of a 24-hour recall food questionnaire that was adapted from the FAO/WHO (220). Participants were requested to recall all foods they had consumed in the preceding 24 hours: first spontaneously, then following probing questions from the interviewer. The questionnaire was prepared in English and translated into Amharic.

8.2.4 Anthropometric and laboratory measurements

Blood pressure of participants was measured using an arm sphygmomanometer after a 10-minute rest. A blood pressure measurement ≤ 140/90 mmHg was taken as normal (140 and 90 refer to SBP and DBP, respectively). The Hgb levels of participants, routinely measured during ANC follow-ups, were taken from ANC registries to determine the anaemia status of enrolled pregnant women. Midwives estimated the gestational age of each participant's pregnancy using the last reported menstrual period method during their ANC visit at the health facility. The urine protein level and stool examination values were taken from the ANC registries.

8.2.5 Data analysis

8.2.5.1 Descriptive analysis

Descriptive statistics were calculated and mean blood pressure was compared across different categories of the independent variables using ANOVA and Stata version 14 (stata.com).

The DDS was computed using data from a 24-hour dietary recall based on the recommendations of FAO/WHO (220). Food items and liquids reported in the 24-hour dietary recall were categorised into 10 food groups. These food groups were the following: 1) Starchy staples (grains, white roots, tubers); 2) Legumes/pulses (beans, peas and lentils); 3) Nuts and seeds; 4) Dairy; 5) Meat, poultry and fish; 6) Eggs; 7) Dark green leafy vegetables; 8) Vitamin A-rich fruits and vegetables; 9) Other vegetables (tomatoes, onions); and 10) Other fruits (apples, bananas). Eating a single item from any of the food groups earned a score of 1; if not consumed, no points were given. The minimum and maximum DDSs were 0 and 10 points, respectively (220). The DDS was grouped into low (< 5) and high DDS (≥5).

8.2.5.2 Propensity score analysis

Propensity score analysis was performed to adjust for significant differences in baseline covariates and to have unbiased estimates. The propensity score (267, 268) is the conditional probability of assigning a variable to a particular group (exposed or unexposed) given a set of observed covariates and avoids selection or confounder bias (269). The propensity score analysis was performed as follows. First, a propensity score for each patient was estimated using the logistic regression model, with the dietary diversity during pregnancy as the endpoint (high coded as 1; low, as 0). The following variables were used to estimate the propensity score:

age, residence, educational status, marital status, occupation, gravidity, ANC, nausea or vomiting, gestational age, eating before pregnancy, change food after pregnancy, food avoided, started new food types, meal patterns, fasting and food craving. The *c* statistic (270) and Hosmer–Lemeshow statistics (271) were used to assess the propensity score model fit. The Hosmer–Lemeshow goodness-of-fit test ($p = 0.63$) and the *c* statistic (0.77) indicated a good calibration and discrimination ability of the propensity score model.

After estimating the propensity score, the study subjects were grouped into seven strata based on the quantiles of population propensity scores (272). Then, the balance of the covariates in the resultant matched data became the main concern of the propensity score analysis (269). The covariate balance between two groups (women with low DDS and women with high DDS) was checked using the standardised mean difference (standardised bias) with the 'pbalchk' command in Stata (273). The covariate balance check result indicated that all of the variables had a less than 0.25 absolute mean standardised difference (max = 0.152; see Table 8.1), which is less than the recommended cut-off value (< 0.25) (274).

Finally, using the propensity score-matched data, a conditional logistic regression model was used to assess the association between maternal DDS and HDPs, with adjustment for covariates (275) to control for the remaining minor differences in the matched sample (276).

Bivariate analysis was undertaken to determine the association between different factors and HDPs, and CORs with 95% confidence intervals were estimated. Multivariable conditional logistic regression was used to identify the independent predictors of HDPs by fitting factors with a $p < 0.25$ in the bivariate analysis. This multivariable logistic regression can also help to adjust for confounders, and a $p < 0.05$ was taken as significant.

Table 8.1 Standardised mean differences before and after propensity score matching, comparing covariate values for study subjects having high vs low DDSs.

	Standardised difference (%)	
Variables	**Before PSM**	**After PSM**
Education _no	–16.9	2.5
Education _primary	–33.4	–3.5
Education _secondary	41.1	2.0
Education _tertiary	18.5	–1.0
Marital status _single	1.9	–0.7
Marital status_ married	–7.3	–8.8
Marital status _divorce/widowed	–11.0	4.2
Residence_ urban	44.9	1.9

Variables	Standardised difference (%)	
	Before PSM	After PSM
Residence _rural	–44.9	–1.9
Age < 30	20.3	15.2
Age >= 30	–20.3	–15.2
Occupation _farmer	–49.8	2.2
Occupation _merchant	0.3	0.7
Occupation _gov't employ	29.0	4.1
Occupation _housewife	17.3	–4.8
Occupation _others	5.0	–1.5
Gravidity _primigravida	–4.2	–1.4
Gravidity _multigravida	4.2	1.4
ANC - yes	7.5	0.0
ANC - no	–7.5	0.0
Gestational age _13–27 weeks	–8.3	–1.6
Gestational age _28–40 weeks	8.3	1.6
Eating patterns before pregnancy - 1–2 times	9.8	0.3
Eating patterns before pregnancy - 3 times	–37.8	–1.1
Eating patterns before pregnancy - >= 4 times	35.1	1.0
Changed food intake in pregnancy - no	–23.9	3.5
Changed food intake in pregnancy - increased	34.2	–3.4
Changed food intake in pregnancy - decreased	–13.4	–0.2
Meal pattern - 2main & 1small	–54.7	0.9
Meal pattern - 2main & 2small	50.3	2.5
Meal pattern - 2main & 3small	6.9	–4.6
Food avoided - yes	7.6	–0.8
Food avoided - no	–7.6	0.8
Food started - yes	41.3	–2.5
Food started - no	–41.3	2.5
Fasting _yes	–7.1	3.3
Fasting _no	7.1	–3.3
Craving _yes	–7.0	–0.3
Craving _no	7.0	0.3
Nausea/vomiting - yes	–22.1	2.0
Nausea/vomiting - no	22.1	–2.0

Note. PSM = propensity score matching; ANC = antenatal care.

8.2.6 Ethics approvals and consent to participate

Ethics approval was obtained from both the University of Newcastle Human Research Ethics Committee (Ref. No. H-2018-0017; see Appendix 6), and Amhara Public Health Institute Research Ethics Committee (Ref. No. HRTT03/163/2018; see Appendix 7). Written permission was obtained from the zonal health department office and each health facility administration.

Written informed consent was obtained from each study participant. To protect against undue influence, the recruitment of participants was performed in an exit interview after they had finished their ANC.

8.3 Results

8.3.1 Sociodemographic characteristics of study participants

A total of 340 study subjects (71 cases and 269 controls) were included in this study. The majority of cases (44%) and controls (58%) were aged 25–34 years. Around 38% of cases and 33% of controls completed up to primary education. More cases (56%) than controls (51%) were classified as primigravida. The mean (±SD) SBPs and DBPs of cases were 144.7 (±10) mmHg and 95 (±7) mmHg, respectively. The corresponding values for controls were 107 (±11) mmHg and 67 (±8) mmHg, respectively (see Table 8.2).

Table 8.2 Sociodemographic characteristics of study participants, 2018/2019.

Sociodemographic variables	**Cases** ***n*** **(%)**	**Controls** ***n*** **(%)**	**Total** ***n*** **(%)**
Age (years), *M* (*SD*, IQR)	26.3 (5.7)	26.2 (4.7)	26.2 (4.9)
Age (years)			
15–24	30 (42.3)	95 (35.3)	125 (36.8)
25–34	31 (43.7)	156 (58.0)	187 (55.0)
≥ 35	10 (14.1)	18 (6.7)	28 (8.2)
Place of residence			
Urban	41 (57.8)	141 (52.4)	182 (53.5)
Rural	30 (42.3)	128 (47.6)	158 (46.5)
Religion			
Orthodox	70 (98.6)	253 (94.1)	323 (95.0)
Others	1 (1.4)	16 (6.0)	17 (5.0)
Ethnicity			
Amhara	70 (98.6)	253 (97.0)	323 (97.4)
Others	1 (1.4)	16 (3.0)	17 (2.7)
Educational status			
No education	15 (21.1)	80 (29.7)	95 (27.9)
Primary	27 (38.0)	90 (33.5)	117 (34.4)
Secondary	21 (29.6)	63 (23.4)	84 (24.7)
Tertiary	8 (11.3)	36 (13.4)	44 (12.9)
Marital status			
Single	2 (2.8)	14 (5.2)	16 (4.7)
Married	66 (93.0)	248 (92.2)	314 (92.4)

Sociodemographic variables	Cases *n* (%)	Controls *n* (%)	Total *n* (%)
Divorced/widowed	3 (4.2)	7 (2.6)	10 (42.9)
Occupation			
Farmer	10 (14.1)	62 (23.1)	72 (21.2)
Merchant	21 (29.6)	49 (18.2)	70 (20.6)
Government employee	9 (12.7)	45 (16.7)	54 (15.9)
Housewife	26 (36.6)	87 (32.3)	113 (33.2)
Other	5 (7.0)	26 (9.7)	31 (9.1)
Monthly income(ETB), *M* (*SD*)	3333.30 (2151.7)	2964.38 (2057.7)	3040.90 (2077.1)
First pregnancy			
Yes	40 (56.3)	137 (50.9)	177 (52.1)
No	31 (43.7)	132 (49.1)	163 (47.9)
History of stillbirth			
Yes	4 (12.9)	3 (2.3)	7 (4.3)
No	27 (87.1)	129 (97.7)	156 (95.7)
Hypertension in a previous pregnancy			
Yes	7 (22.6)	3 (2.3)	10 (6.1)
No	24 (77.4)	129 (97.7)	153 (93.9)
Diabetes mellitus in a previous pregnancy			
Yes	1(3.2)	0	1(0.6)
No	30 (96.8)	132(100)	162(99.4)
Family history of hypertension			
Yes	4 (5.6)	11 (4.1)	15 (4.4)
No	67 (94.4)	258 (95.9)	325 (95.6)
Family history of diabetes mellitus			
Yes	1 (1.4)	3 (1.2)	4 (1.1)
No	70 (98.6)	266 (98.9)	336 (98.8)
Chronic hypertension			
Yes	0 (0.0)	3 (1.1)	3 (0.9)
No	71 (100)	266 (98.9)	337 (99.1)
At least one ANC visit			
Yes	40 (56.3)	137 (50.9)	177 (52.1)
No	31 (43.7)	132 (49.1)	163 (47.9)
Alcohol consumed during pregnancy			
Yes	14 (19.7)	38 (14.1)	52 (15.3)
No	57 (80.3)	231 (85.9)	288 (84.7)
Gestational age (years), *M* (*SD*)	33.76 (6.0)	32.10 (5.1)	32.40 (5.4)
Weight (14) *M* (*SD*)	59.99 (7.3)	59.16 (6.7)	59.30 (6.8)
Height (cm) *M* (*SD*)	160.69 (5.9)	159.60 (6.3)	159.85 (6.3)

Sociodemographic variables	**Cases** *n* (%)	**Controls** *n* (%)	**Total** *n* (%)
MUAC, *M* (*SD*)	24.3 (2.3)	23.5 (2.2)	23.7 (2.3)
< 23 cm	15 (21.1)	98 (36.4)	113 (33.2)
≥ 23 cm	56 (78.9)	171 (63.6)	227 (66.7)
SBP (mmHg), *M* (*SD*)	145(10)	107(11)	115(19)
DBP (mmHg), *M* (*SD*)	95(350)	68(8)	74(14)
Hgb level (g/dL), *M* (*SD*)	12.20 (1.2)	11.30 (1.2)	11.49 (1.3)

Note. IQR = interquartile range; ANC = antenatal care; MUAC = mid-upper arm circumference; SBP = systolic blood pressure; DBP = diastolic blood pressure; ETB=Ethiopian birr.

8.3.2 Maternal feeding habits/practices of study participants

Around 46% of cases and 38% of controls had increased food intake during pregnancy. Nearly 30% of cases and 25% of controls were fasting during pregnancy. The majority, 45% of cases and 40% of controls consumed a daily meal pattern of two main and two small meals. Approximately 51% of cases and 45% of controls had a low DDS (see Table 8.3).

Table 8.3 Maternal feeding habits/practices of study participants, 2018/2019.

Sociodemographic variables	**Cases** *n* (%)	**Controls** *n* (%)	**Total** *n* (%)
Eating patterns before pregnancy			
Once/twice	3 (4.2)	14 (5.2)	17 (5.00)
Three times	54 (76.1)	190 (70.6)	244 (71.8)
Four times	14 (19.7)	65 (24.2)	79 (23.2)
Changed food intake in this pregnancy			
No change	35 (49.30)	124 (46.1)	159 (46.8)
Increased size and number	33 (46.48)	102 (37.9)	135 (39.7)
Decreased size and number	3 (4.23)	43 (16.0)	46 (13.5)
Typical meal pattern			
2 main & 1 small	27 (38.0)	125 (46.5)	152 (44.7)
2 main & 2 main	32 (45.07)	108 (40.2)	140 (41.2)
2 main & 3+ small	12 (16.90)	36 (13.4)	48 (14.1)
Fasting during pregnancy			
Yes	21 (29.58)	67 (25.00)	88 (26.0)
No	50 (70.42)	201 (75.0)	251 (74.0)
Dietary diversity score, *M* (*SD*)	5.00 (1.7)	5.14 (1.9)	5.09 (1.8)
Dietary diversity score			
≥ 5 (good)	35 (49.30)	149 (55.4)	184 (54.1)
< 5 (low)	36 (50.70)	120 (44.6)	156 (45.9)

8.3.3 Factors associated with pregnancy-induced hypertension

The bivariate analysis revealed that a one-unit increase in Hgb level was associated with a 1.94 time increase in the odds of HDPs (COR = 1.94; 95% CI: 1.50, 2.50). Having a previous history of stillbirth (COR = 5.13, 95% CI: 1.11, 23.65), having a MUAC ≥ 23 cm (COR = 2.35; 95% CI: 1.24, 4.46) and a history of pregnancy-induced hypertension (COR = 10.83; 95% CI: 2.64, 4.39) were associated with increased odds of HDPs. However, odds of HDPs were not significantly different with respect to parity, family history of hypertension, age or consumption of alcohol during pregnancy (see Table 8.4).

The multivariable analysis showed that the intake of a diversified diet during pregnancy was associated with decreased odds of HDPs (AOR = 0.45, 95% CI: 0.21, 0.93). Higher odds of HDPs were found in women who reported HDPs in a previous pregnancy (AOR = 27.6; 95% CI: 4.53, 168.06). Similarly, a one-unit increase in Hgb level was associated with a twofold increase in the odds of having HDPs (AOR = 2.26; 95% CI: 1.66, 3.09; see Table 4).

Table 8.4 Determinant factors for the occurrence of HDPs: comparison of cases and controls by bivariate and multivariable logistic regression analyses, 2018/2019.

Sociodemographic variables	Cases *n* (%)	Controls n (%)	COR (95 %CI)	AOR (95 %CI)
Age (years)				
15–24	30 (42.3)	95 (35.3)	1	1
25–34	31 (43.7)	156 (58.0)	0.62 (0.35, 1.10)	0.73 (0.35, 1.53)
≥ 35	10 (14.1)	18 (6.7)	1.62 (0.67, 3.95)	2.42 (0.76, 7.69)
Place of residence			1	1
Urban	41 (57.8)	141 (52.4)	1.41 (0.77, 2.56)	2.23 (0.85, 5.84)
Rural	30 (42.3)	128 (47.6)	1	1
Educational status				
No education	15 (21.3)	80 (29.7)	0.86 (0.32, 2.32)	3.23 (0.64, 16.36)
Primary	27 (38.0)	90 (33.5)	1.56 (0.60, 4.06)	2.68 (0.61, 11.87)
Secondary	21 (29.6)	63 (23.4)	1.82 (0.72, 4.64)	3.71 (0.99, 13.88)
Tertiary	8 (11.3)	36 (13.4)	1	1
Occupation				
Farmer	10 (14.1)	62 (23.1)	1	1
Merchant	21 (29.6)	49 (18.2)	2.96 (1.15, 7.64)	3.71 (1.16, 11.89)
Government employee	9 (12.7)	45 (16.7)	1.47 (0.44, 4.95)	2.77 (0.52, 14.71)
Housewife	26 (36.7)	87 (32.3)	2.42 (0.91, 6.45)	3.54 (1.06, 11.90)
Other	5 (7.0)	26 (9.7)	1.27 (0.34, 4.67)	1.25 (0.25, 6.35)

Income (ETB)				
≤ 1650	10 (14.1)	41 (15.2)	1	1
1651–5250	24 (33.8)	96 (35.7)	1.41 (0.55, 3.63)	0.90 (0.28, 2.87)
≥ 5251	5 (7.0)	12 (4.5)	1.19 (0.48, 2.97)	0.95 (0.32, 2.85)
None/unknown	32 (45.1)	120 (44.6)	1.14 (0.53, 2.44)	118 (0.47, 2.96)
First pregnancy				
Yes	40 (56.3)	137 (50.9)	1.14 (0.67, 1.95)	1.33 (0.64, 2.76)
No	31 (43.7)	132 (49.1)	1	1
History of stillbirth				
Yes	4 (12.9)	3 (2.3)	5.13 (1.11, 23.65)	3.13 (0.47, 20.91)
No	27 (87.1)	129 (97.7)	1	1
Alcohol consumed during pregnancy				
Yes	14 (19.7)	38 (14.1)	1.67 (0.83, 3.37)	2.14 (0.86, 5.33)
No	57 (80.3)	231 (85.9)	1	1
History of HDPs				
Yes	7 (22.6)	3 (2.3)	10.83 (2.64, 44.39)	27.58 (4.53, 168.06)
No	24 (77.4)	129 (97.7)	1	1
Family history of hypertension				
Yes	4 (5.6)	11 (4.1)	1.29 (0.39, 4.21)	1.04 (0.20, 5.29)
No	67 (94.4)	258 (95.9)	1	1
Family history of diabetes				
Yes	1 (1.4)	3 (1.2)	1.34 (0.11, 11.32)	2.99 (0.13, 70.92)
No	70 (98.6)	266 (98.9)	1	1
MUAC				
< 23 cm	15 (21.1)	98 (36.4)	1	1
≥ 23 cm	56 (78.9)	171 (63.6)	2.35 (1.24, 4.46)	2.0 (0.88, 4.43)
Typical meal pattern				
2 main & 1 small	27 (38.0)	125 (46.5)	1	1
2 main & 2 main	32 (45.1)	108 (40.2)	0.57 (0.24, 1.34)	0.78 (0.24, 2.16)
2 main & 3+ small	12 (16.9)	36 (13.4)	0.87 (0.39, 1.94)	1.71 (0.62, 4.79)
Dietary diversity score				
≥ 5 (good)	35 (49.3)	149 (55.4)	1	1
< 5 (low)	36 (50.7)	120 (44.6)	1.43(0.72, 2.63)	2.22(1.07,4.76)
Haemoglobin level	105 (25.2)	312 (74.8)	1.94 (1.50, 2.50)	2.26 (1.66, 3.09)

Note. HDPs = hypertensive disorders of pregnancy; MUAC = mid-upper arm circumference; ETB=Ethiopian birr

8.4 Discussion

The results of this study revealed that being a merchant, having a previous history of HDPs and a high Hgb level was associated with increased odds of HDPs. Women who reported a more diversified food intake had 55% lower odds of HDPs than those who had a less diversified diet. This result is consistent with a study conducted in Norway (351), which reported a lower risk of HDPs with the intake of a diversified diet. A systematic review of observational studies has also indicated that a healthy dietary pattern, with a high intake of fruits, vegetables, wholegrain foods, fish and poultry is associated with a 22% reduced risk of HDPs (352). Numerous mechanisms may exist for the effect of dietary intake on HDPs. One possible mechanism may be that vegetables, fruits and plant foods are rich in antioxidants and vitamins (353), which could prevent oxidative stress (310). Oxidative stress has been linked with increased risk of HDPs (309), and the consumption of a diversified diet could help to remove free radicals, which are a risk for oxidative stress (312).

The results of this study showed that women who had a previous history of HDPs were more likely to have higher odds of HDPs. This is in line with previous studies conducted elsewhere (157, 170, 172). Evidence has also indicated higher odds of HDPs in primipara women compared to multigravida women (122, 165-167). Our results did not show a significant association between gravidity and odds of HDPs. In contrast to previous studies (169-171), our results also did not indicate a significant association between family history of hypertension and increased odds of HDPs.

Previous studies have reported inconsistent findings and causality has not been confirmed concerning the effect of Hgb levels on HDPs. The present study has indicated that a higher Hgb level was associated with an increased odds of HDPs. A one-unit increase in Hgb levels was associated with a twofold increase in the odds of HDPs. Our result is in agreement with studies that have reported that a higher Hgb concentration during gestation increases the odds of gestational hypertension (127, 128). However, other studies have reported contradicting findings in that a low Hgb level increased the risk of pre-eclampsia/eclampsia (123, 354). A cohort study in Iran (124) and a case-control study in Sudan indicated that low Hgb level increases the risk of pre-eclampsia (125). Similarly, other research has shown that a low Hgb level is related to a higher risk of HDPs, especially pre-eclampsia (6, 122). A possible explanation is that free Hgb concentration is the cause of vasoconstriction in HDPs while low levels of Hgb that may lead to an intensification of oxidative stress, which is the causes for HDPs (355)

Limitations: We tried to minimise the effect of confounding variables by adjusting for possible confounding factors. Nonetheless, there may be confounding via unmeasured factors in the present analysis, and the results must be interpreted with caution. Recall bias might also be a problem because this study relied on participants' self-reports (except for anthropometry measurements). Moreover, there may be a misreporting of food intake, even though it would most likely be non-differential. The use of one 24 hour recall might not be representative of the usual dietary intake of women so that there could be inflation or deflation of DDS scores.

8.5 Conclusion

The results of this study demonstrate that diversified food intake is associated with lower odds of HDPs. Similarly, being a merchant, having a previous history of HDPs and a high Hgb level are associated with increased odds of HDPs. Even though a cause-effect relationship cannot be established between dietary patterns and the risk of HDPs, our findings indicate that a diversified diet may be helpful in reducing the occurrence of HDPs. Women should be counselled to consume diversified foods high in vegetables, legumes and fruit.

Chapter 9: General discussion and recommendations

9.1 Discussion

9.1.1 Overview

The previous chapters (Chapters 4–8) presented the findings of this thesis as a series of papers. Chapter 4 consisted of a systematic review and meta-analysis focusing on assessing the effect of maternal dietary patterns on the risk of adverse pregnancy (HDPs and GDM) and birth (PTB and LBW) outcomes using literature from across the globe. The review identified 21 articles, of which 18 were cohort studies and three were cross-sectional. In the included articles, six reported the effect of dietary patterns on HDPs; six, on GDM; nine, on PTB; and two, on LBW. Chapter 5 gave a detailed analysis of the geographical distribution of anaemia among women across the country, using spatial analysis of the EDHS, a recently conducted large population-based survey. The chapter also identified possible predictors of anaemia among women through multilevel analysis, taking into consideration the hierarchical nature of the data. Chapter 6 provided PAF estimates for factors associated with different types of anaemia among women. The PAFs were estimated using AORs from logistic regression. Chapter 7 assessed the effect of dietary patterns on maternal anaemia in the low-resource setting of Ethiopia through a case-control study. The study was conducted using 418 participants from five health facilities. Chapter 8 was a case-control study examining the effect of dietary patterns on HDPs in North Shewa, Ethiopia, with 340 participants

The present chapter draws together the results from the five complementary studies described in Chapters 4–8, providing an integrated and contextualised synthesis of this work. The strengths and limitations of this body of work are also described in this chapter. The chapter ends with conclusions and recommendations for policy/practice and future research based on the main findings of the thesis.

9.1.2 The effect of dietary pattern on adverse pregnancy and birth outcomes

The systematic review and meta-analysis in Chapter 4 summarised existing evidence focusing on the effect of different dietary patterns during pregnancy on adverse pregnancy (HDPs and GDM) and birth (PTB and LBW) outcomes. The results suggest that healthy dietary patterns (high intake of fruits, vegetables, wholegrain foods, fish and poultry) have a positive effect on pregnancy outcomes (pre-eclampsia and GDM). The meta-analysis of four studies assessing the healthy dietary pattern resulted in an effect estimate suggesting decreased odds of pre-eclampsia. The healthy dietary pattern is in line with dietary guidelines, which suggest greater consumption of whole grains, vegetables, fruits, potatoes, pasta, cereals, beans and lentils, and fish (306). Similarly, the beneficial influence of diets high in fibre, potassium, fruits, vegetables, cereals, dark bread and low-fat dairy products was reported as decreasing the odds of pre-eclampsia (307). Another finding was that adherence to a healthy dietary pattern, characterised by the intake of vegetables, fruits, whole grains, fish, milk products, water for drinking and a lower intake of sugar-sweetened beverages and processed meat products is significantly associated with decreased odds of PTB. It is important to note that these results were inconsistent, with most of the evidence coming from high-income countries. Therefore, it was not possible to generalise the findings to women in low-resource settings. Further investigation on the effect of dietary patterns on HDPs is needed in the resource-limited setting of Ethiopia; using a case–control study, this gap was addressed in Chapter 8. The results suggested that having a well-diversified food intake is associated with lower odds of HDPs. Women who reported a more diversified food intake had 59% lower odds of HDPs than those who had less diversified food intake.

The effect of a diversified diet in reducing the risk of adverse pregnancy outcomes could be due to the effect of vitamins, minerals and antioxidants on oxidative stress and inflammation (356, 357). Pregnancy complications and adverse outcomes like pre-eclampsia and PTB have been related to oxidative stresses and associated inflammations (309). Vegetables, fruits and whole grains are sources of vitamins, minerals and antioxidants that have an anti-inflammatory effect (358-360). Intake of a diversified diet containing vegetables, fruits and legumes improves micronutrient and antioxidant intakes, which could improve pregnancy and birth outcomes through reducing oxidative stress and inflammation (319). Antioxidant vitamins (C and E) and essential trace elements (copper and zinc), through the dietary intake of legumes and fruits, which are rich in these nutrients, could decrease the risk of adverse pregnancy outcomes (321-323). Hence, the intake of a diversified diet mainly rich in vegetables (42, 233, 361) and probiotic foods (362, 363) could reduce adverse pregnancy outcomes (pre-eclampsia and PTB). In general, the intake of a diversified diet could reduce adverse pregnancy outcomes through the cumulative effect of nutrients and their biochemical properties. Therefore, the findings from Chapters 4 and 8 reveal that diversified diets and healthy dietary patterns, characterised by the high intake of fruits, vegetables and whole grains, and low intake of added sugar, red meat and processed foods, during pregnancy could have beneficial effects in reducing adverse pregnancy outcomes (319).

9.1.3 Spatial distribution and determinant factors of anaemia among women

Anaemia is a multifactorial disease and is a problem across the life course of women. Thus, to have a full picture of the problem, we first assessed the spatial distribution and determinant factors of anaemia among women of reproductive age in Ethiopia in general (Chapter 5) and then assessed the effect of dietary patterns on anaemia among pregnant women specifically (Chapter 7).

The WHO has set a global target of reducing anaemia prevalence among women of reproductive age by half between 2012 and 2025 (235). The latest global estimates show that no country is on track to achieve this reduction by 2025 (236). In fact, Ethiopia did not show any reduction in the prevalence of anaemia among women between 2012 and 2016 (236). The country-specific determinants of anaemia among women of reproductive age need to be further explored (237) to achieve this WHO goal of reduction by half. A more thorough assessment of anaemia in particular country settings is necessary to successfully address anaemia at the national or regional level. Thus, this thesis identified the contextual and individual predictors of anaemia among women in Ethiopia and provided evidence for effective action and designing locally resonant intervention programs.

The spatial distribution and potential predictors of anaemia among women in Ethiopia were assessed using representative large-scale population-based data (Chapter 5). The results showed that the prevalence rate of anaemia among women in Ethiopia was high and had spatial disparities across the country. The results indicated that anaemia is a moderate public health problem among women (> 20% prevalence) at the national level and a serious public health problem (> 40% prevalence) in five of the 11 regional states, based on WHO criteria (62). A higher proportion of anaemia cases was observed in the eastern and north-eastern parts of the country. The geographical differences of anaemia across the regional states might be attributable to the regional variation of food consumption preferences (55, 56), the occurrence of communicable diseases including HIV, malaria and helminths (364) and differences in the availability of healthcare facilities (68). Besides, a lack of clean water and the use of unimproved latrine facilities may increase the occurrence of soil-transmitted infections (105), which in turn could lead to anaemia (106) and might explain some of the observed geographical differences of anaemia across the country.

Moreover, further analysis was conducted to identify predictors of anaemia among women of reproductive age. The analysis demonstrated that sociodemographic factors (low educational status, low wealth index, rural residence and unimproved latrine facilities) and reproductive/biological factors (including younger age, pregnancy, breastfeeding and high gravidity) are associated with the occurrence of anaemia. In addition, further analysis of the EDHS data was performed to assess the impact of potential factors of anaemia by estimating PAFs (Chapter 6). The AORs from logistic regressions were used to estimate PAFs. PAFs help to estimate the relative impact of factors on the outcome of interest, taking into consideration the strength of association and prevalence of the factors in the population. The result shows that having no education, high gravidity and breastfeeding are factors that have a great impact on the occurrence of mild anaemia among women in Ethiopia. Similarly, a substantial proportion of moderate-severe anaemia cases were observed among women who lived rurally, had a low wealth index, had a birth in the past 5 years and had access to an unimproved latrine facility.

Poverty reduction and quality education are among the target areas in the Sustainable Development Goals (SDG) which are an important determinant of maternal health (336). Evidence shows that low socioeconomic status is a predictor of a higher odds of anaemia among women of reproductive age. Poverty is the main predictor of poor health, and it is associated with poor lifestyle (poor water, sanitation and hygiene, poor dietary habits, reduced access to animal-based foods and low access to healthcare services), which can affect Hgb levels (77, 80, 95, 365). The results of Chapter 5 showed that the lowest wealth quantile was associated with a higher risk of anaemia compared to the highest quantile; this is in line with the results of other studies conducted in other low-income countries (70) like Benin (96) and India (97, 98). Similarly, higher odds of moderate-severe anaemia cases were associated with the poorest wealth quantile (99, 100). This might be due to the fact that having a low income means having less money to buy nutritious foods or to have a balanced diet (36, 219), which in turn leads to inadequate nutrient intake and nutritional status (330). More than 38% of the Ethiopian population belongs to the poor and poorest wealth quintile, which indicates that a large percentage of women are at risk of anaemia because of their low socioeconomic position (48).

Another socioeconomic factor for anaemia is education. The current study indicated that women who did not have formal education had higher odds of anaemia than those with a higher education (Chapter 5). Similar findings were reported in other studies conducted in developing countries, (70) including in Ethiopia (77), Timor-Leste (82), Benin (96) and India (76, 97), in which a low level of education was associated with higher odds of anaemia among women of reproductive age. Formal education could help women in obtaining knowledge that in turn helps them to follow better personal behaviours intake of diversified diet, better health-seeking habits (health literacy) and hygiene practices that can prevent anaemia (100).

Moreover, along with other research findings (70, 102), the results in Chapter 5 revealed that the likelihood of having anaemia was higher for rural residents compared to urban residents. Similarly, evidence showed a noticeable and higher prevalence of moderate-severe anaemia in rural residents (84, 103). Rural residents may have limited access to services (health care, water and sanitation), increased exposure to infectious agents like soil-transmitted infections and a less varied diet compared to urban inhabitants, all of which can increase the risk of anaemia. Furthermore, our study revealed that women from households with unimproved latrine facilities were more likely to be anaemic than women from households with improved latrine facilities. These findings are in line with other research findings from low-income countries (96, 104) like Tanzania (100) and India (76), which reported that unimproved latrine facilities were associated with higher odds of moderate-severe anaemia. These findings might be due to the fact that an unimproved latrine facility exposes women to helminthic infections (105), which in turn results in developing anaemia (106).

The results of Chapter 5 also showed that reproductive/biological factors (pregnancy, breastfeeding, high gravidity and having an HIV infection) were associated with the increased occurrence of anaemia. Pregnant women were 28% more likely to have anaemia than non-pregnant women. Pregnancy predisposes women to low Hgb levels, which in turn results in anaemia. Studies conducted in Nepal (366) and India (80) similarly reported that pregnant women were more likely to be anaemic than non-pregnant women. Similarly, women with high gravidity were more likely to have anaemia than women with low gravidity. Similar studies in Ethiopia (77), Iran (83) Pakistan (78, 81) and Timor-Leste (82) also observed a higher odds of anaemia among women with higher gravidity than women with lower parity. This might be explained by the fact that the more times a woman gives birth, the more she is exposed to blood loss, which, over time, results in low Hgb levels in the blood (85). Similarly, prior births may deplete maternal iron stores due to the increased nutritional demands of pregnancy and puerperal blood loss (86). In combination with previous research, the results of Chapters 5 and 6 suggest that multifaceted prevention approaches need to be designed to address socioeconomic and reproductive/biological factors to reduce the burden of anaemia among women.

9.1.4 The effect of dietary patterns on maternal anaemia

The findings of Chapter 5 indicated a higher odds of anaemia among pregnant women compared to non-pregnant women. Thus, a further assessment was conducted to identify potential predictors of anaemia among pregnant women (Chapter 7). The main hypothesis was that maternal dietary patterns may have an effect on the occurrence of anaemia among pregnant women. The study indicated that a diversified diet intake was associated with reduced odds of anaemia among pregnant women. Furthermore, reducing the frequency and amount of food intake significantly increased the odds of anaemia among pregnant women. The study revealed that women who reported an intake of the less diversified diet were twice more likely to have anaemia than women with a more diversified diet intake. This result is consistent with previous cross-sectional studies from Ethiopia (24, 25) and Ghana (43), which showed an association between a low DDS and higher odds of anaemia among pregnant women. However, contradicting results have been reported in other cross-sectional studies in Ethiopia and Ghana (44, 46, 112).

The association of DDS with the occurrence of anaemia might be due to sufficient and diversified food intake helping to meet the required nutrient (including iron) recommendations to prevent unintended consequences such as anaemia (345). In addition, this might also be due to the fact that an increase in an individual's dietary diversity is a good proxy indicator of micronutrient adequacy in their diet (225, 229) as well as a positive indicator of nutritional status (230, 231). Reducing dietary intake during pregnancy might lead to insufficient food intake, which could result in low iron intake (346) and subsequent lack of macro and micronutrients. Thus, these findings revealed that a diversified dietary intake is one of the modifiable factors that should be targeted for easy and cost-effective prevention of anaemia among pregnant women.

9.2 Strengths and limitations

Though the strengths and limitations of the individual studies were discussed in the respective preceding chapters (Chapters 4–8), the overall strengths and limitations of this thesis are presented here. One of the strengths of this thesis is the generation of evidence using a combination of data sources, including a review of global literature, detailed analysis of large population-based national data and the collection of primary data. In addition, various combinations of methodological techniques and advanced statistical methods (spatial and multilevel analyses) were applied in this thesis, which allowed for the understanding of the role of contextual and geographical factors in the occurrence of anaemia among women of reproductive age. The other strength of this thesis is the use of the case-control study design, which is an important study design for identifying potential factors associated with maternal anaemia. In addition, an advanced statistical analysis (propensity score analysis) was also used, which helped to reduce selection and confounder biases, which are a threat in observational studies.

Along with the strengths of this thesis, some limitations must be acknowledged. Due to the cross-sectional nature of the EDHS data, cause-effect and temporal relationships could not be established based on the study's findings. Some essential factors, such as dietary intake and behavioural factors, were not available in the EDHS survey, so it was not possible to incorporate these variables in the analysis. Furthermore, the EDHS was a questionnaire-based survey, which relied on the memory of the respondents. Therefore, the data lends itself to recall bias in the results, which may be a limitation of this study.

Regarding the case-control study, the possible limitations are social desirability and recall biases, as this study relied on self-reports and the memories of the study subjects. We assessed the dietary intake of women through open recall methods, which leads to a more complete recall of foods and minimises bias. However, there could be a misreporting of food intake even though it would likely be non-differential. Moreover, the use of DDS may not address all foods which missed some food groups such as ultra-processed foods. The case-control study can also only identify an association; it does not establish a temporal or cause-effect relationship, even though the propensity score analysis was applied. Due to resource constraints, it was impossible to measure and incorporate all potential predictors of maternal anaemia. Therefore, there may be the confounding effect of unmeasured factors in the present analysis. As a result, there could be an under-or over-inflation of reported effect sizes. Additionally, the dietary intake of participants was measured only once, and the seasonal variability of dietary intake could not be addressed.

9.3 Recommendations

- In low-income countries, identification of possible determinant factors in specific settings is helpful for choosing the most applicable intervention strategies, such as nutrition-specific (dietary diversification, supplementation of iron/folate) and nutrition-sensitive (improving water and sanitation facilities, improving economic and educational status) intervention approaches (367). Food-based approaches, such as dietary fortification and diversification seems the best sustainable strategies to rise the iron status of a population (368). In this regard, this thesis identified a set of factors including dietary intake, water/sanitation, wealth status and educational status, which are important for setting context-specific prevention strategies for maternal morbidity. Thus, the prevention of anaemia among women requires context-specific and multifaceted intervention approaches, such as improving the economic and educational status of women and improving the availability of clean water and toilet facilities.

- Anaemia prevention strategies or programs need to be prioritised for pregnant women, women who have recently given birth and women living in rural areas. Prevention or intervention programs should be prioritised for regions in the eastern and north-eastern areas (Afar and Somali), as the burden of anaemia is higher in these areas, with more than 50% of women being anaemic. Designing intervention strategies targeting multigravida and breastfeeding women could reduce mild anaemia. Preventing moderate-severe anaemia may require working on improving income, educating women and improving living conditions through the accessibility of hygienic latrines constructed with cement.
- Dietary intake should be included as a core component for the prevention of adverse pregnancy outcomes through strengthening the existing ANC program. The current antenatal program mainly emphasises iron/folate supplementation to prevent anaemia during pregnancy. It lacks other alternatives, such as dietary diversification or food fortification. The current national ANC programs should incorporate a combination of different anaemia prevention strategies, like dietary diversification, and not merely depend on iron/folate supplementation. Women who are pregnant should be strongly advised to increase both the diversity and amount of food intake during pregnancy instead of reducing it. Particular emphasis should be given for dietary diversification. Diversified diet intake has a broad-spectrum effect in which a range of problems can be addressed. This is because dietary diversification is non-specific and can tackle multiple micronutrient deficiencies that cause anaemia. The dietary diversification prevention strategy is cost-effective and can easily be implemented with a simple modification of existing food habits, as it is closer to the population life and culture (108).
- A dietary guideline needs to be developed in Ethiopia to effectively implement nutrition-based prevention approaches across health facilities in the country. Based on the guideline, there should be tailored and culturally resonant counselling and education on diet during pregnancy through public announcements or radio and by using simple and

easily understandable and accessible education materials like posters and brochures. Such materials help women to have clear information about diet and to avoid misperceptions about food intake during pregnancy. In addition, community-based information and education program on anaemia during pregnancy should be designed and implemented to improve knowledge of the community and family members.

- Furthermore, healthcare and agricultural sectors should work in collaboration to design a food-based dietary diversity approach to improve diversified food production and consumption. Agricultural diversity could increase production, which in turn can improve income generation, which would further improve the accessibility of food (108). The agricultural sector has a central role in assisting in the production of diversified foods, and the health sector could have an important role in designing and implementing dietary guidelines as well as disseminating information on the importance of diversified food consumption. In addition, community members, particularly community leaders and religious leaders, should encourage pregnant women to increase the diversity, frequency and quantity of food intake throughout their pregnancy. In this regard, a more effective strategy could be social and behaviour-change communication approaches through interpersonal communication, media, and community mobilization.
- A longitudinal follow-up study should be conducted to identify context-specific predictors of maternal morbidity and confirm the effect of different dietary patterns.
- A mixed-methods study is also necessary for understanding and identifying potential predictors for the diversified food consumption of women and reduction of some food items during pregnancy.
- Since the causes of anaemia are multifactorial and context-specific, implementing a combination of intervention strategies is important. Thus, the effectiveness of combined prevention strategies, like dietary diversification and iron/folate supplementation, need to be assessed using a cluster randomised trial, taking into consideration sociocultural contexts.

9.4 Conclusions

Our evidence indicates the importance of healthy dietary intake during gestation for improving pregnancy and birth outcomes. Dietary patterns with a higher intake of whole grains, vegetables/fruits, legumes and fish were associated with a lower likelihood of adverse pregnancy and birth outcomes, even though inconsistencies have been observed among studies.

The results also demonstrate that diversified food intake during pregnancy has a beneficial effect in reducing the occurrence of anaemia and HDPs.

Considerable geographic variations in the anaemia prevalence rate were observed within Ethiopia. The prevalence rate of anaemia among women in Ethiopia varied and was higher in the eastern and north-eastern parts of the country. Higher odds of anaemia occurred in women of rural residence, had no formal education, were in the poorest wealth index, were currently pregnant, were breastfeeding, had higher gravidity, lacked access to a clean water source and had an unimproved toilet facility in their household. Moreover, mild anaemia was higher in women with no formal education, were currently breastfeeding and with higher gravidity. In addition, higher odds of moderate-severe anaemia were observed among women who were rural residents, had an unimproved latrine facility, gave birth in the past year, were currently pregnant, were in the poorest wealth quantile or who were infected with HIV. The estimates of PAFs suggest that rural residency, low education, low wealth status, pregnancy and high gravidity contribute substantially to the occurrence of any anaemia among women. Therefore, pregnant women, women with high gravidity and those with recent births, women with low education, low wealth status, and women living in rural areas should be prioritised in any intervention program targeting anaemia.

In conclusion, maternal morbidity, such as anaemia and HDPs, can be prevented with multifaceted and integrated prevention approaches.

References

1. Vilela AAeF, Farias DR, Ilana Eshriqui JdSV, Franco-Sena AB, Castro MBT, Olinto MTA, et al. Prepregnancy Healthy Dietary Pattern Is Inversely Associated with Depressive Symptoms among Pregnant Brazilian Women. J Nutr 2014;144:1612-8.
2. Food and Agriculture Organization of the United Nations; International Fund for Agricultural Development; United Nations Children's Fund; World Food Programme; World Health Organization. The state of food security and nutrition in the world 2019: safeguarding against economic slowdowns and downturns. Rome: FAO; 2019 [accessed 2019 October 1]. Available from: http://www.fao.org/3/ca5162en/ca5162en.pdf. 2019.
3. Stevens GA, Finucane MM, De-Regil LM, Paciorek CJ, Flaxman SR, Branca F, et al. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995–2011: a systematic analysis of population-representative data. The Lancet Global Health 2013;1(1):e16-e25.
4. Rahman MM, Abe SK, Rahman MS, Kanda M, Narita S, Bilano V, et al. Maternal anemia and risk of adverse birth and health outcomes in low- and middle-income countries: systematic review and meta-analysis. American Journal of Clinical Nutrition 2016;103(2):495-504.
5. Say L, Chou D, Gemmill A, Tunçalp Ö, Moller A-B, Daniels J, et al. Global causes of maternal death: a WHO systematic analysis. The Lancet Global Health 2014;2(6):e323-e33.
6. Bilano VL, Ota E, Ganchimeg T, Mori R, Souza JP. Risk factors of pre-eclampsia/eclampsia and its adverse outcomes in low- and middle-income countries: a WHO secondary analysis. PLoS One 2014;9(3):e91198.
7. Lumbiganon P, Laopaiboon M, Intarut N, Vogel JP, Souza JP, Gulmezoglu AM, et al. Indirect causes of severe adverse maternal outcomes: a secondary analysis of the WHO Multicountry Survey on Maternal and Newborn Health. BJOG 2014;121 Suppl 1:32-9.
8. Levy A, Fraser D, Katz M, Mazor M, Sheiner E. Maternal anemia during pregnancy is an independent risk factor for low birthweight and preterm delivery. Eur J Obstet Gynecol Reprod Biol 2005;122(2):182-6.
9. Zhou L-M, Yang W-W, Hua J-Z, Deng C-Q, Tao X, Stoltzfus RJ. Relation of Hemoglobin Measured at Different Times in Pregnancy to Preterm Birth and Low Birth Weight in Shanghai, China. Am J Epidemiol 148(10).
10. Liyew EF, Yalew AW, Afework MF, Essen B. Incidence and causes of maternal near-miss in selected hospitals of Addis Ababa, Ethiopia. PLoS One 2017;12(6):e0179013.
11. Kassebaum NJ, Bertozzi-Villa A, Coggeshall MS, Shackelford KA, Steiner C, Heuton KR, et al. Global, regional, and national levels and causes of maternal mortality during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. The Lancet 2014;384(9947):980-1004.
12. Berhan Y, Berhan A. Causes of maternal mortality in ethiopia: a significant decline in abortion related death. Ethiop J Health Sci 2014;(Suppl, doi:10.4314/ejhs.v24i1.3S):15–28.
13. Procter SB, Campbell CG. Position of the Academy of Nutrition and Dietetics: nutrition and lifestyle for a healthy pregnancy outcome. J Acad Nutr Diet 2014;114(7):1099-103.
14. Kaiser LL, Campbell CG, Academy Positions Committee Workgroup. Practice paper of the Academy of Nutrition and Dietetics: nutrition and lifestyle for a healthy pregnancy outcome. J Acad Nutr Diet 2014;Sep;114(9):1447.
15. Abu-Saad K, Fraser D. Maternal nutrition and birth outcomes. Epidemiol Rev 2010;32:5-25.
16. Kramer MS, Kakuma R. Energy and protein intake in pregnancy: Systematic Reviews. Cochrane Database of Systematic Reviews 2003, Issue 4 Art No: CD000032 DOI: 101002/14651858CD000032 2003.
17. Institute of Medicine; Panel on Micronutrients. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington (DC): The National Academies Press; 2001.
18. Institute of Medicine; Panel on Micronutrients. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein, and amino acids (macronutrients). Washington (DC): The Natioanl Academies Press; 2005.

19. Koletzko B, Bauer CP, Bung P, Cremer M, Flothkotter M, Hellmers C, et al. German national consensus recommendations on nutrition and lifestyle in pregnancy by the 'Healthy Start - Young Family Network'. Ann Nutr Metab 2013;63(4):311-22.
20. Sunsaneevithayakul P, Titapant V, Ruangvutilert P, Sutantawibul A, Phatihattakorn C, Wataganara T, et al. Relation between gestational weight gain and pregnancy outcomes. J Obstet Gynaecol Res 2014;40(4):995-1001.
21. Bhavadharini B, Anjana RM, Deepa M, Jayashree G, Nrutya S, Shobana M, et al. Gestational Weight Gain and Pregnancy Outcomes in Relation to Body Mass Index in Asian Indian Women. Indian J Endocrinol Metab 2017;21(4):588-93.
22. Chung JG, Taylor RS, Thompson JM, Anderson NH, Dekker GA, Kenny LC, et al. Gestational weight gain and adverse pregnancy outcomes in a nulliparous cohort. Eur J Obstet Gynecol Reprod Biol 2013;167(2):149-53.
23. Institute of Medicine (US) CoNSDPaL. . Nutrition during pregnancy. Washington (D.C): National Academies of Sciences; 1990.
24. Lebso M, Anato A, Loha E. Prevalence of anemia and associated factors among pregnant women in Southern Ethiopia: A community based cross-sectional study PLoS ONE 12(12): e0188783 https://doiorg/101371/ journalpone018878 2017.
25. Gebremedhin S, Enquselassie F, Umeta M. Prevalence and Correlates of Maternal Anemia in Rural Sidama, Southern Ethiopia. Afr J of Reprod Health 2014;18(1):44-53.
26. Agrawal S, Fledderjohann J, Vellakkal S, Stuckler D. Adequately diversified dietary intake and iron and folic acid supplementation during pregnancy is associated with reduced occurrence of symptoms suggestive of pre-eclampsia or eclampsia in Indian women. PLoS One 2015;10(3):e0119120.
27. Gresham E, Collins CE, Mishra GD, Hure JEBaAJ. Diet quality before or during pregnancy and the relationship with pregnancy and birth outcomes: the Australian Longitudinal Study on Women's Health. Public Health Nutr 2016;19(16):2975-83.
28. Jacques PF, Tucker KL. Are dietary patterns useful for understanding the role of diet in chronic disease? Am J Clin Nutr 2001;73:1–2.
29. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. Curr Opin Lipidol 2002;13(1):3-9.
30. Wirfält E, Drake I, Wallström P. What do review papers conclude about food and dietary patterns? Food & Nutr Res 2013;57:20523. doi:10.3402/fnr.v57i0.
31. Cespedes EM, Hu FB. Dietary patterns: from nutritional epidemiologic analysis to national guidelines. Am J Clin Nutr 2015;101(5):899-900.
32. Balder HF, Virtanen M, Brants HAM, Krogh V. Common and country-specific dietary patterns in four European cohort studies. J Nutr 2003;133(12):4246-51.
33. Mishra G, McNaughton S, Ball K, Brown W, Giles G, Dobson A. Major dietary patterns of young and middle aged women: results from a prospective Australian cohort study. Eur J Clin Nutr 2010;64:1125-33.
34. Sintayehu H, Bedasa W. Dietary diversity and associated factors among pregnant women attending antenatal care at public health facilities in Bale Zone, Southeast Ethiopia. Nutr Diet Supplements 2019;11:1-8.
35. Northstone K, Emmett P, Rogers I. Dietary patterns in pregnancy and associations with socio-demographic and lifestyle factors. Eur J Clin Nutr 2008;62(4):471-9.
36. Lenz A, Olinto MTA, Dias-da-Costa JS, Alves AL, Balbinotti M, Pattussi MP, et al. Socioeconomic, demographic and lifestyle factors associated with dietary patterns of women living in Southern Brazil. Cad Saúde Pública, Rio de Janeiro 2009;25(6):1297-306.
37. Schoenaker DA, Soedamah-Muthu SS, Callaway LK, Mishra GD. Prepregnancy dietary patterns and risk of developing hypertensive disorders of pregnancy: results from the Australian Longitudinal Study on Women's Health. Am J Clin Nutr 2015;102(1):94-101.
38. Englund-Ögge L, Brantsæter AL, Sengpiel V, Haugen M, Birgisdottir BE, Myhre R, et al. Maternal dietary patterns and preterm delivery: results from large prospective cohort study. BMJ 2014;348.

39. Poon AK, Yeung E, Boghossian N, Albert PS, Zhang C. Maternal Dietary Patterns during Third Trimester in Association with Birthweight Characteristics and Early Infant Growth. Hindawi Publishing Corporation Scientifica 2013.
40. Timmermans S, Steegers-Theunissen RPM, Vujkovic M, Bakker R, den Breeijen H, Raat H, et al. Major dietary patterns and blood pressure patterns during pregnancy: the Generation R Study. Am J Obstet Gynecol 2011;205(4):337.e1–12.
41. Bain E, Crane M, Tieu J, Han S, Crowthe CA, Middleton P. Diet and exercise interventions for preventing gestational diabetes mellitus. Cochrane Database Syst Rev 2015;(4):CD010443.
42. Englund-Ogge L, Brantsaeter AL, Sengpiel V, Haugen M, Birgisdottir BE, Myhre R, et al. Maternal dietary patterns and preterm delivery: results from large prospective cohort study. BMJ 2014;348:g1446.
43. Saaka M, Rauf AA. Role of dietary diversity in ensuring adequate haematological status during pregnancy. Int J Med Res Health Sci 2015;4(4):749.
44. Saaka M, Oladele J, Larbi A, Hoeschle-Zeledon I. Dietary Diversity Is Not Associated with Haematological Status of Pregnant Women Resident in Rural Areas of Northern Ghana. J Nutr Metab 2017;2017:8497892.
45. Ali F, Thaver I, Khan SA. Assessment of dietary diversity and nutritional status of pregnant women in Islamabad, Pakistan. J Ayub Med Coll Abbottabad 2014;26(4):506–9.
46. Kedir H, Berhane Y, Worku A. Khat chewing and restrictive dietary behaviors are associated with anemia among pregnant women in high prevalence rural communities in eastern Ethiopia. PLoS One 2013;8(11):e78601.
47. Central Statistical Agency (Ethiopia). Population projections for Ethiopia, 2007–2037. Addis Ababa: Central Statistical Agency. 2013.
48. Central Statistical Agency (CSA) [Ethiopia] and ICF. Ethiopia Demographic and Health Survey 2016. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF. 2016.
49. Central Statistical Agency. 2007 population and housing census of Ethiopia. Addis Ababa: Central Statistical Agency. 2012.
50. Fazzini M, Bisci C, Billi P. The Climate of Ethiopia. In: Billi P, editor. Landscapes and Landforms of Ethiopia. World Geomorphological Landscapes. Dordrecht: Springer; 2015. p. 65-87.
51. International Food Policy Research Institute; Ethiopian Development Research Institute; Central Statistical Agency. Population & Housing Census Atlas of Ethiopia 2007. Addis Ababa: International Food Policy Research Institute. 2010.
52. . Deep from an Ethiopian – an Ethiopian blog [Internet blog]. [place unknown]: [publisher unknown]. Available from: www.deepethiopian.com.
53. Ministry of Health (Ethiopia). Ethiopian health sector development programme IV: 2010/11 – 2014/15. Final draft October 2010. Addis Ababa: Ministry of Health; 2010. 2010.
54. Ministry of Health (Ethiopia). Health and health related indicators, 2015/16 fiscal year. Addis Ababa: Ministry of Health (Ethiopia). 2016.
55. Ethiopian Public Health Institute. Ethiopia national food consumption survey. Addis Ababa: Ethiopian Public Health Institute. 2013.
56. Berhane G, Paulos Z, Tafere K, Tamiru S. Foodgrain consumption and calorie intake patterns in Ethiopia. Addis Ababa: International Food Policy Research Institute. Working Paper No: 23 2011.
57. Amare B, Moges B, Moges F, Fantahun B, Admassu M, Mulu A, et al. Nutritional status and dietary intake of urban residents in Gondar, Northwest Ethiopia. BMC Public Health, 12:752 2012
58. Sisay Alemayehu M. Dietary Practice and Associated Factors among Pregnant Women in Gondar town North West, Ethiopia. Int J Nutr Food Sci 2015;4(6):707.
59. Asayehu TT, Lachat C, Henauw S, Gebreyesus SH. Dietary behaviour, food and nutrient intake of women do not change during pregnancy in Southern Ethiopia. Matern Child Nutr 2016;DOI: 10.1111/mcn.12343.
60. Kuche D, Singh P, Moges D. Dietary Practices and Associated Factors among Pregnant Women in Wondo Genet district, Southern Ethiopia: A Cross-Sectional Study. J Pharm Sci Innov 2015;4(5):270-5.

61. Ona MA, Papafragkakis H, Reddy M. Colonoscopic diagnosis of cecal worms (Trichuris trichiura). Annals of Gastroenterology 2015;28(3):404.
62. World Health Organization. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. Vitamin and Mineral Nutrition Information System. Geneva: World Health Organization; 2011 [accessed 2017 January 9]. Report No.: WHO/NMH/NHD/MNM/11.1. Available from: http://www.who.int/vmnis/indicators/haemoglobin.pd. 2011.
63. Soma-Pillay P, Nelson-Piercy C, Tolppanen H, Mebazaa A. Physiological changes in pregnancy. Cardiovasc J Afr 2016;27(2):89-94.
64. Zijp IM, Korver O, Tijburg LB. Effect of tea and other dietary factors on iron absorption. Crit Rev Food Sci Nutr 2000;40(5):371-98.
65. World Health Organization. The global prevalence of anaemia in 2011. Geneva: World Health Organization. 2015.
66. Melku M, Addis Z, Alem M, Enawgaw B. Prevalence and predictors of maternal anemia during pregnancy in Gondar, Northwest Ethiopia: An institutional based cross-sectional study. Anemia 2014;2014:108593.
67. Addis Alene K, Mohamed Dohe A. Prevalence of Anemia and Associated Factors among Pregnant Women in an Urban Area of Eastern Ethiopia. Anemia 2014;2014:561567.
68. Chaya N. Poor Access to Health Services: Ways Ethiopia is Overcoming Research Commentary 2007; 2(2).
69. Chaparro CM, Suchdev PS. Anemia epidemiology, pathophysiology, and etiology in low- and middle-income countries. Ann N Y Acad Sci 2019;1450(1):15-31.
70. Balarajan Y, Ramakrishnan U, Özaltin E, Shankar AH, Subramanian SV. Anaemia in low-income and middle-income countries. The Lancet 2011;378(9809):2123-35.
71. Haidar J. Prevalence of anaemia, deficiencies of iron and folic acid and their determinants in Ethiopian women. J Health Popul Nutr 2010;28(4):359-68.
72. Petry N, Olofin I, Hurrell RF, Boy E, Wirth JP, Moursi M, et al. The proportion of anemia associated with iron deficiency in low, medium, and high Human Development Index countries: a systematic analysis of national surveys. Nutrients 2016;8(11):693.
73. Allen LH. Causes of vitamin B12 and folate deficiency. Food Nutr Bull 2008;29(2 suppl):s20-s34.
74. Metz J. A high prevalence of biochemical evidence of vitamin B12 or folate deficiency does not translate into a comparable prevalence of anemia. Food Nutr Bull 2008;29(2):s74-s85.
75. Fishman SM, Christian P, Jr KPW. The role of vitamins in the prevention and control of anaemia. Public Health Nutrition 2000;3(2):125 -50.
76. Ganapathi KC, Kumar KS. A cross-sectional study of anemia among women of reproductive age group (15-49 years) in a rural population of Tamil Nadu. Int J Med Sci and PH 2017;6(3):524-9.
77. Asres Y, Yemane T, Gedefaw L. Determinant Factors of Anemia among Nonpregnant Women of Childbearing Age in Southwest Ethiopia: A Community Based Study. Int Sch Res Notices 2014;2014:391580.
78. Habib MA, Soofi SB, Ahmed I, Ali N, Bhutta ZA, Raynes-Greenow C, et al. Prevalence and determinants of iron deficiency anemia among non-pregnant women of reproductive age in Pakistan. Asia Pac J Clin Nutr 2018;27(1):195-203.
79. Win HH, Ko MK. Geographical disparities and determinants of anaemia among women of reproductive age in myanmar: analysis of the 2015–2016 Myanmar Demographic and Health Survey. WHO South-East Asia J Public Health 2018;7(2):107-13.
80. Siddiqui MZ, Goli S, Reja T, Doshi R, Chakravorty S, Tiwari C, et al. Prevalence of Anemia and Its Determinants Among Pregnant, Lactating, and Nonpregnant Nonlactating Women in India. SAGE Open 2017:1 –10 DOI: .1177/2158244017725555.
81. Soofi S, Khan GN, Sadiq K, Ariff S, Habib A, Kureishy S, et al. Prevalence and possible factors associated with anaemia, and vitamin B12 and folate deficiencies in women of reproductive age in Pakistan: analysis of national-level secondary survey data. BMJ Open 2017;7:e018007 doi:101136/ bmjopen-2017-018007.

82. Lover AA, Hartman M, Chia KS, Heymann DL. Demographic and Spatial Predictors of Anemia in Women of Reproductive Age in Timor-Leste: Implications for Health Program Prioritization. PLoS ONE 9(3): e91252 doi:101371/journalpone0091252.
83. Sadeghian M, Fatourechi A, Lesanpezeshki M, Ahmadnezhad E. Prevalence of Anemia and Correlated Factors in the Reproductive Age Women in Rural Areas of Tabas. J Fam Repr Health 2013;7(3):139-44.
84. Perumal V. Reproductive risk factors assessment for anaemia among pregnant women in India using a multinomial logistic regression model Trop Med Int Health 2014;19 (7):841–51 doi:10.1111/tmi.12312.
85. BH R, Patil PS, Joseph J. Multigravidity a Major Risk Factor of Anaemia in Pregnancy and its Comparison in Primigravida Women in Raichur. National J Lab Med 2017;6(4):PO22-PO7.
86. Al-Farsi YM, Brooks DR, Werler MM, Cabral HJ, Al-Shafei MA, Wallenburg HC. Effect of high parity on occurrence of anemia in pregnancy: a cohort study. BMC Pregnancy and Childbirth 2011;11(7):http://www.biomedcentral.com/1471-2393/11/7.
87. World Health Organization CfDCaP. Assessing iron status of populations. 2nd ed. including literature reviews. Geneva: World Health Organization; 2007. Available from: http://www.who.int/nutrition/publications/micronutrients/anaemia_iron_deficiency/9789241596107.pdf.
88. Dreyfus ML, Stoltzfus RJ, Shrestha JB, Pradhan EK, LeClerq SC, Khatry SK, et al. Hookworms, Malaria and Vitamin A Deficiency Contribute to Anemia and Iron Deficiency among Pregnant Women in the Plains of Nepal. J Nutr 2000;130:2527–36.
89. Brooker S, Hotez PJ, Bundy DA. Hookworm-related anaemia among pregnant women: a systematic review. PLoS Negl Trop Dis 2008;2(9):e291.
90. Tefer G. Determinants of Anemia in Pregnant Women with Emphasis on Intestinal Helminthic Infection at SherEthiopia Hospital, Ziway, Southern Ethiopia. Immunology and Infectious Diseases 2014;2(4):33-9.
91. Pasricha SR, Drakesmith H, Black J, Hipgrave D, Biggs BA. Control of iron deficiency anemia in low- and middle-income countries. Blood 2013;121(14):2607-17.
92. Redig A, NancyBerliner. Pathogenesis and clinical implications of HIV-related anemia in 2013. Hematology 2013:377-81.
93. Kokici M, Harxhi A, Como N, Shkurti K, Kokici F, Kraja D. Haematological changes in HIV infection. Int J Ecosyst and Ecol Sci 2016;6 (1):19-24
94. Beyene HB, Tadesse M, Disassa H, Beyene MB. Concurrent Plasmodium infection, anemia and their correlates among newly diagnosed people living with HIV/AIDS in Northern Ethiopia. Acta Trop 2017;169:8-13.
95. Kamruzzaman M, Rabbani MG, Saw A, Sayem MA, Hossain MG. Differentials in the prevalence of anemia among non-pregnant, ever-married women in Bangladesh: multilevel logistic regression analysis of data from the 2011 Bangladesh Demographic and Health Survey BMC Women's Health 2015;15(14):DOI 10.1186/s12905-015-0211-4.
96. Alaofè H, Burney J, Naylor R, Taren D. Prevalence of anaemia, deficiencies of iron and vitamin A and their determinants in rural women and young children: a cross-sectional study in Kalalé district of northern Benin. Public Health Nutrition 2017;20(7):1203–13
97. Balarajan YS, Fawzi WW, Subramanian SV. Changing patterns of social inequalities in anaemia among women in India: cross-sectional study using nationally representative data. BMJ Open 2013;3:e002233. doi:10.1136/bmjopen-2012002233.
98. Rammohan A, Awofeso N, Robitaille M-C. Addressing Female Iron-Deficiency Anaemia in India: Is Vegetarianism the Major Obstacle? Int Sch Res Notices 2012;2012:1-8.
99. Dey S, Goswami S, Goswami M. Prevalence of anaemia in women of reproductive age in Meghalaya: a logistic regression analysis. Turk J Med Sci 2010;40 (5): 783-9.
100. Wilunda C, Massawe S, Jackson C. Determinants of moderate-to-severe anaemia among women of reproductive age in Tanzania: analysis of data from the 2010 Tanzania demographic and health survey. Tropical Medicine and International Health 2013;18(12):1488–97.
101. Ngnie-Teta I, Kuate-Defo B, Receveur O. Multilevel modelling of sociodemographic predictors of various levels of anaemia among women in Mali. Public Health Nutrition 2008;12(9):1462–9 doi:10.017/S1368980008004400.

102. Magalhães RJS, Clements ACA. Mapping the risk of anaemia in preschool-age children: The contribution of malnutrition, malaria, and helminth infections in West Africa. PLoS Medicine 2011;8(6).
103. Ghose B, Tang S, Yaya S, Feng Z. Association between food insecurity and anemia among women of reproductive age. PeerJ 2016;4:e1945.
104. Freeman MC, Garn JV, Sclar GD, Boisson S, Medlicott K, Alexander K, et al. The impact of sanitation on infectious dieseas ans nutritional status: Systematic Review and meta analysis. Int J Hygn & Envt Health 2017;220:928-49.
105. Mara D, Lane J, Scott B, Trouba D. Sanitation and Health. PLoS Med 7(11): e1000363 doi:101371/journalpmed1000363 2010.
106. Tay SCK, Nani EA, Walana W. Parasitic infections and maternal anaemia among expectant mothers in the Dangme East District of Ghana.
107. Beck KL, Conlon CA, Kruger R, Coad J. Dietary determinants of and possible solutions to iron deficiency for young women living in industrialized countries: a review. Nutrients 2014;6(9):3747-76.
108. Nair MK, Augustine LF, Konapur A. Food-Based Interventions to Modify Diet Quality and Diversity to Address Multiple Micronutrient Deficiency. Front Public Health 2015;3:277.
109. Yeneabat T, Adugna H, Asmamaw T, Wubetu M, Admas M, Hailu G, et al. Maternal dietary diversity and micronutrient adequacy during pregnancy and related factors in East Gojjam Zone, Northwest Ethiopia, 2016. BMC Pregnancy Childbirth 2019;19(1):173.
110. Aliwo S, Fentie M, Awoke T, Gizaw Z. Dietary diversity practice and associated factors among pregnant women in North East Ethiopia. BMC Res Notes 2019;12(1):123.
111. Delil R, Tamiru D, Zinab B. Dietary Diversity and Its Association with Anemia among Pregnant Women Attending Public Health Facilities in South Ethiopia. Ethiop J Health Sci 2018;28(5):625-34.
112. Abay A, Yalew HW, Tariku A, Gebeye E. Determinants of prenatal anemia in Ethiopia. Arch Public Health 2017;75:51.
113. Gebre A, Mulugeta A. Prevalence of Anemia and Associated Factors among Pregnant Women in North Western Zone of Tigray, Northern Ethiopia: A Cross-Sectional Study. J Nutr Metab 2015;2015:165430.
114. Kefiyalew F, Zemene E, Asres Y, Gedefaw L. Anemia among pregnant women in Southeast Ethiopia: prevalence, severity and associated risk factors. BMC Research Notes 2014;7(771).
115. Gefeller O. Theory and application of poulation attributable risk estimates in cross sectional studies. Statistical app 1990;2(4):323-31.
116. Rezende LF, Eluf-Neto J. Population attributable fraction: planning of diseases prevention actions in Brazil. Rev Saude Publica 2016;50.
117. Kassebaum NJ, Jasrasaria R, Naghavi M, Wulf SK, Johns N, Lozano R, et al. A systematic analysis of global anemia burden from 1990 to 2010. Blood 2014;123(5):615-24.
118. Brooker S, Clements ACA, Bundy DAP. Global Epidemiology, Ecology and Control of Soil-Transmitted Helminth Infections. Global Mapping of Infectious Diseases: Methods, Examples and Emerging Applications. Advances in Parasitology2006. p. 221-61.
119. Bates I, McKew S, Sarkinfada F. Anaemia: A useful indicator of neglected disease burden and control. PLoS Med 2007;4(8):e231. doi:10.1371/journal. pmed.0040231.
120. Gardner W, Kassebaum N. Global, regional, and national prevalence of anaemia and its causes in 204 countries and territories, 1990–2019. Current Dev Nutr 2020;4(Suppl 2).
121. Allen LH. Anemia and iron deficiency: effects on pregnancy outcome. Am J Clin Nutr 2000;71(suppl):1280S–4S.
122. Abalos E, Cuesta C, Carroli G, Qureshi Z, Widmer M, Vogel JP, et al. Pre-eclampsia, eclampsia and adverse maternal and perinatal outcomes: a secondary analysis of the World Health Organization Multicountry Survey on Maternal and Newborn Health. BJOG 2014;121 Suppl 1:14-24.
123. Karaflahin E, Ceyhan ST, Göktolga Ü, Keskin Uu, Bafler S. Maternal Anemia and Perinatal Outcome. Perinatal Journal 2007;15(3):127-30.
124. Khoigani MG, Goli S, Zadeh AH. The relationship of hemoglobin and hematocrit in the first and second half of pregnancy with pregnancy outcome Ira J Nur and Midwf Res 2012;17(2).

125. Ali AA, Rayis DA, Abdallah TM, Elbashir MI, Adam I. Severe anaemia is associated with a higher risk for preeclampsia and poor perinatal outcomes in Kassala hospital, eastern Sudan. BMC Research Notes 2011;4(311).
126. Lewandowska M, Sajdak S, Lubinski J. Can Serum Iron Concentrations in Early Healthy Pregnancy Be Risk Marker of Pregnancy-Induced Hypertension? Nutrients 2019;11(5).
127. Aghamohammadi A, Zafari M, Tofighi M. High maternal hemoglobin concentration in first trimester as risk factor for pregnancy induced hypertension. Caspian J Intern Med 2011;2(1):194-7.
128. Zafar T, IQBAL Z. IRON STATUS IN PREECLAMPSIA. Professional Med J Mar 2008;15(1):74-80.
129. Gaillard R, Eilers PH, Yassine S, Hofman A, Steegers EA, Jaddoe VW. Risk factors and consequences of maternal anaemia and elevated haemoglobin levels during pregnancy: a population-based prospective cohort study. Paediatr Perinat Epidemiol 2014;28(3):213-26.
130. Albacar G, Sans T, Martin-Santos R, Garcia-Esteve L, Guillamat R, Sanjuan J, et al. An association between plasma ferritin concentrations measured 48 h after delivery and postpartum depression. J Affect Disord 2011;131(1-3):136-42.
131. Corwin EJ, Murray-Kolb LE, Beard JL. Low Hemoglobin Level Is a Risk Factor for Postpartum Depression. J Nutr 2003; 133:4139–42.
132. Yilmaz E, Yilmaz Z, Cakmak B, Gultekin IB, Cekmez Y, Mahmutoglu S, et al. Relationship between anemia and depressive mood in the last trimester of pregnancy. J Matern Fetal Neonatal Med 2017;30(8):977-82.
133. Alizadeh M, Goshtasebi A, Gandevani SB. Association between Maternal Anaemia and Postpartum Depression in an Urban Sample of Pregnant Women in Iran J HEALTH POPUL NUTR 2013 31(3):398-402.
134. Haas JD, Brownlie T. Iron deficiency and reduced work capacity: a critical review of the research to determine a causal relationship. J Nutr 2001;131(Suppl 2):676–88.
135. Haider BA, Olofin I, Wang M, Spiegelman D, Ezzati M, Fawzi WW, et al. Anaemia, prenatal iron use, and risk of adverse pregnancy outcomes: systematic review and meta-analysis. BMJ 2013;346:f3443.
136. Zhang Q, Ananth CV, Li Z, Smulian JC. Maternal anaemia and preterm birth: a prospective cohort study. Int J Epidemiol 2009;38(5):1380-9.
137. Rahmati S, Delpishe A, Azami M, Ahmadi MRH, Sayehmiri K. Maternal Anemia during pregnancy and infant low birth weight: A systematic review and Meta-analysis. Int J Reprod BioMed 2017;15(3):125-34.
138. Little MP, Brocard P, Elliott P, Steer PJ. Hemoglobin concentration in pregnancy and perinatal mortality: a London-based cohort study. Am J Obstet Gynecol 2005;193(1):220-6.
139. Zhang Q, Ananth CV, Rhoads GG, Li Z. The impact of maternal anemia on perinatal mortality: a population-based, prospective cohort study in China. Ann Epidemiol 2009;19(11):793-9.
140. Remacha AF. Strategies for the Prevention and Treatment of Iron Deficiency during Pregnancy. Clin Drug Invest 2000;19 (Suppl. 1).
141. World Health Organization. Guideline: daily iron and folic acid supplementation in pregnant women [Internet]. Geneva: World Health Organization; 2012 [accessed 2017 April 18]. Available from: http://apps.who.int/iris/bitstream/10665/77770/1/9789241501996eng.pdf.
142. Sununtnasuk C, D'Agostino A, Fiedler JL. Iron+folic acid distribution and consumption through antenatal care: identifying barriers across countries. Public Health Nutrition 2015;19(4):732-42.
143. Gebremedhin S, Samuel A, Mamo G, Moges T, Assefa T. Coverage, compliance and factors associated with utilization of iron supplementation during pregnancy in eight rural districts of Ethiopia: a cross-sectional study BMC Public Health 2014;14(607).
144. Seck BC, Jackson RT. Determinants of compliance with iron supplementation among pregnant women in Senegal. Public Health Nutr 2008;11(6):596-605.
145. Reveiz L, Gyte GM, Cuervo LG, Casasbuenas A. Treatments for iron-deficiency anaemia in pregnancy. Cochrane Database Syst Rev 2011;(10):CD003094.

146. Kassa ZY, Awraris T, Daba AK, Tenaw Z. Compliance with iron folic acid and associated factors among pregnant women through pill count in Hawassa city, South Ethiopia: a community based cross-sectional study. Reprod Health 2019;16(1):14.
147. Gebremariam AD, Tiruneh SA, Abate BA, Engidaw MT, Asnakew DT. Adherence to iron with folic acid supplementation and its associated factors among pregnant women attending antenatal care follow up at Debre Tabor General Hospital, Ethiopia, 2017. PLoS One 2019;14(1):e0210086.
148. Birhanu TM, Birarra MK, Mekonnen FA. Compliance to iron and folic acid supplementation in pregnancy, Northwest Ethiopia. BMC Res Notes 2018;11(1):345.
149. Kamau MW, Mirie W, Kimani S. Compliance with Iron and folic acid supplementation (IFAS) and associated factors among pregnant women: results from a cross-sectional study in Kiambu County, Kenya. BMC Public Health 2018;18(1):580.
150. Habib F, Alabdin EH, Alenazy M, Nooh R. Compliance to iron supplementation during pregnancy. J Obstet Gynaecol 2009;29(6):487-92.
151. Ziaei S, Norrozi M, Faghihzadeh S, Jafarbegloo E. A randomised placebo-controlled trial to determine the effect of iron supplementation on pregnancy outcome in pregnant women with haemoglobin > or = 13.2 g/dl. BJOG 2007;114(6):684-8.
152. Pena-Rosas JP, De-Regil LM, Gomez Malave H, Flores-Urrutia MC, Dowswell T. Intermittent oral iron supplementation during pregnancy. Cochrane Database Syst Rev 2015;(10):CD009997.
153. Lassi ZS, Salam RA, Haider BA, Bhutta ZA. Folic acid supplementation during pregnancy for maternal health and pregnancy outcomes. Cochrane Database Syst Rev 2013;(3):CD006896.
154. Haider BA, Bhutta ZA. Multiple-micronutrient supplementation for women during pregnancy. Cochrane Database Syst Rev 2015;(11):CD004905.
155. Xu H, Shatenstein B, Luo ZC, Wei S, Fraser W. Role of nutrition in the risk of preeclampsia. Nutr Rev 2009;67(11):639-57.
156. Mwanri AW, Kinabo JL, Ramaiya K, Feskens EJ. High blood pressure and associated risk factors among women attending antenatal clinics in Tanzania. J Hypertens 2015;33(5):940-7.
157. Hu R, Li YX, Di HH, Li ZW, Zhang CH, Shen XP, et al. Risk factors of hypertensive disorders among Chinese pregnant women. J Huazhong Univ Sci Technolog Med Sci 2015;35(6):801-7.
158. American College of Obstetricians and Gynecologists. Hypertension in pregnancy. Report of the American College of Obstetricians and Gynecologists'Task Force on Hypertension in Pregnancy. Obst Gynecol 2013;122(5):1122-31.
159. Hutcheon JA, Lisonkova S, Joseph KS. Epidemiology of pre-eclampsia and the other hypertensive disorders of pregnancy. Best Pract Res Clin Obstet Gynaecol 2011;25(4):391-403.
160. Terefe W, Getachew Y, Hiruye A, Derbew M, Mariam DH, Mammo D, et al. Patterns of hypertensive disorders of pregnancy and associated factors at Debre Berhan Referral Hospital, North Shoa, Amhara Region. Ethiop Med J 2015;Supp. 2:57-65.
161. Wolde Z, Segni H, Woldie M. Hypertensive disorders of pregnancy in Jimma university specialized hospital. Ethiop J Health Sci 2011;21(3):147-54.
162. Tessema GA, Tekeste A, Ayele TA. Preeclampsia and associated factors among pregnant women attending antenatal care in Dessie referral hospital, Northeast Ethiopia: a hospital-based study. BMC Pregnancy Childbirth 2015;15:73.
163. Umesawa M, Kobashi G. Epidemiology of hypertensive disorders in pregnancy: prevalence, risk factors, predictors and prognosis. Hypertens Res 2017;40(3):213-20.
164. Steegers EAP, von Dadelszen P, Duvekot JJ, Pijnenborg R. Pre-eclampsia. The Lancet 2010;376(9741):631-44.
165. Conde-Agudelo A, Researcher P, Belizh JM. Risk factors for pre-eclampsia in a large cohort of Latin American and Caribbean women BJOG 2000;107(75–83).
166. Lee C-J, Hsieh T-T, Chiu T-H, Chen K-C, Lo L-M, Hung T-H. Risk factors for pre-eclampsia in an Asian population. Int J Gynaecol Obstet 2000; 70: 327–33.
167. Jacobs DJ, Vreeburg SA, Priest KR, Dekker GA, Heard AR, Chan A. Risk factors for hypertension during pregnancy in South Australia. . Aust N Z J Obstet Gynaecol 2003;43:421–8.

168. Catov JM, Ness RB, Kip KE, Olsen J. Risk of early or severe pre-eclampsia related to pre-existing conditions. Int J Epidemiol 2007;36(2):412-9.
169. Duckitt K, Harrington D. Risk factors for pre-eclampsia at antenatal booking: systematic review of controlled studies. BMJ 2005;330(7491):565.
170. Tebeu PM, Foumane P, Mbu R, Fosso G, Biyaga PT, Fomulu JN. Risk Factors for Hypertensive Disorders in Pregnancy: A Report from the Maroua Regional Hospital, Cameroon. J Reprod Infertil 2011;12(3):227-34.
171. Dalmáz Ca, santos KGD, botton mr, roisenberG i. Risk factors for hypertensive disorders of pregnancy in Southern Brazil. Rev Assoc Med Bras 2011;57(6):692-6.
172. Suleiman AK. Risk factors on hypertensive disorders among Jordanian pregnant women. Glob J Health Sci 2013;6(2):138-44.
173. Ye C, Ruan Y, Zou L, Li G, Li C, Chen Y, et al. The 2011 survey on hypertensive disorders of pregnancy (HDP) in China: prevalence, risk factors, complications, pregnancy and perinatal outcomes. PLoS One 2014;9(6):e100180.
174. Ros HS, Cnattingius S, Lipworth L. Comparison of Risk Factors for Preeclampsia and Gestational Hypertension in a Population-based Cohort Study. Am J Epidemiol 1998 147:1062-70.
175. Wolf M. Differential Risk of Hypertensive Disorders of Pregnancy among Hispanic Women. Journal of the American Society of Nephrology 2004;15(5):1330-8.
176. Poon LC, Kametas NA, Chelemen T, Leal A, Nicolaides KH. Maternal risk factors for hypertensive disorders in pregnancy: a multivariate approach. J Hum Hypertens 2010;24(2):104-10.
177. England L, Zhang J. Smoking and risk of pre-eclampsia: a systematic review. Front Biosci 2007;12: 2471–83.
178. Wei J, Liu C-X, Gong T-T, Wu Q-J, Wu L. Cigarette smoking during pregnancy and preeclampsia risk: a systematic review and meta-analysis of prospective studies Oncotarget 2015;6 (41).
179. Conde-Agudelo A, Althabe F, Belizán JM, Kafury-Goeta AC, Montevideo U. Cigarette smoking during pregnancy and risk of preeclampsia: A systematic review. Am J Obstet Gynecol 1999;181:1026-35.
180. Hayashi K, Matsuda Y, Kawamichi Y, Shiozaki A, Saito S. Smoking During Pregnancy Increases Risks of Various Obstetric Complications: A Case-Cohort Study of the Japan Perinatal Registry Network Database. Journal of Epidemiology 2011;21(1):61-6.
181. Nakimuli A, Nakubulwa S, Kakaire O, Osinde MO, Mbalinda SN, Kakande N, et al. The burden of maternal morbidity and mortality attributable to hypertensive disorders in pregnancy: a prospective cohort study from Uganda. BMC Pregnancy Childbirth 2016;16:205.
182. Allen VM, Joseph K, Murphy KE, Magee LA, Ohlsson A. The effect of hypertensive disorders in pregnancy on small for gestational age and stillbirth: a population based study. BMC Pregnancy Childbirth 2004;4(1):17.
183. Vogel JP, Souza JP, Mori R, Morisaki N, Lumbiganon P, Laopaiboon M, et al. Maternal complications and perinatal mortality: findings of the World Health Organization Multicountry Survey on Maternal and Newborn Health. BJOG 2014;121 Suppl 1:76-88.
184. Ananth CV, Basso O. Impact of pregnancy-induced hypertension on stillbirth and neonatal mortality. Epidemiology 2010;21(1):118-23.
185. Browne JL, Vissers KM, Antwi E, Srofenyoh EK, Van der Linden EL, Agyepong IA, et al. Perinatal outcomes after hypertensive disorders in pregnancy in a low resource setting. Trop Med Int Health 2015;20(12):1778-86.
186. Abdella A. Maternal Mortality Trend in Ethiopia [Ethiop J Health Dev 2010;24 (Special Issue 1):115-22.
187. Bezerra Maia EHMS, Marques Lopes L, Murthi P, da Silva Costa F. Prevention of preeclampsia. J Pregnancy 2012;2012:435090.
188. Dekker G, Sibai B. Primary, secondary, and tertiary prevention of pre-eclampsia. Lancet 2001; 357 209–15.
189. World Health Organization. WHO recommendations for Prevention and treatment of pre-eclampsia and eclampsia. Switzerland,Geneva. Available at www.who.int. 2011.

190. Carol_J._Lammi-Keefe, Couch SC, Elliot_Phi. Hand books of nutrition and pregnancy. In: Philipson CJL-KSCCEH, editor. USA: Humana Press; 2008.
191. Hofmeyr GJ, Lawrie TA, Atallah AN, Duley L, Torloni MR. Calcium supplementation during pregnancy for preventing hypertensive disorders and related problems. Cochrane Database Syst Rev 2014;(6):CD001059.
192. Hofmeyr GJ, Duley L, Atallah A. Dietary calcium supplementation for prevention of pre-eclampsia and related problems: a systematic review and commentary. BJOG 2007;114(8):933-43.
193. Imdad A, Jabeen A, Bhutta ZA. Role of calcium supplementation during pregnancy in reducing risk of developing gestational hypertensive disorders: a meta-analysis of studies from developing countries. BMC Public Health 2011;11 Suppl 3:S18.
194. Hofmeyr GJ, Belizan JM, von Dadelszen P, Calcium, Pre-eclampsia Study G. Low-dose calcium supplementation for preventing pre-eclampsia: a systematic review and commentary. BJOG 2014;121(8):951-7.
195. Imdad A, Bhutta ZA. Effects of calcium supplementation during pregnancy on maternal, fetal and birth outcomes. Paediatr Perinat Epidemiol 2012;26 Suppl 1:138-52.
196. Duley L, Henderson-Smart DJ, Meher S, King JF. Antiplatelet agents for preventing pre-eclampsia and its complications. Cochrane Database Syst Rev 2007;(2):CD004659.
197. Askie LM, Duley L, Henderson-Smart DJ, Stewart LA. Antiplatelet agents for prevention of pre-eclampsia: a meta-analysis of individual patient data. The Lancet 2007;369(9575):1791-8.
198. Villar J, Abdel-Aleem H, Merialdi M, Mathai M, Ali MM, Zavaleta N, et al. World Health Organization randomized trial of calcium supplementation among low calcium intake pregnant women. Am J Obstet Gynecol 2006;194(3):639-49.
199. Rogers MS, Fung HYM, Hung CY. Calcium and Low-Dose Aspirin Prophylaxis in Women at High Risk of Pregnancy-Induced Hypertension. Hypertension in Pregnancy 2009;18(2):165-72.
200. Food Medicine Healthcare A, and Control Authority of Ethiopia,. Standard treatment guidelines for primary hospital. 3rd ed. Addis Ababa, Ethiopia [publisher unknown]; 2014.
201. Butte NF, King JC. Energy requirements during pregnancy and lactation. Public Health Nutrition 2007;8(7a).
202. Food and Agriculture Organization of the United Nations; World Health Organization. Human energy requirements. Rome: FAO. 2001.
203. WHO/FAO. Vitamin and mineral requirements in human nutrition: Joint FAO/WHO Expert Consultation on Human Vitamin and Mineral Requirements. Second edition ed2001.
204. Institute of Medicine (US) and National Research Council (US) Committee to Re-examine IOM Pregnancy Weight Guidelines. In: Rasmussen KM, Yaktine AL, editors. Weight gain during pregnancy: re-examining the guidelines The National Academies Collection: Reports funded by National Institutes of Health. Washington (DC): The National Academies Press; 2009.
205. Royal College of Obstetricians and Gynaecologists. Nutrition in pregnancy. London: Royal College of Obstetricians and Gynaecologists; 2010. Scientific Impact Paper No.: 18.
206. Institute of Medicine (US). Dietary reference intakes: the essential guide to nutrient requirements. In: Otten JJ, Hellwig JP, Meyers LD, editors. Washington D.C: National Academies Press; 2006.
207. Ho A, Flynn AC, Pasupathy D. Nutrition in pregnancy. Obstetrics, Gynaecology & Reproductive Medicine 2016;26(9):259-64.
208. Hanson MA, Bardsley A, De-Regil LM, Moore SE, Oken E, Poston L, et al. The International Federation of Gynecology and Obstetrics (FIGO) recommendations on adolescent, preconception, and maternal nutrition: "Think Nutrition First"#. International Journal of Gynecology & Obstetrics 2015;131:S213-S53.
209. Lowensohn RI, Stadler DD, Naze C. Current Concepts of Maternal Nutrition. Obst and Gyn Survey 2016; 71(7):413-26.
210. European Food Safety Authority (EFSA). Scientific Opinion on Dietary Reference Values for water; EFSA Panel on Dietetic Products, Nutrition, and Allergies (NDA). EFSA Journal 2010;8(3):1459.
211. Black RE. Micronutrients in pregnancy. British Journal of Nutrition 2007;85(S2):S193.

212. Christian P. Micronutrients, birth weight, and survival. Annu Rev Nutr 2010;30:83-104.
213. Ladipo OA. Nutrition in pregnancy: mineral and vitamin supplements. Am J Clin Nutr 2000;72(Suppl):280S–90S.
214. Torheim LE, Ferguson EL, Penrose K, Arimond M. Women in resource-poor settings are at risk of inadequate intakes of multiple micronutrients. J Nutr 2010;140(11):2051S-8S.
215. World Health Organization. WHO recommendations on antenatal care for a positive pregnancy experience. [Geneva]: World Health Organization. 2016.
216. Cetin I, Laoreti A. The importance of maternal nutrition for health. J Pediatr Neonatal Individ Med 2015;4(2):e040220
217. Lee SE, Talegawkar SA, Merialdi M, Caulfield LE. Dietary intakes of women during pregnancy in low- and middle-income countries. Public Health Nutr 2013;16(8):1340-53.
218. Sheehy T, Carey E, Sharma S, Biadgilign S. Trends in energy and nutrient supply in Ethiopia: a perspective from FAO food balance sheets. Nutr J 2019;18(1):46.
219. Manoff Group (USAID/ENGINE). Maternal diet and nutrition practices and their determinants: A report on formative research findings and recommendations for social behavior change communication programming in the Amhara, Oromia, SNNP and Tigray regions of Ethiopia. Addis Ababa: USAID/ENGINE; 2014.
220. Food and Agriculture Organization of the United Nations; FHI 360. Minimum Dietary Diversity for Women: A Guide for Measurement. Rome: FAO;2016.
221. Kant AK. Dietary patterns and health outcomes. Journal of the American Dietetic Association 2004;104(4):615-35.
222. Ocke MC. Evaluation of methodologies for assessing the overall diet: dietary quality scores and dietary pattern analysis. Proc Nutr Soc 2013;72(2):191-9.
223. Moeller SM, Reedy J, Millen AE, Dixon LB, Newby PK, Tucker KL, et al. Dietary Patterns: Challenges and Opportunities in Dietary Patterns Research: An Experimental Biology Workshop, April 1, 2006. Journal of the American Dietetic Association 2007;107(7):1233-9.
224. Kennedy G, Ballard T, Dop MC. Guidelines for Measuring Household and Individual Dietary Diversity. Nutrition and Consumer Protection Division, FAO, UN 2011.
225. Arimond M, Wiesmann D, Becquey E, Carriquiry A, Daniels M, Deitchler M, et al. 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, USA, Food and Nutrition Technical Assistance FANTA-2 Bridge and Food Health International FHI 360 2011.
226. Nguyen PH, Avula R, Ruel MT, Saha KK, Ali D, Tran LM, et al. Maternal and child dietary diversity are associated in Bangladesh, Vietnam, and Ethiopia. J Nutr 2013;143(7):1176-83.
227. United Nations System Standing Committee on Nutrition TFoA, Monitoring, and Evaluation, . Fact sheets on food and nutrition security indicators/measures: dietary diversity (DD). [United Nations System Standing Committee on Nutrition]: Rome; 2008.
228. Hoddinott J, Yohannes Y. Dietary diversity as a food security indicator. Food and Nutrition Technical Assistance Project, Academy for Educational Development, Washington, D.C. 2002.
229. Arimond M, Wiesmann D, Becquey E, Carriquiry A, Daniels MC, Deitchler M, et al. Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse, resource-poor settings. J Nutr 2010;140(11):2059S-69S.
230. Zhang Q, Chen X, Liu Z, Varma DS, Wan R, Zhao S. Diet diversity and nutritional status among adults in southwest China. Plos One 2017;12(2):e0172406.
231. Ocampo-Guirindola ML, Garcia-Malabad CJ, Valdeabella-Maniego MLM, Punzalan SLM. Association Between Dietary Diversity Score and Nutritional Status of Filipino Children Aged 6-23 Months. Philippine Journal of Science 2016;145(1):57-69.
232. Alem M, Enawgaw B, Gelaw A, Kena T, Seid M, Olkeba Y. Prevalence of anemia and associated risk factors among pregnant women attending antenatal care in Azezo Health Center Gondar town, Northwest Ethiopia. J Interdiscipl Histopathol 2013;1(3):137-44.
233. Brantsaeter AL, Haugen M, Samuelsen SO, Torjusen H, Trogstad L, Alexander J, et al. A dietary pattern characterized by high intake of vegetables, fruits, and vegetable oils is associated with reduced risk of preeclampsia in nulliparous pregnant Norwegian women. J Nutr 2009;139(6):1162-8.

234. Rifas-Shiman SL, Rich-Edwards JW, Kleinman KP, Oken E, Gillman MW. Dietary quality during pregnancy varies by maternal characteristics in Project Viva: a US cohort. J Am Diet Assoc 2009;109(6):1004-11.
235. World Health Organization. Global nutrition targets 2025: anaemia policy brief. Geneva: World Health Organization; 2014 [accessed 2017 August 27]. Report No.: HO/NMH/NHD/14.4. http://apps.who.int/iris/bitstream/10665/148556/1/WHO_NMH_NHD_14.4_eng.pdf.
236. World Health Organization. Global Health Observatory data repository: prevalence of anaemia in women. Geneva: World Health Organization; 2017. Available from: http://apps.who.int/gho/data/node.main.ANAEMIAWOMEN?lang=en.
237. World Health Organization/United Nations Children's Fund. The extension of the 2025 Maternal, Infant and Young Child nutrition targets to 2030. [Geneva]: World Health Organization; 2019. Available from: https://www.who.int/nutrition/global-target-2025/discussion-paper-extension-targets-2030.pdf. 2019.
238. Academy of Nutrition and Dietetics. Evidence analysis manual: steps in the academy evidence analysis process. Updated April 2016. Chicago: Academy of Nutrition and Dietetics: 2016. Available from: www.andeal.org.
239. Zhang J, Yu KF. What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. JAMA 1998;280( ):1690-1.
240. Higgins JP, Green S, (editors). Cochrane handbook for systematic reviews of interventions [Internet]. Version 5.1.0. Chichester (UK): John Wiley & Sons, Ltd.; 2011 [updated 2011 March]. Available from: http://handbook.cochrane.org. .
241. Wiest MM, Lee KJ, Carlin JB. Statistics for clinicians: An introduction to logistic regression. J Paediatr Child Health 2015;51(7):670-3.
242. Pryor ER. Logistic Regression A Self-Learning Text. 3rd ed. USA: Springer; 2010.
243. Borenstein M, V.Hedges L, JulianP.T.Higgins, Rothstein H. Introduction to Meta-Analysis. 1st eds ed. The Atrium, United Kingdom: John Wiley & Sons, Ltd; 2009.
244. Nkrumah B, Nguah SB, Sarpong N, Dekker D, Idriss A, May J, et al. Hemoglobin estimation by the HemoCue(R) portable hemoglobin photometer in a resource poor setting. BMC Clin Pathol 2011;11:5.
245. Banerjee S. Spatial Data Analysis. Annu Rev Public Health 2016;37:47-60.
246. Lawson AB. Statistical Methods in Spatial Epidemiology. Atrium, Southern Gate, West Sussex, England: John Wiley & Sons Inc; 2006.
247. Anselin L. Exploring Spatial Data with GeoDaTM : A Workbook. Center for Spatially Integrated Social Science http://wwwcsissorg/ 2005.
248. Ord J, Getis A. Local Spatial Autocorrelation Statistics: Distributional Issues and an Application. Geographical Analysis 1995;27(4):286–306.
249. Merlo J, Chaix B, Ohlsson H, Beckman A, Johnell K, Hjerpe P, et al. A brief conceptual tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel logistic regression to investigate contextual phenomena. J Epidemiol Community Health 2006;60(4):290-7.
250. Merlo J, Yang M, Chaix B, Lynch J, Rastam L. A brief conceptual tutorial on multilevel analysis in social epidemiology: investigating contextual phenomena in different groups of people. J Epidemiol Community Health 2005;59(9):729-36.
251. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health: integrating random and fixed effects in multilevel logistic regression. Am J Epidemiol 2005;161(1):81-8.
252. Guo G, Zhao H. Multilevel Modeling for Binary Data. Annual Review Sociology. Annual Review Sociology 2000;26:441–62.
253. Lee ES, Forthofer RN. Analysing Complex Survey Data: Quantitative applications in the social sciences. Thousand Oaks, California: SAGE Publications Inc 2006.
254. SPSS Inc. SPSS complex samples 13.0. Chicago: SPSS Inc.;2004.
255. DHS. DHS Spatial Interpolation Working Group. 2014. Spatial Interpolation with Demographic and Health Survey Data: Key Considerations. DHS Spatial Analysis Reports No. 9. Rockville, Maryland, USA: ICF International. 2014.

256. StataCorp. Stata structural equation modelling reference manual. Version 13. Texas,USA: Stata Press; 2013.
257. Garson GD. Structural Equation Modelling 2015 eddition ed. USA: Statistical Associates Publishing; 2015.
258. Bruzzi P, Green SB, Byar DP, Brinton LA, Schairer C. Estimating the population attributable risk for multiple risk factors using case-control data. Am J Epidemiol 1985;122:904-14.
259. Eide GE, Gefeller O. Sequential and average attributable fractions as aids in the selection of preventive strategies. J Clin Epidemiol 1995;48(5):645 -55.
260. Rückinger S, Kries Rv, Toschke AM. An illustration of and programs estimating attributable fractions in large scale surveys considering multiple risk factors. BMC Med Res Methodol 2009;9(7):doi:10.1186/471-2288-9-7.
261. Gerstman BB. Epidemiology Kept Simple: An introduction to traditional and modern epidemiology. 3rd ed. Atrium,UK : John Wiley & Sons; 2013 2013.
262. Darrow LA, Steenland NK. Confounding and bias in the attributable fraction. Epidemiology 2011;22(1):53-8.
263. Rose G. Sick individuals and sick populations. Int J Epidemiol 2001;30:427–32.
264. Fleiss JL, Levin B, Paik MC. Statistical Methods for Rates and Proportions. New Jersey,USA: John Wiley & Sons, Inc; 2003.
265. Ayele G, Lemma S, Agdew E. Factors Associated with Hypertension during Pregnancy in Derashie Woreda South Ethiopia, Case Control. Quality in Primary Care 2016;24(5):207-13.
266. World Health Organization. Physical status: the use and interpretation of anthropometry. Geneva: World Health Organization; 1995. Report No.: WHO TRS/854.
267. Rosenbaum PR, Rubin DB. Constructing a Control Group Using Multivariate Matched Sampling Methods That Incorporate the Propensity Score. The American Statistician 1985;39(1):33-8.
268. Rubin PRRDB. The Central Role of the Propensity Score in Observational Studies for Causal Effects. Biometrika 1983;70(1):41-55.
269. Stuart EA. Matching Methods for Causal Inference: A Review and a Look Forward Statistical Science 2010;25(1):1–21 DOI: 10.1214/09-STS313.
270. Westreich D, Cole SR, Funk MJ, Brookhart MA, Sturmer T. The role of the c-statistic in variable selection for propensity score models. Pharmacoepidemiol Drug Saf 2011;20(3):317-20.
271. Hosmer DW, Lemeshow S, Sturdivant RX. Applied Logistic Regression. New Jersey, USA: John Wiley & Sons, Inc; 2013.
272. Austin PC. A Tutorial and Case Study in Propensity Score Analysis: An Application to Estimating the Effect of In-Hospital Smoking Cessation Counseling on Mortality. Multivariate Behav Res 2011;46(1):119-51.
273. Lunt M. Propensity analysis [Internet]. [place unknown]: [publisher unknown]; 2014. Available from: http://personalpages.manchester.ac.uk/staff/mark.lunt/propensity.
274. Rubin DB. Using Propensity Scores to Help Design Observational Studies: Application to the Tobacco Litigation. Health Services & Outcomes Research Methodology 2001;2:169–88.
275. Stuart EA, Green KM. Using full matching to estimate causal effects in nonexperimental studies: examining the relationship between adolescent marijuana use and adult outcomes. Dev Psychol 2008;44(2):395-406.
276. Austin PC. Type I Error Rates, Coverage of Confidence Intervals, and Variance Estimation in Propensity-Score Matched Analyses. Int J Biostat 2009;5(1).
277. Gemmell L, Martin L, Murphy KE, Modi N, Hakansson S, Reichman B, et al. Hypertensive disorders of pregnancy and outcomes of preterm infants of 24 to 28 weeks' gestation. J Perinatol 2016;36(12):1067-72.
278. Lawn JE, Gravett MG, Nunes TM, Rubens CE, Stanto C. Global report on preterm birth and stillbirth (1 of 7): defi nitions, description of the burden and opportunities to improve data. BMC Pregnancy and Childbirth 2010;10(Suppl 1:S1).
279. Blencowe H, Cousens S, Chou D, Oestergaard M, Say L, Moller A-B, et al. Born Too Soon: The global epidemiology of 15 million preterm births. Reproductive Health 2013;10(Suppl 1:S2).

280. Blencowe H, Cousens S, Oestergaard MZ, Chou D, Moller A-B, Narwal R, et al. National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: a systematic analysis and implications. The Lancet 2012;379(9832):2162-72.
281. Ramakrishnan U. Nutrition and low birth weight: from research to practice. Am J Clin Nutr 2004;79:17-21.
282. Mahumud RA, Sultana M, Sarker AR. Distribution and Determinants of Low Birth Weight in Developing Countries. J Prev Med Public Health 2017;50(1):18-28.
283. De Seymour J, Chia A, Colega M, Jones B, McKenzie E, Shirong C, et al. Maternal Dietary Patterns and Gestational Diabetes Mellitus in a Multi-Ethnic Asian Cohort: The GUSTO Study. Nutrients 2016;8(9):doi:10.3390/nu8090574.
284. He JR, Yuan MY, Chen NN, Lu JH, Hu CY, Mai WB, et al. Maternal dietary patterns and gestational diabetes mellitus: a large prospective cohort study in China. British Journal of Nutrition 2015;113(8):1292-300.
285. Haugen M, Meltzer HM, Brantsaeter AL, Mikkelsen T, Osterdal ML, Alexander J, et al. Mediterranean-type diet and risk of preterm birth among women in the Norwegian Mother and Child Cohort Study (MoBa): a prospective cohort study. Acta Obstet Gynecol Scand 2008;87(3):319-24.
286. Rasmussen MA, Maslova E, Halldorsson TI, Olsen SF. Characterization of Dietary Patterns in the Danish National Birth Cohort in Relation to Preterm Birth. Plos One 2014;9(4).
287. K.R. Kjøllesdal M, Holmboe-Ottesen G. Dietary Patterns and Birth Weight—a Review. AIMS Bioengineering 2014;1(4):211-25.
288. Borgen I, Aamodt G, Harsem N, Haugen M, Meltzer HM, Brantsaeter AL. Maternal sugar consumption and risk of preeclampsia in nulliparous Norwegian women. Eur J Clin Nutr 2012;66(8):920-5.
289. Zhang C, Schulze MB, Solomon CG, Hu FB. A prospective study of dietary patterns, meat intake and the risk of gestational diabetes mellitus. Diabetologia 2006;49(11):2604-13.
290. Tryggvadottir EA, Medek H, Birgisdottir BE, Geirsson RT, Gunnarsdottir I. Association between healthy maternal dietary pattern and risk for gestational diabetes mellitus. European Journal of Clinical Nutrition 2016;70(2):237-42.
291. Eshriqui I, Vilela AAF, Rebelo F, Farias DR, Castro MBT, Kac G. Gestational dietary patterns are not associated with blood pressure changes during pregnancy and early postpartum in a Brazilian prospective cohort. Eur J Nutr 2016;55(1):21-32.
292. Hillesund ER, Overby NC, Engel SM, Klungsoyr K, Harmon QE, Haugen M, et al. Associations of adherence to the New Nordic Diet with risk of preeclampsia and preterm delivery in the Norwegian Mother and Child Cohort Study (MoBa). Eur J Epidemiol 2014;29(10):753-65.
293. Torjusen H, Brantsaeter AL, Haugen M, Alexander J, Bakketeig LS, Lieblein G, et al. Reduced risk of pre-eclampsia with organic vegetable consumption: results from the prospective Norwegian Mother and Child Cohort Study. BMJ Open 2014;4(9):e006143.
294. Dayeon S, Kyung Won L, Won OS. Dietary Patterns during Pregnancy Are Associated with Risk of Gestational Diabetes Mellitus. Nutrients 2015;7(11):9369-82.
295. Karamanos B, Thanopoulou A, Anastasiou E, Assaad-Khalil S, Albache N, Bachaoui M, et al. Relation of the Mediterranean diet with the incidence of gestational diabetes. European Journal of Clinical Nutrition 2014;68(1):8-13.
296. Nascimento GR, Alves LV, Fonseca CL, Figueiroa JN, Alves JG. Dietary patterns and gestational diabetes mellitus in a low income pregnant women population in Brazil - a cohort study. Archivos Latinoamericanos de Nutricion 2016;66(4):301-8.
297. Chia AR, de Seymour JV, Colega M, Chen LW, Chan YH, Aris IM, et al. A vegetable, fruit, and white rice dietary pattern during pregnancy is associated with a lower risk of preterm birth and larger birth size in a multiethnic Asian cohort: the Growing Up in Singapore Towards healthy Outcomes (GUSTO) cohort study. Am J Clin Nutr 2016;104(5):1416-23.
298. Martin CL, Sotres-Alvarez D, Siega-Riz AM. Maternal Dietary Patterns during the Second Trimester Are Associated with Preterm Birth. Journal of Nutrition 2015;145(8):1857-64.

299. Mikkelsen TB, Osterdal ML, Knudsen VK, Haugen M, Meltzer HM, Bakketeig L, et al. Association between a Mediterranean-type diet and risk of preterm birth among Danish women: a prospective cohort study. Acta Obstet Gynecol Scand 2008;87(3):325-30.
300. Saunders L, Guldner L, Costet N, Kadhel P, Rouget F, Monfort C, et al. Effect of a Mediterranean diet during pregnancy on fetal growth and preterm delivery: results from a French Caribbean Mother-Child Cohort Study (TIMOUN). Paediatr Perinat Epidemiol 2014;28(3):235-44.
301. Zerfu TA, Umeta M, Baye K. Dietary diversity during pregnancy is associated with reduced risk of maternal anemia, preterm delivery, and low birth weight in a prospective cohort study in rural Ethiopia. American Journal of Clinical Nutrition 2016;103(6):1482-8.
302. Abubakari A, Jahn A. Maternal Dietary Patterns and Practices and Birth Weight in Northern Ghana. Plos One 2016;11(9).
303. Poon AK, Yeung E, Boghossian N, Albert PS, Zhang C. Maternal dietary patterns during third trimester in association with birthweight characteristics and early infant growth. Scientifica 2013;2013(786409).
304. Gernand AD, Schulze KJ, Stewart CP, West KP, Jr., Christian P. Micronutrient deficiencies in pregnancy worldwide: health effects and prevention. Nat Rev Endocrinol 2016;12(5):274-89.
305. Wakimoto P, Akabike A, King JC. Maternal Nutrition and Pregnancy Outcome—A Look Back. Nutrition Today 2015;50(5):221-9.
306. World Health Organization Regional Office for Europe Nutrition and Food Security. Healthy Eating during Pregnancy and Breastfeeding: Booklet for Mothers. Geneva: WHO. 2001.
307. Frederick IO, Williams MA, Dashow E, Kestin M, Zhang C, Leisenring WM. Dietary fiber, potassium, magnesium, and calcium in relation to preeclampsia risk. J Reprod Med 2005;50(5):322-44.
308. Pistollato F, Sumalla Cano S, Elio I, Masias Vergara M, Giampieri F, Battino M. Plant-Based and Plant-Rich Diet Patterns during Gestation: Beneficial Effects and Possible Shortcomings. Adv Nutr 2015;6(5):581-91.
309. Hsieh TT, Chen SF, Lo LM, Li MJ, Yeh YL, Hung TH. The association between maternal oxidative stress at mid-gestation and subsequent pregnancy complications. Reprod Sci 2012;19(5):505-12.
310. Kim H, Hwang JY, Ha EH, Park H, Ha M, Lee SH, et al. Fruit and vegetable intake influences the association between exposure to polycyclic aromatic hydrocarbons and a marker of oxidative stress in pregnant women. Eur J Clin Nutr 2011;65(10):1118-25.
311. Raijmakers MT, Dechend R, Poston L. Oxidative stress and preeclampsia: rationale for antioxidant clinical trials. Hypertension 2004;44(4):374-80.
312. Siddiqui IA, Jaleel A, Tamimi W, Al Kadri HM. Role of oxidative stress in the pathogenesis of preeclampsia. Arch Gynecol Obstet 2010;282(5):469-74.
313. Tobias DK, Cuilin Z, Chavarro J, Bowers K, Rich-Edwards J, Rosner B, et al. Prepregnancy adherence to dietary patterns and lower risk of gestational diabetes mellitus. American Journal of Clinical Nutrition 2012;96(2):289-95.
314. Schoenaker D, Soedamah-Muthu SS, Mishra GD. Quantifying the mediating effect of body mass index on the relation between a Mediterranean diet and development of maternal pregnancy complications: the Australian Longitudinal Study on Women's Health. American Journal of Clinical Nutrition 2016;104(3):638-45.
315. Asemi Z, Samimi M, Tabassi Z, Esmaillzadeh A. The effect of DASH diet on pregnancy outcomes in gestational diabetes: a randomized controlled clinical trial. Eur J Clin Nutr 2014;68(4):490-5.
316. Zhang C, Liu S, Solomon CG, Hu FB. Dietary fiber intake, dietary glycemic load, and the risk for gestational diabetes mellitus. Diabetes Care 2006;29(10):2223-30.
317. Gresham E, Bisquera A, Byles JE, Hure AJ. Effects of dietary interventions on pregnancy outcomes: a systematic review and meta-analysis. Matern Child Nutr 2016;12(1):5-23.
318. Gresham E, Byles JE, Bisquera A, Hure AJ. Effects of dietary interventions on neonatal and infant outcomes: a systematic review and meta-analysis. Am J Clin Nutr 2014;100(5):1298-321.

319. King JC. Maternal obesity, metabolism, and pregnancy outcomes. Annu Rev Nutr 2006;26:271-91.
320. Casanueva E, Viteri FE. Iron and Oxidative Stress in Pregnancy. J Nutr 2003;133:1700S–8S.
321. Mistry HD, Williams PJ. The importance of antioxidant micronutrients in pregnancy. Oxid Med Cell Longev 2011;2011:841749.
322. Al-Gubory KH, Fowler PA, Garrel C. The roles of cellular reactive oxygen species, oxidative stress and antioxidants in pregnancy outcomes. Int J Biochem Cell Biol 2010;42(10):1634-50.
323. Zhang Y, Zhou H, Perkins A, Wang Y, Sun J. Maternal Dietary Nutrient Intake and Its Association with Preterm Birth: A Case-control Study in Beijing, China. Nutrients 2017;9(3): doi:10.3390/nu9030221.
324. Asemi Z, Samimi M, Tabassi Z, Sabihi SS, Esmaillzadeh A. A randomized controlled clinical trial investigating the effect of DASH diet on insulin resistance, inflammation, and oxidative stress in gestational diabetes. Nutrition 2013;29(4):619-24.
325. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses BMJ 2003;327:557–60.
326. Haidar JA, Pobocik RS. Iron deficiency anemia is not a rare problem among women of reproductive ages in Ethiopia: a community based cross sectional study. BMC Blood Disord 2009;9(7):doi:10.1186/471-2326-9-7.
327. Umeta M, Haidar J, Demissie T, Akalu G, Ayana G. Iron Deficiency Anaemia among Women of Reproductive Age in Nine Administrative Regions of Ethiopia. EthiopJHealth Dev 2008;22(3):252-8.
328. Pokropek C, Sobolewski P, Getachew R, Paul A, Boura J, Ogunyemi D. Dietary intake patterns and insulin resistance in women with a history of gestational diabetes in the National Health and Nutrition Examination Survey (NHANES) 2000-2010. American Journal of Obstetrics and Gynecology 2015;1):S308.
329. Deress T, Girma M. Plasmodium falciparum and Plasmodium vivax Prevalence in Ethiopia: A Systematic Review and Meta-Analysis. Malar Res Treat 2019;2019:7065064.
330. Desalegn K, Pragya S, Debebe M, Tefera B. Nutritional Status and Associated Factors among Pregnant Women in Wondo Genet District, Southern Ethiopia. Journal of Food Science and Engineering 2015;5(2).
331. Beyene A, Hailu T, Faris K, Kloos H. Current state and trends of access to sanitation in Ethiopia and the need to revise indicators to monitor progress in the Post-2015 era. BMC Public Health (2015) 15:451 DOI 101186/s12889-015-1804-4.
332. Yasutake S, He H, Decker MR, Sonenstein FL, Astone NM. Anemia among Adolescent and Young Women in Low-and-MiddleIncome Countries. Int J Child Health and Nutr 2013;2:105-12.
333. Kavle JA, Stoltzfus RJ, Khalfan SS, Witter F, Tielsch JM, Caulfield LE. Association between Anaemia during Pregnancy and Blood Loss at and after Delivery among Women with Vaginal Births in Pemba Island, Zanzibar, Tanzania. J Health Popul Nutr 2008;26(2):232-40.
334. Lakew Y, Biadgilign S, Haile D. Anaemia prevalence and associated factors among lactating mothers in Ethiopia: evidence from the 2005 and 2011 demographic and health surveys. BMJ Open 2015;5(4):e006001.
335. Bentley M, Griffiths P. The burden of anemia among women in India European Journal of Clinical Nutrition 2003;57:52–60.
336. United Nations 2020. Sustainable development goals. Accsed on 20 Oct 2020 https://www.un.org/sustainabledevelopment/health/.
337. Wirth JP, Woodruff BA, Engle-Stone R, Namaste SM, Temple VJ, Petry N, et al. Predictors of anemia in women of reproductive age: Biomarkers Reflecting Inflammation and Nutritional Determinants of anemia (BRINDA) project. Am J Clin Nutr 2017;106(Suppl):416S–27S.
338. Diégane TJA, Faye Adama DS, Khadim N, Oumar B, Mbacke LMM, Mareme SN, et al. Study of Factors Associated with Anemia among Women in Reproductive Age in Kolda (Senegal). Open J Obs Gyn 2018;8:688-99 https://doi.org/10.4236/ojog.2018.87073.
339. Shaw JG, Friedman JF. Iron Deficiency Anemia: Focus on Infectious Diseases in Lesser Developed Countries. Anemia 2011;Vol. 2011 Article ID 260380:10 pages doi:.1155/2011/260380.

340. Harvey LJ, Armah CN, Dainty JR, Foxall RJ, Lewis DJ, Langford NJ, et al. Impact of menstrual blood loss and diet on iron deficiency among women in the UK. British Journal of Nutrition 2007;94(4):557-64.
341. Benichou J. A review of adjusted estimators of attributable risk. Stat Meth Med Research 2001 10:195–216.
342. Murray CJL, Aravkin AY, Zheng P, Abbafati C, Abbas KM, Abbasi-Kangevari M, et al. Global burden of 87 risk factors in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. The Lancet 2020;396(10258):1223-49.
343. Abriha A, Yesuf ME, Wassie MM. Prevalence and associated factors of anemia among pregnant women of Mekelle town: a cross sectional study. BMC Research Notes 2014 2014; 7(888).
344. Ayoya MA, Gerburg Maria Spiekermann-Brouwer AKT, Stoltzfus RJ, Garza C. Determinants of anemia among pregnant women in Mali. Food and Nutrition Bulletin 2006;27(1).
345. Lartey A. Maternal and child nutrition in Sub-Saharan Africa: challenges and interventions. Proc Nutr Soc 2008;67(1):105-8.
346. Bhargava A, Bouis HE, Scrimshaw NS. Dietary Intakes and Socioeconomic Factors Are Associated with the Hemoglobin Concentration of Bangladeshi Women. J Nutr 2001;131:758–64.
347. Alemu T, Umeta M. Reproductive and Obstetric Factors Are Key Predictors of Maternal Anemia during Pregnancy in Ethiopia: Evidence from Demographic and Health Survey (2011). Anemia 2015;2015:649815.
348. Ayenew F, Abere Y, Timerga G. Pregnancy Anaemia Prevalence and Associated Factors among Women Attending Ante Natal Care in North Shoa Zone, Ethiopia. Reproductive System & Sexual Disorders 2014;03(03).
349. Bekele A, Tilahun M, Mekuria A. Prevalence of Anemia and Its Associated Factors among Pregnant Women Attending Antenatal Care in Health Institutions of Arba Minch Town, Gamo Gofa Zone, Ethiopia: A Cross-Sectional Study. Anemia 2016;2016:1073192.
350. Australian Institute of Health and Welfare 2017. Impact of overweight and obesity as a risk factor for chronic conditions: Australian Burden of Disease Study. Australian Burden of Disease Study series no.11. Cat. no. BOD 12. BOD. Canberra: AIHW.
351. Meltzer HM, Brantsaeter AL, Nilsen RM, Magnus P, Alexander J, Haugen M. Effect of dietary factors in pregnancy on risk of pregnancy complications: results from the Norwegian Mother and Child Cohort Study. Am J Clin Nutr 2011;94(6 Suppl):1970S-4S.
352. Kibret KT, Chojenta C, Gresham E, Tegegne TK, Loxton D. Maternal dietary patterns and risk of adverse pregnancy (hypertensive disorders of pregnancy and gestational diabetes mellitus) and birth (preterm birth and low birth weight) outcomes: a systematic review and meta-analysis. Public Health Nutr 2018:1-15.
353. Slavin JL, Lloyd B. Health benefits of fruits and vegetables. Adv Nutr 2012;3(4):506-16.
354. Patra S, Pasrija S, Trivedi SS, Puri M. Maternal and perinatal outcome in patients with severe anemia in pregnancy. Int J Gynaecol Obstet 2005;91(2):164-5.
355. Hansson SR, Naav A, Erlandsson L. Oxidative stress in preeclampsia and the role of free fetal hemoglobin. Front Physiol 2014;5:516.
356. Arulselvan P, Fard MT, Tan WS, Gothai S, Fakurazi S, Norhaizan ME, et al. Role of Antioxidants and Natural Products in Inflammation. Oxid Med Cell Longev 2016;2016:5276130.
357. Griffiths K, Aggarwal BB, Singh RB, Buttar HS, Wilson D, De Meester F. Food Antioxidants and Their Anti-Inflammatory Properties: A Potential Role in Cardiovascular Diseases and Cancer Prevention. Diseases 2016;4(3).
358. Saito S, Shiozaki A, Nakashima A, Sakai M, Sasaki Y. The role of the immune system in preeclampsia. Mol Aspects Med 2007;28(2):192-209.
359. MacIntyre DA, Sykes L, Teoh TG, Bennett PR. Prevention of preterm labour via the modulation of inflammatory pathways. J Matern Fetal Neonatal Med 2012;25 Suppl 1:17-20.
360. Liu RH. Health-promoting components of fruits and vegetables in the diet. Adv Nutr 2013;4(3):384S-92S.

361. Myhre R, Brantsaeter AL, Myking S, Eggesbo M, Meltzer HM, Haugen M, et al. Intakes of Garlic and Dried Fruits Are Associated with Lower Risk of Spontaneous Preterm Delivery. Journal of Nutrition 2013;143(7):1100-8.
362. Brantsaeter AL, Myhre R, Haugen M, Myking S, Sengpiel V, Magnus P, et al. Intake of probiotic food and risk of preeclampsia in primiparous women: the Norwegian Mother and Child Cohort Study. Am J Epidemiol 2011;174(7):807-15.
363. Myhre R, Brantsaeter AL, Myking S, Gjessing HK, Sengpiel V, Meltzer HM, et al. Intake of probiotic food and risk of spontaneous preterm delivery. Am J Clin Nutr 2011;93(1):151-7.
364. Ministry of Health of Ethiopia. Health and Health Related Indicator, Vertion 1, Addis Ababa, Ethiopia. 2008.
365. Moor MA, Fraga MA, Garfein RS, Rashidi HH, Alcaraz J, Kritz-Silverstein D, et al. Individual and community factors contributing to anemia among women in rural Baja California, Mexico. PLoS ONE 2017;12(11):e0188590. https://doi. org/10.1371/journal.pone.
366. Bhandari S, Sayami JT, Thapa P, Sayami M, Kandel6 BP, Banjara1 MR. Dietary intake patterns and nutritional status of women of reproductive age in Nepal: findings from a health survey. Archives of Public Health 2016;74(2): DOI 10.1186/s13690-016-0114-3.
367. Thompson B. Food-based approaches for combating iron deficiency. Kraemer K ZM, editor. Basel: Sight and Life Press; 2007. 337–58 p.
368. Huma N, Salim Ur R, Anjum FM, Murtaza MA, Sheikh MA. Food fortification strategy--preventing iron deficiency anemia: a review. Crit Rev Food Sci Nutr 2007;47(3):259-65.

Appendix 1: Ethics approval letter for EDHS data from the National Research Ethics Review Committee of Ethiopia

በኢትዮጵያ ፌዴራላዊ ዴሞክራሲያዊ ሪፐብሊክ
የሳይንስና ቴክኖሎጂ ሚኒስቴር
The Federal Democratic Republic of Ethiopia
Ministry of Science and Technology

ቁጥር 3/10/114/2016
Ref. No.
ቀን May 9, 2016
Date

To: Ethiopian Central Statistics Agency

Addis Ababa

Re: 2016 Ethiopian Demographic Survey

Dear Sir/Madam//Mr./Mrs./Dr,

The National Research Ethics Review Committee (NRERC) has reviewed the aforementioned project protocol in an expedited manner. We are writing to advise you that NRERC has granted

Full Approval

To the above named project, for a period of **one year (May 9, 2016- May 8, 2017).** All your most recently submitted documents have been approved for use in this study. The study should comply with the standard international and national scientific and ethical guidelines. Any change to the approved protocol or consent material must be reviewed and approved through the amendment process prior to its implementation. In addition, any adverse or unanticipated events should be reported within 24-48 hours to the NRERC. Please ensure that you submit biannual progress report once in six months and annual renewal application 30 days prior to the expiry date.

We, therefore, request you as PI and your esteemed organization to ensure the commencement and conduct of the study accordingly and wish for the successful completion of the project.

With regards,

Yohannes Sitotaw
Secretary of NRERC

CC: _Ethiopian Public Health Institute (PI)
_ Mr. Asalfew Abera (PI)
_ NRERC Chairperson

ማነጋገር ቢያስፈልግዎ
You may Contact

ፖ.ሳ.ቁ. P.O.Box 2490
አዲስ አበባ ኢትዮጵያ Addis Ababa, Ethiopia
E-mail most@ethionet.et
ስልክ Tel. 251-011-4-674353
Web site:-http://www.most.gov.et
ፋክስ Fax +251-011-4-66 02 41

Appendix 2: Ethics approval letter for EDHS data from ICF Macro International

Ethiopia Demographic and Health Survey
October 15, 2014

Institutional Review Board Findings Form
ICF IRB FWA00000845 (exp. 04/13/2019)

Project Director(s): Yodit Bekele

Project Title: Ethiopia Demographic and Health Survey

ICF Project Number: 132989.0.000.ET.DHS.01

Type of Review:

☒ New ☐ Modification ☐ Annual review

Findings of the Board:

☒ Project complies with all of the requirements of 45 CFR 46, "Protection of Human Subjects"

☐ Project is exempt from IRB review (See IRB Exemption Form)

☐ Project does not comply with all of the requirements of 45 CFR 46

Project Approved Until: June 2017

Next Annual Review Date: October 15, 2016

______________________________ October 15, 2015

Chair, Institutional Review Board *Date*

(Revised 07/18/2014)

List of Approved Project Materials:

1. 2016 EDHS Household Questionnaire
2. 2016 EDHS Woman's Questionnaire
3. 2016 EDHS Man's Questionnaire
4. 2016 EDHS Biomarker Questionnaire
5. 2016 EDHS Health Facility Questionnaire
6. 2016 EDHS Fieldworker Questionnaire

Page 2

Appendix 3: Ethics approval for secondary data from the University of Newcastle Human Research Ethics Committee

HUMAN RESEARCH ETHICS COMMITTEE

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Notification of Expedited Approval

To Chief Investigator or Project Supervisor:	**Doctor Catherine Chojenta**
Cc Co-investigators / Research Students:	**Mr Kelemu Tilahun Kibret** **Professor Deb Loxton** **Miss ELLIE Gresham**
Re Protocol:	**The Spatial Distribution and Determinant Factors of Maternal Anemia in Ethiopia**
Date:	**16-Mar-2018**
Reference No:	**H-2018-0045**
Date of Initial Approval:	**16-Mar-2018**

Thank you for your **Initial Application** submission to the Human Research Ethics Committee (HREC) seeking approval in relation to the above protocol.

Your submission was considered under **L1 Low Risk Research Expedited** review by the Ethics Administrator.

I am pleased to advise that the decision on your submission is **Approved** effective **16-Mar-2018**.

In approving this protocol, the Human Research Ethics Committee (HREC) is of the opinion that the project complies with the provisions contained in the National Statement on Ethical Conduct in Human Research, 2007, and the requirements within this University relating to human research.

Approval will remain valid subject to the submission, and satisfactory assessment, of annual progress reports. *If the approval of an External HREC has been "noted" the approval period is as determined by that HREC.*

The full Committee will be asked to ratify this decision at its next scheduled meeting. A formal *Certificate of Approval* will be available upon request. Your approval number is **H-2018-0045**.

If the research requires the use of an Information Statement, ensure this number is inserted at the relevant point in the Complaints paragraph prior to distribution to potential participants You may then proceed with the research.

Conditions of Approval

This approval has been granted subject to you complying with the requirements for *Monitoring of Progress*, *Reporting of Adverse Events*, and *Variations to the Approved Protocol* as detailed below.

PLEASE NOTE:
In the case where the HREC has "noted" the approval of an External HREC, progress reports and reports of adverse events are to be submitted to the External HREC only. In the case of Variations to the approved protocol, or a Renewal of approval, you will apply to the External HREC for approval in the first instance and then Register that approval with the University's HREC.

- ***Monitoring of Progress***

Other than above, the University is obliged to monitor the progress of research projects involving human participants to ensure that they are conducted according to the protocol as approved by the HREC. A progress report is required on an annual basis. Continuation of your HREC approval for this project is conditional upon receipt, and satisfactory assessment, of annual progress reports. You will be advised when a report is due.

- ***Reporting of Adverse Events***

1. It is the responsibility of the person **first named on this Approval Advice** to report adverse events.
2. Adverse events, however minor, must be recorded by the investigator as observed by the investigator or as volunteered by a participant in the research. Full details are to be documented, whether or not the investigator, or his/her deputies, consider the event to be related to the research substance or procedure.
3. Serious or unforeseen adverse events that occur during the research or within six (6) months of completion of the research, must be reported by the person first named on the Approval Advice to the (HREC) by way of the Adverse Event Report form (via RIMS at https://rims.newcastle.edu.au/login.asp) within 72 hours of the occurrence of the event or the investigator receiving advice of the event.
4. Serious adverse events are defined as:
    - Causing death, life threatening or serious disability.
    - Causing or prolonging hospitalisation.
    - Overdoses, cancers, congenital abnormalities, tissue damage, whether or not they are judged to be caused by the investigational agent or procedure.
    - Causing psycho-social and/or financial harm. This covers everything from perceived invasion of privacy, breach of confidentiality, or the diminution of social reputation, to the creation of psychological fears and trauma.
    - Any other event which might affect the continued ethical acceptability of the project.
5. Reports of adverse events must include:
    - Participant's study identification number;
    - date of birth;
    - date of entry into the study;
    - treatment arm (if applicable);
    - date of event;
    - details of event;
    - the investigator's opinion as to whether the event is related to the research procedures; and
    - action taken in response to the event.
6. Adverse events which do not fall within the definition of serious or unexpected, including those reported from other sites involved in the research, are to be reported in detail at the time of the annual progress report to the HREC.

- ***Variations to approved protocol***

If you wish to change, or deviate from, the approved protocol, you will need to submit an *Application for Variation to Approved Human Research* (via RIMS at https://rims.newcastle.edu.au/login.asp). Variations may include, but are not limited to, changes or additions to investigators, study design, study population, number of participants, methods of recruitment, or participant information/consent documentation. **Variations must be approved by the (HREC) before they are implemented** except when Registering an approval of a variation from an external HREC which has been designated the lead HREC, in which case you may proceed as soon as you receive an acknowledgement of your Registration.

Linkage of ethics approval to a new Grant

HREC approvals cannot be assigned to a new grant or award (ie those that were not identified on the application for ethics approval) without confirmation of the approval from the Human Research Ethics Officer on behalf of the HREC.

Best wishes for a successful project.

Associate Professor Helen Warren-Forward
Chair, Human Research Ethics Committee

For communications and enquiries:
Human Research Ethics Administration

Research & Innovation Services
Research Integrity Unit
The University of Newcastle
Callaghan NSW 2308
T +61 2 492 17894
Human-Ethics@newcastle.edu.au

RIMS website - https://RIMS.newcastle.edu.au/login.asp

Linked University of Newcastle administered funding:

Funding body	Funding project title	First named investigator	Grant Ref

Appendix 4: Questionnaire (English)

Questionnaire

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Questionnaire for the study on: Effect of dietary patterns on maternal morbidity (hypertensive disorder of pregnancy and anemia)

Instruction: This data collection questionnaire is intended to assess the effect of dietary patterns on maternal health in selected health facilities in North Shewa, Ethiopia. This questionnaire/format has to be filed with face to face interview and reviewing the antenatal care logbook. Please circle the choice number that contains the answers provided by the participant. Moreover, write the appropriate answer in the space provided for some questions that request numerical values.

Hhealth facility code: ____________________ Questionnaire ID No.:___________________

Date of interview: _______/________/______ Participant card No. : ___________________

Section 1: Socio-demographic characteristics

NO.	Questions	Coding categories	Skip
101	How old are you?	____________ (years)	
102	What is your ethnicity?	1. Amhara 2. Gurage 3. Oromo 4. Tigray 5. Other (specify) ___________________	
103	What is your religion?	1. Orthodox 2. Muslim 3. Protestant 4. Other (specify) ____________________	
104	What is the highest level of school you completed?	1. No education 2. Primary 3. Secondary 4. Tertiary 5. Other ____________________	
105	What is your occupation?	1. Farmer 2. Merchant 3. Governmental employee	

1

		4. Non-governmental employee 5. House wife 6. Day laborer 7. Other (specify)_________________	
106	What is your marital status?	1. Single 2. Married 3. Divorced 4. Widowed	
107	Where is your place of residence?	1. Urban 2. Rural	
108	What is the main sources of water for your household?	1. Public tap 2. Pipe water at home 3. Protected spring 4. Well water 5. Unprotected spring 6. River 7. Other source (specify)_________________	
109	Toilet facility available in household?	1. No facility/bush/field 2. Pit latrine without slab/open pit 3. Pit latrine with slab 4. Ventilated improved pit latrine (VIPL) 5. Flush or pour flush toilet	
110	Approximate total monthly family income	_________Eth. Birr No income …….1 Don't know ……88 Prefer not to say……99	

Section 2: Maternal and Family Characteristics

NO.	Questions	Coding categories	Skip
201	Is this your first pregnancy?	1. Yes 2. No	If answer is 1 (Yes) go to

			Q209; If answer is 2 (No) go to Q202
202	If 'No', number of pregnancies so far? (including current pregnancy)		
203	Number of live births		
204	Number of abortions (induced or spontaneous abortions) (if any)		
205	Number of stillbirths (if any)		
206	What is the birth date of your youngest child? (dd/mm/yy) (Ethiopian Calender)	___________________	
207	Did you experience hypertension in any of your previous pregnancies?	1. Yes 2. No	
208	Did you experience diabetes mellitus in any of your previous pregnancies?	1. Yes 2. No	
209	Are there any members of your family (parents or siblings) who have hypertension?	1. Yes 2. No	
210	Are there any members of your family (parents or siblings) who have diabetes mellitus?	1. Yes 2. No	
211	Have you been diagnosed with hypertension outside of pregnancy?	1. Yes 2. No	
212	Have you been diagnosed with diabetes?	1. Yes 2. No	
213	Have you ever had antenatal care visits other than today for this pregnancy?	1. Yes 2. No	If answer is 2 (No) go to Q215
214	If 'yes' for Q213, how many times have you visited antenatal care?		
215	Did you experience any nausea and/or vomiting in this pregnancy?	1. Both nausea and vomiting 2. Nausea	

		3. Vomiting 4. No	
216	Do you smoke during this pregnancy?	1. Yes 2. No	
217	Do you consume alcohol during this pregnancy?	1. Yes 2. No	

Section 3: Maternal feeding habit/practices

NO.	Questions	Coding categories	Skip
301	How many times did you usually eat each day before this pregnancy?	1. Once 2. Twice 3. Three times 4. Four times 5. Five or more times	
302	Have you changed your food intake after becoming pregnant?	1. No change 2. Increased size of meals per day 3. Decreased size of meals per day 4. Increased number of meals per day 5. Decreased number of meals per day	More than one answer is possible
303	Have you changed your snack intake since becoming pregnant?	1. No change 2. Increased size of snacks per day 3. Decreased size of snacks per day 4. Increased number of snacks per day 5. Decreased number of snacks per day	More than one answer is possible

4

304	Have you avoided eating any food item after you became pregnant? (during current pregnancy)	1. Yes 2. No	If answer is 2 go to Q306
305	If "Yes" to Q304, which food item did you avoid most?	1. Egg 2. Vegetables 3. Milk and milk products 4. Cereal products 5. Legumes/pulse 6. Fruits 7. Meat 8. Other specify_______	
306	Have you started eating additional food types during this pregnancy?	1. Yes 2. No	If answer is 2 go to Q308
307	If "Yes" to Q306, what food groups/types?	1. Egg 2. Vegetables 3. Milk and milk products 4. Cereal products 5. Legumes/pulse 6. Fruits 7. Meat 8. Other specify_______	
308	What is your most typical meal pattern in a day in this pregnancy?	1. Lunch- dinner 2. Breakfast- lunch- dinner 3. Breakfast-snack - lunch-dinner 4. Breakfast- lunch-snack-dinner 5. Breakfast-snack-lunch-snack- dinner 6. Breakfast-snack- lunch-snack- dinner- snack 7. Other (specify) _________	

5

309	Do you fast while you are pregnant?	1. Yes 2. No	
310	Is there any food or any other item that you crave (i.e. strong desire for) to eat in this pregnancy?	1. Yes 2. No	If answer is 2 go to Q312
311	If 'Yes' to Q310, what do you crave for? (Probe for pica practice- ask food items that they strongly desire to eat)	1. Sweets 2. Fruits 3. Milk 4. Meat 5. Kale or other vegetables 6. Fruits 7. Other specify______________	
312	Are you taking any supplements?	1. No 2. IRON/FOLATE 3. Multivitamins 4. Multiple Micronutrients 5. Other specify _________	If answer is 1 go to Q314
313	If 'answer 2, 3, 4, 5' to Q312, how frequently are you taking it?	1. Daily 2. Weekly 3. Occasionally 4. Other specify	
314	Did you take (or are you currently taking) anti-helminthic drugs /deworming during this pregnancy?	1. Yes 2. No	

Section 4: Maternal dietary intake (24-hour recall).

Instructions: Please describe the foods (meals and snacks) that you ate or drank yesterday during the day and night, whether at home or outside the home. Please include all foods and drinks, any snacks or small meals, as well as any main meals. Remember to include all foods you may have eaten while preparing meals or preparing food for others. Start with the first food or drink of the morning. Write down all foods and drinks mentioned. When composite dishes are mentioned, ask for the list of ingredients. When the respondent has finished, probe for meals and snacks not mentioned. Categorize these meals under Breakfast, Snack, Lunch, Snack, Dinner and Snack.

Breakfast	*Snack*	*Lunch*	*Snack*	*Dinner*	*Snack*

Then you will need to use these questions to be able to categorize the reported food into the categories i.e. when the respondent recall is complete, fill in the food groups (501 – 518) based on the information recorded above. For any food groups not mentioned, ask the respondent if a food item from this group was consumed.

NO.	Food groups	Examples	Yes = 1 No = 0
401	Cereals/grains	teff, wheat, barley, corn/maize, millet, rice, sorghum, oats or any other grains or foods made from these (e.g. 'injera', bread, noodles, porridge, pasta, macaroni, 'firfir' or other grain products)	
402	Vitamin A rich vegetables and roots	pumpkin, carrots, beetroot, sweet potatoes that are orange inside + other locally available vitamin A rich vegetables (e.g. red sweet pepper)	
403	White roots and tubers	white potatoes, white yams, white cassava, or other foods made from roots	
404	Dark green leafy vegetables	dark green/leafy vegetables, including wild ones + locally available vitamin A rich leaves such as amaranth, cassava leaves, kale, spinach, chard etc	

7

405	Other vegetables	other vegetables (e.g. tomato, onion, garlic, cabbage, carrot), including wild vegetables	
406	Vitamin A rich fruits	ripe mangoes, cantaloupe, apricots (fresh or dried), ripe papaya, dried peaches + other locally available vitamin A rich fruits	
407	Other fruits	other fruits, including wild fruits, apple, avocado, banana, grapefruit, grape, lemon, pineapple, strawberry, watermelon	
408	Organ meat	liver, kidney, heart or other organ meats or blood-based foods	
409	Meat and poultry	beef, lamb, goat, chicken	
410	Eggs	chicken, duck, guinea fowl or any other egg	
411	Fish and sea food	fresh or dried fish or shellfish/sea foods	
412	Legumes/pulses	beans, peas, lentils, chickpea (garbanzo), pigeon pea, cowpea, and soybean/soybean or foods made from these products or other legume products like 'wat'	
413	Nuts and seeds	Sesame seed, sunflower seed, or nut/seed "butters", such as pounded groundnut/peanut butter, cashew butter or sesame butter	
414	Milk and milk products	milk, cheese, yogurt or other milk products	
415	Oils and fats	palm oil, oil, fats or butter added to food or used for cooking, vegetable/nut oils	
416	Sweets	sugar, honey, sweetened soda, sweetened juice or sugary foods such as chocolates, candies, cookies and cakes; Biscuits (sweet) or cookies	
417	Spices, condiments, beverages	spices (black pepper, ginger, chilies, salt), condiments (soy sauce, hot sauce), tomato past	
418	Other beverages and foods	alcohol, coffee, tea, alcoholic beverages or local examples ('Tela', Areke', 'Tej')	
419	Did you eat anything (meal or snack) outside the home yesterday?		

Section 5: Anthropometry and laboratory measures (to be filled from antenatal care logbook)

NO.	Variables	Value	Date measure taken
501	Gestational age for current pregnancy (weeks)		
502	Weight (kg)		
503	Height (cm)		
504	Mid-arm muscle circumference (cm)		
505	Systolic blood pressure (mmHg)		
506	Diastolic blood pressure (mmHg)		
507	Hemoglobin value (g/dl)		
508	Urine protein level (dipstick)		
509	Stool examination results	1.Not result/not done 2.Normal 3.Hookworms 4.Ascaris lumbricoids 5.Taenia species 6.Entamoeba histolytica 7.Giardia lamblia 8.Other specify ___________	

Thank you very much!!

Appendix 5: Questionnaire (Amharic)

መጠይቅ

የጥናቱ ርዕስ:- የእናቶች የአመጋገብ ስርዓት በእናቶች ጤና (የደም ግፊት እና የደም ማነስ) ላይ ያለው ተጽዕኖ

መግቢያ: ይህ የመረጃ መሰብሰቢያ መጠይቅ በሰሜን ሸዋ ዞን፣ ኢትዮጵያ በተመረጡ የጤና ተቋማት ውስጥ የእናቶች አመጋገብ ሁኔታ በጤናቸው ላይ የሚያሳድረውን ተጽእኖ ለመገምገም የታሰበ ነው። ይህ መጠይቅ የሚሞላው ቃለ ምልልስ በማድረግ እና የቅድመ ወሊድ ክትትል መዝገብን በመጠቀም ነው ። እባክዎ ተሳታፊዋ የሰጡትን መልስ **ቁጥር ይክበቡ**። በተጨማሪም፣ አሃዛዊ መረጃን ለሚጠይቁ ጥቂት ጥያቄዎች በተቀመጠው ቦታ ላይ ተገቢውን መልስ **በ ቁጥር ይጻፉ።**

የጤና ተቋሙ ኮድ: ____________________ የመጠይቁ መለያ ቁጥር:_______________

መጠይቁ የተደረገበት ቀን: _____/______/____ የተሳታፊዋ መለያ ቁጥር__________________

ክፍል 1: ማህበራዊ ና ግላዊ መረጃ

ተ/ቁ	ጥያቄ	ምድብ/አማራጭ	እለፍ
101	እድሜዎ ስንት ነው?	____________ (ዓመት)	
102	ብሄርዎ ምንድ ነው?	1. አማራ 2. ጉራጌ 3. ኦሮሞ 4. ትግሬ 5. ሌላ (ይጠቀስ) __________________	
103	ሃይማኖትዎ ምንድነው?	1. ኦርቶዶክስ ተዋህዶ 2. ሙስሊም 3. ፕሮቴስታንት 4. ሌላ (ይጠቀስ) _______________	
104	እርስዎ ያጠናቀቁት ከፍተኛ የትምህርት ደረጃ ስንት ነው?	1. ያልተማረ 2. አንደኛ ደረጃ 3. ሁለተኛ ደረጃ 4. ሶስተኛ ደረጃ 5. ሌላ (ይጠቀስ) ________________	
105	ስራዎ ምንድነው?	1. ገበሬ 2. ነጋዴ 3. የመንግስት ሰራተኛ 4. መንግስታዊ ያልሆነ ድርጅት ሰራተኛ 5. የቤት እመቤት 6. የቀን ሰራተኛ 7. ሌላ (ይጠቀስ)_______________	
106	የጋብቻ ሁኔታዎ ምንድነው?	1. ያላገባች 2. ያገባች 3. የፈታች 4. የሞተባት	
107	የመኖሪያ ቦታ የት ነው?	1. ከተማ 2. ገጠር	

1

108	ለቤተሰብዎ ዋናው የውሃ ምንጭ ምንድነው?	1. የህዝብ ቧንቧ/በኖ 2. ቧንቧ በግቢ ውስጥ 3. የተጠበቀ ምንጭ ውኃ 4. የጉድጓድ ውኃ 5. ያልተጠበቀ የምንጭ ውኃ 6. የወንዝ ውኃ 7. ሌላ (ይጠቀስ) _______________	
109	የመፀዳጃ ቤት አገልግሎት ለቤትሰቡ አለ?	1. ሽንት ቤት የለም/በመስክ ላይ 2. ክዳን የሌለው ጉድጓድ ሽንትቤት /ክፍት ጉድጓድ 3. ክዳን ያለው ጉድጓድ ሽንትቤት 4. የተሻሻለ ጉድጓድ መፀዳጃ ቤት 5. በዉሃ የሚታጠብ/የሚደፋበት መጸዳጃ ቤት	
110	በግምት አጠቃላይ ወርሃዊ የቤተሰብ ገቢ ስንት ነው?	________ ብር ገቢ የለግኝም ....1 አላውቀውም ......88 መልስ አለመስጠት እመርጣለሁ......99	

ክፍል 2: የእናቶች እና የቤተሰብ መረጃ

ተ/ቁ	ጥያቄዎች	ምድብ/አማራጭ	እለፍ
201	ይህ የመጀመሪያ እርግዝናዎት ነው?	1. አዎ 2. አይደለም	መልሱ "አዎ" ከሆነ ወደ 209 ይለፉ
202	ለ 201 መልስዎ 'አይደለም' ከሆነ ስንት ጊዜ አርግዘዋል ? (የአሁኑን ጨምሮ)	__________ጊዜ	
203	በሂዎት የተወለዱ ልጆች ብዛት		
204	ፅንስ የተቋረጠ ብዛት (ካለ)		
205	ሞቶ የተዎለደ ጽንስ ብዛት (ካለ)		
206	በዕድሜ ትንሹ ልጅዎን የወለዱበት ቀን መቼ ነው? (ቀን / ወር / ዓመት) (በኢትዮጵያ ቀን አቆጣጠር)	________/________/________	

2

207	በቀድሞ እግርዝናዎ ጊዜ የደም ግፊት አጋጥሞዎት ነበር?	1. አዎ 2. የለም	
208	በቀድሞ እግርዝናዎ የስኳር በሽታ አጋጥምዎት ነበር?	1. አዎ 2. የለም	
209	የደም ግፊት ያለባቸው የቤተሰብዎ አባላት (ወላጆች ወይም እህትማማቾችና ወንድማማቾች) አሉ?	1. አዎ 2. የለም	
210	የስኳር በሽታ ያለባቸው የቤተሰብዎ አባላት (ወላጆች ወይም እህትማማቾችና ወንድማማቾች) አሉ?	1. አዎ 2.የለም	
211	ከእርግዝና ውጪ በህክምና የተረጋገጠ የደም ግፊት በሽታ አለብዎት?	1. አዎ 2. የለም	
212	የተረጋገጠ የስኳር በሽታ አለብዎት?	1. አዎ 2. የለም	
213	ለዚህ እርግዝና ከዛሬ ውጪ ሌላም የወሊድ ክትትል አለዎት?	1. አዎ 2. የለም	መልሱ 2 ከሆነ ወደ 215 እለፍ
214	ለ 213 መልሱ ‘አዎ’ ከሆነ ስንት ጊዜ የዎሊድ ክትትል አድርገዋል? *(ያሁኑን ሳይጨምር)*		
215	በዚህ እርግዝናዎ ማቅለሽለሽ ወይም ማስመለስ አጋጥሞት ነበር?	1. ማቅለሽለሽ እና ማስመለስ 2. ማቅለሽለሽ 3. ማስመለስ 4. የለም	
216	በዚህ እርግዝና ወቅት ሲጃራ ያጨሳሉ?	1. አዎ 2. የለም	
217	በዚህ እርግዝና ወቅት አልኮል ይጠጣሉ ?	1. አዎ 2. የለም	

ክፍል 3: የእናቶች የአመጋገብ ልማድ ወይም ዘይቤ

ተ/ቁ	ጥያቄ	ምርጫ	እለፍ/ዝለል
301	ከዚህ እርግዝና በፊት በየቀኑ ስንት ጊዜ ይመገቡ ነበር?	1. አንድ ጊዜ 2. ሁለት ጊዜ 3. ሶስት ጊዜ 4. አራት ጊዜ 5. አምስት ና ከዚያ በላይ	
302	ከእርግዝና በኋላ አመጋገብዎትን ለውጠዋል?	1. አለወጥኩም 2. በቀን የምግብ መጠን ጨምሪያለሁ 3. በቀን የምግብ መጠን ቀንሼአለሁ 4. በቀን የምግብ ቁጥር ጨምሪያለሁ 5. በቀን የምግብ ቁጥር ቀንሼአለሁ	ከአንድ በላይ መልስ ይቻላል

303	ከእርግዝናዎ በኋላ የመቅሰስ አመጋገብዎን ለውጠዋል?	1. አለወጥኩም 2. በቀን የመቅሰስ መጠን ጨምሬአለሁ 3. በቀን የመቅሰስ መጠን ቀንሼአለሁ 4. በቀን መቅሰስ ቁጥር ጨምሬአለሁ 5. በቀን የመቅሰስ ቁጥር ቀንሼአለሁ	ከአንድ በላይ መልስ ይቻላል
304	በዚህ እርግዝናዎ መመገብ ያቆሙት የምግብ ዓይነት አለ?	1. አዎ 2. የለም	መልሱ 2 ከሆነ ወደ 306 ሂድ
305	ለ ጥያቄ 304 መልሱ አዎ ከሆነ፣ የትኛውን የምግብ አይነት መመገብ አቁመዋል?	1. እንቁላል 2. አትክልቶች 3. ወተትና የወተት ተዋጽኦ 4. ሰብል ምርቶች 5. ጥራጥሬዎች 6. ፍራፍሬዎች 7. ስጋ 8. ሌላ ካለ ይጠቀስ________	
306	በዚህ እርግዝና ወቅት ተጨማሪ የምግብ ዓይነቶችን መመገብ ጀምረዋልን?	1. አዎ 2. የለም	መልሱ 2 ከሆነ ወደ 308 ሂድ
307	ለ ጥያቄ 306 መልሱ አዎ ከሆነ፣ የትኛውን የምግብ አይነት መመገብ ጀምረዋል?	1. እንቁላል 2. አትክልቶች 3. ወተትና የወተት ተዋጽኦ 4. ሰብል ምርቶች 5. ጥራጥሬዎች 6. ፍራፍሬዎች 7. ስጋ 8. ሌላ ካለ ጥቀስ________	
308	በዚህ እርግዝናዎ ወቅት በቀን ውስጥ በጣም የተለመደዉ የአመጋገብዎ ሁኔታ/ስርዓት እንዴት ነው?	1. ምሳ-እራት 2. ቁርስ- ምሳ-እራት 3. ቁርስ- መቅሰስ-ምሳ-እራት 4. ቁርስ-ምሳ-መቅሰስ-እራት 5. ቁርስ-መቅሰስ-ምሳ-መክሰስ- እራት 6. ቁርስ-መቅሰስ-ምሳ-መክሰስ- እራት-መቅሰስ 7. ሌላ ካለ ይጠቀስ _________	
309	በዚህ ነፍሰጡር ጊዜዎ ጾም ይጾማሉ?	1. አዎ 2. የለም	

4

310	በዚህ እርግዝናዎ ለመመገብ በጣም የሚፈልጓቸው ምግቦች ወይም ሌሎች ነገሮች አሉ (ማለትም ለመመገብ በጣም የሚሹት)?	1. አዎ 2. የለም	መልሱ 2 ከሆ ወደ ጥያቄ 312 ሂድ/ጂ
311	ለጥያቄ 310 መልሱ 'አዎን' ከሆነ ምን ምን ነገሮችን ይሻሉ? (በደንብ ጠይቋቸው- ለመመገብ በጣም የሚፈልጉት ምግብ ሊጠይቁ ይችላሉ)	1. ጣፋጭ ነገሮች 2. ፍራፍሬዎች 3. ወተት 4. ስጋ 5. አትክልቶች 6. ሌላ ካለ ይጠቀስ ___________	
312	ተጨማሪ ማሟያዎችን (supplements) እየወሰዱ ነው?	1. አልዎስድም 2. አይረን/ፎሌት 3. ብዙ ቪታሚኖች 4. ብዙ ጥቃቅን ንጥረነገሮች 5. ሌላ ካለ ይጠቀስ ___________	መልሱ 1 ከሆ ወደ 314 ይለፉ
313	ለጥያቄ 312 መልሱ "2፣ 3፣4፣ 5" ከሆነ ምን ያህል ጊዜ ነው የሚወስዱት?	1. በየቀኑ 2. በየሳምንቱ 3. አልፎአልፎ 4. ሌላ ካለ ይጠቀስ ___________	
314	በዚህ እርግዝና ወቅት (ወይም በአሁኑ ጊዜ ፀረ-ትላትል መድሐኒቶች እየወሰዱ ነው)?	1. አዎ 2. የለም	

ክፍል 4: የእናቶች አመጋገብ (የ24 ሰዓት ትውስታ)

ማስታዎሻ: እባክዎትን በትላንትናው እለት ቀንና ማታ በቤት ውስጥ ወይም ከቤት ውጭ የተመገቡትን ወይም የጠጡትን (ምግቦች እና መክሰስ) ይግለጹ። እባክዎን ሁሉንም ምግቦች እና መጠጦች፣ ማንኛውንም መክሰስ ወይም አነስተኛ ምግብ እንዲሁም ማንኛውም ዋና ምግቦችን ያካትቱ። ምግብ ለማዘጋጀት ወይም ለሌሎች ምግብ በማዘጋጀት ወቅት ሊበሉ የሚችሉ ምግቦችን ሁሉ ማካተት አይዘንጉ። ከጧቱ ምግብ ወይም መጠጥ ይጀምሩ። የተጠቀሱትን ምግቦች እና መጠጦች በሙሉ ይፃፉ። የተደባለቁ ምግቦች ሲጠቀሱ ፥ የተደባለቀውን ዝርዝር ይጠይቁ። ምላሽ ሰጭዋ ሲያጠናቅቁ ያልተጠቀሱትን ምግቦች እና መክሰስ ይጠቁሙ። እነዚህን ምግቦች በቁርስ፣ መቅሰስ፣ በምሳ፣ መቅሰስ ፣ እራት፣ እና መቅሰስ ዉስጥ ይመደቡ።

ቁርስ	መቅሰስ	ምሳ	መቅሰስ	እራት	መቅሰስ

ከዚያም እነዚህን ጥያቄዎች በመጠቀም ሪፖርት የተደረጉትን ምግቦች በየምድቦች መጥቀስ ያስፈልጋል፥ ማለትም ምላሽ ሰጪዋ እንዳጠናቀቁ፣ ከላይ የተጠቀሰውን መረጃ በመጠቀም የምግብ ዓይነቶችን (401- 419) መሙላት ።

ተ/ቁ	የምግብ ምድቦች	ዝርዝር ምሳሌ	አዎ = 1 የለም=0
401	ሰብሎች/ እህሎች	ጤፍ፣ ስንዴ፣ ገብስ፣ በቆሎ፣ ሩዝ፣ ማሽላ፣ አጃ ወይም ከነዚህ እህሎች የተሰሩ ምግቦች (ለምሳሌ እንጀራ፣ ዳቦ፣ ቂጣ፣ ገንፎ፣ ፓስታ፣ መኮሮኒ፣ 'ፍርፍር' ወይም ሌሎች የእህል ውጤቶች)	
402	በቫይታሚን "ኤ" የበለጸጉ አትክልቶችና ስራስሮች	ዱባ፣ ብርቱካን፣ ቀይስር,፣ስኳር ድንች፣ ካሮት	
403	ነጭ ስራስሮች ና ግንዶች	ድንች፣ ወይም ከስራስሮች የተሠሩ ሌሎች ምግቦች	
404	ጥቁር አረንጓዴ ቅጠላማ አትክልቶች	ጎመን ፣ ሰማ፣ ጥቅል ጎመን፣ቆስጣ፣ሰላጣ	
405	ሌሎች አትክልቶች	ሌሎች አትክልቶች (ለምሳሌ ቲማቲም፣ ቀይ ሽንኩርት፣ ነጭ ሽንኩርት፣ አበሻ ጎመን፣ ካሮት)፣ የዱር አትክልቶችን ጨምሮ	
406	በ ቪታሚን "ኤ" የበለጸጉ ፍራፍሬዎች	የበሰለ ማንጎ፣ ፓፓያ፣ ኮክ እና ሌሎችም	
407	ሌሎች ፍራፍሬዎች	አፕል፣ አቮካዶ፣ ሙዝ፣ ወይን ፍሬ፣ ሎሚ ፣ አናናስ፣ እንጆሪ፣ ሃባብ፣ የዱር የሆኑ (ኮሽም፣ ቀጋ)	

6

408	ስጋ (የሰውነት ክፍል)	ጉበት፣ ኩላሊት፣ ልብ ፣ ደም ወይም ሌላ የሰውነት ክፍል	
409	ስጋ እና የስጋ ተዋጽኦ	የከብት ስጋ፣ በግ ስጋ፣ ፍየል ስጋ፣ ዶሮ ስጋ እና ከነዚህ የተሰሩ ምግቦች	
410	እንቁላል	የዶሮ እንቁላል፣ የዳክዬ እንቁላል፣ የቆቅ ና የጅግራ እንቁላል	
411	አሳ እና የባህር ምግቦች	ትኩስ ወይም ደረቅ ዓሳ ወይም የባህር ምግቦች	
412	ጥራጥሬዎች	ባቄላ፣ አተር፣ ምስር፣ ሽምብራ፣ አኩሪ አተር፣ በለቄ፣ ወይም ከነዚህ የተሰሩ ምግቦች ምሳሌ “ ወጥ”	
413	ለውዝ ና ዘሮች	ኦቾሎኒ፣ የሰሊጥ ፣ የሱፍ፣ኑግ ዘር ወይም የኦቾሎኒ ቅቤ	
414	ወተት ና የወተት ተዋጽኦ	ወተት፣ አይብ፣ እርጎ፣ አሬራ ወይም ሌሎች የወተት ምርቶች	
415	ዘይት ና ቅባት	ዘይት፣ ቅባት ወይም ቅቤ ተጨምሮባቸው የተሰሩ ምግቦች	
416	ጣፋጮች	ስኳር፣ ማር፣ ጣፋጭ ሶዳ፣ ጣፋጭ ጭማቂ ወይም ጣፋጭ ምግቦች እንደ ቸኮሌት፣ ከረሜላ፣ ኩኪስ እና ኬኮች፣ ብስኩቶች	
417	ቅመሞች ና ማጣፈጫዎች	ቅመሞች (በርበሬ፣ ዝንጅብል፣ ሚጥሚጣ፣ጨው)፣ ቲማቲም ሱጎ	
418	ሌሎች መጠጦች እና ምግቦች	አልኮል፣ ቡና፣ ሻይ፣አካባቢያዊ አልኮል መጠጦች (ጠላ ፣አረቄ ፣ ጠጅ)	
419	ትላንትና ከቤት ውጭ ማንኛውንም ምግብ (ምግብ ወይም መክሰስ) ተመግበዋል?		

ክፍል 5: የአንትሮፖሜትሪ እና የላቦራቶሪ ልኬቶች (ከቅድመ ወሊድ እንክብካቤ መዝገብ የሚሞላ)

ተ/ቁ	የሚለካው / ጥያቄ	መጠን/ ልክ	የተለካበት ቀን
501	የወቅቱ የእርግዝና ዘመን (ሳምንታት)		
502	ክብደት (ኪ.ግ)		
503	ቁመት (ሴ/ሜ)		
504	የክንድ መሃል መጠነ ዙሪያ (MUAC) (ሴ/ሜ)		
505	የላይኛው/ኩምታሬ የደም ግፊት (ሚሜ ሜርኩሪ)		
506	የታቺኛው /ርጋቤ የደም ግፊት (ሚሜ ሜርኩሪ)		
507	የሄሞግሎቢን መጠን (Hgb) (ግ / ዲሊ)		
508	የሽንት ፕሮቲን መጠን (ዲፕስቲክ)		
509	የሰገራ ምርመራ ውጤት	1. ውጤት የለም 2.ንጹህ 3. መንጠቆ ትል 4. አስካሪስ 5. የኮሶ ትል 6. አሜባ 7. ጃያርዲያ 8.ሌላ ካለ ይጠቀስ ___________	

በጣም አመሰግናለሁ !!

7

Appendix 6: Ethics approval for primary data from the University of Newcastle Human Research Ethics Committee

- ***Reporting of Adverse Events***

1. It is the responsibility of the person **first named on the Certificate** to report adverse events.

2. Adverse events, however minor, must be recorded by the investigator as observed by the investigator or as volunteered by a participant in the research. Full details are to be documented, whether or not the investigator, or his/her deputies, consider the event to be related to the research substance or procedure.

3. Serious or unforeseen adverse events that occur during the research or within six (6) months of completion of the research, must be reported by the person first named on the Certificate to the (HREC) by way of the Adverse Event Report form within 72 hours of the occurrence of the event or the investigator receiving advice of the event.

4. Serious adverse events are defined as:
   - Causing death, life threatening or serious disability.
   - Causing or prolonging hospitalisation.
   - Overdoses, cancers, congenital abnormalities, tissue damage, whether or not they are judged to be caused by the investigational agent or procedure.
   - Causing psycho-social and/or financial harm. This covers everything from perceived invasion of privacy, breach of confidentiality, or the diminution of social reputation, to the creation of psychological fears and trauma.
   - Any other event which might affect the continued ethical acceptability of the project.

5. Reports of adverse events must include:
   - Participant's study identification number;
   - date of birth;
   - date of entry into the study;
   - treatment arm (if applicable);
   - date of event;
   - details of event;
   - the investigator's opinion as to whether the event is related to the research procedures; and
   - action taken in response to the event.

6. Adverse events which do not fall within the definition of serious, including those reported from other sites involved in the research, are to be reported in detail at the time of the annual progress report to the HREC.

- ***Variations to approved protocol***

If you wish to change, or deviate from, the approved protocol, you will need to submit an *Application for Variation to Approved Human Research*. Variations may include, but are not limited to, changes or additions to investigators, study design, study population, number of participants, methods of recruitment, or participant information/consent documentation. **Variations must be approved by the (HREC) before they are implemented** except when Registering an approval of a variation from an external HREC which has been designated the lead HREC, in which case you may proceed as soon as you receive an acknowledgement of your Registration.

Linkage of ethics approval to a new Grant

HREC approvals cannot be assigned to a new grant or award (ie those that were not identified on the application for ethics approval) without confirmation of the approval from the Human Research Ethics Officer on behalf of the HREC.

With best wishes for a successful project.

Associate Professor Helen Warren-Forward
Chair, Human Research Ethics Committee

For communications and enquiries:
Human Research Ethics Administration

Research & Innovation Services
Research Integrity Unit
The University of Newcastle
Callaghan NSW 2308
T +61 2 492 17894
Human-Ethics@newcastle.edu.au

RIMS website - https://RIMS.newcastle.edu.au/login.asp

Linked University of Newcastle administered funding:

Funding body	Funding project title	First named investigator	Grant Ref

Appendix 7: Ethics approval from Amhara Public Health Institute

በአማራ ብሔራዊ ክልላዊ መንግስት ጤና ጥበቃ ቢሮ
Amhara National Regional State Health Bureau
Amhara Public Health Institute
የአማራ ህብረተሰብ ጤና ኢንስቲትዩት
ባህር ዳር

ቁጥር የጤ/ም.ቴ.ሽ ዳ ....
Ref.noHRTT 03/163/2018
ቀን ....
Date 7/11/2018 G.C

Amhara Public Health Institute Research Ethics Review Committee Response Form

To- Kelemu Tilahun

Deberbrhan

Subject: Human Subject Ethical Clearance

You have submitted a Research proposal entitled with **The Effect of Dietary Patterns on Hypertensive Disorders of Pregnancy and Anemia in North Shewa, Ethiopia".** to Regional Health Bureau Review Board for Ethical approval. The Regional Health Bureau Research Ethics Review Committee /RERC/ has reviewed the submitted project proposal critically. We are writing to advise you that the RERC has granted **Full approval**.

The project indicated above for a period of **November 7/11/2018- March 29/03/2019**. All your more recently submitted documents have been approved for use in this study. The study should comply with the standard international and national scientific and ethical guideline. Any change to the approved protocol or consent material must be reviewed and approved through the amendment process prior to its implementation. In addition, any adverse or unanticipated events should be reported within 24-48 hours to RERC. Please insure that you submit progressive report prior the expiry date of project.

We, therefore, request your esteemed organization to ensure the commencement and conduct of the study accordingly and wish for the successful completion of the project.

Taye Zeru

Public Health Research and Technology Transfer D/Director

CC//

- APHI G/Director
- APHI D/Director

477 **Tell. 0582263223** **0582220191**

Appendix 8: Support letter from the Amhara Public Health Institute for Zonal Health office

በአማራ ብሔራዊ ክልላዊ መንግስት ጤና ጥበቃ ቢሮ
Amhara National Regional State Health Bureau
Amhara Public Health Institute
የአማራ ህብረተሰብ ጤና ኢንስቲትዩት
ባህር ዳር

Ref No ....
Date ....
ቁጥር የጤ/ም/ቴ/ሽ/ዳ /03/164/2011
ቀን 27/02/2011 ዓ/ም

ለሰሜን ሸዋ ዞን ጤና መምሪያ

ደብረብርሃን

ጉዳዩ፡- ትብብር ስለመጠየቅ

ቀለሙ ጥላሁን በኒውካስትል ዩኒቨርሲቲ በህብረተሰብ ጤና አጠባበቅ ትምህርት ቤት የሶስተኛ ድግሪ ተማሪ ሲሆን "The Effect of Dietary Patterns on Hypertensive Disorders of Pregnancy and Anemia in North Shewa, Ethiopia." በሚል ርዕስ ጥናታዊ ጹሁፍ እንዲሰሩ ኘሮፖዛላቸው በአማራ ህብረተሰብ ጤና ኢንስቲትዩት ኢቲካል ሪቪው ቦርድ ተገምግሞ ተቀባይነት ያገኘ በመሆኑ በመ/ቤታችሁ በኩል አስፈላጊው የስራ ትብብር እንዲደረግለት እያሳወቅን፤ ጥናቱን የሚያካሄደው አካልም ጥናቱን ሲያጠናቅቅ ውጤቱ ጥናቱ ለተካሄደበት ማህበረሰብ ጥቅም ላይ መዋሉን ለመከታተል ያመች ዘንድ ቅጅ ለአማራ ህብረተሰብ ጤና ኢንስቲትዩት የምርምርና ቴክኖሎጅ ሽግግር ዳይሬክቶሬት እንዲያቀርብ እናሳውቃለን።

ከሠላምታ ጋር

ታየ ዘሩ

ህብረተሰብ ጤና ምርምርና ቴክኖሎጂ ሽግግር ዳይሬክቶሬት ዳይሬክተር

Amhara Public Health Institute

ግልባጭ፡

- ✓ ለአማራ ህብረተሰብ ጤና ኢንስቲትዩት ዋና ዳይሬክተር
- ✓ ለምክትል ዋ/ዳይሬክተር
- ✓ ለቀለሙ ጥላሁን
  ባሉበት

✉ 477 Tell. 0582263223 Fax. 0582266701 ፡ 0582263223
0582220191

Appendix 9: Letters for district health offices from the zonal health office

አማራ ብሔራዊ ክልላዊ መንግስት የጤና ቢሮ

የሰሜን ሸዋ ዞን ጤና መምሪያ

Amhara National Regional State Health Buearu

North shoa health Department

✉ 146 ☎(011)- 681 3450/3893/3354 Fax6813936 6813044 /6812956

E-mailnsahealth@yahoo.com

ቁጥር ሰሸጤመ 32/144/11

ቀን 04/03/11

ለ __________ ወ/ጤና ጥበቃ ጽ/ቤት

__________ ፣

ጉዳዩ፡- <u>ትብብር እንዲደረግላቸው ስለመጠየቅ</u>፣

ቀለሙ ጥላሁን በኒውካስትል ዩኒቨርሲቲ በህብረተሰብ ጤና አጠባበቅ ትምህርት ቤት የሶስተኛ ዲግሪ ተማሪ ሲሆን "The Effect of Dietary Patterns on Hypertensive Discorders of Pregnancy and Anemia in North Shewa, Ethiopia." በሚል ርዕስ ጥናታዊ ፅሁፍ እንዲሰሩ ፕሮፖዛላቸው በአማራ ህብረተሰብ ጤና ኢንስቲትዩት ኢቲካል ሪቪው ቦርድ ተገምግሞ ተቀባይነት ያገኘ በመሆኑ በዞናችው በኩል አስፈላጊው የስራ ትብብር እንዲደረግላቸው በማለት በአብክመ ጤና ጥበቃ ቢሮ የአማራ ህብረተሰብ ጤና ኢንስቲትዩት በቁጥር የጤ/ም/ቴ/ሽ/ዳ/03/164/2011 በቀን 27/02/11 ዓ.ም በተፃፈ ደብዳቤ አሳውቆናል፡፡

ስለሆነም በእናንተ ወረዳ ጥናቱን ለሚያካሂዱት ባለሙያ አስፈላጊውን ሁሉ ትብብር እንድታደርጉላቸው እየጠየቅን ለሚደረግላቸው ትብብር በቅድሚያ እናመሰግናለን፡፡

ከመታከም መከላከል ይቅደም

የሰ/ሸ/ዞ/ጤ/መምሪያ ም/ኃላፊ

አማራ ብሔራዊ ክልላዊ መንግስት የጤና ቢሮ
የሰሜን ሸዋ ዞን ጤና መምሪያ
Amhara National Regional State Health Buearu
North shoa health Department
✉ 146 ☎ (011)- 681 3450/3893/3354 Fax6813936 6813044 /6812956
E-mailnsahealth@yahoo.com

ቁጥር ሰሸጤመ 32/144/11

ቀን 04/03/11

ለ እንሳሮ ላሎ ማሆ ወ/ጤና ጥበቃ ጽ/ቤት

መሀል ሜዳ ፤

ጉዳዩ፡- ትብብር እንዲደረግላቸው ስለመጠየቅ፣

ቀለሙ ጥላሁን በኒውካስትል ዩኒቨርሲቲ በህብረተሰብ ጤና አጠባበቅ ትምህርት ቤት የሶስተኛ ዲግሪ ተማሪ ሲሆን "The Effect of Dietary Patterns on Hypertensive Discorders of Pregnancy and Anemia in North Shewa, Ethiopia." በሚል ርዕስ ጥናታዊ ፅሁፍ እንዲሰሩ ፕሮፖዛላቸው በአማራ ህብረተሰብ ጤና ኢንስቲትዩት ኢቲካል ሪቪው ቦርድ ተገምግሞ ተቀባይነት ያገኘ በመሆኑ በሀናችው በኩል አስፈላጊው የስራ ትብብር እንዲደረግላቸው በማለት በአብክመ ጤና ጥበቃ ቢሮ የአማራ ህብረተሰብ ጤና ኢ.ንስቲትዩት በቁጥር የጤ/ም/ቴ/ሽ/ዳ/03/164/2011 በቀን 27/02/11 ዓ.ም በተፃፈ ደብዳቤ አሳውቆናል፡፡

ስለሆነም በእናንተ ወረዳ ጥናቱን ለሚያካሂዱት ባለሙያ አስፈላጊውን ሁሉ ትብብር እንድታደርጉላቸው እየጠየቅን ለሚደረግላቸው ትብብር በቅድሚያ እናመሰግናለን፡፡

ከመታከም መከላከል ይቅደም

የሰ/ሸ/ዞ/ጤ/መምሪያ
ም/ኃላፊ

Appendix 10: Letters from district health offices to health facilities

ቁጥር ደ/ብ/ከ/ስ/ጤ/ጥ/596/2011
ቀን 5/3/2011

በአማራ ብሔራዊ ክልላዊ መንግሥት ጤና ጥበቃ ቢሮ የደ/ብርሃን ከተማ ወረዳ ጤና ጥበቃ ጽ/ቤት
In the Amhara N.R.S. Health Bureau Debre Berhan Town Wereda Health Office

ለደ/ብርሃን ጤና ጣቢያ
ለጠባሴ ጤና ጣቢያ
ለአየር ጤና ጤና ጣቢያ
ደ/ብርሃን፣

ጉዳዩ:- **ትብብር እንዲደረግላቸው ስለመጠየቅ፣**

ከላይ በርእሱ ለመጥቀስ እንደተሞከረው **ቀለሙ ጥላሁን** በኒውካስትል ዩኒቨርሲቲ በህብረተሰብ ጤና አጠባበቅ ትምህርት ቤት የሶስተኛ ዲግሪ ተማሪ ሲሆን " The Effect of Dietary Pattems on Hypertensive discorders of Pregnancy and Anemia in North Shewa, Ethiopia" በሚል ርዕስ ጥናታዊ ፅሁፍ እንዲሰሩ ፕሮፖዛላቸው በአማራ ህብ/ጤ/ኢንስቲትዩት ኢቲካል ሪቪው ቦርድ ተገምግሞ ተቀባይነት ያገኘ በመሆኑ በዞናችሁ በኩል አስፈላጊውን የስራ ትብብር እንዲደረግላቸው በማለት በአብክመ ጤና ጥበቃ ቢሮ የአማራ ህብ/ጤ/ኢን/በቁጥር የጤ/ም/ቴ/ሽ/ዳ/03/164/2011 በቀን 27/2/2011ዓ.ም በተፃፈ ደብዳቤ አሳውቀናል።

ስለሆነም በእናንተ ወረዳ ጥናቱን ለሚያካሄዱት ባለሙያ አስፈላጊውን ሁሉ ትብብር እንድታደርጉላቸው እየጠየቅን ለሚደረግላቸው ትብብር በቅድሚያ እናመሰግናለን ሲሉ የሰ/ሸ/ዞ/ጤና መምሪያ በቁጥር ሰሸጤመ 32/144/11 በቀን 4/3/2011ዓ.ም በተፃፈ ደብዳቤ የገለፁልን ስለሆነ በእናንተ በኩል አስፈላጊው ትብብር እንድታደርጉላቸው የሳክናቸው መሆኑን እንገልፃለን።

" ጤና ለሁሉም "

የደ/ብርሃን ከተማ ወረዳ ጤና ጥበቃ ጽ/ቤት ኃላፊ
Head of Wereda Health Office

ቁጥር ደ/ብ/ከ/አሰ/ጤ/ጥ/596/2011
ቀን 5/3/2011

In the Amhara N.R.S. Health Bureau Debre Berhan Town Wereda Health Office

ለደ/ብርሃን ጤና ጣቢያ
ለጠባሴ ጤና ጣቢያ
ለአየር ጤና ጤና ጣቢያ
ደ/ብርሃን፣

ጉዳዩ፡- ትብብር እንዲደረግላቸው ስለመጠየቅ፣

ከላይ በርእሱ ለመጥቀስ እንደተሞከረው **ቀለሙ ጥላሁን** በኒውካስትል ዩኒቨርሲቲ በህብረተሰብ ጤና አጠባበቅ ትምህርት ቤት የሶስተኛ ዲግሪ ተማሪ ሲሆን “ The Effect of Dietary Pattems on Hypertensive discorders of Pregnancy and Anemia in North Shewa, Ethiopia” በሚል ርዕስ ጥናታዊ ፅሁፍ እንዲሰሩ ·ኘሮፖዛላቸው በአማራ ህብ/ጤ/ኢንስቲትዩት ኢቲካል ሪቪው ቦርድ ተገምግሞ ተቀባይነት ያገኘ በመሆኑ በዞናችሁ በኩል አስፈላጊውን የስራ ትብብር እንዲደረግላቸው በማለት በአብክመ ጤና ጥበቃ ቢሮ የአማራ ህብ/ጤ/ኢን/በቁጥር የጤ/ም/ቴ/ሽ/ዳ/03/164/2011 በቀን 27/2/2011ዓ.ም በተፃፈ ደብዳቤ አሳውቀናል::

ስለሆነም በእናንተ ወረዳ ጥናቱን ለሚያካሄዱት ባለሙያ አስፈላጊውን ሁሉ ትብብር እንድታደርጉላቸው እየጠየቅን ለሚደረግላቸው ትብብር በቅድሚያ እናመሰግናለን ሲሉ የሰ/ሸ/ዞ/ጤና መምሪያ በቁጥር ሰሸጤመ 32/144/11 በቀን 4/3/2011ዓ.ም በተፃፈ ደብዳቤ የገለፁልን ስለሆነ በእናንተ በኩል አስፈላጊው ትብብር እንድታደርጉላቸው የላክናቸው መሆኑን እንገልፃለን::

" ጤና ለሁሉም "

ANRS Health Bureau North Shewa Zone Health Department Debre Birhan City Administration Health Office

Head of Wereda Health Office

በአማራ ብሔራዊ ክልላዊ መንግስት ሰሜን ሸዋ ዞን
የባሶና ወራና ወረዳ ጤና ጥበቃ ጽ/ቤት
Amhara National Regional state North shoa
Bassona Worana health office

Ref.No/ባወወጤ/ 258 /1994/53
Date 29/ 4 /2011

ለ ቀይት ጤና ጣቢያ

ቀይት

ጉዳዩ፡- ትብብር እንዲደረግላቸው ስለመጠየቅ፣

ከላይ በርዕሱ እንደተጠቀሰው ቀለሙ ጥላሁን በኒውካስትል ዩኒቨርስቲ በህብረተሰብ ጤና አጠባበቅ ትምህርት ቤት የሶስተኛ ዲግሪ ተማሪ ሲሆኑ " The Effect of Dietary pattems on Hupertensive Discorders of pregnancy and Anemia in North shewa, Ethiopia" በሚል ርዕስ ጥናታዊ ፅሁፍ እንዲሰሩ ፕሮፖዛላቸው በአማራ ህብረተሰብ ጤና ኢንስቲትዩት ኢቲካል ሪቪው ቦርድ ተገምግሞ ተቀባይነት ያገኘ በመሆኑ በዞናችሁ በኩል አስፈላጊው የሥራ ትብብር እንዲደረግላቸው በማለት በአብክመጤና ጥበቃ ቢሮ የአማራ ህብረተሰብ ጤና ኢንስቲትዩት በቁጥር የጤ /መ /ቴ /ሽ /ዳ /03 /164 /2011 በቀን 27/2/11 ዓ.ም በተጻፈ ደብዳቤ አሳውቆናል ሲሉ የሰሜን ሸዋ ዞን ጤና መምሪያ በቁጥር ሰሸጤመ 32/144/11 በቀን 4/3/11 ዓ.ም በተጻፈ ደብዳቤ አሳውቀውናል ::

ስለዚህ በእናንተ ከቡል ጥናቱን ለሚያካሂዱት ባለሙያ አስፈላጊውን ሁሉ ትብብር እንድታደርጉላቸው እየጠየቅን ለሚደተግላቸው ትብብር በቅድሚያ እናመሰግናለን ::

"" ጤና ለሁም ""

መሰሉ ግርማ አለሙ
Meselu Girma Alemu
የጤና ክብካቦ የሥራ ሂደት
አስተባባሪና የጽ/ቤቱ ም/ኃላፊ

☎ 0116812964
ራዕይ፡- ጤናማ፣ አምራችና የበለጸጉ ኢትዮጲያዊያን ተፈጥረዉ ማየት

Appendix 11: Information statement for health facilities (English)

Dr Catherine Chojenta
Research Centre for Generational Health and Ageing
School of Medicine and Public Health, University of Newcastle
Telephone: +61 2 4042 0672, Email: Catherine.Chojenta@newcastle.edu.au

Health facility Information Statement for study on:

Effect of dietary pattern on maternal health

The involvement of this health facility is on the voluntary basis for the research project identified above, which is being conducted by Mr Kelemu Tilahun as part of his PhD studies at the University of Newcastle under the supervision of Dr Catherine Chojenta, Professor Deborah Loxton and Dr Ellie Gresham.

The aims of this research

This study is intended to assess the effect of dietary patterns on maternal health in North Shewa, Ethiopia.

The participants of this study

The participants of this study are pregnant women who are between 15 and 49 years of age and who are attending the ANC follow up, are permanent residents (> 6 months) in North Shewa Zone. Participation is voluntary and not compulsory.

The role of the health facility for this research

The role of this health facility will be giving permission for this research to be conducted in MCH clinics. This health facility will give permission for the researchers/data collectors to conduct the interview with the participants and access their medical record during an interview. If the health facility give permission, the data collectors will conduct an interview with the participants about their personal information, family characteristics, any previous pregnancies, and their diet. Additionally, the measurements of their weight, height, mid-upper arm circumference, blood pressure and gestational age, and laboratory measurements including hemoglobin level, urine protein, and stool examination will be taken from the antenatal logbook kept at the clinic by the data collectors during the interview. In addition, the health facility will also agree to provide access to all the available support services if participants become distressed.

How the participants will be involved in the research?

Involvement in this study is completely the participants' choice. Only those women who provide their informed consent will be included in the research. After deciding to participate, the participants can withdraw from the study at any time without giving reasons. They have the right to decline the invitation to participate. Their decision regarding participating in this study will not affect their relationship with the health service providers. Whether or not they decide to participate, their decision will not disadvantage them in any way. They will not face any problems if they do not allow the information to be taken from their records and they will not be denied any medical services from the health facility.

How will the information collected be used?

The findings of this study will contribute to Kelemu Tilahun's PhD thesis and will be presented at national and international conferences, published in scientific journals, and reports will be submitted to governmental and nongovernmental organizations. The study results will also be available at the study sites. All information will be destroyed once the analysis of data has finished and all publications and reports have been accepted.

For the further information, please contact Dr Catherine Chojenta (phone: 61 2 4042 0672) or Mr Kelemu Tilahun (phone: 0932518744), Email: KelemuTilahun.Kibret@uon.edu.au. *If you have any concerns and/or complaints about this research, you can also contact the University of Newcastle Human research ethics committee (UON HREC) (phone: +61 2 492 17894; Email: Human-Ethics@newcastle.edu.au).*

Thank you for giving permission to conduct the research in this health facility

Appendix 12: Information statement for health facilities (Amharic)

ለ ጤና ተቋማት መረጃ መስጫ

ዶ/ር ካትሪን ኮጀንታ
የጀኔረሽናል ጤና እና እርጅና ጥናትና ምርምር ማእከል
የህክምና ና የህብረተሰብ ጤና ት/ቤት
ኒውካስትል ዩኒቨርሲቲ
ስልክ: +61 2 4042 0672 ኢሜል: Catherine.Chojenta@newcastle.edu.au

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

ለ ጤና ተቋማት መረጃ መስጫ ለጥናት ፕሮጀክት: የአመጋገብ ስርአት በ እናቶች ጤና ላይ ያለው ተጽእኖ

የዶክመንቱ ቨርሽን 1.4; ቀን 25/01/2011

ከላይ የተጠቀሰው ጥናት የሚሰራው በ አቶ ቀለሙ ጥላሁን ለ ሶስተኛ ዲግሪ ማሟያ በኒውካስትል ዩኒቨርስቲ ውስጥ በዶ/ር ካተሪን ኮጀንታ፣ በፐ/ር ዲቦራ ለክስተን እና ዶ/ር ኢሌይ ግሬሃም አማካሪነት ሲሆን የዚህ ጤና ተቋም ተሳትፎም በፈቃደኝነት ላይ የተመሰረተ ነው ።

የዚህ ጥናት ዓላማዎች

ይህ ጥናት በሰሜን ሸዋ ዞን፣ ኢትዮጵያ በእናቶች ጤና ላይ የአመጋገብ ተጽእኖ ምን እንደሆነ ለመገምገም የታቀደ ነው.

የጠናቱ ተሳታፊዎች

የዚህ ጥናት ተሳታፊዎች ከ 15 እስከ 49 አመት እድሜ ያሉ እና ቅድመ ወሊድ ክትትል እየተካፈሉ የሚገኙ በሰሜን ሸዋ ዞን ቋሚ ነዋሪዎች ናቸው (> 6 ወር) ። ተሳትፎ በበጎ ፈቃደኝነት እንጂ ግዴታ አይደለም።

ለዚህ ጥናት የጤና ተቋም ተግባር/ሚና

የዚህ የጤና ተቋም ሚና/ተግባር ጥናቱ በእናቶችና ህጻናት ክሊኒክ እንዲካሄድ ፈቃድ መስጠት ይሆናል። ይህ የጤና ተቋም ተመራማሪዎቹ ከተሳታፊዎች ጋር ቃለ መጠይቅ እንዲያደርጉ እና በቃለ መጠይቅ ወቅት የሕክምና መዝገቦቻቸውን እንዲያገኙ ያደርጋል። የጤና ተቋሙ ፈቃድ ከሰጠ፣ መረጃ ሰብሳቢዎቹ ከተሳታፊዎቹ ጋር ስለ ግለሰባዊ መረጃዎቻቸው፣ ስለቤተሰባዊ ባህሪያት፣ ስለ ቀድሞ እርግዝናቸው እና ስለ አመጋገባቸው ቃለ መጠይቅ ያደርጋሉ። በተጨማሪም ክብደታቸው፣ ቁመታቸው፣ የክንዳቸው የመካከለኛው መጠነዙሪያ፣ የደም ግፊት እና የእርግዝና ዕድሜ, እንዲሁም የሄሞግሎቢን መጠን፣ የሽንት ፕሮቲን፣ እና የሰገራ ምርመራ ውጤትን መረጃ ሰብስሳቢዎቹ ከቅድመ ወሊድ ክትትል መዝገብ ይወስዳሉ። በተጨማሪም ተሳታፊዎች መረበስሽ ካጋጠማቸው የጤና ተቋማቱ ሁሉንም የድጋፍ አገልግሎቶች ማግኘት እንድችሉ ተስማምቷል።

ተሳታፊዎች በምርምር ውስጥ እንዴት ተሳታፊ ይሆናሉ?

በዚህ ጥናት ውስጥ ተሳትፎ የተሳታፊው ምርጫ ነው። የተስማሙ እናቶች ብቻ ናቸው በጥናቱ ውስጥ የሚሳተፉት። ለመሳተፍ ከወሰኑ ተሳታፊዎቹ ምክንያቱን ሳይገልጹ በማንኛውም ጊዜ ከጥናቱ ሊያቋርጡ ይችላሉ። ከጥናቱ የማቋረጥ መብት አላቸው። በዚህ ጥናት መሳተፋቸው ከጤና አገልግሎት ሰጭዎች ጋር ያላቸውን ግንኙነት አይነካም። ለመሳተፍ ቢወስኑ ወይም ባይወስኑ ውሳኔያቸው በማንኛውም መንገድ ሊጎዳቸው አይችልም። መረጃው ከመዝገባቸው እንዲወሰድ የማይፈቅዱ ቢሆንም እንኳን ከጤና ተቋሙ ምንም ዓይነት የህክምና አገልግሎት አይከለከሉም ።

የተሰበሰበው መረጃ እንዴት ጥቅም ላይ ይውላል?

የዚህ ጥናት ግኝት ለቀለሙ ጥላሁን የዶክትሬት ድግሪ ማሟያ ሲሆን በሳይንሳዊ መጽሔቶች የሚታተም እና በብሔራዊና ዓለም አቀፍ ስብሰባዎች ላይ የሚቀርብ ይሆናል። ሪፖርቶች ደግሞ ለመንግስት እና ለመንግስታዊ ላልሆኑ ድርጅቶች ይቀርባል። የጥናት ውጤቶቹ ጥናቱ በተካሄደባቸው ቦታዎች ላይም እንዲገኙ ይደረጋል። የመረጃ ትንተና ከተጠናቀቀ እና ሁሉም ህትመቶች እና ሪፖርቶች ተቀባይነት ካገኙ ሁሉም መረጃዎች ይሰረዛሉ።

ለተጨማሪ መረጃ እባክዎን ዶ/ር ካትሪን ኮጀንታን (ስልክ ቁጥር 61 2 4042 0672) ወይም አቶ ቀለሙ ጥላሁን (ስልክ: 0932518744), ኢሜል: KeleemTilahun.Kibret@uon.edu.au ማነጋገር ይችላሉ። በዚህ ምርምር ላይ ስጋቶች እና / ወይም ቅሬታዎች ካለዎት የኒው ካስሌል የሰብዓዊ ምርምር ሥነ-ምግባር ኮሚቴ (UON HREC) (ስልክ: +61 2 492 17894; ኢሜይል: Human-Ethics@newcastle.edu.au) ማግኘት ይችላሉ።

በዚህ የጤና ተቋም ውስጥ ምርምር ለማድረግ ፍቃድ ስለሰጡን እናመሰግንዎታለን!!

Appendix 13: Consent form for health facilities (English)

Health facility consent form

Dr Catherine Chojenta
Research Centre for Generational Health and Ageing
School of Medicine and Public Health
University of Newcastle
Telephone: +61 2 4042 0672
Email: Catherine.chojenta@newcastle.edu.au

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Health facility Consent Form for the Research Project:

Effect of dietary pattern on maternal health

- The health facility gives permission for the above research project to be conducted in the MCH clinics as per the protocol.
- The health facility recognizes that the project will be conducted according to the ethical standards.
- The health facility gives permission to conduct a face-to-face interview with the participants to complete a questionnaire.
- The health facility gives permission for the researchers to take the following information from participants' medical record: weight, height, mid-upper arm circumference, blood pressure, gestational age, haemoglobin level, urine protein and stool examination results
- The health facility agree to provide access to all the available support services if participants become distressed

Name of Organization: ____

Name of the Leader/Director: ______________________ Signature ____________Date: _______

Appendix 14: Consent form for health facilities (Amharic)

የጤና ተቋም የስምምነት ቅጽ

ዶ/ር ካትሪን ኮጀንታ
የጀኔረሽናል ጤና እና እርጅና ጥናትና ምርምር ማእከል
የህክምና ና የህብረተሰብ ጤና ት/ቤት
የኒውካስትል ዩኒቨርሲቲ
ስልክ: +61 2 4042 0672 ኢሜል: Catherine.Chojenta@newcastle.edu.au

THE UNIVERSITY OF
NEWCASTLE
AUSTRALIA

የጤና ተቋም የስምምነት ቅጽ ለጥናት ፕሮጀክት: የአመጋገብ ስርአት በ እናቶች ጤና ላይ ያለው ተጽእኖ

- ከላይ የተጠቀሰው ጥናት በ እናቶችና ህጻናት ክሊኒክ እንዲካሄድ ጤና ተቋሙ ፈቅዷል።
- ጥናቱ ስነ ምግባር በጠበቀ በልኩ እንደሚካሄድ ጤና ተቋሙ ተረድቷል።
- መጠይቁን ለመሙላት ከጥናቱ ተሳታፊዎች ጋር ቃለ ምልልስ እንዲደረግ ጤና ተቋሙ ፈቃድ ሰጥቷል።
- ተመራማሪው የ ጥናቱ ተሳታፊዎችን የክብደት ልክ፣ ቁመት፣ የክርን መጠነ-ዙሪያ፣ የደም ግፊት መጠን፣ የእርግዝና ዕድሜ፣ የሄሞግሎቢን መጠን፣ የሽንት ፕሮቲን መጠን እና የሰገራ ምርመራ ውጤቶችን ከህክምና መዝገብ እንዲዎስዱ ጤና ተቋሙ ፈቅዷል።
- ጤና ተቋሙ ማንኛውንም የድጋፍ አገልግሎት የጥናቱ ተሳታፊዎች ካስፈለጋቸው እንዲጠቀሙ ተስማምቷል።

የተቋሙ ስም : ____

የተቋሙ ሃላፊ ስም: ____________________ ፊርማ ____________ቀን ________

Appendix 15: Information statement for participants (English)

Dr Catherine Chojenta
Research Centre for Generational Health and Ageing
School of Medicine and Public Health, University of Newcastle
Telephone: +61 2 4042 0672, Email:
Catherine.Chojenta@newcastle.edu.au

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Information Statement for study on:

Effect of dietary pattern on maternal health
Document Version 1.4; dated 15/10/2018

You are invited to participate in the research project identified above which is being conducted by Mr Kelemu Tilahun as part of his PhD studies at the University of Newcastle under the supervision of Dr Catherine Chojenta, Professor Deborah Loxton and Dr Ellie Gresham.

Why is the research being done?

Dietary intake has an impact on maternal health outcomes including anemia and gestational hypertension. Previous evidence has shown that dietary patterns during pregnancy have effects on maternal health although findings are inconsistent. Therefore, the aim of the research is to assess the effect of dietary patterns on maternal health in North Shewa.

Who can participate in the research?

We are inviting pregnant women to participate in this study who are between 15 and 49 years of age and who are permanent residents (> 6 months) in North Shewa Zone. Women are ineligible to participate if they have difficulty hearing or speaking, are a temporary resident of North Shewa Zone, have any known medical problems (for example, cardiovascular diseases and renal diseases) or if they are not willing to participate and outside the age-range. Participation is voluntary and not compulsory.

What would you be asked to do?

You are providing consent for conducting the interview with the data collectors and access your medical record during an interview. If you agree to participate, you will be asked to complete an interview about your personal information, your family characteristics, any previous pregnancies, and your diet. The data collectors will conduct the interview with you. Additionally, the measurements of your weight, height, mid-upper arm circumference, blood pressure and gestational age, and laboratory measurements including hemoglobin level, urine protein, and stool examination will be taken from the antenatal logbook kept at the clinic by the data collectors during the interview.

What choice do you have in participating in the research?

Involvement in this study is completely your choice. Only those women who provide their informed consent will be included in the research. After deciding to participate, you can withdraw from the study at any time without giving reasons. You have the right to decline the invitation to participate. Your decision regarding participating in this study will not affect your relationship with the health service provider. Whether or not you decide to participate, your decision will not disadvantage you in any way. You will not face any problems if you do not allow the information to be taken from your records and you will not be denied any medical services from the health facility.

When the data collection period will be?

The data collection period at each clinic will be four consecutive months after the ethical approval and getting permission from the health facilities.

How much time will it take?

The questionnaire may take about 15-20 minutes to complete.

What are the risks and benefits of participating?

There are no anticipated risks associated with participating in this study except some minimal distress that might be encountered during interview associated with some questions like previous history of pregnancy. If you participate in the study, the findings will provide evidence and information for governmental and non - governmental organizations who are working in the area of maternal health, and may help to improve the maternal health services offered by these organizations. If you experience any serious or ongoing distress, you can be referred to a counsellor at the health facility.

How will your privacy be protected?

The face-to-face interview will be carried out in a separate private room. Your name and other personally identifying information, will not be recorded in the questionnaire and the information that you give will be kept confidential. Confidentiality will be assured for all the information provided by you. Only the named investigators and data collectors will have access to the recorded data. The data will not be used for any purposes other than this study and will be kept confidential. The questionnaire will be recorded on paper by data collectors and will be stored in a key protected cabinet in Zonal health office for six months. After the data collection is completed, the data will be entered into software and kept in a password-protected computer, which is stored on my UON laptop and the data will be backed up in the cloud.

How will the information collected be used?

The findings of this study will contribute to Kelemu Tilahun's PhD thesis and will be presented at national and international conferences, published in scientific journals, and reports will be submitted to governmental and nongovernmental organizations. Feedback on the result of the study cannot be made available to individual participants, however, the study results will be available at the study sites, ANC clinics. Individual participants will not be identified in any reports arising from the study. All information will be destroyed once the analysis of data has finished and all publications and reports have been accepted.

What do you need to do to participate?

Please read this Information Statement and make sure you understand its contents before you consent to participate. If there is anything you do not understand, or if you have questions, please don't hesitate to ask the interviewer at any time, or contact the researcher. If you would like more time to consider the invitation to participate, you can let the researchers know of your decision within two weeks of receiving the invitation. If you would like to participate, please complete the consent form.

Further information

If you would like further information, please contact Dr Catherine Chojenta (phone: 61 2 4042 0672) or Mr Kelemu Tilahun (phone: 0932518744), Email: KelemuTilahun.Kibret@uon.edu.au. *If you have any concerns and/or complaints about this research, you can also forward to North Shoa Zone health office (phone: +251116812956; email: nshealth@yahoo.com). And any complaints will also be forwarded to the University of Newcastle Human research ethics committee (UON HREC) (phone: +61 2 492 17894; Email: Human-Ethics@newcastle.edu.au).*

Thank you for considering our invitation to participate in this study.

Appendix 16: Information statement for participants (Amharic)

ዶ/ር ካትሪን ኮጀንታ
የጀኔረሽናል ጤና እና እርጅና ጥናትና ምርምር ማእከል
የህክምና ና የህብረተሰብ ጤና አጠባበቅ ት/ቤት
የኒውካስትል ዩኒቨርሲቲ
ስልክ: +61 2 4042 0672 ኢሜል: Catherine.Chojenta@newcastle.edu.au

የመረጃ መግለጫ የአመጋገብ ስርአት በ እናቶች ጤና ላይ ያለው ተጽእኖ

የዶክመንቱ ቨርሽን 1.4; ቀን 25/01/2011

ከዚህ በላይ በተጠቀሰው የምርምር ፕሮጀክት ላይ ማለትም አቶ ቀለሙ ጥላሁን ለ ሶስተኛ ዲግሪ ማሟያ በኒውካስትል ዩኒቨርስቲ ውስጥ በዶ/ር ካተሪን ኮጀንታ፣ በፕ/ር ዲቦራ ለክስተን እና ዶ/ር ኢሌይ ግሬሃም አማካሪነት በሚካሀድ ጥናት ላይ እንዲሳተፉ ተጋብዘዋል።

ጥናቱ ለምን አስፈለገ?

አመጋገብ በደም ማነስ እና ከእርግዝና ጋ የተገናኘ የደም ብዛት ጨምሮ በእናቶች ጤና ላይ ተፅዕኖ አለው። በእርግዝና ወቅት የአመጋገብ ስርዓቶች በእናቶች ጤና ላይ ተጽዕኖ እንደሚያሳድሩ ማስረጃዎች ያሳያሉ፤ ይሁን እንጂ ግኝቶቹ ወጥነት የላቸውም። ስለዚህ የዚህ ምርምር አላማ በሰሜን ሸዋ ዞን ውስጥ በሚገኙ እናቶች ጤና ላይ የአመጋገብ ስርዓት ተጽእኖ ምን እንደሆነ ለማጥናት ነው።

በጥናቱ ውስጥ ሊሳተፍ የሚችለው ማን ነው?

ነፍሰ ጡር እናቶች በ15 እና 49 አመት እድሜ ክልል ውስጥ እና በሰሜን ሸዋ ዞን ቋሚ ኗሪዎች (ከ 6 ወር በላይ) የሆኑ በዚህ ጥናት እንዲሳተፉ እየጋበዝን ነው።. በዚህ ጥናት የማይሳተፉት እናቶች የመስማት ወይም የመናገር ችግር ካለባቸው፣በሰሜን ሸዋ ዞን ጊዚያዊ ኑዋሪ ከሆኑ እና የታወቀ የጤና ችግር ለምሳሌ የልብ ወይም የኩላሊት በሽታ ካለባቸው በዚህ ጥናት አይሳተፉም። በዚህ ጥናት ላይ መሳተፍ ሙሉበሙሉ በፈቃደኝነት ሲሆን መሳተፍ ግደታ አይደለም።

ምን እንዲያደርጉ ይጠየቃሉ ?

ለመሳተፍ ፈቃደኛ ከሆኑ ስለ እርስዎ ግላዊ ሁኔታ፣ ስለ ቤተሰብ ሁኔታ እና ስለ አመጋገብዎ መረጃ እንጠይቅዎታለን። መረጃ ሰብሳቢዎቹ ከእርስዎ ጋር ቃለ-መጠይቅ ያደርጋሉ። በተጨማሪም መረጃ ሰብሳቢዎቹ የእርስዎን ክብደት፣ ቁመት፣ የክርንዎን የላይኛዉ መጠነ ዙሪያ ልክ፣ የደምዎ ግፊት እና የእርግዝና እድሜ እንዲሁም የ ላብራቶሪ ልኬቶች ማለትም ሄሞግሎቢን ሌቬል፣ የደም ዉስጥ ፕሮቴን መጠን እና የሰገራ ምርመራ ውጤት ከ ነፍሰጡር መከታተያ መዝገብ ላይ ይወሰዳል።

በጥናቱ ውስጥ ለመሳተፍ ምን ምርጫ አለዎት?

በዚህ ጥናት ውስጥ ተሳትፎ ሙሉ በሙሉ የእርስዎ ምርጨ ነው። ፈቃደኛ የሆኑ እናቶች ብቻ በጥናቱ ውስት ይሳተፋሉ። ለመሳተፍ ከወሰኑም በኋላ ምክንያት መጥቀስ ሳያስፈልግዎ ጥናቱን በማንኛውም ጊዜ ማቋረጥ ይችላሉ። ለመሳተፍ ግብዣውን ያለመቀበል መብት አለዎት። በዚህ ጥናት መሳተፍ ላይ ያደረጉት ውሳኔ ከጤና አገልግሎት አቅራቢው ጋር ያለዎትን ግንኙነት አይነካም። ለመሳተፍ ቢወስኑም ባይወስኑም ውሳኔዎ በማንኛውም መንገድ ተጎጂ ሊያደርግዎ አይችልም። መረጃው ከመዝገብዎ እንዲወሰድ የማይፈቅዱ ቢሆን እንኳን ምንም ዓይነት ችግር አይገጥመዎትም፥ እንዲሁም ከጤና ተቋሙ ምንም ዓይነት የህክምና አገልግሎት አይከለከሉም።

ምን ያህል ጊዜ ይወስዳል?

መጠይቁን ለማጠናቀቅ ከ15-20 ደቂቃ ያህል ሊወስድ ይችላል።

በዚህ ጥናት መሳተፍ ምን ምን ጉዳቶች እና ጥቅሞች አሉት?

በዚህ ጥናት ውስጥ ከመሳተፍ ጋር ተያይዞ የሚመጡ ምንም አይነት አደጋዎች/ጉዳቶች የሉም። በጥናቱ ከተሳተፉ ግኝቶቹ በእናቶች ጤና ውስጥ ለሚሰሩ መንግስታዊም ሆነ መንግስታዊ ላልሆኑ ድርጅቶች መረጃ እና ማስረጃ ይሆናሉ። እንዲሁም እነዚህ ድርጅቶች የሚሰጡትን የእናቶችን የጤና አገልግሎት ለማሻሻል ሊረዱ ይችላሉ። ማንኛውም የመረበሽ ችግር የሚገጥመዎ ከሆነ ወደ ጤና ተቋሙ አማካሪ ይላካሉ።

እንዴት የእርስዎ ሚስጢር ይጠበቃል?

ከርስዎ ጋር ፊት ለፊት የሚደረገው ቃለ-ምልልስ ለብቻዎ በክፍል ውስጥ ይካሄዳል። ከሜዲካል መዝገብ ቁጥር በስተቀር ስምዎ እና ሌሎች የግል መለያ መረጃዎ በመጠይቁ ውስጥ አይመዘገቡም፥ እንዲሁም የሚሰጡት መረጃ በምስጢር ይያዛል። ለሚሰጡት መረጃዎች ሁሉ ምስጢራዊነት ይጠበቃል። ሁሉም የተመዘገበ መረጃ በህክምና መዝገብ ቁጥር ይለያል። በስም የተጠቀሱት ተመራማሪዎችና መረጃ ሰብሳቢዎች ብቻ ናቸው የተሰበሰበውን መረጃ መድረስ የሚችሉት። መረጃው ከዚህ ጥናት ውጪ ለሆኑ ጉዳዮች ጥቅም ላይ አይውልም እንዲሁም በምስጢር ይጠበቃል። መጠይቁ በመረጃ ሰብሳቢዎች በወረቀት ላይ ይመዘገባል። ከዚያ በዞን ጤና ቢሮ ውስጥ ለስድስት ወራት ቁልፍ ባለው ሳጥን ውስጥ ይቀመጣል። መረጃ መሰብሰቡ ከተጠናቀቀ በኋላ መረጃው ወደ ሶፍትዌር ይገባና በይለፍ ቃል በተጠበቀ በኔ ላፕቶፕ ኮምፒተር ውስጥ ይቀመጣል ።

የተሰበሰበው መረጃ እንዴት ጥቅም ላይ ይውላል?

የዚህ ጥናት ግኝት ለቀለሙ ጥላሁን የዶክትሬት ድግሪ ማሟያ ሲሆን በሳይንሳዊ መጽሔቶች የሚታተም ይሆናል። እንዲሁም በብሔራዊና በዓለም አቀፍ ስብሰባዎች ላይ ይቀርባል። ሪፖርቶችም ደግሞ ለመንግስታዊ እና ለመንግስታዊ ላልሆኑ ድርጅቶች ይቀርባል። ነገር ግን የጥናቱ ውጤት ግብረመልስ ለግለሰብ ተሳታፊዎች ሊደርስ አይችልም፣ የጥናቱ ውጤት ግን በጥናቱ በተካሄደባቸው ጤና ተቋማት እንዲቀመጥ ይደረጋል። ከጥናቱ በሚዎጡ ማናቸውም ሪፖርቶች ውስጥ ግለሰብ ተሳታፊዎች ማንነት አይታዎቅም ወይም አይታዩም። አንዴ የመረጃ ትንተና ከተጠናቀቀ እና ሁሉም ህትመቶች እና ሪፖርቶች ተቀባይነት ካገኙ ሁሉም መረጃዎች ይሰረዛሉ።

ለመሳተፍ ምን ማድረግ ይጠበቅብዎታል?

እባክዎን ይህን የመረጃ መስጫ መግለጫ ያንብቡ እና ለመሳተፍ ከመስማማትዎ በፊት ይዘቱን እንደተረዱት ያረጋግጡ። ያልገባዎት ነገር ካለ ወይም ጥያቄ ካለዎት፣ቃለ-መጠይቅ አድራጊውን በማንኛውም ጊዜ ይጠይቁ ወይም ተመራማሪውን/ዋን ያነጋግሩ። ለጥሪው መልስ ለመስጠት ተጨማሪ ጊዜ ጋስፈለገዎ፥ ለተመራማሪው በሁለት ሳምንት ውስጥ ውሳኔዎትን ያሳውቁ። ለመሳተፍ ከወሰኑ/ከፈለጉ እባክዎን የስምምነት ቅጹን ይሙሉ።

ለተጨማሪ መረጃ

ተጨማሪ መረጃ ከፈለጉ ዶክተር ካተሪን ኮጀንታ (በስልክ ቁጥር 61 2 4042 0672) ወይም ቀለሙ ጥላሁን (በስልክ ቁጥር 0932518744 ኢሜል: KeleemTilahun.Kibret@uon.edu.au) ማግኘት ይችላሉ። *በዚህ ምርምር ላይ ስጋቶች እና / ወይም ቅሬታዎች ካለዎት ወደ ሰሜን ሸዋ ዞን ጤና ጽህፈት ቤት (ስልክ: +251116812956; ኢሜይል: nshealth@yahoo.com) ሊያስተላልፉ ይችላሉ። እንዲሁም ማንኛውም ቅሬታዎች ወደ ኒው ካስትል ዩኒቨርሲቲ የሰዎች የምርምር ሥነ ምግባር ኮሚቴ (ስልክ ቁጥር: +61 2 492 17894; ኢ ሜል: Human-Ethics@newcastle.edu.au) ይላኩ።*

በዚህ ጥናት ለመሳተፍ የቀረበልዎትን ግብዣ ስለተቀበሉ እናመሰግናለን።

Appendix 17: Consent form for participants (English)

Consent Form

Dr Catherine Chojenta
Research Centre for Generational Health and Ageing
School of Medicine and Public Health
University of Newcastle
Telephone: +61 2 4042 0672
Email: Catherine.chojenta@newcastle.edu.au

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

Consent Form for the Research Project:

Effect of dietary pattern on maternal health

Document Version 1.4; dated 15/10/2018

- I agree to participate in the above research project and give my consent freely.
- I understand that the project will be conducted as described in the Information Statement, which I have read or someone else has read to me. I have retained a copy of the Information Statement.
- I understand I can withdraw from the project at any time without there being any negative impact on my health care, and do not have to give any reason for withdrawing.
- I consent to completing a questionnaire with face-to-face interview.
- I consent to the researchers:
  - ✓ To access my information on weight, height, mid-upper arm circumference, blood pressure, gestational age, haemoglobin level, urine protein and stool examination results from medical record   Yes ☐   No ☐
- I understand that my personal information will remain confidential to the researchers.
- I have had the opportunity to have questions answered to my satisfaction.

Print Name:____

Signature/Finger print:___________________________________ Date: _______________

Appendix 18: Consent form for participants (Amharic)

የስምምነት ቅጽ

ዶ/ር ካትሪን ኮጀንታ
የጀኔረሽናል ጤና እና እርጅና ጥናትና ምርምር ማእከል
የህክምና ና የህብረተሰብ ጤና ት/ቤት
የኒውካስትል ዩኒቨርሲቲ
ስልክ: +61 2 4042 0672 ኢሜል: Catherine.Chojenta@newcastle.edu.au

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

የስምምነት ቅጽ ለጥናት ፕሮጀችት: የአመጋገብ ስርአት በ እናቶች ጤና ላይ ያለው ተጽእኖ

የዶክመንቱ ቨርሽን 1.4; ቀን 25/01/2011

- ❖ ከላይ ለተጠቀሰው ጥናት ለመሳተፍ ተስማምቻለሁ እናም በነጻ ፈቃዴን/ስምምነቴን ሰጥቻለሁ።
- ❖ ጥናቱ በተነበበልኝ ወይም ባነበብኩት ገለጻ መሰረት እንደሚካሄድ ተረድቻለሁ፣ ቅጂ ይዤአለሁ።
- ❖ ከጥናቱ በማንኛውም ጊዜ መውጣት/ማቋረጥ እንደምችል ና በጤና ተቋም አገልግሎቴ ላይ ምንም ተጽእኖ እንደማይደርስብኝ ተረድቻለሁ።
- ❖ ቃለ መጠይቅ ለማድረግ ተስማምቻለሁ።
- ❖ የክብደቴን፣ ቁመቴን፣ የክርኔን መጠነ-ዙሪያ፣ የደም ግፊቴን መጠን፣ የእርግዝና ዕድሜ፣ የሂሞግሎቢን መጠን፣ የሽንት ፕሮቲን መጠን እና የሰገራ ምርመራ ውጤቶችን ለተመራማሪዎቹ ከህክምና ሪኮርድ እንዲዎስዱ ተስማምቻለሁ ።

  አዎ ☐ አይደለም ☐
- ❖ የግሌ መረጃ ሚስጥራዊነቱ በተመራማሪዎቹ እንደሚጠበቅ ተረድቻለሁ።
- ❖ ጥያቄ ለመጠየቅ እድል አግኝቼ በሚያረካኝ መልኩ ተመልሶልኛል።

ስም:____

ፊርማ/ጣት አሻራ :____________________________ ቀን: ____________

Appendix 19: [Published manuscript] Maternal dietary patterns and risk of adverse pregnancy outcomes—a systematic review and meta-analysis

Public Health Nutrition: 22(3), 506–520 doi:10.1017/S1368980018002616

Review Article

Maternal dietary patterns and risk of adverse pregnancy (hypertensive disorders of pregnancy and gestational diabetes mellitus) and birth (preterm birth and low birth weight) outcomes: a systematic review and meta-analysis

Kelemu Tilahun Kibret[1,*], Catherine Chojenta[1], Ellie Gresham[2], Teketo K Tegegne[1] and Deborah Loxton[1]
[1]Priority Research Centre for Generational Health and Aging, School of Medicine and Public Health, University of Newcastle, University Drive, Callaghan, NSW 2308, Australia: [2]Health Intelligence Unit, Orange Health Service, Western NSW Health, Orange, New South Wales, Australia

Submitted 15 March 2018: Final revision received 28 August 2018: Accepted 3 September 2018: First published online 15 October 2018

Abstract
Objective: Epidemiological studies have indicated that dietary patterns during pregnancy are associated with adverse pregnancy and birth outcomes such as hypertensive disorders of pregnancy (HDP), gestational diabetes mellitus (GDM), preterm birth (PTB) and low birth weight (LBW). However, the results of these studies are varied and inconsistent. The present study aimed to assess the association between dietary patterns and the risk of adverse pregnancy and birth outcomes.
Design: Systematic review and meta-analysis. Seven databases were searched for articles. Two reviewers performed the study selection and data extraction. A random-effects model was used to estimate pooled effect sizes of eligible studies.
Setting: Studies conducted all over the world were incorporated.
Subjects: The review focused on pregnant women.
Results: A total of twenty-one studies were identified. Adherence to a healthy dietary pattern (intake of vegetables, fruits, legumes, whole grains) was significantly associated with lower odds (OR; 95% CI) of pre-eclampsia (0·78; 0·70, 0·86; $I^2 = 39{\cdot}0\%$, $P = 0{\cdot}178$), GDM (0·78; 0·56, 0·99; $I^2 = 68{\cdot}6\%$, $P = 0{\cdot}013$) and PTB (0·75; 0·57, 0·93; $I^2 = 89{\cdot}6\%$, $P = 0{\cdot}0001$).
Conclusions: Our review suggests that dietary patterns with a higher intake of fruits, vegetables, legumes, whole grains and fish are associated with a decreased likelihood of adverse pregnancy and birth outcomes. Further research should be conducted in low-income countries to understand the impact of limited resources on dietary intake and adverse pregnancy and birth outcomes.

Keywords
Dietary patterns
Dietary intake
Pregnancy
Pregnant women

Hypertensive disorders of pregnancy (HDP) are a group of conditions related to high blood pressure during pregnancy, proteinuria and in some cases convulsions[1]. HDP are responsible for increased morbidity and mortality in mothers and newborns, accounting for approximately 14% of maternal deaths globally between 2003 and 2009[2]. According to an analysis of international cohorts from six countries (Australia/New Zealand, Canada, Israel, Japan, Spain and Sweden), the incidence rate of HDP was 13% (ranging from 10·3 to 16·4%)[3].

Preterm birth (PTB) is the premature delivery of a neonate before 37 weeks of gestation[4]. PTB is most common in low- and middle-income countries and is one of the leading causes of direct neonatal deaths and complications[4], responsible for more than 50% of neonatal mortality in 2010[5]. According to a systematic analysis and estimation of PTB, the rate of PTB was 11% in 2010 globally, ranging from 5% in European countries to 18% in some African countries[6]. Likewise, low birth weight (LWB), which refers to a newborn birth weight of less than 2·5 kg, is

*Corresponding author: Email ktwu27@gmail.com

common (15 %). High rates are reported in many developing countries, especially South Asia (25 %), sub-Saharan Africa (12 %)[7], Pakistan (35 %), Nepal (30 %) and Jordan (22 %)[8].

Evidence has shown that dietary patterns have an influence on adverse pregnancy and birth outcomes[9,10]. When individuals consume foods, they consume a combination of nutrients, not single nutrients[11]. The whole diet with its expected synergistic effects may have a greater influence on the occurrence of health outcomes than single nutrients[11]. Hence, it appears more complete to examine the effect of the whole diet by applying a more all-inclusive method of dietary pattern analysis, because dietary patterns evaluate the usual diet as one complete dietary exposure[12,13].

Dietary pattern analysis aims to assess the usual foods consumed as one overall dietary exposure[12,14]. Dietary patterns are defined as the quantities, proportions, variety or combinations of different foods and beverages in diets and the frequency with which they are regularly consumed[15]. Dietary patterns can be determined by three approaches. The first is the *a priori* approach, which constructs dietary scores or indices based on predefined dietary recommendations[12,14,16]. The second is the *a posteriori* approach, which identifies data-driven dietary patterns using statistical methods (cluster analysis and principal component analysis (PCA))[12,14,16]. The third approach consists of hybrid methods such as reduced rank regression, which combine aspects of the *a priori* and *a posteriori* approaches[16].

Previous studies have indicated that dietary patterns during pregnancy have a varied effect on maternal health and pregnancy outcomes such as HDP[10,17], GDM[18,19], PTB[9,20,21] and LBW[22]. For HDP, intake of vegetables, legumes, nuts, tofu, rice, pasta, rye bread, fish, milk, green leafy vegetables and pulses/beans was associated with a lower odds of pre-eclampsia/eclampsia[10,23], while the consumption of meat and potatoes, processed meat, sweet drinks and salty snacks increased the likelihood of pre-eclampsia[10,24,25]. Other studies have reported contradictory findings; a cohort study in the USA[17] reported that a higher Alternate Healthy Eating Index (AHEI) score comprising vegetables, fruit, fibre, *trans* fat, high PUFA:SFA, folate, Ca and Fe from foods was not associated with pre-eclampsia. For GDM, a Western dietary pattern (high intake of red meat, processed meat, refined grain products, sweets, French fries and pizza) among pregnant women in the USA[26], a pasta–cheese–processed-meat pattern[18] in a Singaporean population and a sweet and seafood pattern in China[19] have been associated with increased odds of GDM.

Regarding the birth outcomes, a 'prudent' dietary pattern with a high intake of vegetables, fruits, oils, water (beverage), wholegrain cereals and fibre-rich breads was associated with a reduced occurrence of PTB[9]. In contrast, a Western pattern (salty and sweet snacks, white bread, desserts and processed meat products)[9] and a Mediterranean diet with a high intake of fish, fruit, vegetables, olive/canola oil, and a low intake of red meat and coffee had no effect on PTB[20]. Contrary to this, in a Danish birth cohort study, the odds of PTB increased in women who adhered to a Western pattern (high in meat and fats and low in fruits and vegetables)[21]. A study from the USA[27] revealed that birth weight and fetal growth were not associated with the maternal AHEI score (high intakes of vegetables, fruit, whole grains, nuts and legumes, long-chain (n-3) fats, polyunsaturated fats, folate, Ca and Fe).

Current epidemiological studies show some evidence for an association between dietary patterns and adverse pregnancy and birth outcomes. However, the findings are inconsistent and there is a need to identify which dietary patterns could have health benefits for pregnant women in preventing adverse pregnancy and birth outcomes. Therefore, our aim was to determine the association between dietary patterns during pregnancy and the risk of pregnancy (HDP, GDM) and birth (PTB and LBW) outcomes through a systematic review and meta-analysis.

Methods

Search strategy

Seven databases were searched, including MEDLINE, EMBASE, CINAHL, Scopus, Cochrane Library, Web of Science, and Maternity and Infant Care. The reference lists of all previous articles were hand-searched.

The following terms, words and combinations of words were searched: ('diet' OR 'nutrition' OR 'food pattern' OR 'meal pattern' OR 'eating practice' OR 'food intake' OR 'food habits' OR 'eating behaviour' OR 'dietary pattern' OR 'dietary diversity score' AND 'pregnancy' OR 'pregnant women' OR 'gravid' OR 'gestation' OR 'prenatal care' OR 'antenatal care' AND 'gestational hypertension' OR 'pregnancy-induced hypertension' OR 'preeclampsia' OR 'pre-eclampsia' OR 'low birth weight' OR 'premature infant' OR 'premature birth' OR 'preterm birth' OR 'pregnancy in diabetics' OR 'gestational diabetes mellitus').

The search was comprised of free text words, title and Medical Subject Heading for outcomes, exposure and participants, as well as applying limits including English language and human subjects.

Study selection

The studies were screened by title and then by abstract by two reviewers (K.T.K., T.K.T.). The full texts of all selected studies were critically reviewed based on the inclusion/exclusion criteria summarized in Table 1.

Data extraction

The following variables were extracted by two reviewers (K.T.K., T.K.T.): authors, publication year, study period, study design, settings/country, sample, dietary patterns with food details, dietary assessment methods and

Table 1 Inclusion and exclusion criteria for the current systematic review and meta-analysis on maternal dietary patterns and risk of adverse pregnancy and birth outcomes

Inclusion criteria
- Pregnant women
- No date restrictions
- Original articles (randomized trials and observational studies)
- Dietary pattern as the exposure variable
- Included one or more of the following outcome variables: HDP, GDM, LBW, PTB

Exclusion criteria
- High-risk populations: women with heart diseases, diabetes, pre-eclampsia or gestational hypertension at baseline
- Unpublished papers
- Animal studies
- Brief communications, case series, editorials, review studies
- Studies that focused on single nutrients

HDP, hypertensive disorders of pregnancy (gestational hypertension, pre-eclampsia and eclampsia); GDM, gestational diabetes mellitus; LBW, low birth weight; PTB, preterm birth.

periods, main outcomes (HDP, GDM, LBW and PTB) and adjustment for confounding factors.

Quality assessments

The quality of selected full-text articles was rated by two reviewers independently (K.T.K., T.K.T.) using the Academy of Nutrition and Dietetics quality appraisal tool[28]. This tool has four relevance questions and ten validity questions. The validity questions appraise the selection, comparability of groups, assessment of exposures or outcomes and statistical analysis for each study separately[28]. The validity of a study is assessed as the responses to all relevant questions being 'yes'. The response for all validity questions is 'yes' if the criterion was fulfilled, 'no' if not fulfilled, 'unclear' if not precisely stated and 'N/A' (not applicable) if the criterion does not apply to the articles[28]. The rating scores of studies were positive (+) if the responses to the validity questions were 'yes' for six or more responses (including all four relevance questions). If the articles did not fulfil the relevance criterion of selection, comparability of groups and measurement of exposures or outcomes, the rating score was neutral (Ø) and if the responses for the validity questions are 'no' or 'unclear' for six or more responses, a negative (−) rating score was given[28].

Statistical analysis

The data were entered into a Microsoft® Excel spreadsheet version 16 and exported to the statistical software package Stata version 13 for analysis. The OR was used as a measure of effect estimate. If an incidence of outcome variable was less than or equal to 20 %, the risk ratio (RR) and OR were pooled together in the meta-analysis; otherwise RR was converted to OR using the proposed methods of Zhang and Yu[29] and Cochrane[30]. If the studies did not report OR/RR but reported the coefficient (β) of the regression, it was converted into OR/RR by exponentiation of the coefficient (i.e. $OR = \exp(\beta)$)[31].

Some articles reported OR/RR based on different references. Some used lower adherence to dietary patterns, while some used good adherence. To make this consistent and unify all results using either the higher or lower group as reference, the new OR/RR was calculated by taking the reciprocal of the reported OR/RR. The lower limit of the new OR/RR is the reciprocal of the upper limit of the old OR/RR and the upper limit of the new OR/RR is reciprocal of the lower limit of the old OR/RR[32].

The random-effects model was used for calculating pooled estimates. Statistical heterogeneity was evaluated by Cochran's Q test (I^2), which shows the amount of heterogeneity between studies. An I^2 value reflects between-study variation (values of 25, 50 and 75 % refer to low, medium and high variation, respectively)[33].

Subgroup analyses were conducted to detect potential sources of heterogeneity. The possible effects of between-study variance of dietary assessment methods (dietary diversity score (DDS), Mediterranean diet score (MDS), PCA) and dietary assessment periods/trimesters (first trimester (1st–12th weeks), second trimester (13th–27th weeks), third trimester (28th–40th weeks)) were assessed.

Dietary patterns detected in each study were different regarding to the country of origin and the approaches used for identifying dietary patterns; however, they had similarities among commonly consumed food items. For instance, most articles identified a prudent, traditional, Mediterranean or healthy dietary pattern which commonly consisted of whole grains, nuts legumes/pulses, vegetables/fruits and fish. These studies were grouped together and analysed by labelling them as 'healthy dietary pattern'.

Similarly, those patterns comprised mostly of refined grains, processed meats or snacks, high-sugar and high-fat dairy products, eggs and white potatoes were grouped together, labelled as the 'Western dietary pattern' and then analysed.

Using the available articles, pooled estimates were determined for the effect of the healthy pattern on HDP, GDM, PTB and LBW. Likewise, meta-analysis was performed for a Western dietary pattern and GDM, HDP and PTB.

Results

Identified studies

Our search identified 6291 records after removal of duplicates. One hundred articles were identified for full-text review, with twenty-one articles incorporated in the systematic review and meta-analysis (Fig. 1).

Study characteristics

Of the twenty-one articles included, the majority (n 15) were conducted in developed countries, with the

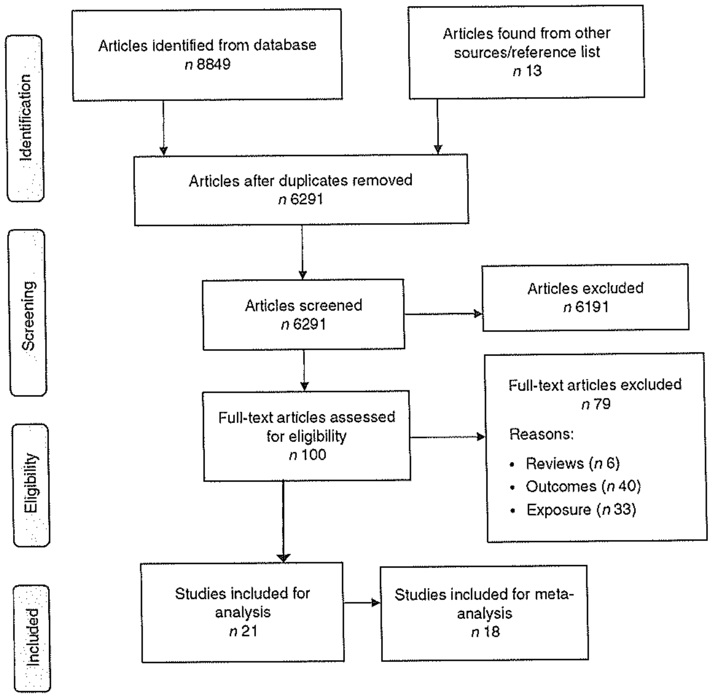


Fig. 1 (colour online) Flowchart of the study selection process for the current systematic review and meta-analysis on maternal dietary patterns and risk of adverse pregnancy and birth outcomes

remainder in developing countries. Out of all included articles, eighteen were cohort studies and three were cross-sectional studies. The articles were published between 2008 and 2016. The sample in each study ranged from 168[34] to 66 000[9] with 302 450 pregnant women in total. In the included articles, six reported the effect of dietary patterns on HDP[10,25,35–38], six reported on GDM[18,19,34,39–41], nine reported on PTB[9,20,21,36,42–46] and two reported on LBW[46,47] (Table 2).

Most of the articles (*n* 15) used an FFQ[9,10,19–21,25,35,36,38,40,41,43–45,47] as the method of dietary assessment, five studies used a 24 h recall[18,37,39,42,46], and one used a four-day food record[34] to assess the dietary intake. Various types of approaches were used to identify dietary patterns. Most studies applied the *a posteriori* approach (PCA; *n* 13)[9,10,18,19,21,25,34,35,38,41–43,47]; seven studies used the *a priori* method, DDS[37,46] or MDS[20,40,44,45] or New Nordic Diet (NND)[36]; and one study used the rank reduced regression method[39] to identify the dietary pattern of the women (Table 2). All studies had a positive score for the quality assessment.

The association of dietary patterns with adverse pregnancy outcomes (hypertensive disorders of pregnancy and gestational diabetes mellitus)

Dietary pattern and hypertensive disorders of pregnancy
Six articles[10,25,35–38] assessed the association between dietary pattern and HDP. These articles identified a range of different dietary patterns like healthy, traditional, Mediterranean and Western patterns, and therefore the results could not be pooled in meta-analysis except the healthy dietary pattern.

Healthy dietary pattern. Four studies[10,25,36,38] were available for meta-analysis that reported the association between a healthy dietary pattern with a high intake of fruits, vegetables, whole-grain foods, fish and poultry and HDP. Based on this pooled analysis, study participants who adhered to a healthy dietary pattern were shown to have significantly lower odds of pre-eclampsia (OR = 0·78, 95 % CI 0·70, 0·86; I^2 = 39·0 %, P = 0·178; Fig. 2).

However, one[37] cross-sectional study in Tanzania indicated that having a high DDS (OR = 5·84; 95 % CI 2·11, 16·15) or a medium DDS (OR = 2·54; 95 % CI 1·04, 6·16) was associated with increased odds of gestational hypertension. On the contrary, in a cohort study, no association

Table 2 Characteristics of the articles included in the current systematic review and meta-analysis on maternal dietary patterns and risk of adverse pregnancy and birth outcomes

Study	Study design; period; country	Sample (*n*)	Dietary assessment: Methods	Dietary assessment: Trimester (period)	Methods of defining dietary pattern	Dietary patterns identified	Main findings	Outcomes	Confounding factors
Brantsaeter *et al.* (2009)[10]	Cohort; 2002–2006; Norway	23 423	255-item FFQ*	2nd (17–22 weeks)	PCA	Vegetable; potato and fish; cakes and sweets; processed food	Vegetable (tertile 3 *v.* tertile 1): OR = 0·72 (95 % CI 0·62, 0·85) Processed food (tertile 3 *v.* tertile 1): OR = 1·21 (95 % CI 1·03, 1·42) Potato and fish (tertile 3 *v.* tertile 1): OR = 1·00 (95 % CI 0·84, 1·18)	PE	BMI, education, age, smoking, height, education status, hypertension prior to pregnancy, TEI, dietary supplement use
Eshriqui *et al.* (2016)[35]	Cohort; 2009–2012; Brazil	299	Eighty-two item FFQ*	3rd (28–38 weeks)	PCA	Healthy; processed; common Brazilian	Mixed-effect regression with SBP: Healthy: $\beta = -0{\cdot}199$ (95 % CI −1·28, 0·88); OR = 0·82 (95 % CI 0·28, 2·10). Processed: $\beta = -0{\cdot}268$ (95 % CI −1·67, 1·14); OR = 0·76 (95 % CI 0·19, 3·13) Mixed-effect regression with DBP: Healthy: $\beta = -0{\cdot}670$ (95 % CI −1·573, 0·232); OR = 0·51 (95 % CI 0·21, 1·26). Processed: $\beta = -0{\cdot}032$ (95 % CI −1·202, 1·138); OR = 0·97 (95 % CI 0·30, 3·12)	Blood pressure (SBP & DBP)	Age, BMI, education, parity, TEI
Mwanri *et al.* (2015)[37]	Cross-sectional; 2011–2012; Tanzania	910	Sixteen-food-group 24 h recall*	2nd & 3rd (20–36 weeks)	DDS	Sixteen food groups	Medium DDS: OR = 2·54 (95 % CI 1·04, 6·16) High DDS: OR = 5·84 (95 % CI 2·11, 16·15)	Hypertension during pregnancy	Residence, age, gestational age, MUAC, parity, GDM, education, PA
Timmermans *et al.* (2011)[25]	Prospective cohort; the Netherlands	3187	293-item FFQ*	All (median 13·5 weeks)	PCA	Mediterranean diet pattern (MDP); traditional dietary pattern	For PE: Low adherence to MDP: OR = 1·2 (95 % CI 0·6, 2·3); adherence to MDP: OR = 0·83 (95 % CI 0·43, 1·60); adherence to traditional: OR = 1·1 (0·6, 2·1) For GHTN: Low adherence to MDP: OR = 1·3 (95 % CI 0·9, 1·9); adherence to MDP: OR = 0·77 (95 % CI 0·53, 1·11); adherence to traditional: OR = 1·3 (95 % CI 0·9, 1·9)	PE & GHTN	Maternal BMI, maternal age, parity, educational level, smoking, vomiting, preconception folic acid use
Torjusen *et al.* (2014)[38]	Cohort; 2002–2008; Norway	28 192	Six-food-group FFQ	2nd (17–22 weeks)	PCA	Healthy pattern; organic vegetables pattern	Healthy pattern, tertile 3 *v.* tertile 1: OR = 0·74 (95 % CI 0·64, 0·85) Organic vegetables, tertile 3 *v.* tertile 1: OR = 0·79 (95 % CI 0·62, 0·99)	PE	Hypertension prior to pregnancy, pre-pregnant BMI, height, age, education, household income, smoking in pregnancy, TEI, gestational weight gain

Table 2 *Continued*

Study	Study design; period; country	Sample (*n*)	Dietary assessment: Methods	Dietary assessment: Trimester (period)	Methods of defining dietary pattern	Dietary patterns identified	Main findings	Outcomes	Confounding factors
Hillesund *et al.* (2014)[36]	Cohort; Norway	72 072	255-item FFQ*	25 weeks	NND score	New Nordic dietary index (NND)	With high NND score: Risk of PE: OR = 0·86 (95 % CI 0·78, 0·95); risk of early PE: OR = 0·71 (95 % CI 0·52, 0·96); risk of PTB: OR = 0·91 (95 % CI 0·80, 1·30)	PE & PTB	Maternal age, height, pre-pregnancy BMI, parity, education, smoking status, exercise during pregnancy, chronic hypertension, diabetes, marital status, energy intake
Dayeon *et al.* (2015)[39]	Cross-sectional; USA	253	Eight-food-group 24 h recall	All (avg. 20 weeks)	RRR	'High refined grains', 'high nuts, seeds, fat and soyabeans, low milk', 'high added sugar and organ meats', 'low fruits, vegetables and seafood'	'High refined grains' pattern: OR = 4·9 (95 % CI 1·4, 17·0) 'High nuts, seeds, fat and soyabeans, low milk' pattern: OR = 7·5 (95 % CI 1·8, 32·3) 'High added sugar and organ meats' pattern: OR = 22·3 (95 % CI 3·9, 127·4)	GDM	Age, race/ethnicity, family poverty income ratio, education, marital status, energy intake, pre-pregnancy BMI, gestational weight gain, log-transformed CRP
De Seymour *et al.* (2016)[18]	Multi-ethnic Asian cohort; Singapore	909	Sixty-eight-food-group 24 h recall*	2nd & 3rd (26–28 weeks)	PCA	Three patterns: vegetable–fruit–rice-based-diet; seafood–noodle-based-diet; pasta–cheese–processed-meat diet	Vegetable–fruit–rice-based-diet: OR = 1·10 (95 % CI 0·90, 1·35) Seafood–noodle-based-diet: OR = 0·74 (95 % CI 0·59, 0·93) Pasta–cheese–processed-meat diet: OR = 0·96 (95 % CI 0·79, 1·17)	GDM	Energy intake, pregnancy BMI, birth order, smoking, alcohol intake, age, ethnicity, education, previous GDM, family history of diabetes, household monthly income, other dietary patterns
He *et al.* (2015)[19]	Prospective cohort, China	3063	Sixty-four-item FFQ*	2nd (24–27 weeks)	PCA	Four dietary patterns: vegetable pattern; protein-rich food pattern; prudent pattern; sweets and seafood pattern	Vegetable pattern: RR = 0·79 (95 % CI 0·64, 0·97) Sweets and seafood pattern: RR = 1·23 (95 % CI 1·02, 1·49) Protein-rich food pattern: RR = 0·95 (95 % CI 0·78, 1·16) Prudent pattern: RR = 1·00 (95 % CI 0·82, 1·22)	GDM	Maternal age, education level, monthly income, parity, pre-pregnancy BMI, family history of diabetes
Karamanos *et al.* (2014)[40]	Prospective cohort; Jan 2010–Jul 2011; ten Mediterranean countries	1076	Seventy-eight-item FFQ*	2nd & 3rd (24–32 weeks)	MDS	Mediterranean diet index	Mediterranean diet: OR = 0·618 (95 % CI 0·401, 0·950)	GDM	Age, BMI, diabetes in the family, weight gain, energy intake
Nascimento *et al.* (2016)[41]	Prospective cohort; Nov 2011–Feb 2014; Spain	841	Eighty-one-item FFQ*	2nd (15–20 weeks)	PCA	Three patterns: traditional pattern; vegetable and Western pattern; mixed pattern	High tertile *v.* low tertile (3 *v.* 1): Traditional pattern: RR = 0·88 (95 % CI 0·49, 1·58) Mixed pattern: RR = 0·93 (95 % CI 0·51, 1·71) Vegetable and Western pattern: RR = 0·78 (95 % CI 0·43, 1·43)	GDM	BMI, age, education, monthly income, family history of diabetes, parity

Table 2 *Continued*

Study	Study design; period; country	Sample (*n*)	Dietary assessment: Methods	Dietary assessment: Trimester (period)	Methods of defining dietary pattern	Dietary patterns identified	Main findings	Outcomes	Confounding factors
Tryggvadottir *et al.* (2016)[34]	Prospective cohort; Apr 2012–Oct 2013; Iceland	168	Eighteen-food-group & 4 d weighed food record	2nd (19–24 weeks)	PCA	Prudent pattern	Adhering to the prudent pattern: OR = 0·44 (95 % 0·21, 0·90)	GDM	Age, parity, pre-pregnancy weight, energy intake, weekly weight gain, total metabolic equivalents of task
Chia *et al.* (2016)[42]	Cohort study; 2009–2010; Singapore	923	Sixty-eight-food-group 24 h recalls and 3 d food diaries	2nd & 3rd (26–28 weeks)	PCA	Vegetable, fruit and white rice; seafood and noodle; pasta, cheese and processed meat	Adherence to vegetable, fruit and white rice pattern: OR = 0·67 (95 % CI 0·50, 0·91) Adherence to seafood and noodle pattern: OR = 1·27 (95 % CI 0·93, 1·74) Adherence to pasta, cheese and processed meat pattern: OR = 0·79 (95 % CI 0·55, 1·12)	PTB	Infant sex, birth order, maternal TEI, maternal age, ethnicity, pre-pregnancy BMI, weight gain until 26–28 week of gestation, height, GDM status, educational status, alcohol use, smoking during pregnancy, other dietary patterns
Englund-Ogge *et al.* (2014)[9]	Prospective cohort; 2002–2008; Norway	66 000	255-item FFQ*	2nd (17–22 weeks)	PCA	'Prudent'; 'Western'; 'traditional'	Prudent: RR = 0·88 (95 % CI 0·80, 0·97) Western: RR = 1·02 (95 % CI 0·92, 1·13) Traditional: RR = 0·91 (95 % CI 0·83, 0·99)	PTB	Maternal age, pre-pregnancy BMI, height, parity, TEI, maternal education, marital status, smoking, previous preterm delivery, household income, other dietary patterns
Haugen *et al.* (2008)[20]	Cohort; Norway	569	255-item FFQ*	2nd (18–22 weeks)	MDS	Mediterranean diet criteria	Mediterranean diet criteria 5 *v.* 0: OR = 0·73 (95 % CI 0·32, 1·68)	PTB	Parity, BMI, maternal height, SES; cohabitant status
Martin *et al.* (2015)[43]	Prospective cohort; USA	3143	Ninety-five-item FFQ	2nd & 3rd (26–29 weeks)	PCA and DASH	Factor 1; Factor 2; Factor 3; Factor 4	Factor 1: OR = 0·87 (95 % CI 0·60, 1·27) Factor 2: OR = 1·53 (95 % CI 1·02, 2·30) Factor 3: OR = 1·55 (95 % CI 1·07, 2·24) Adherence to DASH diet: OR = 0·59 (95 % CI 0·40, 0·85)	PTB	Maternal age, race, maternal pre-pregnancy BMI status, educational level, household income, parity, marital status, smoking status, energy intake
Rasmussen *et al.* (2014)[21]	Longitudinal cohort; Denmark	59 949	360-item FFQ*	2nd & 3rd (avg. 25 weeks)	PCA	Vegetable/prudent; Western; Seafood	Western pattern: OR = 1·30 (95 % CI 1·13, 1·49) Vegetable/prudent pattern: OR = 1·40 (95 % CI 0·80, 1·62) Seafood pattern: OR = 0·90 (95 % CI 0·72, 1·11)	PTB	Maternal age, maternal height, pre-pregnancy BMI, parity, civil status, SES, smoking during pregnancy
Zerfu *et al.* (2016)[46]	Prospective cohort; Ethiopia	432	Nine-food-group 24 h WDDS	2nd & 3rd (24–28 weeks)	DDS	Nine food groups	Low DDS: RR = 4·61 (95 % CI 2·31, 9·19) High DDS: RR = 0·21 (95 % CI 0·11, 0·43)	PTB	Age, height, MUAC, education, Hb level

Table 2 *Continued*

Study	Study design; period; country	Sample (n)	Dietary assessment: Methods	Dietary assessment: Trimester (period)	Methods of defining dietary pattern	Dietary patterns identified	Main findings	Outcomes	Confounding factors
Mikkelsen *et al.* (2008)[44]	Cohort; Denmark	35 530	360-item FFQ	2nd & 3rd (avg. 25 weeks)	MDS	Mediterranean diet criteria: consumption of fish twice/week; intake of olive or rapeseed oil; high consumption of fruits & vegetables (5/d or more); meat (other than poultry and fish) at most twice/week	Mediterranean diet criteria 5 *v.* 0: OR = 0·61 (95 % CI 0·35, 1·05) Mediterranean diet criteria 5 *v.* 1–4: OR = 0·92 (95 % CI 0·69, 1·24) Note: 5 *v.* 0 means fulfilled ≥5 *v.* no fulfilled criteria	PTB	Parity, BMI, maternal height, SES, cohabitant status
Saunders *et al.* (2014)[45]	Cohort; 2004–2007; French Caribbean island	728 (710 with complete data)	214-item FFQ	Days following delivery	MDS	Nine categories of the Mediterranean diet scale (vegetables, legumes, fruits and nuts, cereals, fish, meat and poultry, dairy products, alcohol, fat)	Adherence to Mediterranean diet: OR = 0·9 (95 % CI 0·8, 1·0)	PTB	Maternal place of birth, marital status, pre-pregnancy BMI, maternal education, enrolment site, weight gain during pregnancy, energy intake, maternal smoking during pregnancy
Abubakari and Jahn (2016)[47]	Cross-sectional; Ghana	578	Fifty-five-item FFQ*	2nd trimester and 0–1 month post-birth	PCA	Non-health conscious; health conscious	Health conscious diet: OR = 0·23 (95 % CI 0·12, 0·45) Non-health conscious diet: OR = 1·04 (95 % CI 0·65, 1·67) High DDS: OR = 0·10 (95 % CI 0·04, 0·13)	LBW	Gestational age
Zerfu *et al.*[46]	Cohort; Ethiopia	432	Nine-food-group 24 h WDDS	2nd & 3rd (24–28 weeks)	DDS	Nine food groups	High DDS: RR = 2·06 (95 % CI 1·03, 4·11)	LBW	Education, age, height, MUAC, and Hb level

WDDS, Women Dietary Diversity Score; avg., average; PCA, principal component analysis; DDS, dietary diversity score; RRR, reduced rank regression; MDS, Mediterranean diet score; DASH, Dietary Approaches to Stop Hypertension; SBP, systolic blood pressure; β, regression coefficient; DBP, diastolic blood pressure; PE, pre-eclampsia; GHTN, gestational hypertension; RR, risk ratio; PTB, preterm birth; GDM, gestational diabetes mellitus; LBW, low birth weight; TEI, total energy intake; MUAC, mid-upper arm circumference; PA, physical activity; CPR, C-reactive protein; SES, socio-economic status.
*Validated FFQ or recall was used.

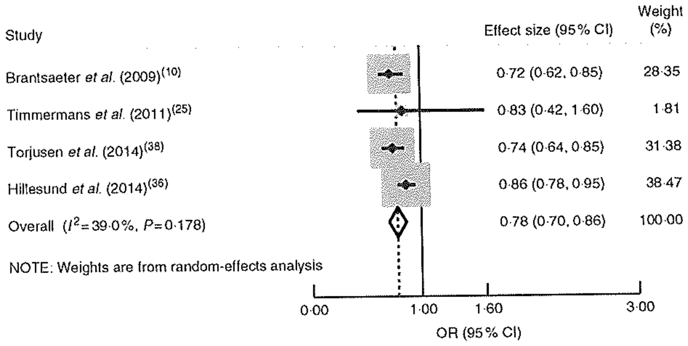


Fig. 2 (colour online) Forest plot for the pooled OR of the association between a healthy dietary pattern and pre-eclampsia. The study-specific OR and 95% CI are represented by the black diamond and the horizontal line, respectively; the area of the grey square is proportional to the specific-study weight to the overall meta-analysis. The centre of the blue open diamond and the red dashed vertical line represent the pooled OR; and the width of the blue open diamond represents the pooled 95% CI

was observed between gestational hypertension and adherence to a Mediterranean pattern (OR = 0·77; 95% CI 0·53, 1·11) or a traditional pattern (OR = 1·3; 95% CI 0·9, 1·9)[25]. Likewise, a cohort study from Brazil[35] revealed that adherence to a healthy dietary pattern did not have an effect on systolic blood pressure (OR = 0·82; 95% CI 0·28, 2·21) or diastolic blood pressure (OR = 0·94; 95% CI 0·18, 1·28).

Western dietary pattern. In a cohort study in Norway[10], a potato and fish dietary pattern (lean fish, cooked potatoes, processed fish; fish burgers, margarine, fish soufflé, meat spread, lean fish and poultry) was not associated with pre-eclampsia (OR = 1·00: 95% CI 0·84, 1·18). Likewise, a cohort study in Brazil[35] reported that adherence to a processed food pattern was not significantly associated with the change in systolic blood pressure (OR = 0·76; 95% CI 0·19, 3·13) and diastolic blood pressure (OR = 0·97; 95% CI 0·30, 3·10) during pregnancy.

Dietary pattern and gestational diabetes mellitus

Healthy dietary pattern. Six studies[18,19,34,39–41] assessed the effect of dietary patterns on GDM. A cohort study in Singapore[18] indicated that a seafood–noodle-based diet was related with lower odds of GDM (OR = 0·74; 95% CI 0·59, 0·93). However, higher *v.* lower adherence to a vegetable–fruit–rice-based diet (OR = 1·10; 95% CI 0·90, 1·35) and a pasta–cheese–processed-meat diet (OR = 0·96; 95% CI 0·79, 1·17) was not associated with GDM. Similarly, adherence to a traditional pattern (RR = 0·88; 95% CI 0·49, 1·58) as well as adherence to a mixed pattern (RR = 0·93; 95% CI 0·51, 1·71) was not associated with the incidence of GDM among Brazilian women[41].

The pooled estimate of a healthy dietary pattern on GDM was determined by using five studies[18,19,34,40,41]. Based on this estimate, women who had higher adherence to a healthy dietary pattern had lower odds of GDM (OR = 0·78; 95% CI 0·56, 0·99), with significant heterogeneity detected between studies (I^2 = 68·6%, P = 0·013; Fig. 3(a)).

Western dietary pattern. Four studies[18,19,39,41] were combined, showing no relationship between adherence to a Western dietary pattern and odds of GDM (OR = 0·94; 95% CI 0·81, 1·07) and no heterogeneity between studies (I^2 = 0·0%, P = 0·825; Fig. 3(b)).

A cross-sectional survey in the USA[39] and a prospective cohort study in China[19] reported that adherence to dietary patterns of refined grains (OR = 4·9; 95% CI 1·4, 17·0), high nuts, seeds, fat and soyabeans, low milk (OR = 7·5; 95% CI 1·8, 32·3), and sweets and seafood (RR = 1·23; 95% CI 1·02, 1·49) during pregnancy was associated with an increased likelihood of GDM.

The association between dietary patterns and adverse birth outcomes (preterm birth and low birth weight)

Dietary pattern and preterm birth

Based on a meta-analysis of nine studies[9,20,21,36,42–46], women who had good adherence to a healthy dietary pattern were shown to have reduced odds of PTB (OR = 0·75; 95% CI 0·57, 0·93), although significant heterogeneity was observed (I^2 = 89·6%, P = 0·0001; Fig. 4(a)). Further subgroup analysis indicated a difference in relation to dietary pattern assessment method (MDS, DDS or PCA; P = 0·001). There was also a significant subgroup difference regarding dietary assessment period (second trimester or both second and third trimesters; P = 0·001; Fig. 4(b)).

On the other hand, the pooled estimate of four studies[9,21,42,43] showed that a Western dietary pattern did not increase the odds of PTB (OR = 1·11; 95% CI 0·87, 1·34; I^2 = 77·8%, P = 0·004; Fig. 4(c)). There were

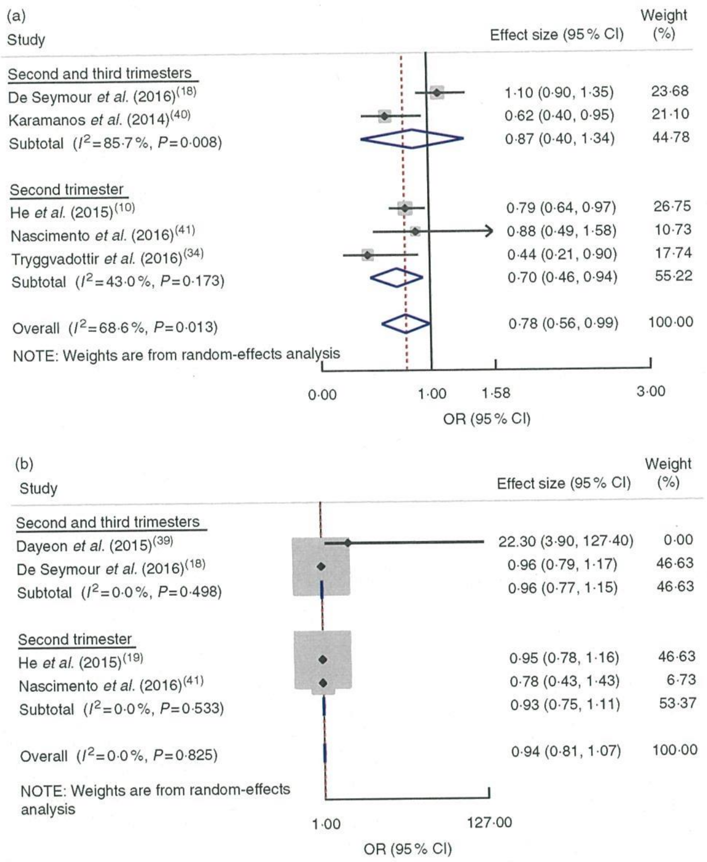


Fig. 3 (colour online) Forest plot for the pooled OR of the association between gestational diabetes mellitus (GDM) and different dietary patterns, with subgroup analysis regarding period of dietary assessment (second trimester *v.* both second and third trimesters): (a) association between GDM and healthy dietary pattern; (b) association between GDM and Western dietary pattern. The study-specific OR and 95 % CI are represented by the black diamond and the horizontal line, respectively; the area of the grey square is proportional to the specific-study weight to the overall meta-analysis. The centre of the blue open diamond and the red dashed vertical line represent the pooled OR; and the width of the blue open diamond represents the pooled 95 % CI

subgroup differences between assessing diet in the second trimester and in both the second and third trimesters with respect to risk of PTB (P = 0·001). We did not undertake a subgroup analysis regarding study design, as all studies had the same design (cohort).

Dietary patterns and low birth weight

Two studies assessed the effect of dietary pattern during gestation on LBW. A study in Ghana[47] reported that a 'health conscious' dietary pattern with a high intake of corn, rice, cassava, yam, fruits, vegetables (carrots, tomatoes, dark green leafy vegetables, cabbage, salad, cucumber), meat and eggs reduced the odds of LBW (OR = 0·23; 95 % CI 0·12, 0·45). Similarly, that study reported that women who had a higher DDS were less likely to deliver an LBW baby *v.* those who had a lower DDS (OR = 0·10; 95 % CI 0·04, 0·13). However, a high consumption of sweetened beverages, ice cream, chocolate, energy drinks, milk and local soft drinks, which was labelled the 'non-health conscious' dietary pattern, was not significantly associated with LBW (OR = 1·04; 95 % CI 0·65, 1·67). Another study in Ethiopia[46] showed that women who had an adequate DDS were less likely to deliver an LBW baby (OR = 0·49; 95 % CI 0·24, 0·97).

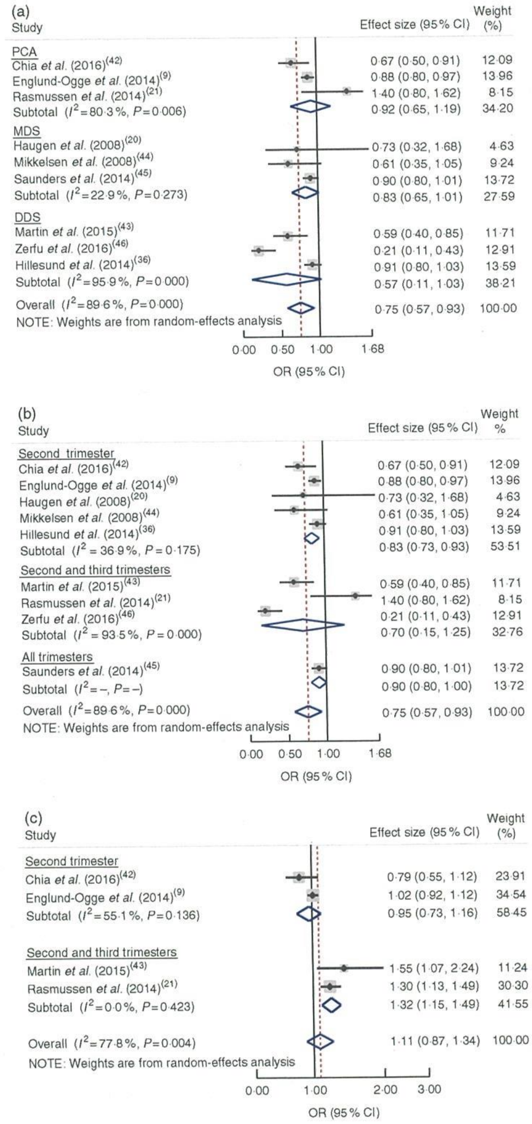


Fig. 4 (colour online) Forest plot for the pooled OR of the association between preterm birth (PTB) and different dietary patterns: (a) association between healthy dietary pattern and PTB, with subgroup analysis in relation to dietary pattern assessment methods (Mediterranean diet score (MDS) v. dietary diversity score (DDS) *v.* principal component analysis (PCA)); (b) association between healthy dietary pattern and PTB, with subgroup analysis regarding period of dietary assessment (second trimester *v.* both second and third trimesters *v.* all trimesters); and (c) association between Western pattern and PTB, with subgroup analysis regarding period of dietary assessment (second trimester *v.* both second and third trimesters). The study-specific OR and 95% CI are represented by the black diamond and the horizontal line, respectively; the area of the grey square is proportional to the specific-study weight to the overall meta-analysis. The centre of the blue open diamond and the red dashed vertical line represent the pooled OR; and the width of the blue open diamond represents the pooled 95% CI

Discussion

The current systematic review and meta-analysis summarizes evidence focusing on the effects of different dietary patterns during pregnancy on adverse pregnancy (HDP and GDM) and birth (PTB and LBW) outcomes. Globally, adverse pregnancy outcomes and nutritional insufficiencies still remain public health problems[48]. Sufficient consumption of energy, protein and micronutrients continues to be essential throughout pregnancy[49].

Hypertensive disorders of pregnancy

The meta-analysis of four studies assessing the healthy diet pattern resulted in pooled estimates suggesting decreased odds of pre-eclampsia. However, other studies reported inconsistent findings on the association between adherence to a healthy dietary pattern and the likelihood of HDP occurrence. A cohort study in the Netherlands[25] revealed that adherence to a Mediterranean diet pattern (vegetables, vegetable oils, pasta, fish, legumes and rice) or a traditional pattern (meat and potatoes) was not associated with gestational hypertension. A cohort study in Brazil[35] revealed that adherence to healthy dietary patterns with high intakes of dairy products, fruit, green vegetables, legumes, fish, cakes, cookies–crackers and tea was not associated with a change in systolic or diastolic blood pressure. On the contrary, a cross-sectional study in Tanzania[37] reported that, compared with a lower score, having a high and medium DDS were associated with increased odds of gestational hypertension.

These inconsistencies might be due to the differences in method and population characteristics. The Tanzanian study was cross-sectional[37] and conducted in a resource-limited setting; however, the other studies were cohort studies conducted in well-resourced settings, except the Brazilian study[35]. These studies also assessed dietary intake using a different number of food items and methods. The Tanzanian study applied a 24 h recall method using sixteen food groups, while the studies from Brazil[35] and the Netherlands[25] assessed dietary intake using an eighty-two-item and a 293-item FFQ, respectively.

The healthy diet pattern is in line with dietary guidelines, which suggest consumption of whole grains, vegetables, fruits, potatoes, pasta, cereals, beans, lentils and fish[50]. Similarly, the beneficiary influence of diets high in fibre, K, fruits, vegetables, cereals, dark bread and low-fat dairy products was reported as decreasing the odds of pre-eclampsia[51]. It was also reported that a lower likelihood of pregnancy-induced hypertension or pre-eclampsia is observed with a diet comprising intake of plant-derived foodstuffs and vegetables[52]. The risk of pregnancy complications like pre-eclampsia and LBW has been linked with maternal oxidative stress in the middle of pregnancy[53]. Evidence indicates that oxidative stress during pregnancy could be reduced by antioxidant compounds from fruit and vegetables[54]. The findings of a multicentre study indicate that oxidative stress could be reduced by sufficient intakes of fruit, vegetables and vitamin C[54]. A combination of vitamin C and E might lower the risk of pre-eclampsia[55] through removal of free radicals which may cause oxidative stress in pregnancy[56]. Therefore, it could be the cumulative effect of nutrients and their biochemical properties that influence pre-eclampsia risk.

Gestational diabetes mellitus

The meta-analyses of five studies assessing the healthy diet pattern resulted in pooled estimates that indicated reduced odds of GDM, but this was not statistically significant, most likely due to insufficient power, since few articles were included. Additionally, there were inconsistent findings among included studies for meta-analysis regarding the healthy dietary patterns and GDM; three studies showed decreased odds of GDM while the remainder reported no association. This might result from unmeasured factors due to the majority of studies not controlling for all possible confounding factors. For instance, He *et al.*[19] could not control for parity, energy intake, blood pressure and family history of type 2 diabetes mellitus. Likewise, parity, energy intake and blood pressure were not adjusted for in the other two studies[40,41]. There was also a difference in assessing dietary intake across these studies, with four studies[18,19,40,41] using a validated FFQ and the other an unvalidated FFQ[34]. The dietary intake was assessed at different trimesters of pregnancy, even though there was no significant difference in subgroup analysis based on dietary intake assessment period. This could be a possible explanation for the variations across different studies.

Evidence indicates that pre-pregnancy adherence to a Mediterranean pattern style, with intake of fruit, vegetables, legumes, nuts, fish and cereals, and to the Dietary Approaches to Stop Hypertension (DASH) diet decreases the odds of GDM[57,58]. Similarly, a clinical trial reported that adhering to the DASH diet, which is high in fruits, vegetables, whole grains and low-fat dairy products, with low amounts of saturated fats, cholesterol and refined grains, reduced the need for insulin treatment[59]. Intake of fibre, fruits and cereals reduced the odds of GDM[60].

A cohort study reported that higher odds of GDM was observed with adherence to a Western dietary pattern, which contained higher intake of refined-grain products, processed meat, red meat, French fries and pizza, sweets and desserts[26]. However, our pooled estimate of four studies did not show a significant relationship between the Western pattern and GDM occurrence. The possible explanation may be the difference in the dietary pattern investigation methods (two studies used FFQ[19,41] and two studies used 24 h recall methods[18,39]) and population (one study was conducted in a Western population[39] and three studies were done in an Asian population[18,19,41]).

Preterm birth

In the current systematic review, a pooled estimate of nine studies indicated that compared with low adherence, higher adherence to a healthy dietary pattern significantly decreased the odds of PTB. Likewise, the pooled estimates of four studies on vegetable pattern and three studies on the Mediterranean diet indicated decreased odds of PTB, but this was not statistically significant. However, the meta-analysis result of four studies assessing the Western pattern and PTB showed that adherence to the Western pattern was not significantly associated with PTB. There were significant differences in subgroup analysis based on dietary intake assessment period. In two articles, the dietary intake was assessed in the second (13–27 weeks) and third (28–40 weeks) trimesters and reported that the Western dietary pattern significantly increased the odds of PTB. Nevertheless, the other two studies assessed the dietary intake in the second trimester (13–27 weeks) and the Western dietary pattern did not significantly increase the odds of PTB. A previous systematic review of randomized controlled trials revealed that macronutrient dietary interventions have reduced PTB[61].

Low birth weight

Two articles assessed the effect of dietary patterns on LBW. A dietary pattern labelled as 'health conscious', characterized by intake of local dishes made from corn flour, vegetables (carrot, tomatoes, dark green leafy vegetables, cabbage, salad, cucumber), rice, meat, a mixture of corn and cassava dough, yam, fruits, water and eggs, was associated with reduced odds of LBW[47]. Similarly, women who had a higher DDS were less likely to deliver an LBW baby[46,47]. However, high consumption of sweetened beverages, ice cream, chocolate, energy drinks, milk and local soft drinks, which was labelled as a 'non-health conscious' dietary pattern, showed a significant effect on risk of LBW[47]. This is in line with the evidence that suggests the occurrence of LBW has decreased through the consumption of foods and fortified foodstuffs[62].

It is suggested that pregnant women should be advised to eat a diet rich in fruits and vegetables, whole grains, beans, lean meats and fish/seafood, and low in added sugar, red meat and processed foods[63]. Intake of vegetables, fruits and legumes improves micronutrient and antioxidant intakes, which could improve pregnancy and birth outcomes[63], particularly at the second trimester since oxidative stress has been shown to reach high levels mid-pregnancy[64]. Pregnancy complications and adverse outcomes like pre-eclampsia and PTB have been related to oxidative stress and associated inflammation[53]. Antioxidant vitamins (C and E) and essential trace elements (Cu and Zn) through dietary intake of legumes and fruits, which are rich in these nutrients, could decrease this risk[65–67]. Oxidative stress-linked adverse pregnancy outcomes could be reduced by antioxidants through an intake of vegetables and fruits[68].

Study limitations

The limitations of the present systematic review must be acknowledged. To acquire complete dietary data, most of the articles reviewed applied FFQ followed by diet scores. Nevertheless, there are unavoidable dietary intake misclassifications, which probably bias the degree of detecting real effects. Furthermore, problems of recall bias are also unavoidable because dietary information is dependent on memory. Including articles written only in the English language is another shortcoming of the systematic review. Due to the nature of nutritional research, it is difficult to make all dietary exposures similar for all study subjects. Heterogeneity among studies is a further issue; however, meta-analysis permits the inconsistent findings among studies to be evaluated, even with heterogeneity[69]. As all included studies were observational epidemiological studies, the effect of confounders may be another limitation of the current review, despite controlling for some possible confounding factors. Publication bias is always a concern in any review. Reviewed studies that had negative results might not have been submitted for publication, and thus are less likely to have been published.

Conclusion

The evidence presented in the current systematic review indicates the inconsistent associations between different dietary patterns and pregnancy and birth outcomes. Some results in the systemic review show the importance of healthy dietary intake during gestation to improve pregnancy and birth outcomes for the mother and infant, even though inconsistencies have been observed among studies. Essentially, the review suggests that dietary patterns with higher intake of whole grains, vegetables/fruits, legumes and fish are associated with lower likelihood of adverse pregnancy and birth outcomes. However, as the evidence presented herein is inconsistent regarding the association between dietary intake and pregnancy and birth outcomes, caution should be given during advising pregnant women about diet. Since most of the articles included in the review were conducted in resource-rich settings, additional studies need to be done in resource-limited settings to elucidate the impact of limited resources on dietary intake and adverse pregnancy and birth outcomes.

Acknowledgements

Acknowledgements: The authors would like to thank Debbie Booth for her help with developing the literature search strategy and use of Endnote. The authors would also like to thank Dr Ryan O'Neill for his unreserved help in editing the English language. *Financial support:* This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Conflict of interest: The authors declare that they have no conflicting interests. *Authorship:* K.T.K., C.C., D.L. and E.G. formulated the research questions. K.T.K., C.C., D.L. and E.G. designed the study. K.T.K., C.C., D.L., E.G. and T.K.T. carried out the analysis. K.T.K., C.C., D.L., E.G. and T.K.T. analysed the data and wrote the manuscript. *Ethics of human subject participation:* Not applicable.

References

1. American College of Obstetricians and Gynecologists (2013) Hypertension in pregnancy. Report of the American College of Obstetricians and Gynecologists' Task Force on Hypertension in Pregnancy. *Obst Gynecol* **122**, 1122–1131.
2. Say L, Chou D, Gemmill A *et al.* (2014) Global causes of maternal death: a WHO systematic analysis. *Lancet Glob Health* **2**, e323–e333.
3. Gemmell L, Martin L, Murphy KE *et al.* (2016) Hypertensive disorders of pregnancy and outcomes of preterm infants of 24 to 28 weeks' gestation. *J Perinatol* **36**, 1067–1072.
4. Lawn JE, Gravett MG, Nunes TM *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 Childbirth* **10**, Suppl. 1, S1.
5. Blencowe H, Cousens S, Chou D *et al.* (2013) Born too soon: the global epidemiology of 15 million preterm births. *Reprod Health* **10**, Suppl. 1, S2.
6. Blencowe H, Cousens S, Oestergaard MZ *et al.* (2012) National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: a systematic analysis and implications. *Lancet* **379**, 2162–2172.
7. Ramakrishnan U (2004) Nutrition and low birth weight: from research to practice. *Am J Clin Nutr*, **79**, 17–21.
8. Mahumud RA, Sultana M & Sarker AR (2017) Distribution and determinants of low birth weight in developing countries. *J Prev Med Public Health* **50**, 18–28.
9. Englund-Ogge L, Brantsaeter AL, Sengpiel V *et al.* (2014) Maternal dietary patterns and preterm delivery: results from large prospective cohort study. *BMJ* **348**, g1446.
10. Brantsaeter AL, Haugen M, Samuelsen SO *et al.* (2009) A dietary pattern characterized by high intake of vegetables, fruits, and vegetable oils is associated with reduced risk of preeclampsia in nulliparous pregnant Norwegian women. *J Nutr* **139**, 1162–1168.
11. Jacques PF & Tucker KL (2001) Are dietary patterns useful for understanding the role of diet in chronic disease? *Am J Clin Nutr* **73**, 1–2.
12. Hu FB (2002) Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol* **13**, 3–9.
13. Wirfält E, Drake I & Wallström P (2013) What do review papers conclude about food and dietary patterns? *Food Nutr Res* **57**, 20523.
14. Kant AK (2004) Dietary patterns and health outcomes. *J Am Diet Assoc* **104**, 615–635.
15. Food Agriculture and Organization of the United Nations & Family Health International 360 (2016) *Minimum Dietary Diversity for Women: A Guide for Measurement.* Rome: FAO.
16. Ocke MC (2013) Evaluation of methodologies for assessing the overall diet: dietary quality scores and dietary pattern analysis. *Proc Nutr Soc* **72**, 191–199.
17. Rifas-Shiman SL, Rich-Edwards JW, Kleinman KP *et al.* (2009) Dietary quality during pregnancy varies by maternal characteristics in Project Viva: a US cohort. *J Am Diet Assoc* **109**, 1004–1011.
18. De Seymour J, Chia A, Colega M *et al.* (2016) Maternal dietary patterns and gestational diabetes mellitus in a multi-ethnic Asian cohort: the GUSTO study. *Nutrients* **8**, E574.
19. He JR, Yuan MY, Chen NN *et al.* (2015) Maternal dietary patterns and gestational diabetes mellitus: a large prospective cohort study in China. *Br J Nutr* **113**, 1292–1300.
20. Haugen M, Meltzer HM, Brantsaeter AL *et al.* (2008) Mediterranean-type diet and risk of preterm birth among women in the Norwegian Mother and Child Cohort Study (MoBa): a prospective cohort study. *Acta Obstet Gynecol Scand* **87**, 319–324.
21. Rasmussen MA, Maslova E, Halldorsson TI *et al.* (2014) Characterization of dietary patterns in the Danish national birth cohort in relation to preterm birth. *PLoS One* **9**, e93644.
22. Kjøllesdal MKR & Holmboe-Ottesen G (2014) Dietary patterns and birth weight – a review. *AIMS Public Health* **1**, 211–225.
23. Agrawal S, Fledderjohann J, Vellakkal S *et al.* (2015) Adequately diversified dietary intake and iron and folic acid supplementation during pregnancy is associated with reduced occurrence of symptoms suggestive of pre-eclampsia or eclampsia in Indian women. *PLoS One* **10**, e0119120.
24. Borgen I, Aamodt G, Harsem N *et al.* (2012) Maternal sugar consumption and risk of preeclampsia in nulliparous Norwegian women. *Eur J Clin Nutr* **66**, 920–925.
25. Timmermans S, Steegers-Theunissen RPM, Vujkovic M *et al.* (2011) Major dietary patterns and blood pressure patterns during pregnancy: the Generation R Study. *Am J Obstet Gynecol* **205**, 337.e1–e12.
26. Zhang C, Schulze MB, Solomon CG *et al.* (2006) A prospective study of dietary patterns, meat intake and the risk of gestational diabetes mellitus. *Diabetologia* **49**, 2604–2613.
27. Poon AK, Yeung E, Boghossian N *et al.* (2013) Maternal dietary patterns during third trimester in association with birthweight characteristics and early infant growth. *Scientifica (Cairo)* **2013**, 786409.
28. Academy of Nutrition and Dietetics (2016) *Evidence Analysis Manual: Steps in the Academy Evidence Analysis Process.* Chicago, IL: Research, International and Strategic Business Development Team, Academy of Nutrition and Dietetics; available at https://www.andeal.org/vault/2440/web/files/2016_April_EA_Manual.pdf
29. Zhang J & Yu KF (1998) What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. *JAMA* **280**, 1690–1691.
30. Higgins JP & Green S (editors) (2011) *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0.* The Cochrane Collaboration; available at http://www.handbook.cochrane.org
31. Wiest MM, Lee KJ & Carlin JB (2015) Statistics for clinicians: An introduction to logistic regression. *J Paediatr Child Health* **51**, 670–673.
32. Pryor ER (2010) *Logistic Regression: A Self-Learning Text*, 3rd ed. New York: Springer.
33. Borenstein M, Hedges LV, Higgins JPT *et al.* (2009) *Introduction to Meta-Analysis*, 1st ed. Chichester: John Wiley & Sons Ltd.
34. Tryggvadottir EA, Medek H, Birgisdottir BE *et al.* (2016) Association between healthy maternal dietary pattern and risk for gestational diabetes mellitus. *Eur J Clin Nutr* **70**, 237–242.
35. Eshriqui I, Vilela AAF, Rebelo F *et al.* (2016) Gestational dietary patterns are not associated with blood pressure changes during pregnancy and early postpartum in a Brazilian prospective cohort. *Eur J Nutr* **55**, 21–32.
36. Hillesund ER, Overby NC, Engel SM *et al.* (2014) Associations of adherence to the New Nordic Diet with risk of preeclampsia and preterm delivery in the Norwegian Mother and Child Cohort Study (MoBa). *Eur J Epidemiol* **29**, 753–765.

37. Mwanri AW, Kinabo JL, Ramaiya K *et al.* (2015) High blood pressure and associated risk factors among women attending antenatal clinics in Tanzania. *J Hypertens* **33**, 940–947.
38. Torjusen H, Brantsaeter AL, Haugen M *et al.* (2014) Reduced risk of pre-eclampsia with organic vegetable consumption: results from the prospective Norwegian Mother and Child Cohort Study. *BMJ Open* **4**, e006143.
39. Dayeon S, Kyung Won L & Won OS (2015) Dietary patterns during pregnancy are associated with risk of gestational diabetes mellitus. *Nutrients* **7**, 9369–9382.
40. Karamanos B, Thanopoulou A, Anastasiou E *et al.* (2014) Relation of the Mediterranean diet with the incidence of gestational diabetes. *Eur J Clin Nutr* **68**, 8–13.
41. Nascimento GR, Alves LV, Fonseca CL *et al.* (2016) Dietary patterns and gestational diabetes mellitus in a low income pregnant women population in Brazil – a cohort study. *Arch Latinoam Nutr* **66**, 301–308.
42. Chia AR, de Seymour JV, Colega M *et al.* (2016) A vegetable, fruit, and white rice dietary pattern during pregnancy is associated with a lower risk of preterm birth and larger birth size in a multiethnic Asian cohort: the Growing Up in Singapore Towards healthy Outcomes (GUSTO) cohort study. *Am J Clin Nutr* **104**, 1416–1423.
43. Martin CL, Sotres-Alvarez D & Siega-Riz AM (2015) Maternal dietary patterns during the second trimester are associated with preterm birth. *J Nutr* **145**, 1857–1864.
44. Mikkelsen TB, Osterdal ML, Knudsen VK *et al.* (2008) Association between a Mediterranean-type diet and risk of preterm birth among Danish women: a prospective cohort study. *Acta Obstet Gynecol Scand* **87**, 325–330.
45. Saunders L, Guldner L, Costet N *et al.* (2014) Effect of a Mediterranean diet during pregnancy on fetal growth and preterm delivery: results from a French Caribbean Mother–Child Cohort Study (TIMOUN). *Paediatr Perinat Epidemiol* **28**, 235–244.
46. Zerfu TA, Umeta M & Baye K (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. *Am J Clin Nutr* **103**, 1482–1488.
47. Abubakari A & Jahn A (2016) Maternal dietary patterns and practices and birth weight in northern Ghana. *PLoS One* **11**, e0162285.
48. Gernand AD, Schulze KJ, Stewart CP *et al.* (2016) Micronutrient deficiencies in pregnancy worldwide: health effects and prevention. *Nat Rev Endocrinol* **12**, 274–289.
49. Wakimoto P, Akabike A & King JC (2015) Maternal nutrition and pregnancy outcome – a look back. *Nutr Today* **50**, 221–229.
50. World Health Organization (2001) *Healthy Eating during Pregnancy and Breastfeeding: Booklet for Mothers.* Copenhagen: WHO Regional Office for Europe, Nutrition and Food Security.
51. Frederick IO, Williams MA, Dashow E *et al.* (2005) Dietary fiber, potassium, magnesium, and calcium in relation to preeclampsia risk. *J Reprod Med* **50**, 322–344.
52. Pistollato F, Sumalla Cano S, Elio I *et al.* (2015) Plant-based and plant-rich diet patterns during gestation: beneficial effects and possible shortcomings. *Adv Nutr* **6**, 581–591.
53. Hsieh TT, Chen SF, Lo LM *et al.* (2012) The association between maternal oxidative stress at mid-gestation and subsequent pregnancy complications. *Reprod Sci* **19**, 505–512.
54. Kim H, Hwang JY, Ha EH *et al.* (2011) Fruit and vegetable intake influences the association between exposure to polycyclic aromatic hydrocarbons and a marker of oxidative stress in pregnant women. *Eur J Clin Nutr* **65**, 1118–1125.
55. Raijmakers MT, Dechend R & Poston L (2004) Oxidative stress and preeclampsia: rationale for antioxidant clinical trials. *Hypertension* **44**, 374–380.
56. Siddiqui IA, Jaleel A, Tamimi W *et al.* (2010) Role of oxidative stress in the pathogenesis of preeclampsia. *Arch Gynecol Obstet* **282**, 469–474.
57. Tobias DK, Cuilin Z, Chavarro J *et al.* (2012) Prepregnancy adherence to dietary patterns and lower risk of gestational diabetes mellitus. *Am J Clin Nutr* **96**, 289–295.
58. Schoenaker D, Soedamah-Muthu SS & Mishra GD (2016) Quantifying the mediating effect of body mass index on the relation between a Mediterranean diet and development of maternal pregnancy complications: the Australian Longitudinal Study on Women's Health. *Am J Clin Nutr* **104**, 638–645.
59. Asemi Z, Samimi M, Tabassi Z *et al.* (2014) The effect of DASH diet on pregnancy outcomes in gestational diabetes: a randomized controlled clinical trial. *Eur J Clin Nutr* **68**, 490–495.
60. Zhang C, Liu S, Solomon CG *et al.* (2006) Dietary fiber intake, dietary glycemic load, and the risk for gestational diabetes mellitus. *Diabetes Care* **29**, 2223–2230.
61. Gresham E, Bisquera A, Byles JE *et al.* (2016) Effects of dietary interventions on pregnancy outcomes: a systematic review and meta-analysis. *Matern Child Nutr* **12**, 5–23.
62. Gresham E, Byles JE, Bisquera A *et al.* (2014) Effects of dietary interventions on neonatal and infant outcomes: a systematic review and meta-analysis. *Am J Clin Nutr* **100**, 1298–1321.
63. King JC (2006) Maternal obesity, metabolism, and pregnancy outcomes. *Annu Rev Nutr* **26**, 271–291.
64. Casanueva E & Viteri FE (2003) Iron and oxidative stress in pregnancy. *J Nutr* **133**, 5 Suppl. 2, 1700S–1708S.
65. Mistry HD & Williams PJ (2011) The importance of antioxidant micronutrients in pregnancy. *Oxid Med Cell Longev* **2011**, 841749.
66. Al-Gubory KH, Fowler PA & Garrel C (2010) The roles of cellular reactive oxygen species, oxidative stress and antioxidants in pregnancy outcomes. *Int J Biochem Cell Biol* **42**, 1634–1650.
67. Zhang Y, Zhou H, Perkins A *et al.* (2017) Maternal dietary nutrient intake and its association with preterm birth: a case–control study in Beijing, China. *Nutrients* **9**, E221.
68. Asemi Z, Samimi M, Tabassi Z *et al.* (2013) A randomized controlled clinical trial investigating the effect of DASH diet on insulin resistance, inflammation, and oxidative stress in gestational diabetes. *Nutrition* **29**, 619–624.
69. Higgins JP, Thompson SG, Deeks JJ *et al.* (2003) Measuring inconsistency in meta-analyses *BMJ* **327**, 557–560.

Appendix 20: [Published manuscript] The spatial distribution and determinant factors of anaemia among women—a multilevel and spatial analysis

Open access Research

BMJ Open

Spatial distribution and determinant factors of anaemia among women of reproductive age in Ethiopia: a multilevel and spatial analysis

Kelemu Tilahun Kibret,[1] Catherine Chojenta,[1] Ellie D'Arcy,[1,2] Deborah Loxton[1]

To cite: Kibret KT, Chojenta C, D'Arcy E, *et al*. Spatial distribution and determinant factors of anaemia among women of reproductive age in Ethiopia: a multilevel and spatial analysis. *BMJ Open* 2019;9:e027276. doi:10.1136/bmjopen-2018-027276

► Prepublication history and additional material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2018-027276).

Received 16 October 2018
Revised 23 January 2019
Accepted 18 February 2019

[1]Priority Research Center for Generational Health and Aging, School of Medicine and Public Health, University of Newcastle, Newcastle, New South Wales, Australia
[2]Western New South Wales, Local Health District, Dubbo, New South Wales, Australia

Correspondence to
Mr Kelemu Tilahun Kibret; ktwu27@gmail.com

ABSTRACT

Objective The aim of this study was to assess the spatial distribution and determinant factors of anaemia among reproductive age women in Ethiopia.

Methods An in-depth analysis of the 2016 Ethiopian Demographic and Health Survey data was undertaken. Getis-Ord Gi* statistics were used to identify the hot and cold spot areas for anaemia among women of reproductive age. A multilevel logistic regression model was used to identify independent predictors of anaemia among women of reproductive age.

Results Older age (adjusted OR [AOR]=0.75; 95% CI 0.64 to 0.96), no education (AOR=1.37; 95% CI 1.102 to 1.72), lowest wealth quantile (AOR=1.29; 95% CI 1.014 to 1.60), currently pregnant (AOR=1.28; 95% CI 1.10 to 1.51, currently breast feeding (AOR=1.09; 95% CI 1.025 to 1.28), high gravidity (AOR=1.39; 95% CI 1.13 to 1.69) and HIV positive (AOR=2.11; 95% CI 1.59 to 2.79) are individual factors associated with the occurrence of anaemia. Likewise, living in a rural area (AOR=1.29; 95% CI 1.02 to 1.63) and availability of unimproved latrine facilities (AOR=1.18; 95% CI 1.01 to 1.39) are community-level factors associated with higher odds of anaemia. The spatial analysis indicated that statistically high hotspots of anaemia were observed in the eastern (Somali, Dire Dawa and Harari regions) and north-eastern (Afar) parts of the country.

Conclusion The prevalence rate of anaemia among women of reproductive age varied across the country. Significant hotspots/high prevalence of anaemia was observed in the eastern and north-eastern parts of Ethiopia. Anaemia prevention strategies need to be targeted on rural residents, women with limited to no education, women who are breast feeding, areas with poor latrine facilities and women who are HIV positive.

Strengths and limitations of this study

- ► Used large population-based data with a large sample size, which is representative of all regions of the country.
- ► A combination of statistical methods (spatial analysis and multilevel logistics analysis) were applied, which allows understanding of the role of contextual and geographical factors in the occurrence of anaemia among women of reproductive age.
- ► The cause/effect and temporal relationship could not be established due to the cross sectional nature of the data.
- ► Essential factors such as dietary intake and behavioural factors were unable to be incorporated in the analysis.

INTRODUCTION

Anaemia refers to a low haemoglobin level (<110 g/L for pregnant women and <120 g/L for non-pregnant women).[1] If an individual's haemoglobin level is low, the red blood cells are unable to carry adequate oxygen for the body's physiological needs.[1] Anaemia is a major public health problem in women and children under 5 years of age.[2] Worldwide, 38% of pregnant women and 29% of non-pregnant women were anaemic in 2011.[2] Pregnant women in low-income and middle-income countries (LMICs) experience high rates of anaemia, in which the highest prevalence rates are reported in Central and West Africa (56%), South Asia (52%) and East Africa (36%).[2] Similarly, a large proportion of non-pregnant women were reportedly anaemic in West and Central Africa (48%), South Asia (47%) and East Africa (28%).[2] Anaemia can have negative effects on a woman's health including maternal mortality and severe morbidity,[3] depression,[4 5] raised blood pressure,[6 7] as well as negative influences on the infant including low birth weight and preterm birth.[8] Thus, anaemia remains one of the global health priority areas at the global level, particularly in resource-limited settings.[9] Reducing anaemia is considered as an essential part of improving the health of women, and the WHO has set a global target of achieving 50% reduction of anaemia among women of reproductive age by 2025.[10]

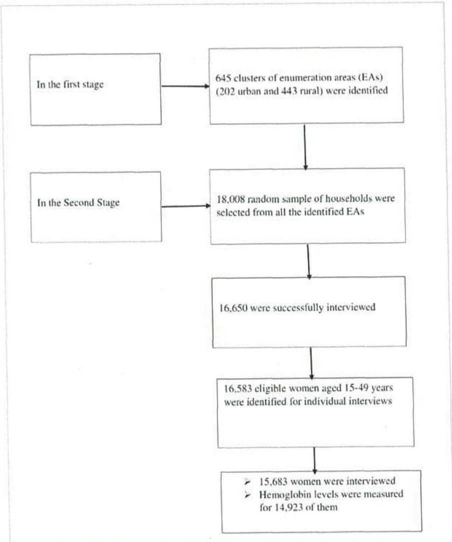


Figure 1 Selection of the sample in the 2016 EDHS. EDHS, Ethiopian Demographic Health Survey.

Anaemia is also a common problem in Ethiopia; the recent Ethiopian Demographic Health Survey (EDHS 2016) reported 29% prevalence of anaemia among pregnant women and 24% among women of reproductive age; these prevalence rate ranging from 16% to 59% across different parts of the country.[11] Likewise, in several pocket studies from different parts of the country, researchers reported varied anaemia prevalence rates among pregnant women, which ranged from 17% in the north,[12] 32% in the south[13] and up to 44%[14] and 57%[15] in the eastern part of Ethiopia. Similarly, in different studies, there was reported to be a 16%[16] prevalence of anaemia among non-pregnant women and 29%[17] and 30%[18 19] among women of reproductive age.

There are a number of different factors contributing to the burden of anaemia, with iron deficiency the main cause of the disease.[20] Other micronutrients (vitamin A, vitamin B_{12} and folate), chronic bleeding, acute or chronic infections and parasitic infections (hookworm and malaria) are also known to cause anaemia.[16 21–23] Based on the geographic distribution and disease burden in LMIC, about half of anaemia cases are attributable to a deficiency of iron and the remainder may be due to diseases like parasitic infections, malaria and HIV.[24] A recent systematic review revealed that the proportion of anaemia caused by iron deficiency was below 50% in LMIC, with regional variations, poor sanitary conditions and subsequent increased occurrence of infections also contributing to anaemia.[25]

In Ethiopia, varied prevalence rates of anaemia among women have been observed with different factors across different parts of the country.[12 15] For instance, large family size, low education status, rural residence, hookworm infestation and HIV infection were identified as factors contributing to anaemia in northern Ethiopia,[12 26] while in studies from the eastern area, it was reported that multigravidas, third trimester of pregnancy and intestinal infestation were factors contributing to anaemia during pregnancy.[14 27] The variation in rates of anaemia among women in Ethiopia might be due to the presence of diverse contextual and geographically variable factors including diet and the incidence of communicable diseases.[9]

To date, spatial analyses have not been conducted to identify areas with hotspots (high prevalence rates) of anaemia among reproductive age women in Ethiopia. Assessing the geographic distributions of anaemia and the impact of risk factors on disease prevalence by area is important to prioritise and design targeted prevention and intervention programmes to address anaemia in women.[28] In addition, the burden of anaemia has been used as a measurable indicator of soil-transmitted helminthiasis, so understanding the geographical distribution of anaemia can help target prevention and control mechanisms for parasitic infections such as these.[29]

Thus, the aims of this study were to assess the spatial distribution and determinant factors of anaemia among women of reproductive age women in Ethiopia.

METHODS

Patient and public involvement

This study used a publicly available data set (EDHS 2016); therefore, there were no patients or members of the public involved.

Study design and setting

An in-depth analysis of the EDHS 2016 data was undertaken for this study. EDHS 2016 was a population-based cross-sectional study conducted across the country. It is the fourth national survey conducted in all parts of Ethiopia (in nine regional states [Tigray, Afar, Amhara, Oromia, Somali, Benishangul-Gumuz, Southern Nations, Nationalities and Peoples' Region [SNNPR], Gambella and Harari] and two city administrations [Addis Ababa and Dire Dawa]).[11] In Ethiopia, the states are administratively further subdivided into zones, zones into *Woredas* and *Woredas* further into the lowest unit called *Kebeles*.

Sampling and data measurements

In the 2016 EDHS, stratified and cluster multistage sampling was used, and it was intended to be representative at the regional and national level in terms of appropriate demographic and health indicators. In the first stage, 645 clusters of enumeration areas (EAs) (202 urban and 443 rural) were identified using probability proportional to the size of EAs. In the second stage, a random sample of 18008 households were selected from all the

Kibret KT, *et al*. *BMJ Open* 2019;9:e027276. doi:10.1136/bmjopen-2018-027276

identified EAs. A total of 15683 women aged 15–49 years were interviewed, and haemoglobin levels were measured for 14923 of them[11] (figure 1). Data collection took place from 18 January 2016 to 27 June 2016.

The sample size for EDHS was determined based on the multistage sampling procedure, taking into consideration the sampling variation. SEs were computed using the Taylor linearisation method. The design effect, which is the ratio between the SE with the given sample design and the SE that would result if a simple random sample had been used, was determined.[11]

Haemoglobin levels of the women were measured using HemoCue, which is the standard test used in the EDHS 2016, and all haemoglobin values were adjusted for both altitude and smoking status.[11] Pregnant women with a haemoglobin value <110 g/L and non-pregnant women with a haemoglobin value <120 g/L were considered anaemic.[1] Similarly, anaemia was classified according to its severity as severe (haemoglobin value <70 g/L), moderate (70 – 99 g/L) in all women and mild (100.0 – 109 g/L) in pregnant women and non-pregnant women (100 – 119 g/L).[1]

Explanatory variables (determinant factors)

Both individual-level and community-level factors were used. The individual-level and community-level factors included in this study are presented in online supplementary table 1 with their definition and coding. The variables were selected based on the literature review for factors affecting anaemia,[12 14 26 27] and sociodemographic, maternal as well as community level factors were identified as important factors for the occurrence of anaemia. Therefore, all the available variables in the data set were included for the analysis. Individual factors included age, religion, marital status, educational status, body mass index, birth interval, use of contraceptives, wealth index, family size, iron-folate intake and gravidity of women, while the community level factors were residence (urban and rural), region, water source and latrine facility type. Community-level measures could also be driven by aggregating individual level variables, for example, the proportion of women in the community who are in the top quantile of wealth index and proportion of women in the community who have clean water access. Community-level factors describe the group of populations living in similar settings.

The assumption of independence of observation has been taken as a basis to determine which variables are analysed at individual and community level. If the observations at the individual level are independent, variables were treated as individual-level factors. Whereas, if the observations were clustered into higher levels of units and if several women have shared features such as place of residence, types of water source, latrine facility and region that could have the same effect on anaemia among women in the locality, then variables are analysed at the community level.

DATA ANALYSIS

Spatial analysis

Spatial analyses were performed using Geoda V.1.8.10 (geodacenter.github.ib), QGIS V.2.18.0 (qgis.org) and Arch GIS software V.10.1 (arcgis.com), and base files of the administrative regions for Ethiopia were obtained from DIVA (diva-gis.org). The spatial analysis was conducted by joining the occurrence of anaemia (as proportions) with each cluster to the corresponding geospatial location (survey cluster values). The values of Demographic Health Survey data were merged with the geographic poisoning system (GPS) dataset in Geoda software, and these values were imported into the QGIS software. Anaemia proportions were then computed at lower (cluster), zonal and regional levels using QGIS.

The spatial pattern of the rate of anaemia among women of reproductive age was visualised, and a spatially smoothed proportion was obtained through empirical Bayes estimation methods.[30] The smoothed proportions present clearer patterns, where the problem was most severe. The spatial empirical Bayes 'smooth' estimates technique was able to deal with spatial heterogeneity. The estimation technique guarantees that estimates of neighbouring states are more alike than estimates of states that are further away.[31]

A standardised prevalence rate, or the ratio of the observed prevalence rate to a national prevalence rate, was determined using Geoda software.[31] Geoda implements this in the form of an excess risk estimate as part of the map. The excess risk rate is the ratio of the observed rate to the average rate computed for all the data.[31]

Furthermore, a spatial analysis was performed to identify the clustering of anaemia in women or hotspot areas (the areas that have higher anaemia prevalence rates compared with the national average) in different regions of Ethiopia. Spatial analysis is an epidemiological method useful to specify geographic areas with high or low rates of disease occurrence and variability over the region or country.[32] Getis-Ord Gi* statistics was used for this spatial analysis. Local Getis-Ord Gi* statistics[33] are important to identify the hot and cold spot areas for anaemia in reproductive age women using GPS latitude and longitude coordinate readings that were taken at the nearest community centre for EAs or EDHS 2016 clusters.[11] An anaemia hotspot refers to the occurrence of high prevalence rates of anaemia clustered together on the map, whereas cold spots refers to the occurrence of low prevalence rates of anaemia clustered together on the map.[33]

A local Getis-Ord G-statistic tool in ArcGIS was used to calculate the spatial variability of high and low prevalence rates of anaemia among women of reproductive age. An autocorrelation can be classified into positive and negative correlations through the local Getis-Ord G statistics.[33] Positive autocorrelation occurs when similar values clustered together on a map (high rates surrounded by nearby high rates or low rates surrounded by nearby low rates). Negative autocorrelation indicates different values clustered together on a map, that is, high values surrounded by nearby low values or low values surrounded by nearby high values. Statistical significance of autocorrelation was determined by z-scores and p value with a 95% level of confidence. The distribution and variations of anaemia prevalence rates among women across the country were displayed on the map.

Statistical analysis

The descriptive statistical analysis was performed using SPSS software V.24.0 (www.spss.com) by complex sample analysis. Frequencies, percentage and SD were used for the descriptive analysis. Since some regions with small populations were oversampled, while others with large population were under-represented, the weighted frequencies and percentages (based on population size of each region) were computed as a correction. The detailed weighting procedure was described in EDHS 2016 report.[11] The mean and SD were computed for blood haemoglobin level. The mean haemoglobin value was also compared across different independent categorical variables using one-way analysis of variance or independent t-test.

The multivariable multilevel logistic regression model was used to determine the effect of different factors on anaemia among women. The analysis was performed by using SAS V.9.4 software (www.sas.com) using Proc Glimmix with Laplace's method. For this multilevel analysis, four models were constructed. The first model was constructed without independent variables to assess the effect of community variation on anaemia among women. Individual-level factors were incorporated in the second model. In the third model, community-level factors were included. Finally, both individual-level and community-level factors were included in the fourth model.

The results of fixed effects were presented as OR with 95% CIs. An adjusted OR (AOR) with 95% CIs was computed to identify the independent factors of anaemia among women, and a p value <0.05 was used as a measure of statistical significance. A muliticollinearity test was done in order to rule out a significant correlation between variables. If the values of variance inflation factor (VIF) was lower than 10, then the collinearity problem was considered as less likely. The random effects (variation of effects) were measured by intracluster correlation coefficient (ICC) (variance partition coefficient),[34] percentage change in variance (PCV)[35] and median OR (MOR),[34 36] which measure the variability between clusters in the multilevel models. ICC explains the cluster variability, while MOR can quantify unexplained cluster variability (heterogeneity). MOR translates cluster variance into OR scale. In the multilevel model, PCV can measure the total variation due to factors at the community and individual level.[35] The ICC, PCV and MOR were determined using the estimated variance of clusters using the following formula[34 35]:

$ICC = \frac{V}{\left(V + \frac{\pi^2}{3}\right)}$ $MOR = \exp\sqrt{2 \times V \times 0.6745} \sim \exp(0.95\sqrt{V})]$

where V is the estimated variance of clusters

and

$PCV = \frac{(V_A - V_B)}{V_B} \times 100$

where V_A=variance of the initial model; V_B=variance of the model with more terms.

The multilevel analysis model is one of the analysis methods that can correctly handle the correlated data.[37] A multilevel model evaluates how factors at different levels affect the dependent variable. A multilevel model provides correct parameter estimates by correcting the biases introduced from clustering by producing correct SEs, thus producing correct CI, and significance tests.[37]

Ethical consideration

Publicly available EDHS 2016 data were used for this study. Informed consent was taken from each participant, and all identifiers were removed.

RESULTS

Sociodemographic characteristics

The data on 14923 women were included in this analysis, including 642 clusters nested in 11 regions. The descriptive statistics of the study participants are presented in table 1. The mean (±SD) age of the respondents was 28.2 years (±9.2 years). The majority of participants lived in a rural area (78%). Nearly two-thirds (66%) of participants were married or living with a partner. Almost half (48%) of the women had no formal education, and around 43% were followers of the Orthodox Tewahdo Christian religion. Only 18% of the households had access to a piped water source for drinking, and 15% had access to an improved latrine facility. Nearly one-third (n=4657; 31.2%) of women were breast feeding at the time of the survey (table 1). The average haemoglobin level among lactating mothers was 126g/L (± 17g/L), and about 28.3% (95% CI 25.7% to 31.0%) of these women were anaemic.

Prevalence rate of anaemia among women

Among all respondents, the mean (±SD) blood haemoglobin level (adjusted for altitude) was 128g/L (±17 g/L). The overall prevalence of anaemia among women of reproductive age across the country was 23.6% (95% CI 22.0 to 25.3). The prevalence of mild, moderate and severe anaemia among all women of reproductive age were 17.8% (95% CI 16.7 to 19), 5.0% (95% CI 4.3 to 5.8) and 0.8% (95% CI 0.5 to 1.2), respectively. There was regional variation in anaemia prevalence among women of reproductive age (p=0.0001) and higher prevalence rates observed in Afar, Somali, Gambella, Dire Dawa and Oromia regions. Lower prevalence of anaemia was observed in Addis Ababa, Tigray and Amhara regions. Rural areas had a higher prevalence, 25.4 (95% CI 23.5 to 27.4) of anaemia in women than urban areas, 17.0 (95% CI 14.4 to 20.0) (p=0.0001). The highest proportion of anaemia among women were found in Somali Regional

Table 1 Sociodemographic and other health-related characteristics of study participants included in the analysis, EDHS 2016 (n=14 923)

Variables	Weighted frequency	Weighted per cent
Age (years)		
15–19	3165	21.2
20–29	5467	36.6
30–39	4078	27.3
40–49	2213	14.8
Place of residence		
Urban	3169	21.2
Rural	11 754	78.8
Educational status		
No education	7215	48.3
Primary	5244	35.1
Secondary	1676	11.2
Higher	789	5.3
Marital status		
Single	3758	25.2
Married	9800	65.7
Divorced/widowed/separated	1365	9.1
Religion		
Orthodox	6447	43.2
Protestant	3514	23.5
Muslim	4645	31.1
Other	317	2.1
Region		
Tigray	1073	7.2
Afar	119	0.8
Amhara	3645	24.4
Oromia	5422	36.3
Somali	417	2.8
Benishangul-Gumuz	146	1.0
SNNPR	3124	20.9
Gambella	42	0.3
Harari	32	0.2
Addis Ababa	825	5.5
Dire Dawa	77	0.5
Wealth index		
Poorest	2519	16.9
Poorer	2717	18.2
Middle	2891	19.4
Richer	2979	20.0
Richest	3816	25.6
BMI		
<18.5	3060	22.1
18.5–24.9	9740	70.5
≥25	1018	7.4

Continued

Table 1 Continued

Variables	Weighted frequency	Weighted per cent
Birth interval		
<24 months	1415	18.3
>=24 months	6305	81.7
Current use of contraceptives		
Yes	1088	7.3
No	13 835	92.7
Iron folate intake during pregnancy (n = 7328)		
Yes	3108	42.4
No/don't know	4220	57.6
Gravidity of women (children ever born)		
0	4745	31.8
1–3	4715	31.6
4+	5464	36.6
Children ever born in the preceding 5 years		
0	7595	50.9
1	4475	30.0
2+	2852	19.1
Currently breast feeding		
Yes	4657	31.2
No	10 266	68.8
Currently pregnant		
Yes	1088	7.3
No	13 835	92.7
Smoking		
Yes	96	0.6
No	14 827	99.4
Birth in the last year		
0	12 474	83.6
1–2	2449	16.4
HIV test		
Positive	187	1.3
Negative	14 724	98.7
Water source		
Piped water	2646	17.7
Other improved	6926	46.4
Unimproved	5351	35.9
Latrine facility type		
Improved toilet	2231	14.9
Unimproved toilet	7877	52.8
Open defecation	4414	29.6
Other	401	2.7
Anaemia status		
Anaemic	3527	23.6

Continued

Table 1 Continued

Variables	Weighted frequency	Weighted per cent
Non-anaemic	11396	76.4
Proportion of women in the community who have clean water source, m(SE)	64.1 (33.6)	
Proportion of women in the community who have unimproved latrine facility; m(SE)	85.1 (25.0)	
Proportion of women in the community who are in lowest quantile of wealth index, m (SE)	35.1 (30.0)	
Percentage of unimproved water per cluster, m (SE)	35.9 (33.6)	

BMI, bodymass index; EDHS, Ethiopian Demographic Health Survey; m, mean; SNNPR, Southern Nations, Nationalities and Peoples' Region.

States, while the lowest proportions were found in Addis Ababa city administration (table 2).

Around 1088 (7.3% [95% CI 6.6 to 8.1]) participants were pregnant at the time of the interview. The mean haemoglobin level among pregnant women was 117 g/L (± 18 g/L) and 29.1% (95% CI 24.9 to 33.7) of these women were anaemic. The prevalence of anaemia was higher among pregnant women, 29.1% (95% CI 24.9% to 33.7%) than non-pregnant women, 23.2% (95% CI 21.6% to 24.9%) (p=0.003) (table 2). The mean haemoglobin value of women in their second and third trimester was significantly lower compared with women in their first trimester (p=0.001). The mean haemoglobin levels in pregnant women who had less than a 24-month birth interval (for their most recent birth) was significantly lower compared with women who had a birth interval of less than or equal to 24 months (p=0.0001). Similarly, receiving iron folate supplements during pregnancy improved the mean haemoglobin values in pregnant women (table 3).

Determinant factors of anaemia among women of reproductive age

Multilevel analysis (fixed effect analysis)

The results of multilevel logistic regression for the individual-level and community-level variables are presented in table 4. In the full model in which all individual-level and community-level factors are included, residence, education, religion, wealth index, pregnancy and breastfeeding status, gravidity of women and lack of availability of an improved latrine were factors significantly associated with anaemia in women. The results of the mulitcollinearity test indicated that no collinearity problem existed, since the VIF value of all variables is lower than 10 (supplementary table 2).

Individual factors

The average haemoglobin value was significantly different across age groups (p=0.0001). The highest mean haemoglobin level, 130 g/L, was observed in the youngest (15–19 years) age group, while the lowest mean haemoglobin level, 127 g/L, in the age group of 30–34 years. The general pattern indicated roughly linear decline among women aged 15–34 years (figure 2). Women aged 40–49 years old were 25% less likely to be anaemic compared with women in the youngest age group (15–19 years old) (AOR=0.75; 95% CI 0.64 to 0.96). Those women with limited education were 1.37 times more likely to be anaemic than women who completed higher education (AOR=1.37; 95% CI 1.102 to 1.72). The odds of anaemia increased by 29% (AOR=1.29; 95% CI 1.014 to 1.60) when comparing the poorest to the richest women. The odds of anaemia were higher in women who were pregnant (AOR=1.28; 95% CI 1.10 to 1.51) compared with those who were not pregnant. Women who were currently breast feeding were 9% (AOR=1.09; 95% CI 1.025 to 1.28) more likely to be anaemic. The odds of anaemia were 39% higher among mothers who had given birth to four or more children (AOR=1.39; 95% CI 1.13 to 1.69). Women who gave birth to two or more children in the preceding 5 years of the survey were at higher risk of having anaemia (AOR=1.31; 95% CI 1.09 to 1.57). In this study, women who were HIV positive had a twofold increased odds of having anaemia compared with women classified as HIV negative (AOR=2.11; 95% CI 1.59 to 2.79) (table 4).

Community-level factors

Living in a rural area was associated with a 29% higher odds of anaemia among women of reproductive age than women who were urban residents (AOR=1.29; 95% CI 1.02 to 1.63). Women from households without access to a latrine had 18% higher odds of anaemia compared with women from households that had an improved latrine facility (AOR=1.18; 95% CI 1.01 to 1.39). Higher odds of anaemia were observed in Somali regional state (AOR=2.16; 95% CI 1.58 to 2.90) compared with Dire Dawa. However, the odds of anaemia among women were lower in Gambella, Addis Ababa, Amhara and Oromia region compared with Dire Dawa (table 4).

Multilevel analysis (random effect analysis)

The results of the random effects model is shown in table 4. Prevalence rate of anaemia varied across communities (t^2=0.88, p=<0.0001). In other words, the anaemia prevalence rate was not similarly distributed across the communities. About 21% of the variance in the odds of anaemia in women could be attributed to community-level factors, as calculated by the ICC based on estimated intercept component variance. After adjusting for individual-level and community-level factors, the variation in anaemia across communities remained statistically significant. About 16% of the odds of anaemia variation across communities was observed in the full model (model 4) (table 4).

Moreover, the MOR indicated that anaemia was attributed to community-level factors. The MOR for anaemia was 2.44 in the empty model (model 1); this showed that there was variation between communities (clustering) since MOR was 2.4 times higher than the reference (MOR=1). The

Table 2 The variation of anaemia prevalence rates across different regions and different sociodemographic characteristics of women in Ethiopia, 2016

Variables	Weighted frequency		Weighted proportion of anaemia (95% CI)	P value
	Anaemic	Non-anaemic		
Place of residence				
Urban	538	2630	17.0 (14.4 to20.0)	0.0001
Rural	2989	8766	25.4 (23.5 to 27.4)	
Region				
Tigray	212	861	19.7 (16.8 to 23.0)	0.0001
Afar	53	66	44.7 (39.9 to 49.6)	
Amhara	627	3019	17.2 (14.9 to 19.7)	
Oromia	1480	3942	27.2 (23.8 to 31.1)	
Somali	248	169	59.5 (55.2 to 63.7)	
Benishangul-Gumuz	28	118	19.2 (16.1 to 22.7)	
SNNPR	704	2420	22.5 (19.4 to 26.0)	
Gambella	11	31	26.1 (21.3 to 31.5)	
Harari	9	23	27.7 (23.7 to 32.1)	
Addis Ababa	132	693	16 (13.5 to 18.8)	
Dire Dawa	23	54	30 (25.8 to 34.8)	
Education status				
No education	2002	5212	27.8 (25.4 to 30.2)	0.0001
Primary	1136	4108	21.7 (19.8 to 23.7)	
Secondary	297	1378	17.8 (14.9 to 21.0)	
Higher	91	697	11.5 (8.2 to 16.0)	
Wealth index				
Poorest	863	1656	34.3 (29.7 to 39.1)	0.0001
Poorer	688	2028	25.3 (22.6 to 28.3)	
Middle	686	2205	23.7 (21.2 to 26.5)	
Richer	625	2354	21.0 (18.6 to 23.6)	
Richest	664	3152	17.4 (15.1 to 19.9)	
Currently pregnant				
Yes	317	771	29.1 (24.9 to 33.7)	0.003
No	3210	10625	23.2 (21.6 to 24.9)	
Currently breast feeding				
Yes	1317	3340	28.3 (25.7 to 31.0)	0.0001
No	2210	8055	21.5 (20.0 to 23.2)	
Total	3527	11396	23.6 (22.0 to 25.3)	

SNNPR, Southern Nations, Nationalities and Peoples' Region.

unexplained community variation in anaemia decreased to MOR of 2.1 when all factors were added to the null model (empty model). This indicates that when all factors are included, the effect of clustering is still statistically significant in the full model (table 4).

Spatial data analysis

Figure 3 displays the empirical Bayes smoothed proportion estimate of anaemia among women across regions in Ethiopia. A severe anaemia prevalence rate (≥40%) among women of reproductive age was observed in Afar and Somali Regional States. Likewise, a moderate anaemia prevalence rate (20%–40%) occurred in Oromia, Gambella, SNNPR, Harari and Dire Dawa Regional States. Whereas, a mild anaemia prevalence rate (<20%) was observed in Tigray and Amhara Regional Sates and Addis Ababa.

Similarly, the standardised prevalence ratio by regions (standardised to the national average prevalence of

Table 3 Haemoglobin level among pregnant women in Ethiopia, 2016

Variables	Number	Haemoglobin level (g/L) (mean(SD))	P values of ANOVA or independent t-test
Total Children ever born	1088		0.0001
0	213	121 (17)	
1–3	484	117 (18)	
4+	390	115 (18)	
Pregnancy stage	1088		0.0001
1st trimester	226	124 (17)	
2nd trimester	433	116 (16)	
3rd trimester	429	115 (19)	
Children ever born in last 5 years	1088		0.0001
0	339	121 (17)	
1	484	117 (18)	
2+	265	114 (19)	
Fe-Fol supplementation	749		0.018
Yes	251	118 (15)	
No	498	115 (19)	
Birth interval	702		0.0001
<24months	206	112 (20)	
>=24 months	497	119 (15)	

ANOVA, analysis of variance; Fe-Fol, ironfolate.

23.6%), ranging from 0.63 to 2.39, was displayed on the map (figure 4). A higher prevalence ratio of anaemia was observed in Somali (2.39), Afar (1.8) Oromia (1.17), Dire Dawa (1.15) and Gambella (1.12) regional states (figure 4), whereas a lower prevalence ratio of anaemia occurred in other regional states: Addis Ababa (0.64), Amhara (0.76), Benishangul-Gumuz (0.79), SNNPR (0.96) and Tigray (0.85) (figure 4).

Figure 5 displays the smoothed anaemia prevalence rates at zonal level where higher anaemia rates were observed in all zones in Afar and Somali regions, as well as in some zones in Oromia. Likewise, the higher standardised ratio of anaemia was observed in all zones in Afar and Somali regions as well as in some zones in Oromia (figure 6).

The spatial distributions of anaemia among women at the lower level (cluster level) is displayed in figure 7. The spatial investigation at the cluster level indicated that statistically high hotspots of anaemia were observed in the eastern (Somali, Dire Dawa and Harari regions) and in north-eastern (Afar) parts of the country, while cold spots of anaemia were observed in the northern (Tigray and Amhara), central (Addis Ababa and Oromia) and western (Benishangul-Gumuz and Gambella) parts of the country (figure 7).

DISCUSSION

Approximately a quarter of women of reproductive age were anaemic in the current study, indicating that anaemia is a moderate public health problem at the national level in Ethiopia.[1] However, geographic differences demonstrated that anaemia is a serious public health problem in 5 of the 11 Ethiopian states. A higher proportion of anaemia cases was observed in the eastern and north-eastern parts of the country, which are less developed compared with other Ethiopian states in terms of economy, gender, healthcare facility and food availability.[38] The geographical difference of anaemia across the regional states might be attributable to the regional variation of food consumption preferences,[39 40] the occurrence of communicable diseases[41] and differences in availability of healthcare facilities.[42] In addition, lack of clean water and unimproved latrine facilities would increase the occurrence of soil transmitted infection[43] which, in turn, could lead to anaemia,[44] which might explain some of the observed geographical differences.

According to the final model, both individual-level and community-level factors were responsible for about 43% of the disparity of anaemia prevalence rates among women of reproductive age in Ethiopia. After adjusting for all factors in the model, the likelihood of having anaemia was higher among those of younger age, with lower levels of education, living in rural areas, in the lowest wealth quantile, who were currently pregnant or breast feeding, with high gravidity, who had given birth in the year prior to the survey and who were without access to an improved latrine facility.

Women aged 40–49years had a lower likelihood of being anaemic compared with women aged between

Table 4 Multivariable multilevel logistic regression analysis for determinant factors associated with anaemia among Ethiopian women, 2016

Variables	Model 1	Model 2 Individual-level factors	Model 3 Community-level factors	Model 4 Individual+community-level factors
Individual-level factors				
Age (years)				
15–19		1		1
20–29		0.93 (0.81 to 1.07)		0.96 (0.82 to 1.19)
30–39		0.89 (0.75 to 1.10)		0.92 (0.78 to 1.11)
40–49		0.76 (0.61 to 0.92)		0.75 (0.64 to 0.96)
Educational status				
No education		1.41 (1.13 to 1.76)		1.37 (1.10 to 1.72)
Primary		1.22 (0.99 to 1.51)		1.24 (1.00 to 1.53)
Secondary		1.22 (0.98 to 1.5)		1.23 (0.98 to 1.52)
Higher		1		1
Marital status				
Single		0.99 (0.80 to 1.22)		0.97 (0.81 to 1.22)
Married		1.07 (0.92 to 1.23)		1.09 (0.91 to 1.23)
Divorced/widowed/separated		1		1
Religion				
Orthodox		1		
Protestant		1.36 (1.16 to 1.58)		1.37 (1.15 to 1.63)
Muslim		2.04 (1.79 to 2.33)		1.36 (1.16 to 1.58)
Other		1.49 (1.05 to 2.12)		1.525 (1.06 to 2.13)
Wealth index				
Poorest		1.73 (1.48 to 2.03)		1.29 (1.014 to 1.60)
Poorer		1.31 (1.10 to 1.54)		1.21 (0.96 to 1.45)
Middle		1.28 (1.08 to 1.51)		1.22 (0.98 to 1.50)
Richer		1.04 (0.88 to 1.24)		1.01 (0.82 to 1.24)
Richest		1		1
Current using contraceptives				
Yes		0.99 (0.90 to 1.10)		1.0 (0.91 to 1.11)
No		1		1
Currently pregnant				
Yes		1.30 (1.11 to 1.52)		1.28 (1.10 to 1.51)
no		1		1
Currently breast feeding				
yes		1.12 (1.00 to 1.24)		1.09 (1.03 to 1.28)
No		1		1
Gravidity of women (total children ever born)				
0		1		1
1–3		1.23 (1.03 to 1.46)		1.22 (1.02 to 1.44)
4+		1.40 (1.15 to 1.72)		1.39 (1.13 to 1.69)
Smoking				
Yes		0.98 (0.64 to 1.50)		1.05 (0.69 to 1.61)
No		1		1
Birth in the last 1 year				
0		1		1

Continued

Table 4 Continued

Variables	Model 1	Model 2 Individual-level factors	Model 3 Community-level factors	Model 4 Individual+community-level factors
1–2		1.20 (1.05 to 1.37)		1.15 (1.01 to 1.32)
Children ever born in preceding 5 years				
0		1		1
1		1.12 (0.96 to 1.29)		1.10 (0.95 to 1.27)
2+		1.39 (1.16 to 1.66)		1.31 (1.09 to 1.57)
HIV test				
Positive		2.19 (1.65 to 2.91)		2.11 (1.59 to 2.79)
Negative		1		1
Community-level factors				
Place of residence				
Urban			1	1
Rural			1.67 (1.35 to 2.05)	1.29 (1.02 to 1.63)
Region				
Tigray			0.39 (0.28 to 0.53)	0.52 (0.38 to 0.72)
Afar			1.25 (0.91 to 1.7)	1.14 (0.83 to 1.56)
Amhara			0.30 (0.22 to 0.41)	0.39 (0.28 to 0.54)
Oromia			0.55 (0.41 to 0.75)	0.57 (0.42 to 0.78)
Somali			2.40 (1.78 to 3.27)	2.16 (1.58 to 2.90)
Benishangul-Gumuz			0.36 (0.25 to 0.50)	0.37 (0.26 to 0.52)
SNNPR			0.40 (0.29 to 0.54)	0.41 (0.29 to 0.57)
Gambella			0.63 (0.45 to 0.87)	0.63 (0.45 to 0.89)
Harari			0.74 (0.53 to 1.04)	0.76 (0.54 to 1.04)
Addis Ababa			0.54 (0.39 to 0.73)	0.67 (0.49 to 0.91)
Dire Dawa			1	1
Water source				
Piped water			1	1
Other improved			1.15 (0.95 to 1.39)	1.04 (0.86 to 1.26)
Unimproved			1.18 (0.95 to 1.44)	1.03 (0.83 to 1.27)
Latrine facility type				
Improved toilet			1	1
Unimproved toilet			1.12 (0.97 to 1.29)	1.08 (0.94 to 1.25)
Open defecation			1.33 (1.15 to 1.55)	1.18 (1.00 to 1.39)
Other			0.86 (0.64 to 1.17)	0.94 (0.69 to 1.27)
Random effects (effect of variation / measure of variation for anaemia)				
Community level variance (SE)	0.888 (0.07)	0.46 (0.05)	0.32 (0.04)	0.31 (0.035)
P value	0.001	0.001	0.001	0.001
DIC (−2log likelihood)	7926.056	7749.25	7720.74	7613.56
ICC (%)	21.25	16.1	18.3	15.86
Explained variation – PCV (%)	Reference	40.95	21.0	43.1
MOR	2.44	2.13	2.3	2.1

Note: Model 1=empty model (without the predictors); model 2=adjusted for individual factors; model 3=adjusted for community-level factors; model 4=adjusted for both community-level and individual-level factors.
DIC, deviance information criterion; ICC, intracluster correlation coefficient; MOR, median OR; PCV, percentage change in variance; SNNPR, Southern Nations, Nationalities and Peoples' Region.

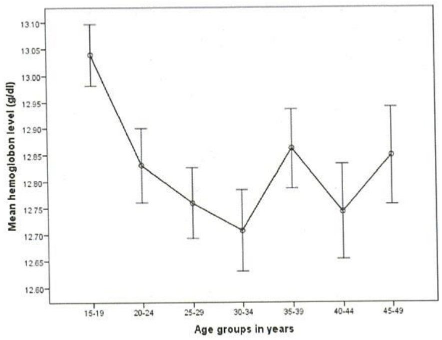


Figure 2 Average haemoglobin value with 95% CI for women of reproductive age at different age groups, Ethiopia, 2016.

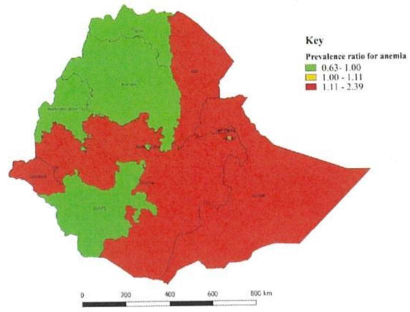


Figure 4 Standardised prevalence ratio for anaemia among women of reproductive age across the regions in Ethiopia (standardised to national prevalence of 23.6%), EDHS, 2016. EDHS, Ethiopian Demographic Health Survey.

15 years and 19years. This finding is in line with other study findings from Ethiopia[16 19] and Benin.[45] This could be due to the fact that low fertility rates occurred in this age group.[11 40–49] However, in Iran,[46] it has been reported that women aged 20–24 years were less likely to be anaemic compared with those aged 45–49 years; this might be a result of Iran having a targeted intervention for younger women or women of reproductive age.[46]

In this study, it was found that there is variation of the anaemia rate in terms of education status of the women. A higher proportion of anaemic cases were observed among women with no education. It was found that women who did not have formal education had higher odds of anaemia than those with higher education. This is consistent with other studies conducted in developing countries[24] including Ethiopia,[16] Timor-Leste,[47] Benin[45] and India[48 49] in which it was reported that a low level of education was associated with higher odds of anaemia among women of reproductive age. Formal education might assist women to obtain knowledge that in turn helps them to follow better lifestyle behaviours like good nutrition and to form better health-seeking habits and hygiene practices that can prevent anaemia among women.

A higher proportion of anaemic cases were observed among women in the poorest wealth quantile. The lowest wealth quantile compared with highest quantile was associated with a higher risk of anaemia. Results of this study show that women who were in the poorest wealth quintile were 30% more likely to be anaemic than women who belong to the richest quintile; this is in line with the results of other studies conducted in other developing countries[24] like Benin[45] and India.[49 50] This might be due to the fact that having a low income would mean having less money to buy nutritious foods or have a balanced diet[51 52] which, in turn, leads to inadequate nutrient

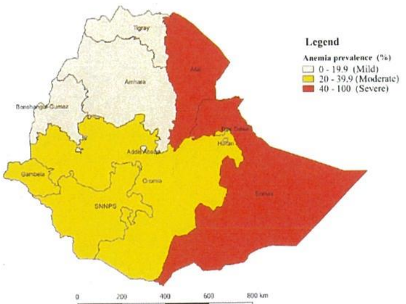


Figure 3 Spatial empirical Bayesian smoothed percentage of anaemia among women of reproductive age across regions, EDHS, 2016. EDHS, Ethiopian Demographic Health Survey.

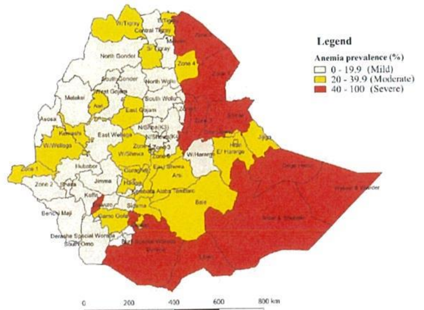


Figure 5 Spatial empirical Bayesian smoothed percentage of anaemia among women of reproductive age across Zones, EDHS, 2016. EDHS, Ethiopian Demographic Health Survey.

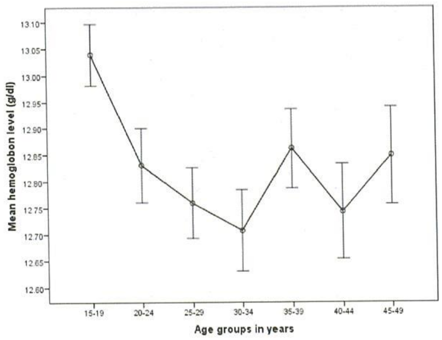


Figure 2 Average haemoglobin value with 95% CI for women of reproductive age at different age groups, Ethiopia, 2016.

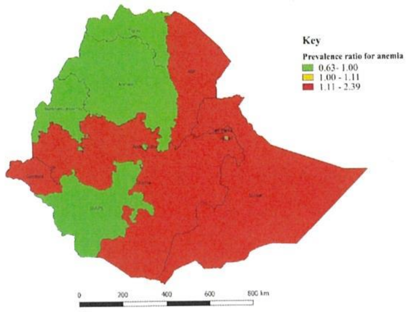


Figure 4 Standardised prevalence ratio for anaemia among women of reproductive age across the regions in Ethiopia (standardised to national prevalence of 23.6%), EDHS, 2016. EDHS, Ethiopian Demographic Health Survey.

15 years and 19 years. This finding is in line with other study findings from Ethiopia[16 19] and Benin.[45] This could be due to the fact that low fertility rates occurred in this age group.[11 40–49] However, in Iran,[46] it has been reported that women aged 20–24 years were less likely to be anaemic compared with those aged 45–49 years; this might be a result of Iran having a targeted intervention for younger women or women of reproductive age.[46]

In this study, it was found that there is variation of the anaemia rate in terms of education status of the women. A higher proportion of anaemic cases were observed among women with no education. It was found that women who did not have formal education had higher odds of anaemia than those with higher education. This is consistent with other studies conducted in developing countries[24] including Ethiopia,[16] Timor-Leste,[47] Benin[45] and India[48 49] in which it was reported that a low level of education was associated with higher odds of anaemia among women of reproductive age. Formal education might assist women to obtain knowledge that in turn helps them to follow better lifestyle behaviours like good nutrition and to form better health-seeking habits and hygiene practices that can prevent anaemia among women.

A higher proportion of anaemic cases were observed among women in the poorest wealth quantile. The lowest wealth quantile compared with highest quantile was associated with a higher risk of anaemia. Results of this study show that women who were in the poorest wealth quintile were 30% more likely to be anaemic than women who belong to the richest quintile; this is in line with the results of other studies conducted in other developing countries[24] like Benin[45] and India.[49 50] This might be due to the fact that having a low income would mean having less money to buy nutritious foods or have a balanced diet[51 52] which, in turn, leads to inadequate nutrient

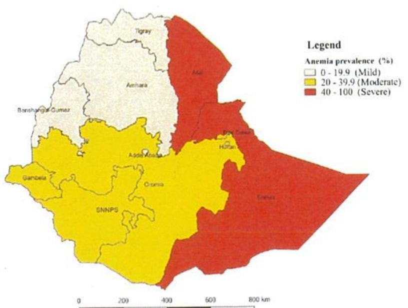


Figure 3 Spatial empirical Bayesian smoothed percentage of anaemia among women of reproductive age across regions, EDHS, 2016. EDHS, Ethiopian Demographic Health Survey.

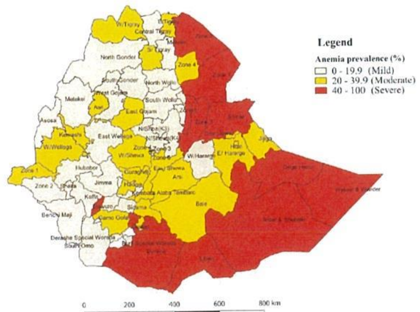


Figure 5 Spatial empirical Bayesian smoothed percentage of anaemia among women of reproductive age across Zones, EDHS, 2016. EDHS, Ethiopian Demographic Health Survey.

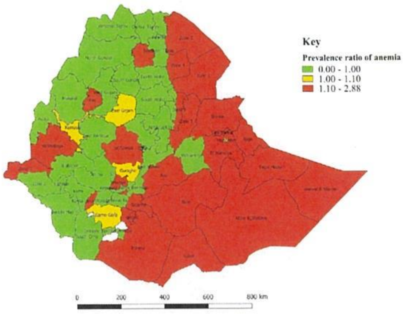


Figure 6 Standardised prevalence ratio for anaemia among women of reproductive age across Zones in Ethiopia (standardised to national prevalence of 23.6%), EDHS, 2016. EDHS, Ethiopian Demographic Health Survey.

intake and nutritional status.[53] More than 38% of the Ethiopian population belongs to the poorer and poorest wealth quintile, which indicates a large percentage of women are at risk for anaemia because of low socioeconomic position.[11]

Lactating mothers were 9% more likely to have anaemia than non-lactating mothers. Lactating may predispose women to low haemoglobin, which results in anaemia. In a study conducted in India,[54] a similar finding was reported that lactating mothers were more likely to be anaemic than non-lactating women.

The findings of our study clearly show the role of women's fertility in anaemia. Increased odds of anaemia was associated with high gravidity, births in the past 5 years of the survey and having a birth in the last year. Similar studies in Ethiopia,[16] Iran[46] and Timor-Leste[47] also document this association between parity and risk of anaemia. The study results from Pakistan[55 56] and Iran[46] indicate that women with a parity of four or more were found to be at increased risk of anaemia than women with lower parity. This might be explained by the fact that the more the women give birth, the more they are exposed to blood loss which, in turn, results in low haemoglobin levels in the blood.[57] Similarly, prior births may deplete maternal iron stores due to the increased nutritional demands of pregnancy and puerperal blood loss.[58] Consequently, emphasis needs to be placed on family planning services. Increased odds of anaemia were observed in women who were HIV positive. In this study, women who were HIV positive had twofold increased odds for anaemia. This could be due to the direct effects of the HIV infection on the bone marrow and depletion of haemoglobin levels in the blood.[59] Many of the opportunistic infections to which HIV patients are susceptible might also lead to anaemia.[59]

This study revealed there to be a significant difference in the proportion of anaemic cases according to place of residence (urban/rural). The likelihood of having anaemia was higher for rural residents compared with urban residents. This is in agreement with a study conducted in low-income countries in which it was revealed that living in a rural area was a determinant factor for anaemia.[24] A recent report illustrated that more than half of the Ethiopian population had access to unimproved toilet facilities.[60] Our study findings revealed that women from households with unimproved latrine facilities were more likely to be anaemic than women from households with improved latrine facilities, which is in agreement with other research findings.[45 61] The possible justification might be that an unimproved latrine facility would expose women to helminthic infections,[43] which in turn resulted them developing anaemia.[44]

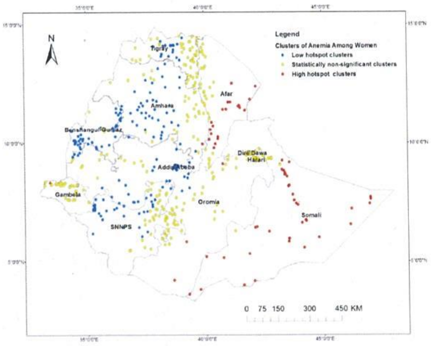


Figure 7 Spatial pattern of hotspots and cold spots of anaemia rate among women of reproductive age at cluster level in Ethiopia, EDHS, 2016. EDHS, Ethiopian Demographic Health Survey.

Strengths and limitations

This study used large population-based data with a large sample size, which is representative of all regions of Ethiopia. Furthermore, a combination of statistical methods (spatial analysis and multilevel logistics analysis) were applied for this study that allows for the understanding of the role of contextual and geographical factors in the occurrence of anaemia among women of reproductive age. Due to the cross-sectional nature of the EDHS data, the cause/effect and temporal relationship could not be established based on these study findings. Similarly, essential factors such as dietary intake and behavioural factors were not available in the EDHS so that it was not possible to incorporate these variables in the analysis. Furthermore, EDHS was a questionnaire-based survey and relied on the memory of the respondents, and as such, recall bias in the results might be a weakness for this study.

CONCLUSION

This study indicates that considerable geographic disparities in anaemia prevalence rate occur within Ethiopia. The results of this study revealed that anaemia among women varied across the country; significant anaemia hotspots were observed in the eastern and north-eastern part of the country, while anaemia cold spots were observed in the northern and western parts of the country. About 43% of the disparity in anaemia occurrence across communities was attributable to both individual-level and community-level factors. The increased occurrence of anaemia among women was associated with individual-level and community-level factors. For women, being of rural residence, having no formal education, being in the poorest wealth index, either currently pregnant or breast feeding and higher gravidity were factors that increased the odds of anaemia at the individual level, whereas lack of a clean water source and access to an unimproved toilet facility were factors significantly associated with anaemia among women.

Accordingly, the prevention of anaemia among women requires multifaceted intervention approaches, for instance, improving the economic and educational status of women and improving the availability of clean water and toilet facilities. Anaemia prevention strategies must be targeted on these identified factors. Priority should be given for those states or areas that have anaemia hotspots. Particularly, any intervention programmes need to be prioritised for pregnant women, women recently giving birth, those with lower levels of education and women living in rural areas. The regions with the greatest numbers of anaemic women (Afar and Somali) should be prioritised, as the burden of anaemia is higher in these areas, with more than 50% of women being anaemic.

Acknowledgements We would like to thank the Demographic and Health Survey (DHS) programme for allowing the use of Ethiopian Demographic and Health Survey (EDHS) data for this study. We are also very grateful to Dr Ryan O'Neill for his help in language editing.

Contributors Formulating the research question(s): all authors; designing the study: all authors; analysing the data: KTK; interpreting the results: all authors; drafting, writing, reviewing and approving the final manuscript: all authors.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval The EDHS 2016 was approved by the National Research Ethics Review Committee of Ethiopia and ICF Macro International. MEASURE DHS approval was obtained to use EDHS 2016. This analysis was approved by the University of Newcastle Human Research Ethics Committee (H-2018–0045).

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement There will not be any unpublished data.

REFERENCES

1. WHO Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity. *Vitamin and mineral nutrition information system*. Geneva: World Health Organization, 2011.
2. Stevens GA, Finucane MM, De-Regil LM, *et al*. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995-2011: a systematic analysis of population-representative data. *Lancet Glob Health* 2013;1:e16–e25.
3. Lumbiganon P, Laopaiboon M, Intarut N, *et al*. Indirect causes of severe adverse maternal outcomes: a secondary analysis of the WHO Multicountry Survey on Maternal and Newborn Health. *BJOG* 2014;121:32–9.
4. Albacar G, Sans T, Martín-Santos R, *et al*. An association between plasma ferritin concentrations measured 48 h after delivery and postpartum depression. *J Affect Disord* 2011;131:136–42.
5. Corwin EJ, Murray-Kolb LE, Beard JL. Low hemoglobin level is a risk factor for postpartum depression. *J Nutr* 2003;133:4139–42.
6. Aghamohammadi A, Zafari M, Tofighi M. High maternal hemoglobin concentration in first trimester as risk factor for pregnancy induced hypertension. *Caspian J Intern Med* 2011;2:194–7.
7. Zafar T. IQBAL Z iron status in preeclampsia. *Professional Med J* 2008;15:74–80.
8. Rahman MM, Abe SK, Rahman MS, *et al*. Maternal anemia and risk of adverse birth and health outcomes in low- and middle-income countries: systematic review and meta-analysis. *Am J Clin Nutr* 2016;103:495–504.
9. Kassebaum NJ, Jasrasaria R, Naghavi M, *et al*. A systematic analysis of global anemia burden from 1990 to 2010. *Blood* 2014;123:615–24.
10. WHO. *Global nutrition targets 2025: anaemia policy brief (WHO/NMH/NHD/14.4*. Geneva: World Health Organization, 2014.
11. Central Statistical Agency (CSA). *Central Statistical Agency (CSA) [Ethiopia] and ICF Ethiopia demographic and health Survey 2016*. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: CSA and ICF, 2016.
12. Melku M, Addis Z, Alem M, *et al*. prevalence and predictors of maternal anemia during pregnancy in gondar, northwest Ethiopia: an institutional based cross-sectional study. *Anemia* 2014;2014:108593.
13. Gebremedhin S, Enquselassie F. Umeta m prevalence and correlates of maternal anemia in rural sidama, Southern Ethiopia. *African Journal of Reproductive Health / La Revue Africaine de la Santé Reproductive* 2014;18:44–53.
14. Kedir H, Berhane Y, Worku A. Khat chewing and restrictive dietary behaviors are associated with anemia among pregnant women in high prevalence rural communities in eastern Ethiopia. *PLoS One* 2013;8:e78601.
15. Addis Alene K, Mohamed Dohe A. Prevalence of anemia and associated factors among pregnant women in an urban area of Eastern Ethiopia. *Anemia* 2014;2014:561567:1–7.
16. Asres Y, Yemane T, Gedefaw L. Determinant factors of anemia among nonpregnant women of childbearing age in southwest Ethiopia: a community based study. *Int Sch Res Notices* 2014;2014:391580.
17. Haidar JA, Pobocik RS. Iron deficiency anemia is not a rare problem among women of reproductive ages in Ethiopia: a community based cross sectional study. *BMC Blood Disord* 2009;9:7.
18. Haidar J. Prevalence of anaemia, deficiencies of iron and folic acid and their determinants in Ethiopian women. *J Health Popul Nutr* 2010;28:359–68.
19. Umeta M, Haidar J, Demissie T, *et al*. Iron deficiency anaemia among women of reproductive age in nine administrative regions of Ethiopia. *EthiopJHealth Dev* 2008;22:252–8.
20. Pokropek C, Sobolewski P, Getachew R, *et al*. 621: Dietary intake patterns and insulin resistance in women with a history of gestational diabetes in the National Health and Nutrition Examination Survey (NHANES) 2000-2010. *American Journal of Obstetrics and Gynecology* 2015;212:S308.
21. WHO. *Assessing iron status of populations: report of a joint WHO/CDC technical consultation on the assessment of iron status at the population level*. 2nd ed. Geneva: WHO, 2007.
22. Dreyfuss ML, Stoltzfus RJ, Shrestha JB, *et al*. Hookworms, malaria and vitamin A deficiency contribute to anemia and iron deficiency among pregnant women in the plains of Nepal. *J Nutr* 2000;130:2527–36.
23. Brooker S, Hotez PJ, Bundy DA. Hookworm-related anaemia among pregnant women: a systematic review. *PLoS Negl Trop Dis* 2008;2:e291.
24. Balarajan Y, Ramakrishnan U, Özaltin E, *et al*. Anaemia in low-income and middle-income countries. *The Lancet* 2011;378:2123–35.
25. Petry N, Olofin I, Hurrell RF, *et al*. The proportion of anemia associated with iron deficiency in low, medium, and high human

development index countries: a systematic analysis of national surveys. *Nutrients* 2016;8:693.
26. Gebre A, Mulugeta A. Prevalence of anemia and associated factors among pregnant women in north western zone of tigray, northern Ethiopia: a cross-sectional study. *J Nutr Metab* 2015;2015:1–7.
27. Kefiyalew F, Zemene E, Asres Y, *et al*. Anemia among pregnant women in Southeast Ethiopia: prevalence, severity and associated risk factors. *BMC Res Notes* 2014;7:771.
28. Rezende LF. Eluf-Neto J Population attributable fraction: planning of diseases prevention actions in Brazil. *Rev Saude Publica* 2016:50.
29. Bates I, McKew S, Sarkinfada F. Anaemia: a useful indicator of neglected disease burden and control. *PLoS Med* 2007;4:e231.
30. Lawson AB. *Statistical methods in spatial epidemiology*. Atrium, Southern Gate, West Sussex, England: John Wiley and Sons Inc, 2006.
31. Anselin L. Exploring Spatial Data with GeoDaTM: a workbook. center for spatially integrated social science. 2005.
32. Banerjee S. Spatial Data Analysis. *Annu Rev Public Health* 2016;37:47–60.
33. Ord JK, Getis A. Local spatial autocorrelation statistics: distributional issues and an application. *Geographical Analysis* 1995;27:286–306.
34. Merlo J, Chaix B, Ohlsson H, *et al*. A brief conceptual tutorial of multilevel analysis in social epidemiology: using measures of clustering in multilevel logistic regression to investigate contextual phenomena. *J Epidemiol Community Health* 2006;60:290–7.
35. Merlo J, Yang M, Chaix B, *et al*. A brief conceptual tutorial on multilevel analysis in social epidemiology: investigating contextual phenomena in different groups of people. *J Epidemiol Community Health* 2005;59:729–36.
36. Larsen K, Merlo J. Appropriate assessment of neighborhood effects on individual health: integrating random and fixed effects in multilevel logistic regression. *Am J Epidemiol* 2005;161:81–8.
37. Guo G, Zhao H. Multilevel modeling for binary data. *Annu Rev Sociol* 2000;26:441–62.
38. International food policy research Institute (IFPRI) and Central Statistical agency (CSA). *Population and housing census atlas of Ethiopia 2007*. Ethiopia: Addis Ababa, 2010.
39. Ethiopian Public Health Institute Food Consumption Survey. *Ethiopian food consumption survey report*. Addis Ababa, Ethiopia: Ethiopian Public Health Institute Food Consumption Survey, 2013.
40. Berhane G, Paulos Z, Tafere K, *et al*. Foodgrain consumption and calorie intake patterns in Ethiopia, Ethiopia strategy support program II (ESSP II). *Working Paper* 2011;23.
41. Ministry of Health of Ethiopia. *Health and health related indicator, Vertion 1*. Ethiopia: Addis Ababa, 2008.
42. Chaya N Poor Access to Health Services. Ways Ethiopia is Overcoming Research Commentary. 2007;2.
43. Mara D, Lane J, Scott B, *et al*. Sanitation and health. *PLoS Med* 2010;7:e1000363.
44. Tay SC, Nani EA, Walana W. Parasitic infections and maternal anaemia among expectant mothers in the Dangme East District of Ghana. *BMC Res Notes* 2017;10:3.
45. Alaofè H, Burney J, Naylor R, *et al*. Prevalence of anaemia, deficiencies of iron and vitamin A and their determinants in rural women and young children: a cross-sectional study in Kalalé district of northern Benin. *Public Health Nutr* 2017;20:1203–13.
46. Sadeghian M, Fatourechi A, Lesanpezeshki M, *et al*. Prevalence of anemia and correlated factors in the reproductive age women in rural areas of tabas. *J Family Reprod Health* 2013;7:139–44.
47. Lover AA, Hartman M, Chia KS, *et al*. Demographic and spatial predictors of anemia in women of reproductive age in Timor-Leste: implications for health program prioritization. *PLoS One* 2014;9:e91252.
48. K CG, K SK. K CG, K SK A cross-sectional study of anemia among women of reproductive age group (15- 49 years) in a rural population of Tamil Nadu. *Int J Med Sci and PH* 2017;6.
49. Balarajan YS, Fawzi WW, Subramanian SV. Changing patterns of social inequalities in anaemia among women in India: cross-sectional study using nationally representative data. *BMJ Open* 2013;3:e002233.
50. Rammohan A, Awofeso N, Robitaille M-C. Addressing female iron-deficiency anaemia in india: is vegetarianism the major obstacle? *ISRN Public Health* 2012;2012:1–8.
51. Lenz A, Olinto MT, Dias-da-Costa JS, *et al*. Socioeconomic, demographic and lifestyle factors associated with dietary patterns of women living in Southern Brazil. *Cad Saude Publica* 2009;25:1297–306.
52. USAID/ENGINE. Maternal diet and nutrition practices and their determinants: a report on formative research finding. 2014.
53. Kuche D, Singh P, Moges D, *et al*. Nutritional status and associated factors among pregnant women in wondo genet district, Southern Ethiopia. *Journal of Food Science and Engineering* 2015;5.
54. Siddiqui MZ, Goli S, Reja T, *et al*. Prevalence of anemia and its determinants among pregnant, lactating, and nonpregnant nonlactating women in India. *SAGE Open* 2017;7:215824401772555–10.
55. Soofi S, Khan GN, Sadiq K, *et al*. Prevalence and possible factors associated with anaemia, and vitamin B and folate deficiencies in women of reproductive age in Pakistan: analysis of national-level secondary survey data. *BMJ Open* 2017;7:e018007.
56. Habib MA, Raynes-Greenow C, Soofi SB, *et al*. Prevalence and determinants of iron deficiency anemia among non-pregnant women of reproductive age in Pakistan. *Asia Pac J Clin Nutr* 2018;27:195–203.
57. Bh R, Patil PS, Joseph J. Multigravidity a major risk factor of anaemia in pregnancy and its comparison in primigravida women in raichur. *National J Lab Med* 2017;6:PO22-PO7.
58. Al-Farsi YM, Brooks DR, Werler MM, *et al*. Effect of high parity on occurrence of anemia in pregnancy: a cohort study. *BMC Pregnancy Childbirth* 2011;11:7.
59. Kokici M, Harxhi A, Como N, *et al*. Haematological changes in HIV infection. *Int J Ecosyst and Ecol Sci* 2016;6:19–24.
60. Beyene A, Hailu T, Faris K, *et al*. Current state and trends of access to sanitation in Ethiopia and the need to revise indicators to monitor progress in the Post-2015 era. *BMC Public Health* 2015;15:451.
61. Freeman MC, Garn JV, Sclar GD, *et al*. The impact of sanitation on infectious disease and nutritional status: a systematic review and meta-analysis. *Int J Hyg Environ Health* 2017;220:928–49.