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Cork  
School of Food and Nutritional Sciences  
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**Nutritional status of lactating mothers and their children 6-23  
months of age in pre- and post-harvest seasons in two agro-  
ecological zones of rural Ethiopia**

**Thesis presented by  
Kedir Teji Roba**

**For the degree of  
Doctor of Philosophy in Nutritional Sciences  
January, 2016**

**Dedication:**

To my brother Ayub Teji (RIP), my grandmother Shuko Beketa (RIP),  
and my father-in-law Abdo Komicha (RIP).

## **Table of contents**

	Page Number
Declaration	I
Acknowledgements	ii
Publications	v
Abstract	Vi
<b>Chapter 1</b>	
Literature review	<b>1</b>
Specific objectives	<b>30</b>
<b>Chapter 2</b>	<b>46</b>
Seasonal variation in nutritional status and anaemia among lactating mothers in two agro-ecological zones of rural Ethiopia: A longitudinal study	
<b>Chapter 3</b>	<b>69</b>
Prevalence of stunting and anaemia among children 6-23 months of age in two agro-ecological zones of rural Ethiopia	
<b>Chapter 4</b>	<b>95</b>
Serum zinc, iron and urinary iodine levels and their relationship to other indices of malnutrition among lactating mothers in two agro-ecological zones of rural Ethiopia	
<b>Chapter 5</b>	<b>118</b>
Concurrent micronutrient deficiencies in lactating mothers and their children 6-23 months of age in two agro-ecological zones of rural Ethiopia	

<b>Chapter 6</b>	<b>146</b>
Infant and Young Child Feeding (IYCF) practices among mothers of children aged 6–23 months in two agro-ecological zones of rural Ethiopia	
<b>Chapter 7</b>	<b>169</b>
Variations between post- and pre-harvest seasons in stunting, wasting, Infant and Young Child Feeding (IYCF) practices among children 6-23 months of age in lowland and midland agro-ecological zones of rural Ethiopia	
<b>Chapter 8</b>	<b>190</b>
General discussion	

## **DECLARATION**

This is to declare that the content of this thesis is my own work and has not been submitted for another degree, either at University College Cork or elsewhere.

**Signed:** \_\_\_\_\_ **Date:** \_\_\_\_\_

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## **Publications**

### **Research papers**

1. Roba, K.T., O'Connor, T.P., Belachew, T. and O'Brien, N.M. (2015). Seasonal variation in nutritional status and anaemia among lactating mothers in two agro-ecological zones of Rural Ethiopia: A longitudinal study. *Nutrition* **31**, 1213-1218.
2. Roba, K.T., O'Connor, T.P., Belachew, T. and O'Brien, N.M. (2015) Prevalence of stunting and anaemia among children 6-23 months of age in two agro-ecological zones of Rural Ethiopia. *Journal of Nutritional Sciences* (submitted).

### **Presentations**

1. Roba, K.T. (2014) How can agriculture contribute to better nutrition? Developing the evidence based in Ethiopia. Presentation at 3<sup>rd</sup> AgriDiet Workshop, 3-4<sup>th</sup> November 2014, University College Cork.
2. Roba, K.T., O'Connor, T.P., Belachew, T. and O'Brien, N.M. (2015) Stunting and anaemia among children 6-23 months of age in two agro-ecological zones of Rural Ethiopia (Poster at: 26<sup>th</sup> Annual Conference of the Ethiopian Public Health Association (EPHA), 26-28<sup>th</sup> February 2015, Bahir Dar, Gondor, Ethiopia).
3. Roba, K.T., O'Connor, T.P., Belachew, T. and O'Brien, N.M. (2015) Iron and zinc deficiencies among children 6-23 months of age and their mothers in rural Ethiopia (Poster at: AgriDiet Conference. Enhancing Nutrition through Agricultural Policies and Programmes, 17<sup>th</sup> July 2015, Addis Ababa).
4. Roba, K.T., O'Connor, T.P., Belachew, T. and O'Brien, N.M. (2015) Seasonal variation in nutritional status and anaemia among lactating mothers in two agro-ecological zones of rural Ethiopia: A longitudinal study (Poster at: AgriDiet Conference. Enhancing Nutrition through Agricultural Policies and Programmes, 17<sup>th</sup> July 2015, Addis Ababa).

## **Abstract**

The objective of this study was to assess seasonal variation in nutritional status and feeding practices among lactating mothers and their children 6-23 months of age in two different agro-ecological zones of rural Ethiopia (lowland zone and midland zone). Food availability and access are strongly affected by seasonality in Ethiopia. However, there are few published data on the effects of seasonal food fluctuations on nutritional status and dietary diversity patterns of mothers and children in rural Ethiopia.

A longitudinal study was conducted among 216 mothers in two agro-ecological zones of rural Ethiopia during pre and post-harvest seasons. Data were collected on many parameters including anthropometry, blood levels of haemoglobin and ferritin and zinc, urinary iodine levels, questionnaire data regarding demographic and household parameters and health issues, and infant and young child feeding practices, 24 h food recall to determine dietary diversity scores, and household use of iodized salt. Chi-square and multivariable regression models were used to identify independent predictors of nutritional status.

A wide variety of results were generated including the following highlights. It was found that 95.4% of children were breastfed, of whom 59.7% were initially breastfed within one hour of birth, 22.2% received pre-lacteal feeds, and 50.9% of children received complementary feedings by 6 months of age. Iron deficiency was found in 44.4% of children and 19.8% of mothers. Low Zinc status was found in 72.2% of children and 67.3% of mothers. Of the study subjects, 52.5% of the children and 19.1% of the mothers were anaemic, and 29.6% of children and 10.5% of mothers had iron deficiency anaemia. Among the mothers with low serum iron status, 81.2% and 56.2% of their children had low serum zinc and iron, respectively. Similarly, among the low serum zinc status mothers, 75.2% and 45.3% of their children had low serum in zinc and iron, respectively. There was a strong correlation between the micronutrient status of the mothers and the children for ferritin, zinc and haemoglobin ( $P < 0.001$ ). There was also statistically significant difference between agro-ecological zones for micronutrient deficiencies among the mothers ( $p < 0.001$ ) but not for their children. The majority (97.6%) of mothers in the lowland zone were deficient in at least one micronutrient biomarker (zinc or ferritin or haemoglobin).

Deficiencies in one, two, or all three biomarkers of micronutrient status were observed in 48.1%, 16.7% and 9.9% of mothers and 35.8%, 29.0%, and 23.5%, of children, respectively. Additionally, about 42.6% of mothers had low levels of urinary iodine and 35.2% of lactating mothers had goitre. Total goitre prevalence rates and urinary iodine levels of lactating mothers were not significantly different across agro-ecological zones. Adequately iodised salt was available in 36.6% of households.

The prevalence of anaemia increased from post-harvest (21.8%) to pre-harvest seasons (40.9%) among lactating mothers. Increases were from 8.6% to 34.4% in midland and from 34.2% to 46.3% in lowland agro-ecological zones. Fifteen percent of mothers were anaemic during both seasons. Predictors of anaemia were high parity of mother and low dietary diversity.

The proportion of stunted and underweight children increased from 39.8% and 27% in post-harvest season to 46.0% and 31.8% in pre-harvest season, respectively. However, wasting in children decreased from 11.6% to 8.5%. Major variations in stunting and underweight were noted in midland compared to lowland agro-ecological zones. Anthropometric measurements in mothers indicated high levels of undernutrition. The prevalence of undernutrition in mothers ( $BMI < 18.5 \text{ kg/m}^2$ ) increased from 41.7 to 54.7% between post- and pre-harvest seasons. The seasonal effect was generally higher in the midland community for all forms of malnutrition. Parity, number of children under five years and regional variation were predictors of low BMI among lactating mothers. There were differences in minimum meal frequency, minimum acceptable diet and dietary diversity in children in pre-harvest and post-harvest seasons and these parameters were poor in both seasons. Dietary diversity among mothers was higher in lowland zone but was poor in both zones across the seasons.

In conclusion, malnutrition and micronutrient deficiencies are very prevalent among lactating mothers and their children 6-23 months old in the study areas. There are significant seasonal variations in malnutrition and dietary diversity, in addition to significant differences between lowland and midland agro-ecological zones. These findings suggest a need to design effective preventive public health nutrition programs to address both the mothers' and children's needs particularly in the pre-harvest season.

## **Chapter 1**

### **Literature review**

## **INTRODUCTION**

Malnutrition is a health condition caused primarily by an improper or inadequate diet and it has several manifestations: under nourishment, overweight and obesity, and micronutrient deficiency among others [1]. However, malnutrition is frequently used to mean under nutrition caused by inadequate intake of specific dietary components for whatever reason [2]. In this study, the term malnutrition refers to under nutrition. Major causes of malnutrition in developing countries include poverty [3], high food prices, poor dietary practices, [4] low agricultural productivity, high prevalence of diseases and infections [5]. Poor socioeconomic status is associated with chronic malnutrition since it inhibits purchase of nutritious food items [3]. Even though malnutrition by itself is not a health outcome, it is known that malnutrition directly influences health, mental development, and work productivity of human beings [6]. Malnutrition can result in long lasting developmental deficits [6], increased levels of chronic illnesses in adulthood and adverse pregnancy outcomes, and in children it contributes to illness and death. Among survivors, many will develop impairments and reduced capacity to learn, produce, and contribute to a country's economy throughout life. Among micronutrient deficiencies, iodine deficiency can lead to irreversible impairment of intellectual capacities, and untreated vitamin A deficiency can lead to blindness [7, 8]. Zinc deficiency is associated with impaired physical growth, immunity, reproductive function and neuro-behavioural development [9]. Iron deficiency affects function of both the endocrine and immune systems and is associated with low birth weight, premature delivery, and a host of perinatal complications among mothers [10].

In less developed countries, 19.4% of children less than five years of age were underweight and 29.9% were stunted in the year 2011 [11]. In Sub-Saharan Africa (SSA), more than 200 million people are malnourished [12], up to 40% of children are stunted and more than 3.4 million children less than five are dying [13, 14]. Malnutrition is more devastating among vulnerable women and children in situations of food shortage. In addition to political and economic strife, the HIV/AIDS pandemic has orphaned many children, putting them at greater risk of having poor nutritional status [15]. Malnutrition and micronutrient deficiency in reproductive age women increase the risk of maternal morbidity and mortality. Stunting (short

stature) and iron deficiency anaemia are related to at least 20 percent of maternal mortality [6]. The nutritional status of a woman before and during pregnancy is important for a healthy pregnancy outcome [16]. For example, pregnant mothers with severe anaemia have higher risk of maternal mortality [17]. It is estimated that vitamin A and iodine deficiency each affect up to one-third of children less than five, of which 18% also suffer from iron deficiency anaemia.

Appropriate infant and young child feeding (IYCF) is recognized as an essential child survival intervention. WHO and UNICEF recommend exclusive breastfeeding in the first six months, beginning from the first hour of life, to meet the infant's nutritional requirements and achieve optimal growth, development and health. The mother is advised to continue to breastfeed the child up to two years of age or more and to begin nutritionally adequate, safe, and appropriate solid or semi-solid complementary foods at the age of six months in order to meet the evolving needs of the growing infant [1].

Out of 84 million Ethiopian population in 2012, nearly 14% are children under five years of age [18], of which 44% [19] were stunted. In Ethiopia children and their mothers are affected inordinately by poor health and under nutrition. In fact, under nutrition is the ultimate cause of 57% of child mortality in the country according to Save the Children UK [20], with highest rates of stunting and underweight in the world. UNICEF estimates that over one-third of child deaths in Ethiopia are due to under nutrition, mostly from increased severity of disease [21]. Similarly, over a quarter of women have a low body mass index (BMI) (<18.5). Ethiopia faces the four major forms of under nutrition: acute and chronic under nutrition, vitamin A deficiency (VAD), iron deficiency anaemia (IDA), and iodine deficiency disorder (IDD).

Late initiation of breastfeeding after birth, not taking colostrum and improper complementary feeding are reported risk factors for malnutrition in children [22]. Various studies indicate that the problem of malnutrition in Ethiopia also begins early in life, mainly during the first 12 months, when growth-faltering takes hold due to sub-optimal infant feeding practices [23]. A study in northern part of Wollo showed that breastfeeding pattern is the most important factor affecting malnutrition in children aged less than 6 months. Children who were not exclusively breastfed were more likely to be malnourished than those who exclusively breastfed [20]. In addition, a study in Gondar also indicated that the risk of severe acute malnutrition

was associated with non-exclusive breastfeeding for the first six months of life and late initiation of complementary food [24].

Children who are undernourished between conception and age two are at high risk for impaired cognitive development, which adversely affects a country's productivity and growth. It has been estimated that the annual value of the loss in productivity that can be attributed to child stunting is 2.9 billion Ethiopian Birr. Childhood anaemia alone is associated with a 2.5% drop in adult wages. About 1 in 5 infants are born with a low birth weight [21]. Moreover, iodine deficiency, which results in irreversible impairment of intellectual capacities, has been estimated to cost the Ethiopian economy 1.35 billion ETB per year. Similarly, it is estimated that Ethiopia loses over US\$450 million in GDP to vitamin and mineral deficiencies annually [21].

Even though the severe negative impact of malnutrition in children 6-23 months of age and their mothers is well established, there is little research conducted on prevalence of macro and micronutrient deficiency and feeding practices in Ethiopia. Most of the data for planning and implementation has been generated in the EDHS which is conducted every five years [19]. Most Ethiopian studies on children and reproductive-age mothers' nutrition were conducted in a single region rather than in different agro-ecological zones; they are normally cross sectional in design. Even though available data indicate that malnutrition starts very early in life and children typically become progressively more malnourished during the first two years of life, studies did not consider co-existence of malnutrition among children and their respective mothers. Our study provides information about the levels of macro and selected micronutrient deficiencies among mothers and their infants in two agro-ecological zones of rural Ethiopia.

This literature review examines in detail infant and young child feeding practices, prevalence of malnutrition and its determinants among infants and their mothers. It also reviews the role of underpinning causes of malnutrition in developing countries, particularly in Ethiopia. The review also examines the prevalence and predictors of malnutrition. Focus is given to micronutrient deficiencies, particularly iron, iodine and zinc deficiencies. Factors that may contribute to under nutrition among children and their respective mothers are also reviewed. In general, a core objective of this review is to assess critically infant and young child feeding (IYCF) practices among



children 6-23 months of age, magnitude of macro and micronutrient deficiencies among mothers and their infants.

### **Infant and young child feeding (IYCF) practices**

Child feeding is a multidimensional concept and feeding practices are age-specific and change rapidly with age. Appropriate child feeding practices are defined within narrow age ranges and these key feeding practices, within a continuum of child feeding, are used as an indicator of nutritional care practices [25]. In 2011, UNICEF highlighted that breastfeeding is a preventive intervention and the most important element in reducing child mortality [26]. In contrast, poor breastfeeding and complementary feeding, together with high rates of morbidity and mortality from infectious diseases, are the main reasons for undernourishment in the first two years of life [26]. In addition, appropriate complementary feeding has been shown to be most effective in improving child growth, and in reducing stunting among children 6–24 months of age [26, 27].

Studies in Kenya showed that the main social and structural barriers to optimal breastfeeding and not following WHO recommendations were: poverty, early and single motherhood, livelihood and living arrangements, poor social and professional support, poor knowledge, myths and misconceptions and unintended pregnancies [28].

In Ethiopia, being aware of the low prevalence of appropriate infant and young child feeding practices and the importance of exclusive breastfeeding, the government developed the Infant and Young Child Feeding (IYCF) guidelines in 2004 [29]. Subsequently, there were various levels of interventions about the importance of appropriate feeding, and messages regarding exclusive breastfeeding even though there is no national evidence-base on the progress made as a result of these interventions.

### **Extent of optimal breastfeeding practice**

To avoid misclassification that can result from co-existence of both good and bad nutritional care practice, a child feeding summary index was created by UNICEF which comprises of eight core and seven optional indicators. If one of them is not fulfilled, the child will be identified as sub-optimally fed [26]. Prevalence estimates for breastfeeding indicators by UN region indicated that the rates of exclusive

breastfeeding in developing countries are low (39%) and only 25% of infants were exclusively breastfed in Africa. Similarly, it is found in other developing countries that the majority of infants were breastfed, as only 5.6% of the children were not breastfed with a range from 4% in Africa to 18% in Latin America [30]. However, the main problems in developing countries including Ethiopia were related to age-appropriate feeding practices among children. For example, the EDHS revealed that complementary feeding practices are far from acceptable as only 2.9% of breastfed children age 6-23 months received the minimum acceptable diet [19].

It is established that breastfeeding in many developing countries is almost universal, but the proportion of children who are exclusively breastfed rarely exceeds thirty percent in most regions [30]. For example, 97.5% of children in Ethiopia were ever breastfed, but the proportion of exclusively breastfed children up to 6 months is only 52%. Nearly half (51.5%) of all newborns receive breast milk within one hour after birth and 80.2% of them receive breast milk in one day, while 27.1% of the newborn consumed pre-lacteal food. Similarly, 31.8% of infants were exclusively breastfed at 4-5 months of age and this figure dropped to 16.9% at age of 6-8 months; 71.4% of children between 9–11 months of age were receiving appropriate complementary foods [19].

A study in Bahir Dar (northern Ethiopia) showed that 99.5% of the children had history of being breastfed, of these 87.0% initiated breastfeeding within one hour of birth, 83.3% had consumed colostrum and 27.0% received pre-lacteal foods [31]. Another study in Debre Markos indicated that only 51.8% of infants initiated breastfeeding immediately/within one hour of birth and 75.8% of infants were given pre-lacteal feeding within three days after birth [32].

In addition, a base line survey in Ethiopia indicated that 70% of children under five were sub-optimally breastfed, 54 percent were exclusively breastfeeding during the first 6 months, and only 43 percent of children 6-9 months were optimally fed with complementary food. The rest were either weaned totally, or exclusive breastfeeding was unduly prolonged, or breast milk and other liquids were given together [33]. These outcomes strongly support the need for improvement in optimal child feeding practices.

A study in Ankesha Guagusa districts of northwest Ethiopia showed that 57.1% of infants stop exclusive breastfeeding before six months, while 37.0% ceased at six months of age and 5.9% ceased after 6 months [34]. The factors significantly

associated with stopping of breastfeeding before six months were maternal and paternal occupation, place of residence, mode of delivery, postnatal counselling on exclusive breast-feeding, and birth order of the index infant [34].

### **Initiation of breastfeeding**

As stated above, breastfeeding pattern in developing countries is almost universal; however sub-optimal feeding practices such as delayed initiation of breastfeeding, non-exclusive breastfeeding, pre-lacteal feeding and bottle feeding were prevalent in most of the sub-Saharan countries [14]. In Ethiopia, as stated above, around 51.5 % of children were breastfed within one hour of birth and 80.2% within one day after birth [19]. Baseline nutrition survey conducted in Ethiopia showed that 46% of children were breastfed within the first hour of life and 60% of them received colostrum [35]. Similarly, a study in Addis Ababa indicated 47.6% of mothers started breastfeeding within 12 hours of birth, 8.4% between 12-24 hours of birth and the remaining 40% of them initiated after 24 hours of birth [36]. In addition, a study in Sidama zone and Goba district indicated that 68% and 52.4% of the children were breastfed within one hour after birth, respectively. About 11% of mothers in Goba district initiated breastfeeding after three days of birth [37, 38].

A study in Arba Minch Zuria indicated that the majority (89%) of mothers had a history of colostrum feeding to their infants but only 42.8% of the mothers started breastfeeding within one hour after childbirth [39], while breastfeeding within one hour after childbirth was 37% in another part of south west Ethiopia [40]. The factors associated with delayed initiation of breastfeeding in Arba Minch Zuria were: lack of maternal education; whereas maternal knowledge about the duration of exclusive breastfeeding, attending primary health education, and delivery assisted by health personnel were factors reducing the risk of delay in initiation of breastfeeding practices [39].

### **Pre-lacteal feeding**

Infant feeding has great implications for immediate and future health. Colostrum is an exceptionally good source of nutrition and immunogenic for newborns [41, 42]. Nonetheless, its avoidance has been reported internationally and pre-lacteal foods are commonly introduced when breastfeeding is delayed [43]. Pre-lacteal foods are those foods given to newborns before breastfeeding is established or before breast

milk starts or “comes in,” typically in the first day of life or within the first three day after birth [44]. WHO and UNICEF recommend successful steps in breastfeeding, avoiding pre-lacteal feeding is among them [45].

Pre-lacteal foods may lead to lactation failure, inadequate milk production, infection, diarrhoea, and short duration of breastfeeding [46]. It is observed that there is a vicious cycle between pre-lacteal foods and delayed initiation of breastfeeding; consequently, pre-lacteal food may delay the production of breastmilk which may encourage the use of pre-lacteal food (15). WHO/UNICEF discourages the use of pre-lacteal foods without being medically indicated [26].

About 58% of newborns received pre-lacteal feeds in Egypt. The commonest pre-lacteal feed was sugar/glucose water (39.6%). The most frequent reasons for giving pre-lacteal feed are tradition (61.0%) and mother’s/mother-in-law’s advice (58.3%). The logistic regression revealed that the independent predictors of pre-lacteal feeding were urban residence, maternal education, father’s education, low or middle or high social class compared to very low social class, maternal obesity, receiving antenatal care at private clinics and no antenatal care, caesarean section, female babies, low birth weight, and admission to neonatal intensive care [47].

In Ethiopia, the percentage of children who received pre-lacteal feeding was 27.1% [19], whereas it was as high as 75.8% in eastern Ethiopia [48] and lower (17.2%) in Goba district of south east Ethiopia [37]. The lowest proportion (8.9%) of mothers who gave pre-lacteal feeds was reported in Arba Minch Zuria [39]. A study in Addis Ababa reported that the first food given to children was breast milk in 60% and cow’s milk in 24.3% of the children. In addition, plain water or water with sugar, and tea were frequently used pre-lacteal foods [36]. A baseline survey conducted by Ministry of Health in different districts of Ethiopia showed that only 10% of children were given breast milk alone and 73% of children were given butter as a first feed before initiating breastfeeding [49]. Another study in Gondar revealed butter as the most commonly used pre-lacteal feed (52.8%), followed by sugar water solution, cow’s milk and fenugreek. The most common reasons for giving pre-lacteal food were to soften the gastrointestinal tract, to keep the infant healthy and strong, and to avoid abdominal pain, and tradition [50]. Another study in Kobo district revealed that 38.8% of infants were given pre-lacteal feed, with the most common reasons given by mothers to protect against “evil eye”, illness and to clean infant’s stomach. The identified risk factors for pre-lacteal feeding were home delivery, no knowledge

about risk associated with pre-lacteal feeding, and late initiation of breastfeeding [51].

### **Exclusive breastfeeding**

In Ethiopia breastfeeding is near universal as 97.5% of the mothers breastfed their children but the proportion of women who practiced exclusive breastfeeding and predominant breastfeeding up to six months were 51.5% and 19%, respectively [19]. The National Nutrition Survey in Ethiopia showed that 51.5% of infants less than six months were exclusively breastfed [35].

A study conducted in Bahir Dar showed that 50.3% of children were exclusively breastfed and factors independently associated with exclusive breastfeeding were age of the infant, the mother being a housewife, having a prenatal exclusive breastfeeding plan, birth at a health facility, vaginal delivery and receiving infant feeding counselling/advice [31]. Similarly, a study conducted by Mekuria *et al* [32] indicated that 60.8% of the children were exclusively breastfed. Unemployed mothers, mothers who received breastfeeding counselling during antenatal care and infant feeding counselling during postnatal care, and mothers who had adequate knowledge about breastfeeding were more likely to practice exclusive breastfeeding than their counterparts [32].

A study in the southern part of Ethiopia also demonstrated that only 10% in the 6–8 months age group were exclusively breastfed [38]. But studies in Goba district and Goba Lafto of North Wollo indicated that exclusive breastfeeding at six months was 71.3% and 90%, respectively [20, 37]. Nonetheless, among mothers who had experience of breastfeeding at least once in their life time, 35% of them had a history of discarded the colostrum [37]. Exclusive breastfeeding rates begin to decline after two months and are only about 60-70% by the time the child is 5 months old [20]. In Addis Ababa city, the mean durations of exclusive breastfeeding and total breastfeeding were 4.9 and 22.9 months, respectively. However this study also reported exclusive breastfeeding was practiced until mean age of 2.89 months [36]. Similarly, a recent study conducted in Addis Ababa public health centres revealed that 29.3% of the mothers exclusively breastfed and associated factors were antenatal and postnatal counselling, spontaneous vaginal delivery and being in low income group [52].

### **Reasons for sub-optimal breastfeeding**

Studies have identified reasons for pre-lacteal feeding, late initiation of breastfeeding, and non-exclusive breastfeeding practices by mothers for the first six months. The reasons mentioned by mothers and family members in different countries were related to a belief in the need for water for the infant, baby not wanting to breastfeed, belief that baby did not get adequate milk, belief that the supply of breast milk was insufficient, advice from health professionals to feed water with breast milk, and the mother not having breast milk. In addition, some mothers stated other reasons including going away from their homes, use of contraceptives reduced milk supply, belief that inadequate consumption of good food reduced milk, returning to work before the baby reached six months, and baby had mouth sores so could not suck breast milk correctly [20, 36, 37, 53].

Different ideas and reasons were raised related to discarding colostrum in Ethiopia. In Goba district colostrum was not considered as white milk, rather it was considered as the cause of infant illness by inducing abdominal cramp. Regarding late initiation of breastfeeding, the mothers in this district also mentioned having abdominal cramp themselves immediately after delivery. In addition, a health extension worker in this district also said that; "... most mothers who deliver in hospital do not breastfeed till they come to our health post which may take about three hours to walk" [37]. In addition, among mothers who gave birth at health institutions and who had antenatal care follow up, only 70% of mothers were counselled on breastfeeding and complementary feeding practices. Neighbours and grandmothers also played some role in non-optimal breastfeeding practice [36].

Exclusive breastfeeding depends not only on a mother knowing that exclusive breastfeeding is best, but also on her being able to spend enough time with her child to provide sufficient breast milk. Any woman who has to spend a lot of time away from her child, for example to go to the market, may not be able to breastfeed her child exclusively. The results of a study in North Wollo showed that those who spent more than two hours away from their child were significantly less likely to exclusively breastfeed their children than those who spent less time away from home [20]. However, the study in Addis Ababa indicated that 22% of mothers who stayed at home and 23.4% of mothers who worked outside their home stopped breastfeeding before six months of age [36].

The same study in Addis Ababa showed that 43.4% of single mothers and 23% of married mothers stopped breastfeeding before six months of age [36]. Household income and maternal education were one of the determinants for cessation of breastfeeding. Households with monthly income less than 500 ETB were more likely to stop breastfeeding before six months compared to counterparts (54% vs 45.6%) [36]. Similarly, it was found that 29% of mothers who attended secondary school or less and 14.4% of mothers with higher education stopped breastfeeding before their babies were six months of age [36]. Other studies also showed that maternal education has prominent effects on child nutritional care/feeding practice [24, 26, 35].

Infants less than two months of age were more likely to be exclusively breastfed than infant aged four to six months. Likewise women in the wealth index ranking of middle and above the reference category were two times more likely to exclusively breastfeed [54]. However, a study done in Addis Ababa indicated that monthly income of mothers less than or greater than 500 Birr was not found to be statistically significantly associated with cessation of breastfeeding before their babies were six months of age [36]. Additionally, association was not found regarding place of residence, maternal age, occupation of women, and access to mass media, attending antenatal care, and sex of the child [54].

Timely initiation of breastfeeding was significantly related with institutional delivery, place of residence, post-natal advice on breast feeding and educational status [37, 54]. A national study in Ethiopia indicated that rural children were more likely than urban children to start breastfeeding within one hour [54]. In contrast to this finding, a study in Goba found that urban mothers tended to initiate breastfeeding earlier when compared to their rural counterparts [37].

Highly educated mothers were less likely than those with little or no education to put their newborn to the breast within the first hour or day of birth [54]. However, study in Goba showed that mothers who had formal education were 1.4 times as likely to initiate breastfeeding within an hour after birth as compared to those mothers who had no formal education [37]. Early initiation of breastfeeding was more common among mothers who were assisted by a trained traditional birth attendant or delivered at health institutions than mothers who delivered at home [37, 54].

### **Complementary feeding practice**

WHO recognized three guiding principles used as indicators for feeding breastfed and non-breastfed children of age 6-23 months. These are: continued breastfeeding; feeding appropriate solid or semi-solid food; and dietary diversity (feeding from at least four food groups) depending on breastfeeding status [26]. The proportion of children continued breastfeeding at one year was about 86% in the developing countries, but about 92% in Africa - but this figure drops to 70% for children 12–23 months of age in Africa [30].

In Ethiopia complementary foods are introduced at different months regardless of the recommendations to introduce foods at six months of age. A few earlier nationally representative studies in Ethiopia indicated that 22% of children aged 6-23 months were fed in accordance with all three IYCF recommended practices [55]. The three IYCF practices are: continued breastfeeding or feeding with appropriate calcium-rich foods if not breastfed; feeding solid or semi-solid food for a minimum number of times per day according to age and breastfeeding status; and including foods from a minimum number of food groups per day according to breastfeeding status. Around 72% and 31% of children in Ethiopia breastfeed for up to two years and three years, respectively [49].

Similarly, local studies also suggested that there are low levels of appropriate complementary feeding practices in Ethiopia. Among children already started on complementary feeding in Addis Ababa, about 53.5% were younger than four months, 43.2% between 4 - 6 months and 3.3% were beyond 6 months of age [36]. In another study, 20% of mothers of children aged 8-10 months in north Wollo reported giving only breastmilk to their child in the 24 hours prior to the interview [20].

It is the recommendation of UNICEF that babies should be fed with cups and spoons. Bottle-feeding is not recommended because improper sanitation and formula preparation with bottle-feeding can introduce microorganisms to the infant that increase the child's risk of illness and malnutrition [26]. However, the rate of bottle-feeding varies in developing countries. Nationally, bottle-feeding practice was found as 28.5% in Ethiopia [19]. The study also revealed that in Addis Ababa about 54.2% of mothers used bottle, 36.8% used combination of bottle and cups, and 7.3% used spoon and cups to feed complementary food to their children [36].



Studies found that the most common complementary foods being given to children were cow's milk, plain water, powdered milk (formula milk), fruit juice or crushed (milled) fruits, porridge cereals, vegetable soup and/or ready prepared food [36, 37, 53]. At 6 to 7 months of age only about 34% of children received adequate complementary food and this proportion increased to 84% at 16 to 19 months [49]. The EDHS 2011 also indicated that the proportion of children aged 6-23 months consuming foods made from grains (66%) was the highest, while only 5% of children consume meat, fish, shellfish, poultry and 8% feed on eggs. Consumption of liquids other than milk peaks at 6-8 months (48%) [19]. Plain water (71%) and fresh animal (goat's) milk (20%) were fed most frequently to infants before 6 months of age in addition to breast milk by almost all of the mothers in Sidama zone [38]. Whereas in Addis Ababa, 52.5% of the mothers gave formula milk followed by cow's milk alone or in combination with other foods (35.7%) as complementary food [36].

Among mothers in Addis Ababa who expressed their opinion about the appropriate age for starting complementary feeding, 88.3% reported that the age between four to six months is the correct age to initiate complementary feeding while 5% identified six months as appropriate. Though 88.4% of mothers stopped exclusive breastfeeding before six months of age, they reported 22.9 months for mean duration of total breast-feeding for the children [36]. In Ethiopia, among children 6 to 23 months of age and still breastfeeding, only 29% met the recommended minimum dietary diversity of eating from four food groups per day [35]. Almost none or very few (6%) of the children were fed according to good infant and young child feeding practices [38]. Most of the children consumed only 0-2 food groups, which rarely included foods rich in vitamin A or iron. Grains (like maize and sorghum), roots or tubers were the most frequently consumed food group among Ethiopian households [24, 38].

### **Reasons for sub-optimal complementary feeding**

Evidence from different studies identified various reasons that made mothers introduce complementary foods before six months of age. These included: the mother had no or insufficient breast milk, did not know when to start, sickness of the mother or child, child refusal, baby bites, husbands advised the mother to stop breastfeeding, breastfed babies feed too frequently, breastfeeding takes longer time,

mother got pregnant, and maternal breast problems. Predictors of early introduction of complementary foods indicated by various studies included the mother's marital status, her ethnicity, her level of education, desirability of the pregnancy, place of delivery, place of residence and mother's employment status [36]. A study in Addis Ababa indicated that the reasons for initiating complementary feeding before six months included that 35% of mothers felt that the child was at the right age to start and 28.6% gave the reason that they did not have enough breast milk. Sickness of the mother and/or sickness of the child was the reason given by 14.6% of the respondents and 8.9% gave difficulty because they had to work as their reason; while about 5.3% and 5.4 % gave reasons of child refusal and maternal breast problem, respectively [36]. In Gondar, more than fifty percent of the mothers perceived that their supply of breast milk was insufficient [50].

There is also a report of gender difference in feeding of complementary foods in some regions. It is found that boys were more likely to be introduced to complementary feeding early compared with girls; the reason given was breast milk alone does not meet their feeding demands [54].

Factors associated with early introduction of complementary foods in Kenya were maternal education, place of delivery, pregnancy desirability, and slum residence [28]. A study in Addis Ababa showed that mothers with low education breastfed their children for a longer period of time than those who attended higher education [36]. Similarly, maternal working place away from home was a factor associated with stopping breastfeeding before six months of age [36].

### **Dietary diversity**

Humans require at least minimum energy to maintain basal metabolism and vital body functions and this energy can be obtained from consumption of a diet consisting of roots, tubers and cereals. However, the body also requires nutrients for growth and protection from infection and disease, and this imposes the need for selection of varied foods as the best means of ensuring an adequate supply of the essential nutrients. Breast milk is recognized as the only food that can provide all the nutrients required to support optimal growth in early infancy [45]. However, at six months all infants should start receiving nutritionally adequate, safe and appropriate foods to complement breast milk [26]. A perfect complementary food would be one that is sufficient to fill the gap left by breast milk in supplying the

energy and nutrients required to maintain optimal growth in the infant and young child. An imbalance in this regard is reflected in retarded growth and poor development [6, 27].

Dietary variety, dietary diversity, diet diversity and food diversity are terms that relate to the range of foods or food groups constituting the diet of a given individual, household or community [56]. This review uses the term dietary diversity to include the whole range of terms that imply variety in unique foods and food groups. Dietary diversity is mainly measured by counting of food groups consumed during the recall period (summarizing consumption data into scores for food groups) and food variety score (FVS) (count of all dietary items consumed during the recall period) [57].

At the household level, dietary diversity is frequently reflected as a measure of access to food (e.g., of households' capacity to access costly food groups), while at individual level it is a measure of dietary quality, indicating the general micronutrient adequacy of the diet. The reference period can be the previous seven days, three days or 24 hours [57].

Feeding of different varieties within a species of crop may have a significant impact on nutritional contribution of that species, as significant differences in nutrient composition have been found among different varieties of the same crops. This goes to demonstrate that intake of a given variety as opposed to an alternative variety could have an impact on nutritional outcome within society [13]. According to WHO, the minimum dietary diversity for children 6 to 23 months of age is to consume at least 4 different food groups out of 7 in the previous 24 hours. Eating at least 4 groups is associated with a better quality diet [6, 26]. But in Ethiopia, among those children 6 to 23 months of age and still breastfeeding, only 29 percent consumed a minimum of 4 different food groups, and only 38% of those who had stopped breastfeeding had consumed at least 4 food groups [35].

A study conducted in the northwest part of Ethiopia indicated that 12.6 and 50.4 % of children met the minimum dietary diversity and meal frequency, respectively. It indicated that mothers' education, age of child, birth order of index child, living in urban area, having home garden, and media exposure were positively associated with dietary diversity; whereas age of the child, birth order of index child, mothers' involvement in decision making, media exposure and having postnatal visit were associated with meal frequency [58]. It indicated that only 26% of children less than

five years consumed vitamin A-rich foods and 13% consumed iron-rich foods [19]. In contrast, the median dietary diversity score of lactating mothers in north Ethiopia is 5 out of 14 food groups [59].

### **Household food insecurity**

Dietary diversity has been proposed as a food security indicator that could measure household or individual level access to food [60], and it can also serve as a measure of the nutritional adequacy of diet in relation to health outcomes. The Food and Agriculture Organization (FAO) [61] definition of household food insecurity has two broad components: insufficient access to a nutritionally adequate and safe food supply and underutilization of these foods by household members. The access part comprises three main domains: “anxiety and uncertainty about household food supply, inadequate quality of food, and insufficient food to eat by household members” [62, 63]. The utilization component is affected mostly by nutritional knowledge and beliefs; however, access to healthcare, water, sanitation services, hygiene and childhood illness management are also factors [61]. The negative effects of household food insecurity are: decreased food consumption, which comprises of reduced dietary variety and nutrient intake, and under nutrition of household members.

As food insecurity has negative effects on health and development of humans, household food insecurity, dietary diversity and nutrition issues are at the top of the planning agenda in many countries in sub-Saharan Africa. In 2015, 220 million people (23.2% prevalence) in sub-Saharan Africa lack adequate food for a healthy and active life, and high food prices and drought are pushing more people into poverty and hunger [64]. Household food security depends not only on the availability of an adequate and sustainable supply of food but also on the means employed by households to acquire the needed food. “A household is food secure when it has access to the food needed for a healthy life for all its members (adequate in terms of quality, quantity, safety, and cultural acceptability), and when it is not at undue risk of losing such access” [12, 61].

The key challenges to reduce food insecurity and under nourishment in the world, predominantly in Sub-Saharan Africa (SSA) and South Asia, are: climate change, spiking food prices and the increasing demands on arable land to produce biofuel energy. Due to change in climate and other global environmental changes such as

land ruin and changes in essential ecosystems, agricultural production systems and access to food are at high risk of declining dramatically [65]. This will increase the risk of hunger and malnutrition in the two regions that are home to 60% of undernourished people. In addition, environmental change is expected to aggravate under nutrition through its effects on illnesses, such as diarrhoea, malaria and other infectious diseases [65].

Rapid population growth creates further challenges in averting hunger and food insecurity in SSA [66]. Nearly 30 million children (one in five) are underweight and 5 million SSA children die each year from causes associated with hunger and malnutrition, while many survivors are continuously affected by hunger-related diseases [12]. Concerning food insecurity in Ethiopia, different studies reported different magnitude; 70% and 45% in eastern Ethiopia [67, 68] and nationally 35% [35] of the households are food insecure. In Jimma, in the south-west part of Ethiopia, 35% of the households are food insecure [69].

### **Prevalence and determinants of malnutrition**

Exposure in early life is increasingly being recognized and studied with respect to subsequent health outcome in later childhood and adulthood. Nutritional insults in early life, especially in the first two years of life, can lead to irreversible linear growth retardation (stunting) [70]. It has been recognised that malnutrition during the first 1000 days of a child's life, commencing at conception, has adverse effects much later in the life course, like increased risk of non-communicable disease, reduced cognitive development and reduced economic productivity [6, 71]. It is recognised that the period of 6 to 23 months of age is critical in the growth of the child during which malnutrition can have a terrible consequence. The incidence of stunting is highest in this age group, as children have great demand for nutrients on the one hand and there are limitations in the quality and quantity of available foods, especially after exclusive breastfeeding ends [72, 73].

The root cause of most undernutrition is scarcity of resources. Even though less developed countries have the highest burden of malnutrition, including micronutrient deficiencies, these deficiencies also occur even in some population groups in developed countries [74]. Similar to poverty, undernutrition and micronutrient deficiency often occur as part of an intergenerational cycle [75]. Malnutrition affects all age groups and populations, in particular the poor and vulnerable age groups of

the population are at high risk [1, 6, 70]. A 2013 global report showed that about 6.3 million children died before five years, of which 44% died before one year [76], greater than 50% of all infant deaths that occur worldwide are due to malnutrition [77].

### **Prevalence of malnutrition (macro-nutrient) among children**

Recurrent infections and diarrhoea due to poor hygiene and sanitation are major contributors to malnutrition in addition to poor dietary diversity. In less developed countries, 19.4% of children less than five years of age were underweight, 29.9% were stunted in the year 2011 [11]. In Sub Saharan Africa (SSA), over 3.4 million children less than five are dying each year and up to 40% of children are stunted [13, 14]. Over one-third of child deaths in Ethiopia are typically from increased severity of disease associated with malnutrition [78].

A study conducted in the northwest part of Ethiopia reported the prevalence of stunting, underweight, and wasting among school children was 23%, 21%, and 11%, respectively [79]. Similarly, a recent study among school children revealed that 25.6% of children were stunted, of which 10.3% of the children were severely stunted, and 14% were wasted [80]. In Ethiopia, studies report the prevalence of stunting among children less than five ranges from 23 to 48% [81-86] and wasting ranges from 4.5 to 16.7% [85-87].

A study conducted in Wag-Himra zone of northern Ethiopia showed that 23.6% of children under two years were stunted [81]; and in North Wollo, 33% of children aged 12-23 months were stunted [82]. A study conducted in the southern part of Ethiopia reported that the prevalence of stunting among infants aged 6 to 8 and 9 to 23 months was 43% and 39%, respectively [83]. Similarly, a recent study in Somali region stated that prevalence of wasting, stunting and underweight among infants and young children were 17.5 %, 22.9 % and 19.5 %, respectively [88].

Factors associated with wasting were sub-optimal breastfeeding and diarrhoea in the past 15 days, while stunting was associated with poor dietary diversity score and introduction of complementary feeding at before 6 months. Bottle-feeding was also associated with increased odds of stunting. Similarly, breastfeeding was related with reduced risk of underweight, whereas diarrheal disease were positively associated with underweight [88].

A study conducted in Butajira (southern Ethiopia), revealed that at 6 months prevalence of infant stunting is 26.7%, with 21.7% underweight, and 16.7% wasted. On repeated assessment at 12 months of age, the prevalence of stunting rose to 48.1% [85]. Similarly, a study in Sidama zone showed that 23% of infants were stunted at six months of age and these figures increase to 36% at 9 months, where the 23% of infants classified as stunted at 6 months were still stunted at 9 months [84]. These data show that malnutrition, particularly stunting, begins at early age, even less than six months, in Ethiopia.

A study of children under 5 years old in northern Gondar in Ethiopia [86] stated that underweight, stunting, and wasting were seen in 14.6%, 37.2%, and 4.5% of children, respectively. Moreover, severe underweight, severe stunting, and severe wasting were seen in 2.9%, 14.8%, and 0.5% of the children, respectively. Malnutrition affected 41.4% of all children, with those 12-23 months old suffering the most (66.7%). This study noted that smaller family size and younger age of children were related to higher occurrence of malnutrition among children.

### **Determinants of malnutrition among children**

World Health Organization estimates that inappropriate feeding of infants and young children is responsible for one-third of the cases of malnutrition worldwide [89]. Studies have also established that giving complementary foods too late increases the chance of nutritional stunting. On the other hand, maternal under nutrition is also a common problem in developing countries which are vulnerable to household food insecurity and susceptible to recurrent and frequent parasitic infections. Poor health care services availability and accessibility, in addition to heavy workloads and gender inequities, also affect many mothers [6, 70].

The risk factors for under nutrition differ across age groups. For children, the common causes of malnutrition include: not eating sufficient food, not taking supplementary vitamin A and inadequate deworming with consequent high rate of parasitic infestation, recurrent infections, high parity of the mother, lack of exclusive breastfeeding, low birth weight [90]. Diarrhoea, inappropriate pre-lacteal feeding and breastfeeding, educational level of the parents especially for mothers, and household incomes [91] are also contributing factors for malnutrition [92, 93]. Similarly, a higher level of stunting was reported among children who had never

been breastfed, who had been breastfed for less than 1 year, or had been fed with semi-solid foods of poor quality [94].

A study in Kenya [95] indicated that maternal education is a strong predictor of child stunting with some minimal attenuation of the association by other factors at maternal, household and community level. Other factors including at child level: child birth weight and gender; at maternal level: marital status, parity, pregnancy intentions, and health seeking behaviour; and at household level: socio-economic status are also independently and significantly associated with stunting [95]. The main contributing factors for under-five stunting were found to be sex of the child, child's age, diarrhoea episode, deprivation of colostrum, duration of breastfeeding, pre-lacteal feeding, type of food, age of introduction of complementary feeding and method of feeding [23].

Epidemiological studies conducted in developing countries have identified several factors associated with undernutrition, including low parental education, poverty, low maternal intelligence, food insecurity, maternal depression, rural residential area and sub-optimal infant feeding practices [6, 8]. Significant and consistent predictors of infant undernutrition in Ethiopia are male gender, low birth weight, poor maternal nutritional status, poor household sanitary facilities and living in a rural residence. Compared to girls, boys had twice the odds of being underweight at 6 months and being stunted at 6 months and at 12 months of age. Infant undernutrition at 6 and 12 months of age was not associated with infant feeding practices in the first two months of life in Butajira [85].

### **Prevalence of malnutrition among reproductive age mothers**

Malnutrition among women is likely to have a major impact on their own health as well as their children's health. More than 3.5 million women and children under age five in developing countries die each year due to the underlying cause of under nutrition [96]. Women in low-income settings often consume inadequate amount of micronutrients because of resource scarcity. They have a limited intake of animal source foods, fruits and vegetables. Intakes of micronutrients less than the recommended values increase women's risk of micronutrient deficiencies [6]. Adequate nutritional status of women is important for good health and increased work capacity of women themselves as well as for the health of their offspring [6].



Women are more likely to suffer from nutritional deficiency than men for several reasons including their reproductive biology, low social status, poverty and lack of education. In addition, socio-cultural traditions and disparities in household work patterns can also increase women's chance of being malnourished [97].

A study showed that 27% of reproductive age women in Ethiopia were thin or undernourished (BMI less than 18.5 kg/m<sup>2</sup>), [98] and the EDHS reported prevalence of under nourishment in women as 29.4% [19] of which 22 % were pregnant. Iron supplementation among women was 6%, and 83% did not take iron tablets during pregnancy. Even among mothers who took iron during their pregnancy, only 1% took iron supplements for the recommended 90 days or more [19]. Similarly, a study in northern Ethiopia (Tigray) among lactating mothers showed that 31% were underweight, 25% have chronic energy deficiency and 2.2% were stunted [59].

### **Determinants of malnutrition among reproductive age mothers**

Factors associated with under nourishment of reproductive age women in Sub-Saharan Africa are: low household income, food-shortage, high burden of disease, low level of knowledge about continuing effects of under nourishment, low quantity and quality of food, and low access to health and nutrition services [99]. A study in Samre Woreda, South Eastern Zone of Tigray, identified that the factors significantly associated with the nutritional status of the study participants (as determined by BMI and MUAC) were size of farm land, length of years of marriage, maize cultivation, frequency of antenatal care visit and age of breastfeeding child [59]. Mothers who are breastfeeding, recently had severe illness, and have multiple children below 2 years of age are more likely to have poor nutritional status in a study conducted in Kenya [100].

### **Micronutrient deficiency**

Micronutrient is the term used to represent important minerals and vitamins required from food to sustain health and all normal cellular and molecular functions [89]. Micronutrient adequacy level can be determined by using dietary intake data, biomarkers, or nonspecific functional indicators, like low birth weight or stunting. Ideally, micronutrient deficiency is measured by valid and reliable biomarkers that

are defined as biological measurements from blood, urine, or any tissue organs that are used to indicate normal or pathogenic biological processes [101].

Even though the amounts of micronutrients required for appropriate functioning of the body are very small, micronutrient deficiencies (MND) have wide-ranging health impacts that will ultimately result in morbidity and mortality if untreated. Micronutrient deficiencies often happen as part of a continuum of malnutrition and may be associated with protein or energy malnutrition (macro-nutrient deficiency) [102].

Despite ongoing efforts to control micronutrient deficiencies in low-income countries, deficiencies in iodine, iron, zinc, and vitamin A remain major public health problems. In the Lancet series on maternal and child undernutrition, deficiencies of vitamin A and zinc were estimated to be responsible for 600,000 and 500,000 deaths per year, respectively, and a combined 9.8% of global childhood Disability-Adjusted Life Years [103].

Deficiencies of micronutrients often coexist [104], possibly because of similar causal factors, such as (1) inadequate dietary intake and/or absorption from predominantly plant-based diets; (2) sub-optimal breastfeeding practices; (3) diseases that either induce excessive losses or impair use of the micronutrients; and (4) physiological states that increase requirements, such as periods of rapid growth during childhood and pregnancy.

### **Micronutrient deficiency among children**

A study conducted in China showed that the percentage of children not meeting the estimated average requirement for zinc, vitamin A, iron, and protein or the adequate intake for calcium was 87.2%, 80.8%, 66.3%, 7.6%, and 100.0%, respectively. Altogether, 19.2% and 78.5% of children were below the acceptable macronutrient distribution range for percentage of energy from protein and fat, respectively. Stunted children were more deficient in vitamin A and more anaemic. Growth faltering, combined with findings of anaemia and suboptimal intake of a variety of nutrients, suggests a high prevalence of chronic dietary inadequacy [105].

Among under five children in Ethiopia, only 26% consumed vitamin A-rich and 13% consumed iron-rich foods [19]. In Ethiopia 4 out of 10 preschool age children are vitamin A deficient, deworming covered 21% of children 6-59 months old [19], and consumption of iodized salt varied in different studies: one-fifth of households [78],

16% of the household [19], and 5 % household [35]. Overall around 2.5 million infants remain unprotected from iodine deficiency disorders [78]. A study among school age children in the Amhara region reported that 79.5% of the children had at least one micronutrient deficiency, and 40.5% had more than one coexisting micronutrient deficiency. Of the micronutrients, deficiency prevalence was 12.5% for zinc, 13.9% for folate, 3.7% for ferritin while 30.9% of the children were anaemic [106].

### **Low serum Iron among children**

Iron status in the body is assessed using biomarkers including serum ferritin, haemoglobin and transferrin saturation. Ferritin is an indicator of body iron stores, haemoglobin is most commonly used to determine anaemia [10]. Children born to iron deficient mothers are at risk of having low iron stores, and suffering from reduced physical and cognitive development that can affect human potential [38, 107, 108].

Iron supplies for infants less than six months old are not well defined, because requirements are difficult to estimate for exclusively breastfed infants. Likewise, during the first 4-6 months of age, infants benefit from iron stores present at birth, which are accumulated primarily during the last 10 weeks of gestation [110, 111] and an additional small quantity (<0.5 mg per day) of iron received from breast milk [112]. For this reason, supplementation of iron for breastfed term infants less than six months old is typically not recommended. But supplementation may be recommended for infants less than six months old that have lower birth iron stores due to different reasons [112]. However, for infants greater than six months old, consuming iron at 11mg/day for 7–12-month olds and 7mg/day for 1–3-year olds is recommended [112].

The global prevalence of iron deficiency with or without anaemia is unknown, as most nutritional surveys measured anaemia prevalence only. World Health Organization [10] estimated that approximately 25% of the population worldwide suffers from anaemia, with the highest prevalence among pre-school children (47%), pregnant (42%) and non-pregnant women (30%). The prevalence among African children was 64.7% [10]. Most countries in the regions have estimated prevalence of above 40% [113], with the highest rate of 75% in Western and Central African Region [10].

In Ethiopia the prevalence of iron deficiency is not documented so far and most of the data available are for anaemia only. The prevalence of anaemia in children in Ethiopia ranges from 34% to 68.5% [81, 84, 114, 115]. The national data from EDHS showed that the prevalence of anaemia among children less than five is 44% [19]. A study conducted by Habte *et al.* showed that the prevalence of anaemia among children 6-59 months old was 50.3% with peak at age of 6-11 months (68.5%) [115], while prevalence of anaemia is reported about 37 % in Northern Ethiopia with higher magnitude among children less than 6-11 months (53.2%) [114]. These findings suggest that the prevalence of anaemia among children less than five is higher for the younger age children.

There are relatively few studies regarding prevalence of anaemia among children 6-23 months of age in Ethiopia. According to EDHS, the prevalence of anaemia in this age group is 60.9% [19]. Woldie *et al.* reported anaemia prevalence of 66.6% in Northern Ethiopia [81]. Another study conducted in the Sidama region of southern Ethiopia revealed that 24% of children were anaemic at 6 months and increased to 36% at 9 months [84]. The identified risk factors associated with ID were haemoglobin and ferritin concentration of the mothers [116], and infant haemoglobin was associated with maternal haemoglobin [116].

### **Iron deficiency among lactating mothers**

Iron requirement is critical during pregnancy because of rapid cell and tissue development during foetal growth. Pregnancy has a net iron requirement ranging 600–800 mg [75, 117]. Approximately 300 mg of iron are required for the foetus, 25 mg for the placenta and about 500 mg for the increased red blood cells volumes [118, 119]. So the recommended iron requirements during pregnancy of 27 mg per day far surpass those for non-pregnant women (18 mg per day) [75].

Iron deficiency (ID) during pregnancy not only affects the mother, but also her infant. Low iron stores during pregnancy not only can lead to anaemia, they are also associated with fatigue, weakness, reduced cognitive performance and immune response. Low stores also increase the risk of preterm delivery, low birth weight and neonatal mortality[120]. ID during pregnancy also increases the risk of iron deficiency anaemia during lactation [75]. Among lactating women, ID has similar effects as in non-pregnant women of reproductive age. These include increased risk of IDA, reduced work and mental capacity, increased risk of emotional disorders like postpartum depression and

also reduced mother-child interactions [120]. It is estimated that in developing countries 22% of maternal deaths are associated with severe anaemia [121, 122].

Prevalence of iron deficiency is estimated to be about 2.5-times the prevalence of iron deficiency anaemia in many settings. Anaemia affects 46% of non-pregnant women in developing countries [123] and can affect up to 75% of them in the malaria setting of SSA [10]. Postpartum, it is estimated that it may affect up to 50%–80% in developing country settings [124]. A study conducted by Umeta *et al.* [125] in Ethiopia showed that the prevalence of anaemia, ID and IDA was 30.4%, 49.7% and 17%, respectively. Similarly, another study among reproductive age women found that 30.4% had anaemia, 50.1% were ID and 18.1% had IDA [126]. These studies indicate that prevalence of IDA is a major public health problem among reproductive-age Ethiopian women.

There is a scarcity of studies among lactating mothers in Ethiopia. The prevalence of anaemia was 22% among lactating mothers in Addis Ababa slums [127]. The EDHS in 2011 [19] also reported that national prevalence of anaemia among lactating mothers was 22%, with the highest rate of 48.3% in the Somali region. The prevalence in Oromia and Tigray was 20.1 and 13.4%, respectively [19]. Similarly, a study conducted in St. Paul's Hospital, Addis Ababa, showed that 23.6% of lactating mothers had IDA [116].

Iron deficiency among pregnant women in developing countries is exacerbated by the fact that so many enter pregnancy without adequate iron stores [120]. Dietary inadequacy in consumption of animal source foods (haem), and interferences in iron absorption by inhibitors (e.g., calcium, phytates) [128], infections like malaria, and multiple pregnancies all contribute to ID [110, 119, 120]. The risk factors for lactating women include all of the risk factors identified for pregnant women and, additionally, delivery-induced bleeding [124]. Women who had more children aged less than five years but above two years, open-field toilet habits, chronic illnesses, and having intestinal parasites were more likely to be anaemic. Women who had no formal education and who did not use contraceptives were less likely to be anaemic [126].

### **Zinc deficiency**

Zinc is a trace element and a vital micronutrient involved in basic physiologic and metabolic functions of human beings [129]. Zinc deficiency is a major public health problem in many developing countries including sub-Saharan Africa. Zinc

deficiency has many adverse consequences: it impairs immunity which increases the risk of childhood infections such as pneumonia and diarrhoea and subsequent increased rates of mortality; reduced growth and development of infants and children; effects on maternal health and pregnancy outcomes like pregnancy-induced hypertension, placental abruption, premature rupture of membrane, prolonged labour, infections, haemorrhage, intrauterine growth retardation, congenital anomalies, low birth weight, higher risk of neonatal morbidity and reduced neurobehavioral development [130]. Many studies suggest that deficiency of zinc is a common public health problem in the world. WHO estimated that zinc deficiency affects about 31% of the world's population ranging from 4-73% in different regions. According to IZiNCG, in Ethiopia, it is estimated that 21.1% population is at risk of inadequate dietary zinc intake [131].

#### **Prevalence of zinc deficiency among children**

The importance of zinc deficiency in childhood growth and development has been long recognised and subclinical deficiency of zinc is recognised as a limiting factor for growth among children worldwide [132]. It is estimated that nearly 6.9 million children under 5 years of age died worldwide in 2011, of which suboptimal breastfeeding, deficiency of vitamin A, and zinc deficiency were responsible for more than one-third of these deaths and contributed to more than 11% of the global total disease burden [133]. A study in the northwest part of Ethiopia indicated that zinc deficiency occurred in 47% of school children [79]. In contrast, a recent study in Libo Kemkem and Fogera Districts of the Amhara region indicated that only 12.5% of school children were zinc deficient [106].

#### **Prevalence of zinc deficiency among mothers**

A study in Sidama, southern Ethiopia, indicated that 53.0% of pregnant women were zinc deficient [134]. This finding is lower than Abebe *et al.* (72%) study conducted in the same region in 2008 [135]. The identified predictors of zinc deficiency among the study subjects were age and maternal income, poor dietary diversity, and low consumption of animal source foods. It is found that zinc deficiency was higher among maize consumers compared to consumers of Enset (false banana). Maternal education, frequency of coffee intake and haemoglobin concentrations were also associated with zinc levels among pregnant women [134].

### **Iodine Deficiency Disorder and universal salt iodization**

Iodine deficiency disorder is related to life threatening health conditions throughout the lifecycle and is associated with mental impairment in children, goitre in adults and pregnancy complications including stillbirth and congenital anomalies [136]; and can lead to irreversible foetal brain damage in pregnancy [137]. There is also evidence in Ethiopia that iodine deficiencies can affect academic performance. It is reported that children with goitre are more likely to be absent from school and record lower grades in school [138].

In population studies, median values for urinary iodine above 200µg/L in adults are not recommended because of the risk of iodine-induced hyperthyroidism. Iodine intakes of greater than 300µg/L per day are considered excessive and should be discouraged in order to avoid possible adverse health consequences [139]. Epidemiologic criteria for assessing iodine nutrition based on urinary iodine concentration in pregnant and lactating women were published in 2007. These criteria specified that measurements should be made using urine samples collected in the morning or from spot urine [136, 140].

It is reported that due to metabolic changes during pregnancy and lactation the demand of iodine greatly increases [140, 141]. During pregnancy, thyroxine and iodine transfer from the mother to the foetus [141]. During lactation, the breastfeeding mother provides the nursing infant with its only source of iodine when exclusively breastfed [140]. However, the amount of iodine present in breast milk reduces slowly over the course of the six months after birth in iodine deficient mothers [142]. Maternal and child iodine, iron, and zinc deficiencies are common in low and middle income countries. These deficiencies often occur simultaneously and inordinately affect pregnant women and children less than five years of age [6]. The World Health Organization has estimated 1.9 billion individuals (31% of world population) have insufficient dietary iodine intake and this is a major public health problem in about 47 countries [143]. Among school age children worldwide, 241 million (29.8%) are estimated to have insufficient iodine intakes with 58 million (39% prevalence) of these children in Africa [144].

Understanding the importance of iodine, WHO/ICCIDD/UNICEF recommended that median urinary iodine level of more than 150, 100 and 100µg/L should be considered for iodine sufficiency of pregnant women, lactating women and children

less than two years, respectively. The figures for urinary iodine among lactating women take account of the approximately 75-200 µg iodine which are secreted in breast milk daily [19, 20]. Therefore, the iodine requirement during lactation ranges from 225-350µg/day [145, 146].

Universal salt iodization is recommended as a safe, sustainable and cost effective strategy to safeguard acceptable intake of iodine by all populations. In Ethiopia, more than 6 million women in reproductive age groups are affected by goitre with the highest rates among communities living in endemic areas including Oromia and Tigray [147]. It is estimated that in Ethiopia the median Urinary Iodine Concentration (UIC) is <100µg/L which makes the country among the top iodine deficient countries in the world [148]. The major causes of the problem can be partly attributed to lack of awareness about the importance of iodine and its consequence on health, lack of access to iodized salt in households, as well as soil losses by erosion.

Iodine deficiency among school-age children is considered an indicator of the prevalence of iodine deficiency disorders in a population. Nationally, goitre prevalence rate among school children and household members ranged from 0.4% to 66.3%, with an average value of 35%, but prevalence was also reported up to 71 % in some regions [138, 149].

A cross-sectional community based survey conducted in Ethiopia showed that total goitre prevalence was 35.8% of women, of which 24.3% had palpable goitre and 11.5% visible goitre. High prevalence rates were reported in four regional states (Oromia, Amhara, South Nations and Nationalities, and Tigray) where about 60 % of the country's population is living. The survey reported that more than 6 million women in reproductive age were affected by goitre [149]. Similarly, baseline data on the magnitude of Iodine Deficiency Disorder (IDD) and the demand for iodized salt supplementation revealed that prevalence of goitre was 71.4%, with 59.5% in males and 80.2% in females, in Tigray with an adjusted total goitre prevalence of 57.2%. The lowest estimated rates of cretinism were 37.7 per thousand people [150]. Another study in southern Ethiopia indicated that the goitre rate ranged between 15.9 - 59.9% among women [151]. In Burie and Wombera district of northern Ethiopia, the prevalence rate of total goitre was 30.1% among women in reproductive age [152], while 82% of pregnant women in Haramaya district of eastern Ethiopia were suffering from mild iodine deficiency [153].



It is established that deficiency of iodine is a major public health problem around the globe and the major cause of preventable brain damage in childhood. This situation is the main driving force behind current worldwide initiatives to reduce iodine deficiency disorder through universal salt iodization [154]. Salt iodization is an established method to eliminate iodine deficiency disorders with the objective of making all edible salt iodized, since salt is an ideal method for introducing iodine into people's diet. On top of this, salt is consumed by nearly every household and person, roughly in equal amounts and throughout the year [143].

Studies in East Africa revealed a varied level of household consumption of iodized salt with the highest rate in Uganda (96%) [155] and very low rate in Somalia (6.7%) [156]. The EDHS reported that only 15.4% of Ethiopian households consumed iodized salt with the higher rate in urban (23.2%) than in rural (13.3%) communities [19]. Regarding regional variation, Benishangul-Gumuz had higher rate of utilization (40%), followed by Addis Ababa (30%), but Dire Dawa and Harari regions had the lowest (6%) rate of utilization. In Tigray, 22.3% of households used iodized salt [19]. A local study in Laelay Maychew district in Tigray region indicated that 33% of the households consumed iodized salt [157]. This indicated that Ethiopia is far below the WHO recommendation of 90% coverage to eliminate IDD [143]. The lowest (1.15%) record of household use of iodized salt was found in west Gojjam of Amhara region [152]. Deficiency of iodine can be reduced by utilization of iodized salt as well as by intake of milk twice or more times in a month. Risk of deficiency is increased by maternal illiteracy [153], and low dietary diversity [152]. A recent study in southern Ethiopia indicated that 93.8% the households did not use iodized salt of which 87.6% did not know the importance of using iodized salt. The participants suggested that causes of goitre were drinking dirty water, drinking tap water and drinking rain water [151].

**Specific objectives were to investigate the following:**

1. Seasonal variation in nutritional status and anaemia among lactating mothers in two agro-ecological zones of rural Ethiopia (Chapter 2).
2. The prevalence of anaemia and malnutrition among 6-23 months of age children in different agro-ecological zones of Ethiopia (Chapter 3).
3. The magnitude of iron, iodine and zinc deficiencies among lactating mothers (Chapter 4).
4. Concurrent micronutrient deficiencies in lactating mothers and their children 6-23 months of age in two agro-ecological zones of rural Ethiopia (Chapter 5).
5. Infant and young child feeding practices among mothers of children 6-23 months of age in two agro-ecological zones of rural Ethiopia (Chapter 6).
6. Seasonal variation in infant and young child feeding practices and malnutrition among children 6-23 months of age (Chapter 7).

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## **Chapter 2**

### **Seasonal variation in nutritional status and anaemia among lactating mothers in two agro-ecological zones of rural Ethiopia: A longitudinal study**

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## **ABSTRACT**

*Objective:* The objectives of this study were to determine seasonal and agro-ecological variations in nutritional status, anaemia and associated factors among lactating women in rural Ethiopia.

*Research Methods & Procedures:* A longitudinal study was conducted among 216 mothers in pre and post-harvest seasons in two agro-ecological zones of rural Ethiopia. Interviews using a structured questionnaire, anthropometric measurements and blood tests for anaemia were conducted. Multivariable linear regression models were used to identify independent predictors.

*Results:* The prevalence of anaemia increased from post-harvest (21.8%) to pre-harvest seasons (40.9%). Increases were from 8.6% to 34.4% in midland and from 34.2% to 46.3% in lowland agro-ecological zones. Fifteen percent of mothers were anaemic during both seasons. The prevalence of under nutrition, assessed using BMI  $<18.5\text{kg/m}^2$ , increased from 41.7 to 54.7% between post- and pre-harvest seasons. Prevalence of maternal mid upper arm circumferences (MUAC) less than 22cm also increased from 43.1 to 55.2% during pre-harvest season. The seasonal effect was generally more pronounced in the midland community for all forms of malnutrition. Predictors of anaemia were high parity of mother and low dietary diversity. Parity, number of children under five years and regional variation were predictors of low BMI among lactating mothers.

*Conclusion:* The magnitude of malnutrition and anaemia was significantly influenced by variation in season and agro-ecological zones. Interventions focused on agro-ecology and seasonal variation should be considered in addition to current strategies to alleviate malnutrition in lactating mothers.

**Key words:** Anaemia; BMI; Pre-harvest; Post-harvest; Lowland; Midland

## Introduction

It is estimated that around 1.62 billion people are affected by anaemia globally. The highest burden (90%) of cases exists in Low Income Countries. It is estimated that, globally, anaemia affects 47.4% of preschool children, 42.0% of pregnant and 30.0% of non-pregnant women. In Africa, 64.6% of preschool children, 55.8% of pregnant and 44.0% of non-pregnant women are anaemic [1].

At least half of anaemia globally is due to iron deficiency (ID). ID is predominantly due to a deficiency of bioavailable dietary iron and/or increased demands such as during childhood, pregnancy and lactation [2]. A high demand for iron during menstrual blood loss, pregnancy, lactation and nutritional deficiencies are the most common causes of iron deficiency in reproductive age women [3, 4]. Caloric requirements during lactation are greater than during pregnancy due to physiological change, breast feeding and work load. A nursing mother produces 0.7 to 0.8 litre of milk per day. This needs an extra energy expenditure of at least 2090KJ per day [5]. The quality of breast milk is only affected in extreme cases of deficiency, or by excessive consumption of particular food items [6]. Nonetheless the quantity of milk depends very much on the mother's diet. Food consumed by a nursing mother not only fulfils her own nutritional demands, but also enables her to produce milk for her baby [5]. Severely malnourished mothers have reduced lactation performance contributing to the increased risk of child mortality [7].

Lactating mothers from low-income settings are considered a nutritionally vulnerable group [8]. Low income setting was estimated to be an underlying factor for 22% of maternal deaths around the world of which severe anaemia is a major contributor [9,10]. In Ethiopia, 27% of women are undernourished or thin (BMI less than 18.5 kg/m<sup>2</sup>). Similarly, 17% of mothers are anaemic, of which 19% of lactating mothers are anaemic [11]. According to a study conducted in Ethiopia by Umeta *et al.* [12], the prevalence of anaemia was 17%. The prevalence of anaemia among lactating mothers in a slum in Addis Ababa was 22% [13]. No study focusing on seasonal variation of anaemia and nutritional status among women in Africa has been documented, particularly in Ethiopia. The few studies conducted among lactating mothers in Ethiopia were cross sectional in design and focused on one geographical location and season. Research that documents seasonal and agro-ecological variations in lactating mothers' nutritional status is lacking. This study

was carried out to provide information regarding the nutritional status including prevalence of anaemia among lactating women in two agro-ecological zones of rural Ethiopia during both the post- and pre-harvest seasons in line with the wishes of the funding agency (Irish Aid).

## **Materials and Methods**

### ***Study setting and subjects***

The study was conducted in the Babile, Endreta and Hintalo Wajirat districts of Ethiopia from January to February 2014 (post-harvest season) and from July to August 2014 (pre-harvest season). Babile District (Woreda) which is 560 km away from Addis Ababa in the eastern part of Ethiopia is representing a lowland agro-ecological zone. The altitude of Babile Woreda ranges from 950 to 2000 meters above sea level. Data were collected from 1000-1500 meters above sea level. The major agricultural product for consumption was sorghum, and oil seeds and groundnuts are used as cash crops. Hintalo Wajirat and Endreta districts are 683 km and 773 km away from Addis Ababa in the northern part of Ethiopia, respectively and represent midland agro-ecological zones. Data were collected from altitude of greater than 2000 meters above sea level where the majority produce cereals (Teff and barley) and are involved in animal husbandry.

A community based longitudinal study was conducted in four randomly selected kebeles (smallest administrative unit in Ethiopia) from each geographical district. Two hundred and sixteen mother/child pairs were included in the study. Mothers were selected randomly from a list of registration available in each kebele and used by researchers to verify maternal and child age and current feeding status. After identification of each mother who had children between 6 – 24 months old, mothers who were breastfeeding at the time of the survey were randomly selected with proportional to size allocation for each kebele.

### ***Measurements***

#### ***Dietary assessment***

Dietary diversity was measured using a tool developed by FANTA [14, 15]. A simple questionnaire allowed all types of foods consumed during each of the 24 previous hours to be noted. Each woman involved in the study was asked to recall all the communal dishes she had eaten inside and outside the compound during the

previous 24 hour period. The recall was randomly made on weekdays or on weekend days, since weekends do not have any special significance with respect to dietary intake in the context of our study. We took care not to include atypical days (local feasts or celebrations) in the recall.

### ***Anthropometric data***

The anthropometric measurements were performed on mothers using the standardized procedures recommended by WHO [16-18]. Weights of the lactating women were measured to the nearest 0.1 kg on a battery powered digital scale (Seca 770, Hanover, Germany) with a weighing capacity of 0 to 140 kg and heights were measured to the nearest 0.1 cm using a wooden height-measuring board with a sliding head bar following standard anthropometric techniques [19]. Mid upper arm circumference (MUAC) was also measured using a non-stretchable MUAC tape (MUAC measuring tape/PAC-50) [19] on the left upper arm of the mothers. To measure weight and height, study subjects removed their shoes, jackets and wore light clothing. To avoid variability among the data collectors, all the anthropometric measurements were taken by two different data collectors and compared. In case of variation among the data collectors, the principal investigator took the measurement again for validation. The BMI [ $\text{weight/height}^2$  ( $\text{kg/m}^2$ )] was calculated and the threshold of  $18.5 \text{ kg/m}^2$  was used to identify underweight women. Pregnant mothers were excluded from the survey.

### ***Haemoglobin measurement***

A small portion of whole blood from the syringe was used to test haemoglobin level of the mothers immediately on site by using portable HemoCue analyser (HemoCue® Hb 301) which is considered to be a gold standard for field work in postharvest seasons. In pre-harvest season a blood sample was collected from each mother by a trained nurse and laboratory technologist from the tip of the middle finger after the site was cleaned with disinfectant. The third drop of blood was added to the cuvettes for measuring haemoglobin concentration after two drops were wiped away. The variation between venous and finger blood samples was checked and was found to be insignificant during pre-test. The accuracy of this procedure for estimation of haemoglobin in a resource-poor setting has been previously established [20]. Haemoglobin level of the mothers was tested immediately on site by using a

portable HemoCue analyser (HemoCue® Hb 301). The haemoglobin values were adjusted for altitude using correction factors at every 500 meters for altitudes more than 1000 meters above sea level [21]. The threshold criteria used to determine the severity of anaemia as a mild, moderate or severe public health problem were prevalence of 5.0-19.9%, 20.0-39.9% and >40%, respectively. The cut-off point for anaemia was based on WHO (2011) recommendation for mothers and categorized as mild anaemia (Hgb 10.0-11.9 g/dl), moderate anaemia (Hgb 7.0-9.9 g/dl) and severe anaemia (Hgb less than 7.0 g/dl) [21].

### ***Data collection and quality control***

The questionnaire was prepared first in English then translated to Tigrigna and Afan Oromo language and data collectors were native speakers of the languages. The process of data collection was overseen by supervisors and principal investigator. Sufficient data collectors, good organization, and excellent co-operation from local authorities greatly facilitated the efficient conduct of this study. Data were collected by 10 data collectors, together with 10 assistants for carrying measuring board and scale, and 3-5 guides from each selected community who assisted in rapidly locating the selected households. Each team collected data from 2 households per day and occasionally from 3 households. Data collectors were trained for five days prior to the first round of data collection and for four days prior to the second round. The same data collectors were employed for the second round. Two vehicles were used to facilitate the progress of data collection with the capacity of carrying 12-15 passengers. Letters of support and ethical clearances from Haramaya University and National Science and Technology Ministry research and ethical review committee were sent to all concerned local bodies before actual data collection which facilitated very cooperative and supportive interactions. In the second round of data collection the households were already identified, data collectors knew all the localities very well from the first round, and lessons learned from the first round facilitated more rapid and efficient data collection in the second round.

A pilot survey was conducted on 5% of the total sample size in another rural area, which has similar characteristics, and problems identified during the pilot survey were corrected before the start of the actual survey. Two different measurements were taken for the height, weight and MUAC by two different measurement takers for every study subject. The average of the two was considered for the analysis if

there was variation in measurements. Finally, the principal investigator was responsible for co-ordination and supervision of the overall data collection process. Dependent variables were anaemia and nutritional status of lactating mothers. The independent variables were the socio-demographic and economic status, health status of mothers, water, sanitation, health services utilization and cultural/social characteristics related to feeding style of the mother. Women's Dietary Diversity Score (WDDS) and meal frequency, maternal and child health service utilization and health seeking behavior of the family were also assessed.

### ***Data processing and analysis***

Data entry and cleaning were co-ordinated by the first author (KT) in Haramaya University in Ethiopia in compliance with procedures agreed with the other three co-authors. Data analysis using appropriate statistical software and manuscript preparation were conducted in University College Cork in Ireland and involved all authors.

The data were double entered by separate data clerks into EPI Data version 3.1. Data cleaning and editing were undertaken before analysis. For analysis, data were transferred to SPSS (v.16.0) statistical packages and Stata (v.11). The independent variables entered in the multivariable logistic regression model were grouped as socio-demographic information including age, education, family size and number of children less than five years, water source, own toilet, and hand washing behaviour after toilet, while dietary habits of respondents were dietary diversity level, food frequency and frequency of consumption of iron-rich foods, vegetable, chewing Khat/ drinking Tella (the local alcohol) and consumption of tea/coffee. The anthropometric measurements included in the analysis were MUAC and BMI. For comparison purposes, data were grouped into two levels based on season and agro-ecological zones.

Descriptive statistics were used to show the magnitude of each variable. Cross tabulations and linear regression were used to assess the difference across the agro-ecological zones, season and associations of different variables. For WDDS, BMI, anthropometric measurements, and haemoglobin level mean and standard deviation were analysed. Multivariable binary logistic and linear regressions were applied to control for confounding after testing binary linear regression. The results were



presented using odds ratios, beta coefficients and 95% confidence intervals. P-values of less than 0.05 were used to declare significance in differences.

### ***Ethical consideration***

Ethical clearance was obtained from relevant authorities at both University College Cork and Haramaya University and the final approval of the protocol was granted by the Ethiopian National Ministry of Science and Technology Ethical Review Committee. Informed consent was obtained from the mothers and they were informed that they had the right to refuse or exit from the study at any time and refusing to participate in the study would not have any negative implications for them.

### **Results**

Of the 216 subjects (90% of whom were farmer/housewife by occupation) who enrolled and completed the study for structured interview and haemoglobin measurement in the post-harvest season, 206 (95%) were interviewed and 203 (94%) were retested for haemoglobin in the pre-harvest season. The major reasons for loss to follow up were fear of injection, migration and pregnancy. Table 1 provides an overview of the 216 study subjects. Table 2 provides further data on the study subjects broken down for the two agro-ecological zones where the study was conducted.

### ***Prevalence of under nutrition and anaemia by season (pre- and post-harvest)***

The magnitude of malnutrition and anaemia varied across agricultural production period (season), with lower prevalence of anaemia (21.8%) recorded in post-harvest season, when there is surplus farm production in homes compared to the pre-harvest period (food shortage/lean season) (40.9%). Thus, prevalence of anaemia in the lean season was 19.1% higher than in the post-harvest season. In the post-harvest season the proportion of lactating mothers with anaemia was higher among lowland mothers (34.2%) compared to midland (8.5%). In the pre-harvest season, 46.3% of mothers were anaemic in lowland and 34.4% were anaemic in midland agro-ecological zones (Table 3). The seasonal change in the proportion of anaemic mothers was 19.1% and the major increment was recorded in the midland agro-ecological zones (25.9% in

midland versus 12.1% in lowland). All anaemic lactating mothers involved in this study had a mild or moderate type of anaemia in both agro-ecological zones and seasons (Table 4).

Similarly, the proportion of mothers with low BMI was 13.0% higher in the pre-harvest season than in the post-harvest season (41.7 vs 54.7%). Out of 90 mothers (41.7% prevalence) with low BMI (BMI <18.5 kg/m<sup>2</sup>) in the post-harvest season, a prevalence of 39.6% existed in lowland and 43.8% in midland agro-ecological zones. In pre-harvest season, the prevalences changed to 52.8 and 56.7%, respectively. Similarly, based on MUAC (<22 cm), the prevalence of malnutrition in the post-harvest season was 51.4% in lowland and 37.4 % in midland. These prevalences increased to 54.2 and 56.2%, respectively, in pre-harvest season (Table 3).

Indicators of malnutrition measured in this study were higher in pre-harvest season compared to post-harvest.

Further analysis of our data showed that the most vulnerable age group affected by anaemia and low BMI was the 25-34 age group in both pre- and post-harvest season. The lowest rate of under nutrition was recorded among age 35-49 years of age, but the lowest rate of anaemia was recorded among 15-24 age groups (Table 4).

Evaluation of factors related to anaemia and undernourishment in this study indicated that marital status, occupation, family size of respondents, age of mother, birth interval, source of drinking water, owning a toilet, and hand washing after toilet were not associated with risk of anaemia and malnutrition in both seasons. These factors were then not included in the models.

Multivariable linear regression models for maternal anaemia (Table 5) indicated that as maternal BMI and WDDS of the mothers increase, the haemoglobin level of the mothers also increases and this was significant. As the BMI of the mothers increases by one unit, the haemoglobin level of the mothers increased by 0.1 g/dl (p=0.028). Similarly, as the dietary diversity score of the mothers increases by one unit, haemoglobin levels of the mothers increased by 0.29 g/dl (p=0.016). As the parity of the mother increases, haemoglobin level decreased, showing that high parity is negatively associated with anaemia among this study group ( $\beta=-0.45$ , P=0.025) (Table 5).

In the second model (pre-harvest predictors), parity and maternal education were significantly associated with anaemia but agro-ecological zones, maternal MUAC and WDDS lost their significance in multivariable linear regressions. Uneducated

mothers (mothers who were unable to read and write) were more likely to be anaemic than educated mothers ( $P=0.008$ ) (Table 5).

In model 3 (predictors of low BMI), among variables entered into the model, maternal MUAC, parity, number of children less than five years of age, and agro-ecological zones have significant association with BMI. As the MUAC of the mother increased by one centimetre, body mass index (BMI) of the mothers increased also ( $\beta= 0.237$ ,  $P<0.001$ ). Similarly, as parity and number of children less than five years of age increased by one unit, the BMI of the lactating mothers decreased ( $P<0.01$ ). The BMI values overall were lower in midland agro-ecological zones compared to lowland agro-ecological zones ( $P=0.042$ ) (Table 5).

We provide Pearson correlation coefficients in Table 6 for maternal haemoglobin, BMI and WDDS. Maternal haemoglobin was significantly correlated in post-harvest with both BMI and WDDS.

**Table 1: Descriptive statistics for the 216 lactating mothers included in the study**

<b>Variables</b>	<b>Mean</b>	<b>SD</b>
Age of mothers in years	28.6	6.1
Average number of children	5.7	2.0
% Illiteracy	73.1	
Haemoglobin post-harvest (g Hgb/dl)	13.1	1.3
% Anaemia post-harvest	21.8	
Haemoglobin pre-harvest (g Hgb/dl)	12.3	1.5
% Anaemia pre-harvest	40.9	
Maternal weight post-harvest (kg)	48.8	6.3
Maternal weight pre-harvest (kg)	47.5	5.8
Number of children less than five years	1.6	0.6

**Table 2: Distribution of selected socio-demographic and maternal characteristics of lactating mothers in two agro-ecological zones of rural Ethiopia (n=216)**

Variables	Category	Total n(%)	Lowland* n(%)	Midland** n(%)	Chi <sup>2</sup>	p-value
Age of mothers	15-24	51(23.6)	25(22.5)	26(24.8)	1.0	
	25-34	120(55.5)	65(58.6)	55(52.4)	0.38	0.54
	35-49	45(20.8)	21(18.9)	24(22.9)	0.05	0.8
Education	Illiterate	148(73.1)	82(73.9)	66(61)	3.04	0.08
	Read or write	68(26.8)	29(26.1)	39(39)	1.00	
Occupation of mothers	Farmer/housewife	197(91.2)	104(93.7)	93(88.6)	1.76	0.18
	Trader/others	19(8.8)	7(6.3)	12(11.5)	1.00	
Parity	≤ 3	74(34.3)	41(36.9)	33(31.4)	0.73	0.39
	>=4	142(65.7)	70(63.1)	72(68.6)	1.00	
Ever used contraception	No	105(48.6)	71(64.0)	34(32.4)	21.5	0.000
	Yes	111(51.4)	40(36.0)	71(67.6)	1.00	
Family size	1-5	105(48.6)	57(51.4)	48(45.7)	0.69	0.41
	>5	111(51.4)	54(48.6)	57(54.4)	1.00	
Number of children <5 years	1 Child	84(38.9)	32(28.8)	52(49.6)	1.00	
	2 children	117(54.2)	64(57.7)	53(50.5)	5.4	0.02
	3 children	15(6.9)	15(13.5)	0	--	--
Household own toilet	Yes	121(56.0)	56(50.5)	65(61.9)	1.00	
	No	95(43.9)	55(49.5)	40(38.1)	2.87	0.90
Hand washing after toilet	Yes	156(70.4)	82(73.9)	74(70.5)	1.00	
	No	60(27.8)	29(26.1)	31(29.5)	0.31	0.58
Birth interval	First birth	29(13.4)	13(11.7)	16(15.5)	1.00	
	1-2 years	97(44.9)	64(57.7)	33(31.4)	4.2	0.04
	>2	90(41.7)	34(30.6)	56(53.3)	0.46	0.5
Consumption of animal source food in a month	Never	125(57.8)	90(81.1)	35(33.3)	13.4	0.00
	<1 times	80(37.0)	19(17.1)	61(58.1)	0.17	0.68
	>2-4 times	11(5.1)	2(1.8)	9(8.6)	1.00	
Egg consumption in a month	Never	105(48.6)	80(72.1)	25(23.8)	55.0	0.00
	1-2 times	42(19.3)	18(16.2)	24(22.9)	7.5	0.01
	3-6 times	69(31.9)	13(11.7)	56(53.3)	1.00	
Consumption of tea/coffee in week	No	83(38.4)	27(24.3)	56(53.3)	19.2	0.00
	Yes	133(61.6)	84(75.7)	49(46.7)	1.00	

\*Babile District (Woreda) which is 560 km away from Addis Ababa in the eastern part of Ethiopia is representing a lowland agro-ecological zone. \*\*Hintalo Wajirat and Endreta districts are 683 km and 773 km away from Addis Ababa in the northern part of Ethiopia, respectively and represent midland agro-ecological zones, -- Chi<sup>2</sup> is not calculated because one of the cells is zero. 1.00 in both P-Values and X<sup>2</sup> is the reference category.

**Table 3: Prevalence of anaemia and malnutrition among lactating women aged 15-49 years by season and by agro-ecological zones in rural Ethiopia**

Variables	Lowland*	Midland**	Total	95% CI
	n(%)	n(%)	n(%)	
Level of anaemia (post-harvest)				
Mild (10.0-11.9g Hgb/dl)	32(28.8)	9(8.6)	41(19)	(14-25)
Moderate (7.0-9.9g Hgb/dl)	6(5.4)	0	6(2.8)	(1.0-5.9)
Prevalence of anaemia (n=216)	38(34.2)	9(8.5)	47(21.8)	(16.4-28.0)
BMI (post-harvest, n=216)				
<18.5 (kg/m <sup>2</sup> )	44(39.6)	46(43.8)	90(41.7)	(35.0-48.5)
>18.5 (kg/m <sup>2</sup> )	67(60.4)	59(56.2)	126(58.33)	(51.4-65.0)
MUAC (post-harvest, n=216)				
< 22 cm	57(51.4)	39(37.4)	93(43.1)	(36.0-49.9)
≥ 22 cm	54(48.6)	66(65.7)	120(55.6)	(50-63)
Level of anaemia (pre-harvest)				
Mild (10.0-11.9g Hgb/dl)	41(38)	29(30.2)	70(34.2)	(28.5-43.0)
Moderate (7.0-9.9g Hgb/dl)	9(8.3)	4(4.2)	13(6.4)	(3.5-11.0)
Prevalence of anaemia (n=203)	50(46.3)	33(34.4)	83(40.9)	(35.0-49.5)
BMI (pre-harvest, n=203)				
<18.5(kg/m <sup>2</sup> )	56(52.8)	55(56.7)	111(54.7)	(48-62)
>18.5(kg/m <sup>2</sup> )	50(47.8)	42(43.3)	92(45.3)	(38.5-51.9)
MUAC (pre-harvest, n=203)				
<22 cm	58(54.2)	54(56.2)	112(55.2)	(48-62)
>22 cm	49(45.8)	42(43.8)	91(44.8)	(38.5-51.9)

BMI: Body Mass Index calculated as weight in kg/height in metre<sup>2</sup> (kg/m<sup>2</sup>); MUAC: Mid Upper Arm Circumference; Hgb: Haemoglobin. \*Babile District (Woreda) which is 560 km away from Addis Ababa in the eastern part of Ethiopia is representing a lowland agro-ecological zone. \*\*Hintalo Wajirat and Endreta districts are 683 km and 773 km away from Addis Ababa in the northern part of Ethiopia, respectively and represent midland agro-ecological zones.

**Table 4: Distribution of anaemia and malnutrition by age of the lactating mothers in post-harvest and pre-harvest seasons in rural Ethiopia**

Variables	n/total	Age of the mothers (years)		
		15-24 n(%)	25-34 n(%)	35-49 n(%)
Anaemia Hgb <12g/dl (post-harvest)	47/216	7(14.9)	29(61.7)	11(23.4)
Maternal BMI <18.5 (post-harvest)	90/216	26(28.9)	49(54.4)	15(16.7)
Maternal MUAC <22 (post-harvest)	93/216	15(16.1)	58(62.4)	20(21.5)
Anaemia Hgb <12g/dl (pre-harvest)	83/203	14(16.9)	46(55.4)	23(27.7)
Maternal BMI <18.5 (pre-harvest)	111/203	31(28.2)	60(53.6)	20(18.2)
Maternal MUAC <22 (pre-harvest )	112/203	34(30.4)	58(51.8)	20(17.9)

\*BMI: Body Mass Index calculated as weight in kg/height in metre<sup>2</sup> (kg/m<sup>2</sup>); MUAC: Mid Upper Arm Circumference (cm); Hgb: Haemoglobin.

**Table 5: Predictors\*\* of anaemia and chronic under nutrition among lactating women aged 15-49 years in post-harvest and pre-harvest seasons, Ethiopia.**

**Linear regression**

<b>Model</b>	<b><math>\beta</math></b>	<b>Std. Error</b>	<b>P-Value</b>
<b>Model 1: Predictors of Maternal Anaemia (post-harvest season) (adjusted <math>R^2 = 0.086</math>) n=216</b>			
			<0.001
<b>F( 4,176) = 5.23, Root MSE = 1 .337</b>			
Maternal BMI	0.1	0.04	0.028
Parity of the mothers	-0.45	0.2	0.025
Women dietary diversity score (WDDS)	0.29	0.11	0.016
Agro-ecological zone	0.46	0.22	0.41
<b>Model 2: Predictors of Maternal Anaemia (pre-harvest season) (adjusted <math>R^2 = 0.04</math>) n=169</b>			
			0.028
<b>F( 4,164) = 2.77, Root MSE = 1.56</b>			
Parity of the mothers	-0.63	0.24	0.009
Agro-ecological zone	0.48	0.23	0.44
Maternal education	0.33	0.12	0.008
Maternal MUAC	0.03	0.03	0.25
WDDS	0.02	0.13	0.8
<b>Model 3: Predictors of Maternal Wasting (low BMI) for pre harvest season (adjusted <math>R^2 = 0.0075</math>) n=176</b>			
			<0.003
<b>F( 5,170) = 3.9, Root MSE = 1.53</b>			
Parity of the mother	0.798	0.298	0.008
Number of children less than five	-0.755	0.26	0.004
Agro-ecological zone	-0.64	0.31	0.042

BMI: Body Mass Index; MUAC; mid upper arm circumference; Root MSE: Root Mean Squared Error.

\*\* Only significant predictors are presented here in models.



**Table 6: Correlation between maternal haemoglobin, body mass index (BMI) and women dietary diversity score (WDDS)**

<b>Variables</b>	<b>Statistical tests</b>	<b>Maternal haemoglobin pre-harvest</b>	<b>Maternal haemoglobin post-harvest</b>
Maternal BMI	Pearson correlation	-0.056	0.140*
	Sig (2-tailed )	0.436	0.040
WDDS	Pearson correlation	0.058	0.181**
	Sig (2-tailed )	0.410	0.008

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

## Discussion

This study demonstrated that high levels of anaemia and malnutrition occur in lactating mothers in rural villages of Ethiopia. The prevalences of anaemia and malnutrition were increased during pre-harvest season compared to post-harvest season. These seasonal increases which were observed in both agro-ecological zones could be due to greater food shortage in the rural community in the pre-harvest season.

Populations in these two rural agro-ecological zones have different tradition, culture, life style and diets. The tradition in the lowland agro-ecological zone is mainly feeding on sorghum and maize-based food called Lafiso/Hulbat (the thin local unleavened bread made from sorghum/maize) mixed with locally prepared sauce (Danfa made with small fenugreeks, tomato and/or palm oil). A small portion of the population in this zone feed on wheat bread. This community eat their breakfast in the morning at 8-10 a.m. and eat their supper/dinner at 5:00 p.m. consisting of the same food as breakfast or else porridge of maize/ sorghum with milk if they have it or with oil (palm oil).

The midland agro-ecological community feed primarily on the staple traditional food *injera* and wheat bread. *Injera* is a locally made unleavened bread from fermented *Teff* (*Eragrostis Teff*, cereal) served together with locally prepared sauces. The diet of the midland community is principally *injera* with sauce of Kik wat (broad bean, palm oil, shallot, salt) or Habsh (broad bean flour (60%), chickpea flour (40%), palm oil, shallot) or Hilbet (broad bean flour (75%), lentil flour (15%), fenugreek flour (10%), water) or Meten shiro wat (pea flour (roasted), chilli, shallot, palm oil). *Injera* (local name Tayeta) is fermented and made up of Teff 75% and wheat 25% or Teff 75% and barley 25%. The midlands community usually eat breakfast at the same times as the lowland community, eat their lunch at 1-2 p.m. during holy days, and eat supper at 5-6 p.m. consisting of the same food as breakfast or else roasted barley, 'Nefro' (boiled maize or wheat or mixture of both) with local alcohols.

In this study in both agro-ecological zones the consumption of animal source foods, which are a source of heme iron, was very low but intake of phytate-rich cereal based foodstuffs was high. Both these factors clearly influence anaemia risk. Additionally, the WDDS indicate that intake is low of vitamin C rich foods which can increase the bioavailability of non-heme iron. Furthermore, consumption of tea/coffee which can inhibit iron absorption was very high. The lowland community

consumes plain coffee (sometimes with light addition of milk called Hojja) both during and after meals. The main refreshment and luxury habit of the lowland community is chewing Khat (*Catha edulis*), which is a stimulant often used when drinking coffee or tea. Drinking hojja, while chewing Khat, increases the stimulation and mood of euphoria. However, in the midland community, coffee is usually consumed in the morning with breakfast but not usually with the main meal. This could be a potential contributing factor in explaining the lower rates of anaemia in the midland community. The stimulant mainly consumed in the midland zone is a homemade alcoholic drink (in Amharic 'Tella' and in Tigrinya 'Suwa') made with local roasted barley and fermented *gesho* (*Rhamnus prinoides*) and eaten with Nefro.

Among study participants the prevalence of anaemia was 21.8% and 40.9% in post and pre-harvest seasons, respectively. The change in prevalence overall was as high as 19.1%. The greatest increase was observed in the midland agro-ecological zone where it rose from 8.6% to 34.4% between post- and pre-harvest seasons, respectively, suggesting that food shortage has a greater seasonal impact in this community compared to the lowland area. The corresponding increase in prevalence of anaemia in the lowland zone was from 34.2% to 46.3% between post- and pre-harvest seasons, respectively. About 15% of the mothers overall were chronically anaemic in both seasons. The total prevalence of anaemia in post-harvest was similar to that reported for lactating mothers in Addis Ababa (22%) [13], but lower than for other non-pregnant mothers [12, 22, 23]. When this figure is disaggregated by agro-ecological zones, the prevalence was higher in the lowland area as discussed above and much higher than prevalence in the populations referenced above. Levels of physical activity among the mothers were similar in both agro-ecological zones and were high in both. No information was available on the incidence of intestinal parasites such as hookworm which can influence risk of anaemia.

A further implication of our findings with respect to the variation in prevalence of anaemia between seasons is that single point measurements (by cross-sectional study) may not show the real extent of the problem. This change in prevalence was very high especially in midland agro-ecological zones where most of the community rely on farming compared to lowland zones where, in the pre-harvest season, production of cash crops (Khat) takes place during the rainy food shortage season.

The proportion of undernourished lactating mothers (BMI <18.5 kg/m<sup>2</sup>) was 41.7% in post-harvest and 54.7% in pre-harvest season where there is greater food shortage. The prevalence of undernutrition was higher than reported in other studies conducted in Ethiopia [11, 13, 24]. These differences may be due to the fact that our study focuses only on lactating mothers. Body mass index data show lower prevalence of undernutrition in lowland agro-ecological zones in contrast to anaemia which was more prevalent in the lowland zone compared to the midland zone.

Women aged 25-34 years had the highest risk of anaemia. This might be due to the fact that this age category is fertility intensive. Ethiopian Demographic and Health Survey (2011) reported that nearly 60% of all births occurred in this age category [11, 25]. Studies conducted elsewhere have reported various patterns of association between age and anaemia. Studies in Ethiopia [7] and Tanzania [15] reported higher prevalence in older age groups. A study in Mexico documented higher prevalence in the 20-29 year age group than the younger or older age categories [26].

Maternal education and dietary diversity were factors associated with anaemia. This is also reported in other studies [23, 25]. Hence, empowering women in terms of education and economic status should have positive contributions to alleviate the problem of anaemia. Maternal anaemia risk may also be positively influenced by achieving adequate dietary diversity.

The impact of parity in contributing to anaemia is clearly observed in this study. The risk of anaemia was directly associated with cumulative parity. As the parity of the mother increases the haemoglobin level decreases (P<0.05) in all models which indicates that a persistent factor associated with maternal malnutrition is parity. Similar findings are also documented elsewhere in Ethiopia [25, 27]. This suggests that initiatives to encourage greater child spacing should be considered as a positive contribution to reducing anaemia prevalence in conjunction with other factors (greater dietary diversity, iron supplementation, parasite control) which can modulate anaemia risk.

## **Conclusions**

The main novelty and strength of this study was its longitudinal design as it assessed variations in anaemia and undernutrition across seasons in two different agro-ecological zones in the same country. The prevalence of both anaemia and undernutrition was clearly higher during the lean season (pre-harvest). Explanation

of the variations between agro-ecological zones was not as apparent. Future research should focus on elucidation of the reasons for variation in prevalence of malnutrition among different agro-ecological zones in rural Ethiopia. The significant difference in prevalence of anaemia between pre- and post-harvest suggests that cross-sectional studies conducted during the food surplus season (post-harvest) may not show the real situation over the course of the year. WDDS and consumption of iron-rich foods were very low in these rural communities in Ethiopia.

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**Chapter 8**  
**General discussion**

The core aim of this thesis was to investigate the nutritional status of lactating mothers and their children 6-23 months of age in pre- and post-harvest seasons in two agro-ecological zones of rural Ethiopia, using a longitudinal study design. Prior to this study, there had been no comparable study that assessed seasonal variation in different agro-ecological zones, and correlated malnutrition in lactating mothers with their children. In addition to determining prevalence of malnutrition (stunting, wasting and underweight) in children and maternal undernutrition (as measured by body mass index less than 18.5 kg/m<sup>2</sup>), the study also assessed selected biomarkers of micronutrient status (haemoglobin, zinc and ferritin) for both mothers and children, urinary iodine and total goitre rate of lactating mothers, as well as testing household salt for iodine. Our data determining variations in malnutrition, dietary diversity and IYCF practices across season and agro-ecology provide an evidence base for the importance of different interventions in different settings.

Chapter 1 of the thesis presents a comprehensive overview of background literature relevant to our objectives with particular focus on the existing evidence base in Ethiopia.

In Chapter 2 the focus is on lactating mothers. The main novelty and strength of this aspect of the study was its longitudinal design as it assessed variations in anaemia and undernutrition across seasons in two different agro-ecological zones in the same country. Clear evidence is provided that the prevalence of both anaemia and undernutrition was higher during the lean season (pre-harvest). Explanation of the variations between agro-ecological zones was not as apparent as very many aspects of both zones differ substantially. Future research should focus on elucidation of the reasons for variation in prevalence of malnutrition among different agro-ecological zones in rural Ethiopia. The data showing significant difference in prevalence of anaemia between pre- and post-harvest seasons suggest that cross-sectional studies conducted during the food surplus season (post-harvest) may not show the real situation over the course of the year as anaemia was significantly worse during the lean season. WDDS and consumption of iron-rich foods were very low in these rural communities in Ethiopia.

The next focus of the thesis was the 6-23 month old children of the lactating mothers. Once again the data clearly show that anaemia and malnutrition among children 6-23 months of age is a major public health problem in rural Ethiopia. These data also provide strong evidence that short stature mothers have stunted babies compared to counterparts. Additionally, children born to anaemic mothers are more likely to be anaemic compared to children born to non-anaemic mothers. Anaemia in this cohort of children was also associated with recent illness and hand washing behaviours of their mothers. This aspect of the thesis strengthens the evidence base demonstrating that interventions focusing on improving maternal and child nutritional status, achieving at least minimum meal feeding frequency for children at an early age, and emphasis on maternal hygiene and antenatal care should be targeted to reduce the devastating impact of child malnutrition. With respect to agro-ecological zones, the prevalence of anaemia and stunting was more pronounced in the lowland compared to midland zone. These data also suggest the need to undertake agro-ecological based studies in various parts of Ethiopia to determine causal associations with malnutrition in different zones and design appropriate interventions.

Chapter 4 focuses on assessment of selected biomarkers of maternal micronutrient status in serum and urine. Serum zinc and ferritin, IDA, urinary iodine concentration based on one spot test, palpable goitre and household use of iodised salt were assessed. The results indicate a high prevalence of micronutrient deficiencies, independently as well as concurrently, among lactating mothers in both agro-ecological zones. However, the deficiencies were more pronounced in the lowland compared to midland agro-ecological zone. Once again, these data suggest the need to undertake agro-ecological based studies in various parts of Ethiopia to determine appropriate nutritional and other interventions in all reproductive age mothers. The selected biomarkers assessed in this study clearly indicate that increased animal food consumption and increased consumption of vegetables and fruits is recommended in this population group. Additionally, universal household use of iodised salt is recommended.

Very few published studies exist looking at concurrent micronutrient deficiencies in lactating mothers and their children. Chapter 5 strengthens the evidence base in this

regard. The data show that anaemia, low serum levels of iron and zinc are very prevalent among lactating mothers and their children 6-23 months old in both agro-ecological zones. Biomarker status (ferritin, zinc and anaemia) among the lactating mothers correlated significantly with their children suggesting that micronutrient deficiency is intergenerational, even though the mechanisms involved have not yet been explained adequately. Furthermore, many of the low iron status mothers and children were also had low zinc level, suggesting that there is an association between iron and zinc levels. The fact that multiple micronutrient deficiencies co-exist within this study population suggests a need to establish effective maternal and child preventive public health nutrition programs. The data presented in Chapter 5 also demonstrate very low consumption of iron- and zinc-rich flesh foods in this study population which is further exacerbated by high intakes of phytate-rich foods that can decrease zinc bioavailability.

Poor infant and young child feeding (IYCF) practices in our study population are reported in Chapter 6, apart from the high proportion of children who were breastfed. Even though the midland community is better off than the lowland community in this assessment, both are far below the WHO recommendations for appropriate IYCF practices. Only one out of every nine children in our study received appropriate diet for their age. Appropriate complementary feeding emphasising good dietary diversity and meal frequency is well recognised as a crucial factor in reducing childhood mortality and improving growth and development. Information should be given to mothers regarding all components of IYCF during their visits/contacts with health workers/health extension. This is particularly relevant in the lowland agro-ecological zone based on the data presented in Chapter 6.

Finally, Chapter 7 presents data on seasonal variations in stunting, wasting, IYCF practices among 6-23 month old children in both the lowland and midland agro-ecological zones. Malnutrition and poor IYCF practices among children aged 6-23 months of age were apparent in both pre- and post-harvest seasons in both agro-ecological zones. Poor IYCF practices among children in both seasons may be the major underlining causes of malnutrition. Results suggest that the lean season affects children in the midland agro-ecological zone more than the lowland. However, children in the midland zone had better anthropometric measures and

IYCF practices in the post-harvest season but these indices deteriorated significantly during the lean season compared to the lowland children. On the other hand, the indices of malnutrition and IYCF practices among the lowland children were very poor in both seasons. Women's dietary diversity was a predictor of child dietary diversity in both seasons. Interventions focusing on improving both maternal nutrition and appropriate IYCF practices at an early age should be emphasised to prevent child malnutrition and its devastating impact on growth, development and mortality with special focus on agro-ecological zones.

In conclusion, this thesis adds to the literature on nutritional status of lactating mothers and their children among rural communities in low income nations. This study has novelty as it assesses nutritional status and dietary diversity of lactating mother and their children longitudinally between pre- and post-harvest seasons and in two different agro-ecological zones. The presence of interrelationships between maternal and child nutritional status stresses the importance of addressing maternal nutritional status with the aim of improving both maternal and child health outcomes and breaking the vicious intergenerational cycle of malnutrition. A high priority to improving IYCF practices is also warranted. Information should be disseminated to all reproductive age women and mothers on appropriate healthy food choices during contact with health care providers. Strategies focused on season and agro-ecology could be sensible approaches to reduce malnutrition in poor rural communities. Similar strategies have also been identified by FAO in a recent (November 2015) publication entitled "Designing nutrition-sensitive agriculture investments - Checklist and guidance for programme formulation" which states as a key recommendation: "Assess the context at the local level, to design appropriate activities to address the types and causes of malnutrition, including chronic or acute undernutrition, vitamin and mineral deficiencies, and obesity and chronic disease. Context assessment can include potential food resources, agro-ecology, seasonality of production and income, access to productive resources such as land, market opportunities and infrastructure, gender dynamics." This thesis provides evidence that helps underpin FAO's recommendation with respect to seasonality and agro-ecology.