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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

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Dedication:

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

Table of contents

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 3rd Agridiet Workshop, 3-4th 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: 26th Annual Conference of the Ethiopian Public Health Association (EPHA), 26-28th 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, 17th 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, 17th 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 $<18.5 kg/m^2$) 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 Guba 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/m2), [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 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 $<18.5kg/m^2$, 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^2). 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 [weight/height^2 (kg/m^2)] was calculated and the threshold of 18.5 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^2) 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 (β=-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

Variables	Mean	SD
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^2	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^2 is not calculated because one of the cells is zero. 1.00 in both P-Values and X^2 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* n(%)**	**Midland** n(%)**	**Total n(%)**	**95% CI**
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^2)	44(39.6)	46(43.8)	90(41.7)	(35.0-48.5)
>18.5 (kg/m^2)	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^2)	56(52.8)	55(56.7)	111(54.7)	(48-62)
>18.5(kg/m^2)	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^2 (kg/m^2); 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^2 (kg/m^2); 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**

Model	β	Std. Error	P-Value
Model 1: Predictors of Maternal Anaemia (post-harvest season) (adjusted R^2 = 0.086) n=216 F(4,176) = 5.23, Root MSE = 1 .337			<0.001
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
Model 2: Predictors of Maternal Anaemia (pre-harvest season) (adjusted R^2 = 0.04) n=169 F(4,164) = 2.77, Root MSE = 1.56			0.028
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
Model 3: Predictors of Maternal Wasting (low BMI) for pre harvest season (adjusted R^2 = 0.0.075) n=176 F(5,170) = 3.9, Root MSE = 1.53			<0.003
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)

Variables	Statistical tests	Maternal haemoglobin pre-harvest	Maternal haemoglobin post-harvest
Maternal BMI	Pearson correlation Sig (2-tailed)	-0.056 0.436	0.140* 0.040
WDDS	Pearson correlation Sig (2-tailed)	0.058 0.410	0.181** 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^2) 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 3

Prevalence of stunting and anaemia among children 6-23 months of age in two agro-ecological zones of Rural Ethiopia

Abstract

Child malnutrition during the first 1000 days, commencing at conception, can have lifetime consequences. This study investigates the prevalence of anaemia and stunting among children in different agro-ecological zones of Ethiopia. Cross-sectional data examining socio-demographic, anthropometry, haemoglobin levels and meal frequency indicators were collected from 216 infants aged 6-23 months with their mothers randomly selected from eight rural villages from lowland and midland agro-ecological zones of rural Ethiopia. Out of 216 children, 53.7% were anaemic, 39.8% were stunted, 26.9% were underweight, and 11.6% were wasted. Prevalence of anaemia was higher in lowland agro-ecological zone (59.5%) than midland (47.6%). Among stunted, underweight and wasted, 63.5, 66.7 and 68.0% were anaemic, respectively. Child anaemia was significantly associated with child not achieving minimum meal frequency, sickness during the last two weeks before the survey, stunting and low Body Mass Index and with maternal haemoglobin and hand washing behaviour. Prevalence of stunting was higher in lowland agro-ecological zone (42.3%) than midland (36.2%). Predictors of stunting were age and sex of the child, not achieving minimum meal frequency, maternal Body Mass Index and age. As maternal height increases the length for age of the children increases (p=0.003). The overall prevalence of anaemia and stunting among children 6-23 months of age in these study areas is very high. Prevalence was more pronounced in lowland compared to midland agro-ecological zone. Health information strategies focusing on both maternal and children nutrition could be sensible approaches to reducing stunting and anaemia.

Introduction

It has long been recognised that child malnutrition and anaemia have both acute and long term adverse effects on human development [1]. In this study, the term malnutrition is used to refer to under nutrition. About one-third of deaths in children less than five years of age are due to underlying malnutrition, which includes stunting, severe wasting, deficiencies of vitamin A, zinc, iron and suboptimum breastfeeding [2].

The period of 6 to 23 months of age is one of the most critical periods in the growth of the infant when malnutrition can have a dire 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 breast feeding, on the other [2, 3]. Additionally, frequent episodes of diarrhoea due to poor hygiene and sanitation are major contributors to malnutrition.

In less developed countries, 19.4% of children less than five years of age were underweight (weight-for-age Z score, WAZ<-2) and about 29.9% were stunted (height-for-age Z score) in the year 2011 [4]. In Sub Saharan Africa (SSA), over 3.4 million children less than five are dying from malnutrition and up to 40% of children are stunted [5, 6]. In recent times, there have been a limited number of studies reporting prevalence of malnutrition among children in Ethiopia. Findings from a study conducted in Wag-Himra zone of northern Ethiopia showed that 23.6% of children under two years were stunted and 66.6% were anaemic [7]. In North Wollo, Ethiopia, Baye *et al.* [8] reported that 33% of children aged 12-23 months were stunted. 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 [9]. In Gondar (North West of Ethiopia), 15.1% of school aged children were underweight, 25.2% stunted and 8.9% thin/wasted (weight-for-height Z score) [10]. A more recent study from Ethiopia again highlighted the extent of malnutrition among school children aged 7-14 years of age [11]. Stunting was found to be a common nutritional problem, in which 25.6% of studied children were found to be below negative two standard deviation (-2SD) while 10.3% of the children were severely stunted (<-3SD). Based on the Body Mass Index (BMI) for age status, 14% of school children were wasted while 19% of them were underweight [11].

Over one-third of child deaths are due to malnutrition, typically from increased severity of disease associated with poor nutritional status [12]. The annual costs associated with child malnutrition are estimated at Ethiopian birr (ETB) 55.5 billion, which is equivalent to 16.5% of GDP [13]. Ethiopian Demographic and Health Survey (2011) reports that 44%, 44%, 10% and 29% of children under five years of age are anaemic, stunted, wasted and underweight, respectively [14].

Thus, the limited data available indicate that, in Ethiopia, malnutrition starts very early in life and more children progressively become malnourished during the first two years of age. From the reports published, it appears rates of malnutrition in children can vary across different regions of Ethiopia. A recent study reported significant variations in nutritional status of lactating mothers in two agro-ecological zones of rural Ethiopia, one in the northern part and the second in the eastern part of the country [15]. Therefore, given the present importance and high priority on the health of children around the globe in general, and in Ethiopia in particular, this study attempts to build on the current limited database on malnutrition in young children and to 1) explore the levels of anaemia and malnutrition among children 6-23 months of age; 2) determine agro-ecological variations in nutritional status and anaemia and 3) identify predictors of anaemia and stunting in the children in two different agro-ecological zones of rural Ethiopia.

Materials and Methods

Study area

This study was conducted in the Babile, Enderta and Hintalowajirat districts of Ethiopia from January to February 2014. These districts were selected due to their proximity to the two Ethiopian universities who were partner institutions in this project. Babile District (Woreda), which is 560 km away from Addis Ababa in the eastern part of Ethiopia and adjacent to Haramaya University, represented a lowland agro-ecological zone. The altitude of Babile Woreda ranges from 950 to 2000 meters above sea level and data were collected from 1000-1500 meters above sea level. The major agricultural product for consumption is sorghum and oil seeds; and groundnuts are used as cash crop. Hintalo Wajirat and Endreta districts (683 km and 773 km away from Addis Ababa in the Northern part of Ethiopia, respectively and adjacent to Mekelle University) 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 cross sectional survey was conducted in four kebeles randomly selected from each geographical area. Two hundred sixteen mother/child pairs were included in the study and the ages of children were 6-23 months old. Mothers were selected randomly from a list of registration available in each kebele and used by researchers to verify maternal and child age.

Dietary Data

Dietary diversity was calculated in a standardized way using a tool developed by FANTA [16, 17]. A simple questionnaire allowed all types of food 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 and given to her child in the compound during this period. Information collected on dietary consumption allowed us to calculate a Dietary Diversity Score (DDS) using a seven food group classification [16]: cereals/roots/tubers; pulses/nuts; vitamin A rich fruits/vegetables; other vegetables and fruits; flesh foods; eggs; milk/dairy products.

Frequency and the amount of food consumed were taken into consideration and DDS was calculated over a 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 to not include atypical days (local feasts or celebrations) in the recall.

Anthropometric Data

The anthropometric measurements for mothers and children were performed using the standardized procedures recommended by World Health Organization (WHO) [18-20]. The study participants were weighed to the nearest 100 g on electronic scales (SECA, Germany) with a weighing capacity of 0 to 140 kg with minimal (light) clothing and removed their shoes and hats during the measurement. Children were weighed together with the mother of the child, and the child’s weight was calculated by subtracting the respective mother’s weight, and this was recorded on the form during the fieldwork and confirmed later on by supervisors. Recumbent length was taken for the 6-23 month old children. Their length was measured to the nearest 0.1 cm with portable device consisting of a board with an upright wooden base and a movable headpiece, on a flat surface (SECA 2006 sliding board). The BMI was calculated by dividing weight by height/length in meters squared [weight/height^2 (kg/m^2)]. The mid-upper arm circumference (MUAC) of the left arm was measured to the nearest mm with a non-stretch measuring tape (MUAC 12.5 measuring tape/PAC-50).

Haemoglobin measurement

A blood sample was collected from each mother and child by a trained nurse and laboratory technologist from the tip of the middle finger after cleaning with disinfectant. The third drop of blood was added to the cuvettes for measuring haemoglobin concentration after two drops were wiped away. The accuracy of this procedure for estimation of haemoglobin in a resource-poor setting has been previously established [21]. Haemoglobin level 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 cut-off point for anaemia was based on WHO (2001) recommendations for mother. Anaemia is defined for children as haemoglobin less than 11g/dl and less than 12g/dl for mothers. Adjustment was made for altitude [21].

Data collectors and quality control

Diploma and above nurse data collectors were recruited and trained intensively on the data collection procedures, the context of specific questions across the questionnaire and anthropometric measurement procedures to be used. Blood for haemoglobin analysis was collected and tested by trained BSc and above laboratory technologists. The questionnaire was prepared first in English, then translated to Tigrigna and Afan Oromo language as both agro-ecological zones have their own local languages. Data were collected by their local language. Training was provided for the data collectors and the process of data collection was overseen by supervisors and principal investigators.

A pre-test survey was conducted on 5% of the total sample size in another rural area which has similar characteristics. Problems identified during the pre-test survey were corrected before the start of the actual survey. Two different measurements were taken for length, weight and MUAC of every study subject by different data collectors. The average of the two was considered for the analysis if there were variations in measurements. Finally the principal investigator was responsible for co-ordination and supervision of the overall data collection process. All children were apparently healthy during data collection and children with apparent sign of fever, diarrhoea, or any acute illness were excluded from the survey. Dependent variables were anaemia and nutritional status (undernutrition/normal/over nutrition). The independent variables were the socio-demographic and economic status, household level characteristics, health status of mothers and children, breast feeding, housing, sanitation, health services utilization and cultural/social characteristics related to feeding style. Frequency of complementary feeding, dietary diversity and child illness and health seeking behavior of the family were also assessed.

Data processing and analysis

The data were double entered by separate data clerks into EPI Data version 3.1. Data cleaning and editing were undertaken before analyses. For analyses, data were transferred to SPSS (v 16.0) statistical packages. Frequency, mean, standard deviation, correlation were computed for the variables of interest. Normality was checked graphically using different plots (P-P and/or Q-Q-plot). Meal frequency, anthropometric and haemoglobin mean and standard deviation values were considered. The WHO Anthro2005 and ENA software of the WHO were used for calculating the Z-scores. Weight-for-age WAZ (underweight); Weight-for-length WLZ (wasting); Length-for-age LAZ (stunting); Body mass index BAZ; and MUACZ and cut-off points of -2 were used to define malnutrition. Multivariable logistic and linear regressions were applied to isolate independent effect of predictors. Assumption including normality, homoscedasticity and linearity were checked.

Ethical standards disclosure

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by University College Cork, Ireland and Haramaya University College of Health and Medical Sciences Institution, Ethiopia, Research Ethics Review Committees. Subsequently, the final approval of the protocol was granted by the Ethiopian

National Ministry of Science and Technology Ethical Review Committee. Verbal informed consent was obtained from the caregivers of the children; they were informed that they have 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. Verbal consent was witnessed and formally recorded. Children and women who were found to be under nourished during assessment were referred to the nearest health institution for health care services.

Results

Socio-demographic characteristics and anthropometric status

Out of 220 children aged between 6 and 23 months recruited, 216 (98.2%) were analysed. Reasons for non-participation were fear of providing a blood sample for haemoglobin tests, one mother missed her appointment at the health centre and another mother refused to give a blood sample. Additionally, the process of data cleansing resulted in the exclusion of one child for specific variable age less than six months.

The majority (68.5%) of the mothers were illiterate, 53.2% reported to have access to safe drinking water and 45.0% of the households had no latrine. Health service utilisation was low as 67.8% of the mothers reported that they gave birth at home. But 52.0% of mothers reported that they had access to family planning services. The majority (87.0%) of the mothers were married. Descriptive measures of the study population (children and their mothers) are provided in Table 1.

Regarding the nutritional status of the study participants, 41.7% of the mothers were undernourished based on their body mass index (BMI < 18.5). The mean and standard deviations of LAZ, WAZ and WLZ for the children were -1.76 (0.1), -1.3 (0.08), and -0.5 (0.09), respectively, and mean and standard deviations for haemoglobin was 11.4 (0.12) g/dl. The mean difference between lowland and midland agro-ecological zone for LAZ score was significant (P=0.05) (Table 1).

Prevalence of malnutrition among children 6-23 months of age

Among 216 children assessed, 11.6, 26.9, and 39.8% were malnourished as measured by WLZ (wasting), WAZ (underweight), and LAZ (stunting) scores, respectively (Table 2). The magnitude of malnutrition peaked at 12-17 months (Table 3).

Prevalence of anaemia among children 6-23 months of age

Among 216 children included in analysis, 116 (53.7%) had anaemia of which 7.9, 23.1 and 22.7% had severe, moderate and mild anaemia, respectively (Table 2). The proportion of anaemia was higher but not significantly among male children (58.3%) compared to female (50.0%) (Table 5). The proportion of anaemia was higher among lowland children (59.5%) compared to midland children (47.6%) even though significance was lost after controlling for confounding (Table 2). Concerning classification of anaemia and malnutrition by age, the incidence of both anaemia and stunting increased from 6-11 months to 12-17 months age group and reduced again at 18-23 months age group (Table 3).

Predictors of stunting

Maternal and infant dietary diversity, minimum acceptable diet, household own latrine, child took deworming tablet in the past three months, child sickness within 15 days before the survey, maternal and paternal education and occupation do not show association in the bivariate models and were removed from the models. Among variables included in final models, children who achieved minimum meal frequency, age and sex of the child, BMI, age and height of the mothers were found to be significantly associated with LAZ (stunting) of the children. Children who achieved minimum meal frequency had higher Z score compared to those who did not consume adequate meals ($p=0.043$) (Table 4). The proportion of child stunting increased as the age of the child increased ($\beta = -0.039$, $p=0.009$) but female children have lower rate of stunting than male (p value <0.015). Similarly, as the height of the mother increases the LAZ of the children increases ($p=0.003$). As the BMI and age of the mothers increase, LAZ of children increases significantly. Those children born in lowland area and children who had low haemoglobin level were at greater risk for stunting compared to their counterparts in midland area even though significance was lost after controlling for confounding.

Predictors of anaemia

Child age, sex, source of drinking water for household, family planning utilization, taking deworming tablets in the past three months for mothers, maternal and infant dietary diversity, minimum acceptable diet, household own latrine, child took deworming tablet in the past three months, maternal and paternal education and occupation do not show association in the bivariate models and were removed from the models. All variables included in the models were selected based on their biological plausibility. Multivariable logistic regression analyses showed that the predictors of child anaemia were child illness in the last 2 weeks, child not having minimum meal frequency, mothers who do not wash their hands after toilet and mothers' ANC follow up. Children who received the minimum meal frequency per day were less likely to be anaemic compared to children who do not achieve minimum meal frequency (AOR 0.32, 95% CI = 0.15, 0.68) (Table 5). Mothers who received four focused Antenatal Care (ANC) visits were less likely to have children with anaemia compared to those mothers who received less than four ANC (AOR, 0.38: 95% CI, 0.17, 0.84). Similarly, this study indicated that those children who were sick in the 15 days before the survey were more likely to be anaemic compared to healthy group (AOR, 5.6, 95% CI, 2.6, 12.17). Among continuous variables included in the same model, maternal haemoglobin level, LAZ of child and mother BMI were significantly associated with child anaemia (Table 5). As the LAZ score of the child increased, the risk of the children being anaemic decreased by 25% (AOR 0.75, 95% CI, 0.56, 0.99). Similarly, as the haemoglobin level of the mothers increased the risk of the child being anaemic decreased (β =0.036, P=0.003) (Table 5).

Associations between malnutrition and anaemia

Among stunted, wasted and underweight children, 63.5%, 68.0%, and 66.7% were anaemic, respectively. These proportions were relatively higher than those for children without anaemia. Anaemia in this age group was significantly associated with being stunted and underweight (Table 6).

Table 1: Descriptive measures of children and their mothers in rural Ethiopia (n = 216 mother-child pairs)

	Mean and SD		Mean difference between lowland and midland zones*	
Variables	Mean	SD	Mean difference	t(p-value)
Child age (months)	13.35	4.8	-0.3	-0.5(0.6)
Child weight (kg)	8.21	0.1	0.02	0.1(0.9)
Child Length (cm)	71.38	0.38	-0.67	-0.9(0.4)
Child haemoglobin (g/dl)	11.41	0.12	-0.02	-1.9(0.059)
MUACZ	-1.61	0.07	0.05	0.32(0.7)
LAZ	-1.76	0.1	0.43	2.0(0.05)
WAZ	-1.30	0.08	0.03	0.16(0.9)
WLZ	-0.51	0.09	0.15	0.84(0.4)
BAZ of children	-0.33	0.09	0.24	1.3(0.2)
Maternal age (years)	28.52	0.42	-0.8	-0.9(0.4)
Maternal weight (kg)	48.85	0.43	1.3	1.4(0.1)
Maternal height (cm)	159.47	0.37	0.4	0.6(0.6)
Maternal BMI (kg/m^2)	19.21	0.15	0.4	1.2(0.3)
Maternal MUAC in cm	22.21	0.24	0.7	1.5(0.1)
Maternal haemoglobin (g/dl)	13.96	0.1	-0.4	-2.1(0.04)

MUACZ, Mid Upper Arm Circumference for age Z score; LAZ, Length-for-Age Z score; WAZ, Weight-for-Age Z score; WLZ, Weight-for-Length Z score; BAZ, Body mass index for Age Z score.

*Lowland agro-ecological zone is represented by Babile District (Woreda) which is 560 km away from Addis Ababa in the eastern part of Ethiopia and midland agro-ecological zone is represented by Hintalo Wajirat and Endreta districts which are 683 km and 773 km away from Addis Ababa in the northern part of Ethiopia. Lowland and midland zones were compared by unpaired t test and p values are show.

Table 2: Prevalence of stunting and anaemia among children 6-23 months of age by agro-ecology in rural Ethiopia (n = 111 children in Lowland, n = 105 children in Midland)

Variables	category	Lowland*	Midland**	Overall prevalence
WLZ	≤ -2	14(12.6)	11(10.5)	25(11.6)
	> -2	97(87.4)	94(89.5)	191(88.4)
WAZ	≤ -2	32(28.8)	26(24.8)	58(26.9)
	> -2	79(71.2)	79(75.2)	158(73.1)
LAZ	≤ -2	48(43.2)	38(36.2)	86(39.8)
	>-2	63(56.8)	67(63.8)	130(60.2)
Level of anaemia				
Severe (Hgb<7 g/dl)		12(10.8)	5(4.8)	17(7.9)
Moderate (Hgb 7.0-9.9 g/dl)		27(24.3)	23(21.9)	50(23.1)
Mild (Hgb 10.0-10.9 g/dl)		27(24.3)	22(21.0)	49(22.7)
Overall anaemic (Hgb<11 g/dl)		66(59.5)	50(47.6)	116(53.7)
Non anaemic (Hgb 11 g/dl)		45(40.5)	55(52.4)	100(46.3)
MUICK	≤ -2	44(39.6)	34(32.4)	78(36.1)
	>-2	67(60.4)	71(67.6)	138(63.9)
Children received Minimum	Yes	14(12.6)	12(11.4)	26(12.0)
acceptable diet	No	97(87.4)	93(88.6)	190(88.0)
Child Dietary Diversity Score	<4	80(72.1)	88(83.8)	168(77.8)
	≥ 4	31(27.9)	17(16.2)	48(22.2)
Child drank milk in the last 24 hours	Yes	78(70.3)	24(22.9)	102(47.2)
	No	33(29.7)	81(77.1)	114(52.8)

*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. WLZ, Weight-for-Length Z score; WAZ, Weight-for-Age Z score; LAZ, Length-for-Age Z score; Hgb, Haemoglobin; MUACZ, Mid Upper Arm Circumference for Age Z score; Minimum Meal Frequency, proportion of breastfed and non-breastfed children 6–23 months of age who receive solid, semi-solid or soft foods the minimum number of times or more (minimum is defined as: two times for breastfed infants 6–8 months; three times for breastfed children 9–23 months; and four times for non-breastfed children 6–23 months) in the previous day.

Table 3: Prevalence of malnutrition and anaemia among children 6-23 months of age by age categories in rural Ethiopia (n = 216 children)

Variables Classification		Age categories in months n (%)		
		6-11	**12-17**	**18-23**
WAZ	WAZ ≤ -3	1(1.3)	12(11.3)	4(13.3)
	WAZ ≤ -2	11(13.8)	39(36.8)	8(26.7)
	Normal	69(86.3)	67(63.2)	22(73.3)
LAZ	HAZ ≤ -3	8(10)	29(27.4)	7(23.4)
	HAZ ≤ -2	19(23.7)	56(52.8)	11(36.7)
	Normal	61(76.2)	50(47.2)	19(63.3)
WLZ	WHZ ≤ -3	1(1.2)	6(5.6)	0
	WHZ ≤ -2	2(2.5)	20(18.9)	3(10)
	Normal	78(97.5)	86(81.1)	27(90)
Hgb	Severe anaemia (<7)	3(3.75)	5(4.8)	1(3.3)
	Moderate anaemia (7-9.9)	14(17.5)	36(34.3)	8(26.7)
	Mild anaemia(10-10.9)	25(31.2)	19(17.1)	5(16.7)
	No anaemia (≥ 11)	38(47.5)	46(43.8)	16(53.3)
	Overall anaemia	42(52.5)	60(56.6)	14(46.7)
MUACZ	MUACZ ≤ -3	7(8.7)	13(12.3)	2(6.7)
	MUACZ≤ -2	21(26.2)	50(47.2)	7(23.3)
	Normal	59(73.7)	56(52.8)	23(76.7)

WAZ, Weight-for-Age Z score; LAZ, Length-for-Age Z score; WLZ, Weight-for-Length Z score; Hgb, Haemoglobin (g/dl); MUACZ, Mid Upper Arm Circumference for Age Z score.

Table 4: Predictors of Length for Age Z-score among children 6-23 months of age in rural Ethiopia (n = 216 children)

Model 1 **Predictors of LAZ (adjusted R^2 =0.5199) n=216** **F(12, 203) = 20.40, Root MSE = .99175**	β	Std. Error	**P** **<0.001**
MUACZ Score of the children	-0.029	0.08	0.73
Mothers BMI	0.08	0.033	0.017**
Haemoglobin level of the children	-0.025	0.4	0.56
Haemoglobin level of the mother	0.009	0.05	0.86
Sex of the child	0.34	0.14	0.015**
Age of the child in months	-0.039	0.015	0.009**
Age of the mother in years	0.024	0.011	0.038**
Maternal height	0.036	0.012	0.003**
Child received Minimum Meal Frequency	0.31	0.115	0.043**
Place of delivery	-0.11	0.19	0.45
Agro-ecological zones	0.19	0.17	0.22

LAZ, Length-for-Age Z-score;

β, coefficient for the predictor value;

MUACZ, Mid Upper Arm Circumference for age Z score; BMI, Body Mass Index; Minimum Meal Frequency: proportion of breastfed and non-breastfed children 6–23 months of age who receive solid, semi-solid or soft foods the minimum number of times or more (minimum is defined as: two times for breastfed infants 6–8 months; three times for breastfed children 9–23 months; and four times for non-breastfed children 6–23 months) in the previous day; WAZ, Weight-for-Age Z score.

Table 5: Predictors of anaemia among children 6-23 months of age in two agro-ecological zones of rural Ethiopia (n = 216 children)

Variables	Anaemic			
	Yes (n)	No (n)	COR [95% C.I]	AOR [95% C.I]
Child was sick in the last 15 days				
Yes	72	24	5.3(2.8, 10.1)*	5.6(2.6, 12.17)**
No	43	76	1	1
Sex of the child				
Male	56	40	1.4(0.78, 2.49)	
Female	60	60	1	-
Agro ecological zones				
Lowland	66	45	1.6(0.9, 2.8)	
Midland	50	55	1	-
Maternal education				
Illiterate	80	68	1.04(0.58, 1.86)	
Attend school	36	32	1	-
Child received Minimum Meal Frequency				
Yes	42	74	0.27(0.15 ,0.5)	0.32(0.15, 0.68)**
No	67	33	1	1
Hand washing after toilet(mothers)				
Yes	70	46	0.22(0.10, 0.47)*	0.3(0.12, 0.72)**
No	87	13	1	1
Child took deworming tablets in the last month				
Yes	25	40	0.62(0.32, 1.2)	
No	60	60	1	-
Source of drinking water				
Unprotected	58	39	1.5(0.87, 2.7)	
Protected	58	61	1	-
ANC follow up (N=179) >4 times	25	38	0.48(0.24, 0.94)*	0.38(0.17,0.84) **
<4 times	67	49	1	1

Table 5 continued

Continuous variables included in the model

Haemoglobin level of the mothers	-0.21(-0.41, -0.07)*	0.71(0.53, 0.96)**
BMI of the mothers	-0.13(-0.25, -0.003) *	0.87,(0.7, 1.03) **
Age of the children	-0 (-0.07, 0.04)	--
LAZ of the child	-0.28(-0.47, -0.08)*	0.75(0.56, 0.99)**

COR, Crude Odds Ratio; AOR, Adjusted Odds Ratio

*Significant by bivariate analysis.

**Significant by multiple variable analysis after adjusting for confounding.

Minimum Meal Frequency, proportion of breastfed and non-breastfed children 6–23 months of age who receive solid, semi-solid or soft foods the minimum number of times or more (minimum is defined as: two times for breastfed infants 6–8 months; three times for breastfed children 9–23 months; and four times for non-breastfed children 6–23 months) in the previous day; ANC, antenatal care; BMI, Body Mass Index; LAZ, length-for-Age Z score.

Table 6: Association of stunting with anaemia among children 6-23 months of age in rural Ethiopia

Variables	Anaemic n (%)	Non-anaemic n (%)	Total n (%)	OR (95% CI)	p-value
Underweight					
Yes	38(66.7)	19(33.3)	57(100)	0.47(0.25, 0.9)	0.021
No	77(48.7)	81(51.3)	158(100)	1	1
Stunting					
Yes	54(63.5)	31(36.5)	85(100)	0.51(0.29, 0.9)	0.018
No	61(46.9)	69(53.1)	130(100)	1	1
Wasting					
Yes	17(68)	8(32)	25(100)	0.5(0.2, 1.2)	0.125
No	98(51.6)	92(48.4)	190(100)	1	1

OR: odds ratio

CI: confidence interval

Discussion

We found that anaemia was very common among 6–23 month of age children in both agro-ecological zones with a higher rate in lowland of the eastern part of Ethiopia. Out of 116 children with anaemia, 59.5% were from lowland and 47.6% were from midland zones. The prevalence of anaemia in 6-23 month-old children from the lowland zone was very similar to the Ethiopian Demographic and Health Survey (EDHS) which reported overall prevalence (60.9%) for children under two years (6-23 months) [14]. These results are also similar to reported anaemia prevalence in a study from Brazil (51%) [22]. Our findings were lower than those reported in a study conducted among children of the same age (6-23 months) in Wag-Himra zone of Northern Ethiopia (66.6% anaemia) [7]. Furthermore, these authors reported that the peak age for anaemia was the 9-11 month age group [7]. Another study conducted in Northern Ethiopia, Kilte Awulaelo Woreda, reported that children aged 6-11 months were the most affected age group with anaemia prevalence of 53.2%, and prevalence rates of 50.6% in the 12-23 month age category [23]. Indeed, in our study when we looked at the prevalence of anaemia by age category (Table 3), we report that 52.5% of children 6-11 months were anaemic, 56.6% in the 12-17 months category and 46.7% in the 18-23 month age group. There are also published data on anaemia prevalence in children under 5 years of age [23-26]. These data indicate a decreasing trend in anaemia prevalence with age particularly in children above 23 months. Risk of anaemia is greatest in the first 2 years of age when growth velocity is highest [27]. High prevalence of anaemia in children under 24 months of age is influenced by increased iron requirements in this age group due to rapid growth, inadequate intake of iron rich foods and poor diet diversity. In our study, we found a high percentage of children (88.0%) did not receive the minimum acceptable diet and 77.8% had poor DDS of less than 4 (Table 2). Since DD is a good proxy indicator for micronutrient adequacy of diet [28, 29], low availability of foods rich in micronutrients such as iron and vitamin C is a likely contributor to the high rates of anaemia we report in our study population.

Our study showed anaemic children were 5.6 times as likely to have had recent infections (15 days preceding the interview). The presence of infections can result in loss of appetite and malabsorption of nutrients which increases risk for anaemia and also increases metabolic rate after infection. This finding is similar to that reported by Woldie *et al.* [7] in children of the same age category. In a study of children aged

6-60 months conducted in Northern Ethiopia, those with diarrhoea or fever or stunted were at significantly greater risk for anaemia than their counterparts [24]. In our study, hand washing habit of the mother after toilet had a significant association with child anaemia.

Maternal anaemia level is a determinant of child anaemia. As the haemoglobin level of the mother increased, the risk of the child being anaemic decreased by 29%. Similarly, as mothers' BMI increased the likelihood of the children being anaemic decreased. Our study provides strong evidence that there is a relationship between child anaemia and maternal nutritional status. A similar finding was also reported by a study conducted in Brazil [22]. According to another study conducted by Habte *et al.* [30], childhood anaemia demonstrated an increasing trend as maternal anaemia level increased.

Among the analysed variables related to children, low LAZ was positively associated with anaemia after controlling for other variables. As the LAZ score of the child increased, the risk of the children being anaemic decreased by 25%. The association between these anthropometric indices and anaemia has also been observed in several other studies [22, 30-34]. The causal relationships between stunting and anaemia are uncertain. Low haemoglobin levels may have negative impact on linear growth. Additionally, it is possible that deficiencies of other micronutrients and stunting may synergistically increase the risk for anaemia.

Children from the lowland agro-ecological zone had a higher rate of anaemia compared to the midland agro-ecological zone even though the difference was not significant after adjustments for confounding. There was little difference in the children's minimum meal frequency and DDS between the two agro-ecological zones (Table 2). Both indices indicate an undiversified diet and a diet inadequate in terms of micronutrients. An undiversified diet (cereal based monotonous diet) is known to cause micronutrient deficiency including anaemia [28, 29]. A higher percentage of children (70.3%) from the lowland agro-ecological zone drank milk in the last 24 hours compared to midland zone (22.9%). However, factors associated with anaemia among children are complex and multidimensional. In addition to nutritional, these involve socioeconomic, environmental, cultural and biological factors. We have previously reported on the nutritional status and anaemia among the lactating mothers of these children in the same two agro-ecological zones [15]. The mothers from the lowland agro-ecological zone had higher prevalence of anaemia. Details on diets plus other factors such as traditions, cultures and lifestyles of these two agro-ecological zones were provided in the earlier publication [15].

Stunting is an indicator of chronic malnutrition and is a hindrance to linear growth, which is the product of a cumulative history of stressful episodes that is unlikely to be compensated by catch-up growth during more favourable periods. The prevalence of stunting in children under 5 years has decreased during the past two decades, but is higher in south Asia and sub-Saharan Africa than elsewhere [2]. Stunting affected at least 165 million children globally in 2011[2]. The prevalence of stunting in our study was greater than some other studies [7, 11, 34], and slightly lower than the EDHS [14]. The result of multivariate analysis indicated that the prevalence of stunting among the study children increased with increase in age of child. Female children were less stunted than male children. This finding was also reported by other studies [35, 36]. Mothers with lower BMI, younger age and shorter stature are more likely to have stunted children. This suggests that malnutrition is intergenerational from mother to child, a finding that is also supported by others [35]. In contrast to other studies [22, 34], in our survey maternal characteristics such as education level and access to family planning services and household characteristics such as access to toilet and safe drinking water were not significantly associated with child malnutrition. A higher percentage of children from the lowland agro-ecological zone were stunted (43.2%) compared to the midland agro-ecological zone (36.2%) (Table 2). This difference was significant at p=0.05 (Table 1). Evidence for a close association between stunting, dietary diversity and micronutrient deficiencies in developing countries is well documented [28, 29, 37, 38].

In summary, anaemia and malnutrition (stunting and wasting and underweight) among children aged 6–23 months in rural communities of Ethiopia are major community concerns. Moreover, there were strong relationships between child morbidity in the last two weeks and maternal hand washing habits and anaemia among children in these rural areas. In general, the contributing factors for stunting in children were nutritional status of the mother, age and sex of the child, age and height of the mother and feeding practices of the children as measured by minimum meal frequency.

The strong points of this study include its design and use of both binary logistic and linear regression models to assess infant nutritional status with their mothers (infant-mother pairing) and focusing on limited age of the vulnerable population segments. We were able to measure the magnitude of the problems in this transition period from breast feeding/predominately breast feeding to complementary food. This age group is at high risk for many infectious diseases, inappropriate feeding practices particularly in a developing country, as well as being in the window period where the effects of malnutrition are not averted at later age of development. A further strength of this study is that anthropometric data were collected by two separate recorders and, if there were variations in data between the two recorders, the mean of the two recorders was used for analysis (unless the variation was so large that it necessitated-measuring of any suspected error cases within one day). Any resulting error is likely to be random. Even though there is no evidence of variation in haemoglobin level between morning and afternoon, the tests were conducted in the morning for all participants and the HemoCue machines were checked every morning to control reading errors.

There are identified limitations in our study that might have affected our findings. Most of the risk factors were determined from maternal reports as there was no other means of obtaining that information for the children, this may introduce recall bias. Nonetheless, the duration prior to recall was short and we included some double checking in the questionnaire for validation of results. Thus, maternal recall bias is less likely to have affected the observed relationships.

Conclusions

In conclusion, our study showed that anaemia and malnutrition among children between 6-23 months of age is a major public health problem in rural Ethiopia. Our findings strongly suggest that short stature mothers have stunted babies compared to counterparts. Also, children born from anaemic mothers are more anaemic compared to children born from non-anaemic mothers. Similarly, recent illness and hand washing behaviours of mothers is also associated with child anaemia. Interventions focusing on improving nutritional status of the mother and children, achieving at least minimum meal feeding frequency for children at an early age and emphasis on hygienic conditions and antenatal care of the mothers should be targeted to reduce the devastating impact of child malnutrition. Additionally, prevalence of anaemia and stunting were more pronounced in lowland compared to midland agro-ecological zone of rural Ethiopia. These data suggest the need to undertake agro-ecological based studies in various parts of Ethiopia to determine appropriate interventions.

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Chapter 4

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

Abstract

There are limited studies on the magnitude and severity of zinc, iron and iodine deficiency, in addition to inadequate serum ferritin levels and anaemia, among lactating mothers across different agro-ecological zones of rural Ethiopia. A cross-sectional study examining socio-demographic parameters, anthropometry, dietary diversity, household salt usage, urinary iodine and blood tests for zinc, ferritin and anaemia was conducted in 202 mothers among eight rural villages from lowland and midland agro-ecological zones of Ethiopia. Goitre was determined by palpation. The prevalence of low status of serum zinc, ferritin, iron deficiency anaemia (IDA), and total goitre rates among lactating mothers irrespective of their agro-ecological zones were 71.8%, 60.4%, 10.9%, and 35.2%, respectively. The median urinary iodine was 120µg/L. Low level of serum zinc, iron and IDA was significantly higher in lowland mothers (96.2%, 89.4% and 20.2%) than in midland agro-ecological zone (45.9%, 29.9%, and 1.0%). Prevalence of goitre among lactating mothers was not significantly different across agro-ecological zones. Adequately iodised salt was available in 36.6% of households. Of the mothers, 37.5% in lowland were deficient in both biomarkers (zinc and ferritin) while only 2.0% in midland agro-ecological zone were deficient. None of the lactating mothers were aware of iodine deficiency diseases or the importance of using iodised salt. Haemoglobin levels were significantly correlated with maternal body mass index (BMI), mid-upper arm circumference (MUAC) and dietary diversity. Lactating mothers in rural Ethiopia are at high risk of micronutrient deficiencies. The prevalence of micronutrient deficiencies was significantly influenced by agro-ecological zone.

Introduction

Micronutrient deficiencies are a major public health problem in many developing countries, particularly in infants and pregnant women. In 2011, 116,000 deaths in children under 5 years were attributable to zinc deficiency (1.7% of mortalities in this group) [1]. Approximately, 2 billion people (over 30% of world population) are anaemic, many due to iron deficiency [2]. Additionally, about 1.88 billion (28%) of the world's population are considered to have insufficient iodine intake and hence are at risk of iodine deficiency, of whom more than 321 million are Africans [3].

Zinc is a micronutrient with diverse physiologic and metabolic functions [4]. It is involved in all the main biochemical pathways and plays multiple roles in cellular proliferation and differentiation. It affects physical growth, immunity, reproductive function and neuro-behavioural development [5]. The amount of zinc required for non-pregnant adult women (19+ years) is 9 mg per day. This amount increases to 11 mg zinc/d in pregnancy and in lactation to 12 mg/d [6].

Iron deficiency occurs predominantly due to a deficiency of bioavailable dietary iron and/or increased demands such as during childhood, pregnancy and lactation [7]. High demands for iron due to menstrual blood loss, pregnancy, lactation and nutritional deficiencies are the most common causes of iron deficiency anaemia in reproductive-age women [8]. Nutritional requirements during lactation are greater than during pregnancy [9]. The quantity of milk produced by mothers depends very much on the mother's diet [9]. Severely malnourished mothers have reduced lactation performance contributing to increased risk of child mortality [10].

Lactating mothers from low-income settings are considered as a nutritionally vulnerable group [11]. Anaemia was estimated to be an underlying factor for 22% of maternal deaths around the world, of which severe anaemia is a major contributor [12, 13]. The few studies conducted among Ethiopian mothers on prevalence of zinc and iron deficiency suggest there is very high level of prevalence. A study conducted in Gondar (Northwest Ethiopia) among pregnant and non-pregnant mothers reported prevalence of low zinc status was 74% and 55%, respectively [14]. Similarly, another study evaluating zinc deficiency among pregnant women in rural Sidam, South Ethiopia, reported prevalence of 53% [15]. According to a study in nine different regions of Ethiopia conducted by Umeta *et al.* [16], the prevalence of anaemia, ID and iron deficiency anaemia (IDA) were 30.4, 49.7 and 17.0%, respectively. The single study in Ethiopia documenting the prevalence of low serum ferritin among lactating mothers in a slum of Addis Ababa reported that the prevalence was 22.3% [17]. Similarly, iodine deficiency in eastern Ethiopia has a prevalence of 82% among pregnant women [18]. In Ethiopia, goitre rates are reported to range from 34.5% to 37.0% among childbearing women [19].

Although low serum level of zinc and iron, and iodine deficiency is increasingly being recognized as a widespread problem in Ethiopia, there are very limited studies on the prevalence and severity of these deficiencies among lactating mothers across different agro-ecological zones in Africa, particularly in Ethiopia. This study was conducted in two agro-ecological zones of rural Ethiopia with the aim of assessing the prevalence and variations of maternal zinc, iron and iodine deficiency across these zones and their relationship to other indices of malnutrition.

Materials and Methods

Participants and study design

The study was conducted in the Babile, Enderta and Hintalo Wajirat districts of Ethiopia. These districts were selected due to their proximity to the two Ethiopian universities who were partner institutions in this project funded by Irish Aid. Babile District (Woreda), which is 560 km away from Addis Ababa in the eastern part of Ethiopia and adjacent to Haramaya University, represented a lowland agro-ecological zone. The altitude of Babile Woreda ranges from 950 to 2000 meters above sea level and data were collected from 1000-1500 meters above sea level. The major agricultural product for consumption is sorghum, and oil seeds and groundnuts are used as cash crops. Hintalo Wajirat and Endreta districts (683 km and 773 km away from Addis Ababa in the Northern part of Ethiopia, respectively and adjacent to Mekelle University) 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 cross sectional study was conducted in four kebeles randomly selected from each geographical area. The study was conducted from January to February 2014 which is the post-harvest season. Data on socio-demographic status, anthropometry and feeding practices were generated. Blood and urine samples were collected from the mothers. Out of the 208 mothers who gave samples of blood for test of ferritin, haemoglobin and zinc, 202 (97%) samples were analysed, while the remaining samples were discarded due to insufficiency (3 samples) and haemolyses (3 samples). Urinary iodine levels and salt iodine concentration were measured and goitre rates were assessed by palpation.

Socio-demographic status and anthropometric measures

Socio-demographic characteristics of the participants were assessed using a pre-tested questionnaire that included questions on education levels, health services utilization and water and sanitary facilities. 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 [20]. Mid upper arm circumference (MUAC) was also measured using a non-stretchable MUAC tape (MUAC measuring tape/PAC-50) [20] 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 researcher (the first author) took the measurement again for validation. The Body Mass Index (BMI) [weight/height^2 (kg/m^2)] was calculated and the threshold of 18.5 kg/m^2 was used to identify underweight women.

Dietary intake assessment

Dietary intake was assessed by simple questionnaire that 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 in the compound during this 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 to not include atypical days (local feasts or celebrations) in the recall. The protocol of Women Dietary Diversity Score (WDDS) was standardized by FANTA [21].

Blood collection, serum separation and micronutrient measurements

Five millilitres of venous blood were collected aseptically in the morning [22] from the antecubital vein of the participants and was aliquoted into tubes without anticoagulants by a trained health professional. Samples of serum were collected in to zinc/metal free vacutainers and gloves were free of talcum powder. A sample was allowed to clot and centrifuged to separate serum. Serum was stored frozen at -20 ^{O}C and transported by plane to the Ethiopian Public Health Institution (EPHI http://www.ephi.gov.et), Addis Ababa. Serum ferritin, which reflects body iron stores, was analyzed using an enzyme-linked immunosorbent assay (ELISA) with a fully automated Elecsys 1020 using commercial kits purchased from Boerrhinger Mannheim, Germany by a senior medical technologist. Serum ferritin (SF) levels were defined as: iron deficiency if SF <15 µg/litre as recommended by WHO [23].

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. The cut-off point for anaemia was based on WHO (2011) recommendation for non-pregnant mother. The threshold criteria used to determine the severity of anaemia as a mild, moderate or severe public health problem were as follows: prevalence rate of anaemia was mild 5.0-19.9%, moderate was 20-39.9% and severe was >40%, respectively. Level of anaemia was classified as: mild anaemia (Hgb 10-11.9 g/dl), moderate anaemia (Hgb 7-9.9 g/dl) and severe anaemia (Hgb less than 7 g/dl). Haemoglobin level was adjusted by altitude. Iron deficiency anaemia was defined as serum ferritin less than 15 µg /litre and haemoglobin less than 12 g/dl [24].

For the determination of zinc, frozen sera were shipped to EPHI on dry ice in polystyrene packaging material. The concentration of zinc in serum was determined at the National Food, Medicines, Health Service Administration and Control Authority (FMHACA) laboratory by using Shimadzu Flame Atomic Absorption Spectroscopy (AA 6800 model, Japan). Serum samples (200µL) were added to a trace metal-free plastic test tube and diluted by addition of 6% butanol in 1:5 ratios. Calibration of the Atomic Absorption Spectrophotometer was carried out using a series of standards of zinc, 0, 0.1, 0.2, 0.3 and 0.4 ppm by dilution from stock of 1000 ppm AAS zinc standards. Each series of standards was diluted with 5% glycerol to equate with viscosity of serum. Zinc concentration was measured using an air-acetylene flame at a wavelength of 213.9 nm and a slit width of 0.7 nm. The results were calculated from two runs [25, 26]. To minimize the risk of contamination, all glassware and plastic tubes used were immersed in 10% (v/v) solution of nitric acid for 24 h, washed with distilled water and rinsed with deionized water before use. Because blood samples in this survey were not necessarily obtained fasting but collected in the morning between 8-10 a.m., we used a cut-off value of 66μg/dl for mothers and 65μg/dl for children, as recommended by the International Zinc Nutrition Consultative Group (IZiNCG) [22].

Urinary iodine

Five to ten millilitres of spot urine samples were collected from all mothers to examine urinary iodine concentration (UIC). Samples were tightly sealed in plastic tubes that were free from iodine or any other chemical to avoid leakage and cross-contaminations with iodine from other sources. The urine samples were kept in a cold box until analyses were performed in duplicate in the iodine laboratory of the EPHI using the method based on the Sandell-Kolthoff reaction [27]. UIC was expressed as the median micrograms of iodine per liter (µg/litre) of urine. Urinary iodine status of the lactating mothers was classified using WHO/UNICEF/ICCIDD recommended cut-off points for urinary iodine concentration for populations [28]. That is ≥ 100 μg/litre is categorized as adequate and <100 μg/litre insufficient.

Goitre rates

All mothers were clinically examined by trained nurses for goitre using palpation of the thyroid. Five day practical training was given on how to palpate neck for goitre and demonstration and evaluation was given during pretesting of the tools. Classification of goitre rate was made as recommended by WHO/UNICEF/ICCIDD [29].

Variables

Dependent variables were micronutrients and biomarkers of micronutrient status (serum zinc, ferritin, iron deficiency anaemia, urinary iodine) among 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. Nutritional knowledge of mother, WDDS and meal frequency, and health seeking behavior of the family was also assessed.

Data processing and analysis

The data were double entered by separate data clerks into EPI Data version 3.1. Data cleaning and editing were undertaken before analysis. Data were checked for normality by using the Kolomogrov-Smirnov test. Data were transferred to SPSS (v 16.0) statistical packages and Stata (v.11) for analysis. Descriptive statistics were used to show the magnitude of each variable. Cross tabulations and linear regression were used to see the difference across the agro-ecological regions and associations of different variables. For WDDS, BMI, anthropometric data, haemoglobin and serum ferritin levels, mean and standard deviation were analysed. Multiple binary and linear logistic regressions were applied to control for confounding after testing binary linear regression.

Ethical consideration

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by University College Cork, Ireland and Haramaya University College of Health and Medical Sciences Institution, Ethiopia, Research Ethics Review Committees. Subsequently, 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. Women who were found to be undernourished during assessment were referred to the nearest health institution for health care services.

Results

The majority 137 (67.8%) of the mothers were illiterate. Health service utilization was low as 138 (68.3%) of the mothers reported that they gave birth at home. The majority 145 (71.8%) of the mothers wash their hands after toilet but only 113 (55.9%) households have toilet facility (Table 1).

Concerning feeding practices, 56.9 % of the households never consumed meat and 47% never consumed egg at least one time in the previous month. The majority

(60.9%) of mothers reported that they drink coffee or tea more than four times in a week, and 86.6% drank coffee the day preceding the survey. Only 27.7% drink milk or milk with coffee. About 78.7% of the households reported that they cook salt with food and 18.3% of households reported washing their salt before use as majority of the households in rural Ethiopia use crystal salt (Table 1).

Comparison of maternal characteristic between the two agro-ecological zones

Among 202 participants included in the survey, mean and standard deviation of age were 28.5 ± 5.9 years. Comparing maternal characteristics of lowland and midland, midland had significantly ($p<0.05$) higher rate of focused antenatal care, haemoglobin, serum zinc, and serum ferritin concentrations than their lowland counterparts, while the latter had a statistically significant ($p<0.05$) higher number of children aged less than five and low birth interval (Table 2).

Prevalence of low Zinc, iron and iron deficiency anaemia

The mean serum zinc concentration of the study participants was 57.5 ± 23.1 μg/litre (Table 2) with a low serum level of (serum zinc <66 μg/litre) in 145 participants (71.8%) (Table 3). Mean serum ferritin (SF) concentration of the participants was 52.7 ± 4.8 μg/litre (Table 2). The prevalence of iron deficiency (ID) determined by serum ferritin (<15 μg/litre) was 20.8% (Table 3). Iron deficiency anaemia (low haemoglobin + SF) was observed in 22 participants (10.9%). Among 41 (20.3%) mothers with zinc and ID in combination, 39 (95.1%) of them also were from lowland agro-ecological zones (Table 3).

Prevalence of Iodized salt utilization and Total Goitre Rate

Adequate iodized salt (with > 15ppm) was found in 36.6% of the households (Table 3), about half (50.5%) of households have salt with less than 15 ppm and the remaining households (12.9%) use non-iodized salt. The median Urinary Iodine Concentration (UIC) of lactating mothers was 120 μg/litre, and 42.6% of the mothers had UIC less than 100 μg/litre (Table 3). The weighted total goitre (TGR) rate among lactating mothers in this study group was 35.2% (95%, CI = 28.6 - 42.1), 32.7% palpable and 2.5% visible goitre (Table 3).

Prevalence of low serum zinc, iron and urinary iodine by agro-ecological zone

The proportion of lactating mothers with zinc, iron deficiency and iron deficiency anaemia was considerably higher among lowland residents compared to midland (Table 3). Greater than 96% of mothers in the lowland region had serum zine levels less than 66 μg/litre. On the other hand, about 46% of mothers had zinc level below this cut-off in the midland zone. Higher prevalence of ID (serum ferritin levels <15 μg/litre) was observed among lowland agro-ecological zones (37.5% versus 3.1% in midland) (Table 3). The levels of anaemia in the two zones paralleled the ID rates. Overall levels of ID in this study population, as assessed by serum ferritin concentration, were very high. Nearly 21% of surveyed mothers had serum ferritin concentrations less than 15 μg/litre which is an indicator of ID (Table 3). (Table 3).

The prevalence of Total Goitre Rate (TGR) was very similar in both zones with slightly higher incidence in the lowland (36.5%) agro-ecological zone compared to the midland (33.7%). The number of mothers with visible goitre was 4 in the lowland and 1 individual in midland region (Table 3).

About 20% of mothers surveyed were deficient in both biomarkers (zinc and iron) with higher rate (37.5%) in the lowland zone while only 2.0% of mothers in the midland zone were deficient in both biomarkers measured in this study (Table 3).

Table 5 shows the correlation between micronutrient status, malnutrition and dietary diversity scores among lactating mothers in rural Ethiopia. Maternal serum ferritin concentration levels were significantly associated with serum zinc ($r = 0.374$, $p = 0.000$) and haemoglobin level ($r = 0.21$, $p = 0.003$). Haemoglobin levels were associated with maternal BMI ($r = 0.165$, $p=0.019$), MUAC ($r = 0.175$, $p = 0.013$) and Women Dietary Diversity Score ($r = 0.192$, $p = 0.006$) in addition to serum ferritin. Maternal MUAC was positively associated with maternal BMI ($r = 0.619$, $p = 0.000$) in addition to haemoglobin levels.

Table 1: Distribution of selected socio-demographic and maternal characteristics of lactating mothers in two agro-ecological zones of rural Ethiopia (N = 202)

Variables	Category	Total n (%)	Lowland* n (%)	Midland** n (%)	*P*-value
Age (y)	15-24	48 (23.8)	22 (21.2)	26 (26.5)	1.00
	25-34	114 (56.4)	63 (60.6)	51 (52.0)	0.52
	35-49	40 (19.8)	19 (18.2)	21 (21.5)	0.93
Education	Illiterate	137 (67.8)	78 (75.0)	59 (60.2)	0.19
	Attend school	65 (32.2)	29 (25.0)	39 (39.8)	
Parity	3 and below	71 (35.1)	38 (36.5)	33 (33.7)	0.80
	>=4	131 (64.9)	66 (63.5)	65 (66.3)	
Took deworming tablets during pregnancy	No	132 (65.3)	65 (62.3)	67 (68.4)	0.60
	Yes	70 (34.7)	39 (37.7)	31 (31.6)	
Family size	1-5	100(49.5)	54 (51.9)	48(46.9)	0.80
	>5	102(50.5)	50 (48.1)	52(53.1)	
Number of children <5 y	1 child	79 (39.1)	30 (28.8)	49 (50)	1.00
	2 children	110 (54.5)	61 (58.7)	49 (50)	0.19
	3 children	13 (6.4)	13 (12.5)	0	-----
Household with toilet	Yes	113 (55.9)	52 (50.0)	61 (62.2)	0.30
	No	89 (44.1)	52 (50.0)	37 (37.8)	
Hand washing after toilet	Yes	145 (71.8)	76 (73.1)	69 (70.4)	0.80
	No	57 (28.2)	28 (26.9)	29 (29.6)	0.70
Birth interval	First birth	27 (13.4)	11 (10.6)	16 (16.3)	1.00
	1-2 y	89 (44.1)	59 (56.7)	30 (30.6)	0.14
	>2 y	86 (42.5)	34 (32.7)	52 (53.1)	0.96
Attend antenatal care	No	32 (15.8)	22 (21.2)	10 (10.2)	0.20
	Yes	170 (84.2)	82 (78.8)	88 (89.8)	
Place of delivery of index child	Home	138 (68.3)	86 (82.7)	52 (53.1)	0.01
	Health institution	64 (31.7)	18 (17.3)	46 (46.9)	
Meat consumption in a month	Never	115 (56.9)	84 (80.8)	31 (31.6)	0.00
	1-2 times	87 (43.1)	20 (19.2)	67 (68.4)	
Egg consumption in a month	Never	95 (47.0)	73 (70.2)	22 (22.4)	<.001
	1-2 times	67 (33.2)	13 (12.5)	54 (55.2)	0.23
	3-6 times	40 (19.8)	18 (17.3)	22 (22.4)	1.00
Eat legumes yesterday	No	60 (29.7)	59 (56.7)	1 (1)	<0.001
	Yes	142 (70.3)	45 (43.3)	97 (99)	
Consumption of tea/ coffee in a week	<4 times	79 (39.1)	25 (24.0)	54 (55.1)	0.009
	>4 times	123 (60.9)	79 (76.0)	44 (44.9)	
Drink coffee yesterday	No	27 (13.4)	18 (17.3)	9 (9.2)	0.30
	Yes	175 (86.6)	86 (82.7)	89 (90.8)	
Drink milk yesterday	No	146 (72.3)	51 (49.0)	95 (96.9)	<0.001
	Yes	56 (27.7)	53 (51.0)	3 (3.1)	
Wash salt before use	No	165 (81.7)	87 (83.7)	78 (79.6)	0.66
	Yes	37 (18.3)	17 (16.3)	20 (20.4)	
Practice of using salt	Add after cooking	43 (21.3)	9 (8.7)	34 (34.7)	0.01
	Cook with food	159 (78.7)	95 (91.3)	64 (65.3)	

*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 2: Comparison of maternal characteristics of lactating mothers in two agro-ecological zones of rural Ethiopia (N = 202)

Parameters	Lowland# (n=104)	Midland## (n=98)	P-Value
Age (y)	28.3 ± 5.2	28.6 ± 6.6	0.751
BMI	19.2 ± 2.3	18.9 ± 1.8	0.365
Parity	4.4 ± 2.2	4.3 ± 2.5	0.813
Children <5 y	1.8 ± 0.6	1.5 ± 0.5	0.000**
Attended antenatal care	2.7 ± 1.2	3.8 ± 1.5	0.000**
Haemoglobin (g/dl)	12.9 ± 2.0	13.4 ± 0.8	0.023**
Serum zinc (µg/l)	45.0 ± 14.0	68.8 ± 24.0	0.000**
Serum ferritin (µg/l)	26.8 ± 23.6	80.2 ± 51.0	0.000**
Median urinary iodine (µg/l)	122.1 ± 108.8	118.2 ± 83.6	0.970
Family size (total in home)	5.8 ± 2.0	5.7 ± 2.0	0.906
MUAC (cm)	22.0 ± 1.6	21.7 ± 1.4	0.930
Height of mothers (cm)	159.7 ± 5.8	159.2 ± 5.4	0.597
Birth interval (y)	2.2 ± 1.5	2.9 ± 2.0	0.014**
Weight of mothers (kg)	49.1 ± 6.8	48.1 ± 4.9	0.225
WDDS	3.0 ± 1.1	3.1 ± 0.4	0.767
Mean duration of lactation (months)	13.3 ± 4.4	13.3 ± 5.3	0.988

Values are expressed as mean ± standard deviation; BMI: Body Mass Index calculated as weight in kg/height in meter squared (kg/m^2); MUAC: Mid Upper Arm Circumference; WDDS: Women Dietary Diversity Score.

**P-Values statistically significant at $P < 0.05$.

#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 3: Prevalence of micronutrient deficiency among lactating mothers in two agro-ecological zones of rural Ethiopia (N = 202)

	Responses	Total n (%)	Lowland# n (%)	Midland## n (%)	P-value
Iron deficiency (serum ferritin SF)	Severe (<15 µg/l)	42 (20.8)	39 (37.5)	3 (3.1)	0.000
	Normal ferritin value (>15 µg/l)	160 (79.2)	65(62.5)	95 (96.9)	
IDA (low Hgb +SF)	Yes	22 (10.9)	21 (20.2)	1 (1)	0.000
	No	180 (89.1)	83 (79.8)	97 (99)	
Level of anaemia (haemoglobin)	Moderate (7-9.9 g/dl)	5 (2.5)	5 (4.8)	0	NA
	Mild (10-11.9 g/dl)	37 (17.8)	30 (28.8)	7 (6.1)	0.000
	Overall anaemia (Hgb<12g/dl)	42 (20.3)	35 (33.6)	7 (6.1)	0.000
	Non anaemic mothers	160 (79.7)	69 (66.4)	91 (93.9)	
Serum zinc	<66 µg/l	145 (71.8)	100 (96.2)	45 (45.9)	0.000
	>=66µg/l	57 (28.2)	4 (3.8)	53 (54.1)	
MUAC	<22 cm	84 (41.6)	51 (49.0)	33 (33.7)	0.027
	>22 cm	118 (58.4)	53 (51.0)	65 (66.3)	
BMI	<18.5 (kg/m^2)	85 (42.1)	42 (40.4)	43 (43.9)	0.702
	>18.5 (kg/m^2)	117 (57.9)	61 (59.6)	56 (56.1)	
Urinary iodine	<100 µg/l	86 (42.6)	47 (45.2)	39 (39.8)	0.440
	>=100 µg/l	116 (57.4)	57 (54.8)	59 (60.2)	
Salt iodine	0 ppm	26 (12.9)	12 (11.5)	14 (14.3)	0.380
	15ppm	102 (50.5)	65 (62.5)	37 (37.7)	0.004
	>15ppm	74 (36.6)	27 (26.0)	47 (48.0)	
Goitre rate	Grade 2 (Visible)	5 (2.5)	4 (3.8)	1 (1)	0.190
	Grade 1 (Palpable)	66 (32.7)	34 (32.7)	32 (32.7)	0.880
	Grade 0 (No goitre)	131 (64.9)	66 (63.5)	65 (66.3)	
	Total goitre rate (TGR) (visible + palpable)	71 (35.2)	38 (36.5)	33 (33.7)	
Ferritin and zinc deficient**	Yes	41 (20.0)	39 (37.5)	2 (2.0)	0.000
	No	161 (80.0)	65 (62.5)	96 (98.0)	

BMI: Body Mass Index calculated as weight in kg/height in meter squared (kg/m^2); MUAC: Mid Upper Arm Circumference; Hgb: Haemoglobin; SF: Serum ferritin; WDDS: Women Dietary Diversity Score.

**Ferritin and zinc deficient is defined as mothers with serum ferritin less than 15 µg/l and zinc level less than 66 µg/l

#Babile District (Woreda) which is 560 km away from Addis Ababa in the eastern part of Ethiopia is representing a lowland agro-ecological zone. ##HintaloWajirat 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 5: Correlation between micronutrients, malnutrition and Women Dietary Diversity Score among lactating mothers in rural Ethiopia (N = 202)

Variables		Ferritin	Zinc	Haemo-globin	BMI	MUAC	WDDS
Ferritin	P. Correlation	1.00					
	Sig. (2-tailed)						
Zinc	P. Correlation	.374**	1.00				
	Sig. (2-tailed)	.000					
Haemoglobin	P. Correlation	.211**	.096	1.00			
	Sig. (2-tailed)	.003	.173				
BMI	P. Correlation	-0.075	-.146*	.165*	1.00		
	Sig. (2-tailed)	0.291	.039	.019			
MUAC	P. Correlation	-0.078	-.074	.175*	.619*	1.00	
	Sig. (2-tailed)	0.270	.295	.013	*.000		
WDDS	P. Correlation	.093	.104	.192**	-.034	-.030	1.00
	Sig. (2-tailed)	.189	.139	.006	.627	.668	

P: Pearson correlation; BMI: Body Mass Index calculated as weight in kg/height in meter (kg/m^2); MUAC: Mid Upper Arm Circumference; WDDS: Women Dietary Diversity Score.
**Correlation is significant at the 0.05 level (2-tailed).*
***Correlation is significant at the 0.01 level (2-tailed).*

Discussion

This study conducted in lactating mothers confirmed that 71.8% had low serum zinc, 60.4% had low iron status and 42.6% of the mothers had UIC less than 100 µg/L. Of the mothers with low iron status, 10.9% had IDA. The deficiencies were more pronounced in lowland (96.2% for zinc and 89.4% for iron) compared to midland (45.9% for zinc and 29.6% for iron) agro-ecological zones.

Our observation of zinc deficiency of 71.8% is similar to that reported in pregnant women in Ethiopia at 74% [30]. The higher prevalence of low serum zinc found in the present study could be due to an inadequate zinc intake and/or poor bioavailability. It is worthy to note that several dietary factors are known to affect zinc absorption as a result of physico-chemical interactions in the intestine. Phytate, a component in plants with the highest concentration found in seeds (cereal grains/legumes/nuts), inhibits zinc absorption [31]. This might hold true in the subjects of the present study, as cereal is a staple food in both agro-ecological zones. Additionally, good sources of bioavailable zinc, like meat and egg, were poorly consumed especially in the lowland agro-ecological zone.

On the basis of the WHO cut-off points for serum ferritin [23], the prevalence of iron deficiency in the present study population was 20.8%. When we compare prevalence of iron deficiency among agro-ecological zones, an exceptionally higher prevalence was recorded among lowland community (37.5% versus 3.1%). This prevalence is larger than reported in other studies conducted in Ethiopia [16, 32].

The WDDS was similar but low in both agro-ecological zones (Table 2). Evidence for a close association between dietary diversity and micronutrient deficiencies in developing countries is well documented [33, 34]. Some cereal crops, notably teff the main cereal consumed in the midland agro-ecological zone, are high in iron and fermented enset may increase non-heme iron absorption. Additionally, a marked observation in the present study is the lower intakes of meat (source of heme iron) and eggs among mothers from the lowland zone (Table 1). Heme iron from animal foods is much better absorbed than non-heme iron from plant source food where iron absorption may range from as low as 1 to 10%. A striking difference was noted for legume consumption among the study participants between the two agro-ecological zones. Ninety nine percent of mothers in the midland zone reported consuming legumes the day prior to the study while only 43.3% of mothers in the lowland zone consumed these foods. Legumes are a rich source of vitamin C and this could be another factor related to the differences in iron deficiency anaemia between the two zones. Frequent consumption of coffee and tea was observed. Consumption of these beverages was much higher in the lowland zone. Coffee and tea contain phenolic compounds that inhibit the absorption of iron. In addition to their appetite-suppressing effects, these beverages are of low nutrient density, thus when consumed especially with sugar, they may displace more nutritious foods.

Women frequently enter pregnancy with insufficient nutrient stores, and the increased demands associated with pregnancy and lactation are reported to increase risk of developing anaemia [35]. Our data show that antenatal care and birth interval were greater in the midland agro-ecological zone compared to lowland. These factors could also be contributing to the differences in anaemia rates between the two zones. On the other hand, no differences in parity and family size were seen between the zones.

Although the presence of parasitic infections, particularly hookworm, is associated with bleeding and hence higher levels of iron deficiency, this did not appear to contribute significantly to the differences in iron deficiency between the lowland and midland zones in the present study. There was no significant difference between the lowland and midland zones with respect to the practice of taking deworming tablets, households with toilet, hand washing practices and mother being sick in past 15 days. Thus, our findings suggest that difference in iron deficiency between the two agro-ecological zones is mainly caused by dietary factors. Additionally, we have previously reported variations in dietary diversity and traditional feeding habits between these two agro-ecological zones in rural Ethiopia [36].

The 10.9% prevalence of IDA in the present study is lower than reported for lactating mothers in an urban slum of Addis Ababa (22%) [17], non-pregnant Ethiopian women [16], and similar to the figure (13%) reported in pregnant mothers in southern Ethiopia [30]. Prevalence of IDA was higher in the lowland agro-ecological zone (37.5%) compared to lactating mothers from Addis Ababa (22%) [17]. These differences are again most likely to be related to variations in dietary pattern in the different zones of rural Ethiopia [16].

This study also demonstrated that deficiencies of zinc and iron occur concurrently. Once again, prevalences were higher in the lowland agro-ecological zone. The coexistence of zinc and iron deficiencies is probably related to high intakes of cereal which is rich in phytate and very low intakes of animal proteins [31, 36]. In addition to dietary factors, mothers living in less developed countries, like Ethiopia, are exposed to frequent diarrhoea and respiratory infections, recurrent pregnancy and prolonged lactation all of which can influence micronutrient status [37].

The prevalence of goitre observed among lactating mothers in this study (35.2%) is similar to that reported in other studies among reproductive age Ethiopian women [38, 39]. Our data are in accord with previous work in Ethiopia [38] which reported >30% TGR in Tigray, Oromia, the Southern Nations, and Beshangul-Gumuz. According to WHO/UNICEF/ICCIDD [29], a total goitre rate of 5% is a cut-off point indicating a public health risk of adverse functional consequences and when TGR is higher than 30% the problem is severe. The percentage of lactating mothers with UIC less than 100 µg/L was 42.6%. However, even higher prevalences have been reported in Papua New Guinea, 60% [40] and Niger, 69.7% [41]. WHO/UNICEF/ICCIDD recommended cut-off point of < 100 µg/L for urinary iodine concentration (UIC) is for population groups [28]. This cut-off point is a good indicator of iodine status in populations but there is no good established urinary biomarker for iodine status of individuals. UIC is associated with high intra- and inter-individual variation and hence the determination of UIC in a single spot sample should not ideally be used to categorise an individual. Konig et al. (2011) presented data indicating that 10 spot urine samples were needed to assess individual iodine status with 20% precision [42]. These authors noted the major limitation of this large number of repeated urine samples needed to estimate individual iodine status. This is particularly the case with respect to our study conducted in rural zones in Ethiopia. Thus, our findings and inferences with respect to UIC need to be evaluated in light of this limitation. High prevalence of suboptimal status of iodine nutrition among lactating mothers is of concern because of the association between subclinical iodine deficiency in lactating mothers and the potential risk of abnormal brain development in breastfed infants. The breast feeding mother provides the nursing infant with its sole source of iodine while the infant is exclusively breastfed [43, 44].

Iodized salt was found in 36.6% of the households in our study which is greater than that reported in other studies conducted elsewhere in Ethiopia [39, 44]. However, the Ethiopian government has set up a Universal Salt Iodization program even though there is a lot more to do to achieve WHO/UNICEF guidelines [43].

Among the participants, 20% mothers were deficient in both biomarkers (zinc, iron). This prevalence is greater than reported in studies in Gondar [14]. Our data indicate that the majority of the mothers in the study area are affected by at least a single micronutrient deficiency, with the coexistence of micronutrient deficiencies most likely due to common aetiology and underlying mechanisms. For instance, a diet rich in phytate and low in animal proteins is common in most developing countries including Ethiopia; such a dietary pattern predisposes individuals to insufficient intake and absorption of zinc and iron [46, 47].

This study showed that ferritin level is positively and significantly correlated with haemoglobin and zinc. As the level of ferritin increases, the serum levels of haemoglobin and zinc will also increase. The associations between zinc, iron and anaemia were reported in others studies [48, 49]. Likewise haemoglobin levels were significantly correlated with maternal BMI, MUAC and WDDS which suggests that intervention directed to alleviate micronutrient deficiencies should be multidimensional.

A limitation of this study is that although bloods were collected from apparently healthy individuals, acute phase proteins, including C-reactive protein (CRP), tests were not conducted due to financial reasons and absence of reagents at national level during this study period. For data collected by interview, social desirability bias could not be totally excluded.

Conclusions

In summary, the results of the present study reveal a high magnitude of micronutrient deficiencies, independently as well as concurrently, among lactating mothers in both agro-ecological zones. However, the deficiencies were more pronounced in lowland compared to midland agro-ecological zone of rural Ethiopia. These data suggest the need to undertake agro-ecological based studies in various parts of Ethiopia to determine appropriate interventions in all reproductive age mothers. Increased animal food consumption and increased consumption of vegetables and fruits is recommended in this population group.

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Chapter 5

Concurrent micronutrient deficiencies in lactating mothers and their children 6-23 months of age in two agro-ecological zones of rural Ethiopia

Abstract

Background: Deficiencies of ferritin and zinc and low levels of haemoglobin are common among mothers and their children in developing countries. Little attention has been given to co-existence of these deficiencies among lactating mothers and their breast fed children.

Methods: Data were collected from 162 lactating mothers and their breast fed children (aged 6-23 months) who were living in two different agro-ecological zones of rural Ethiopia. The data were collected via a structured interview, anthropometric measurements, and blood tests for zinc, ferritin and anaemia. Correlation and Chi square tests were used to determine the association between nutritional status and agro-ecological zones.

Results: Low serum iron was found in 44.4% of the children and 19.8% of the mothers. Low serum zinc was found in 72.2% of the mothers and 67.3% of the children. Of the study subjects, 52.5% of the children and 19.1% of the mothers were anaemic, and 29.6% of the children and 10.5% of the 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 mothers with low serum zinc level, 75.2% and 45.3% of their children had low zinc and iron status, respectively. There was a strong correlation between the micronutrient status of the mothers and the children for ferritin, zinc and anaemia ($P < 0.001$). There was also a statistically significant association between micronutrient deficiency and agro-ecological zones among the mothers ($p<0.001$) but not with their children. Deficiency in one, two, or all three biomarkers of micronutrient status was observed in 48.1%, 16.7% and 9.9% of the mothers and 35.8%, 29.0%, and 23.5%, of their children, respectively. In the 24h before the survey, 82.1% of mothers and 91.9% of their infants consumed foods that can decrease zinc bioavailability while only 2.5% of mothers and 3.7% of their infants consumed flesh foods.

Conclusion: This study shows that low iron and zinc status are very prevalent micronutrient deficiencies among lactating mothers and their children, with variation in prevalence across the agro-ecological zones. This finding calls for a need to design effective preventive public health nutrition programs to address both the mothers' and their children's needs.

Introduction

The first two years of life are crucial for children's long term physical, mental, and emotional development [1]. In many developing countries, micronutrient deficiencies are major public health problems in young children and women especially during pregnancy and lactation [2]. Nutritional requirements during lactation are greater than during pregnancy [3]. Growing children require extra micronutrients to maintain optimal growth and development. Low status of iron, zinc and vitamin A often co-occur and have independent and interacting effects on health, growth, and immunological response [4, 5]. Iron deficiency is the most common cause of nutritional anaemia and is the most common micronutrient deficiency worldwide; it has negative effects on the motor and mental development of young children [6, 7]. Similarly, low zinc status has a negative influence on growth and development and increases the risk of diarrhoea and acute respiratory infections among children [8-10]. It is estimated that 22% of the maternal deaths around the globe are related to severe anaemia [11, 12]. In Ethiopia, the magnitude of anaemia, zinc and iron deficiency among mothers and children is reported to be very high. A study conducted in Gondar among non-pregnant women reported prevalence of 74% for zinc and 55% for iron deficiencies, respectively [13]. In rural Sidama, South Ethiopia, 53.0% of pregnant mothers were deficient in zinc [14]. Umeta *et al.*[15] reported that 30.4% were anaemic, 49.7% were iron deficient (ID) and 17% had iron deficiency anaemia (IDA). The single study documenting the magnitude of ferritin status among lactating mothers in a slum of Addis Ababa showed that the prevalence of low ferritin status was 22.3% [16]. Similarly, studies of anaemia prevalence in children reported levels of 66.6% in children 6-23 months old [17], 60.6% [18] and 37% among under five children [19].

No study has been published to our knowledge on the interrelation of micronutrient deficiencies among lactating mothers and their children in Africa, particularly in Ethiopia. Most studies have focused on only one micronutrient or on one segment of a population group, whereas many populations can be expected to be deficient in several micronutrients at the same time. The aim of this study was to explore the prevalence of concomitant micronutrient deficiencies in lactating mothers and their children (6-23 months) across agro-ecological zones of rural Ethiopia.

Materials and Methods

Study area and participants

This study was conducted in the Babile, Enderta and Hintalowajirat districts of Ethiopia from January to February 2014. Babile District (Woreda), which is 560 km away from Addis Ababa, in the eastern part of Ethiopia, is a lowland agro-ecological area. Its altitude ranges from 950 to 2000 meters above sea level, and data were collected from 1000-1500 meters above sea level. The major agricultural product for consumption is sorghum, and oil seeds and groundnuts are used as cash crops. Hintalo Wajirat and Endreta districts (683 km and 773 km away from Addis Ababa in the Northern part of Ethiopia, respectively) represented midland agro-ecological areas. Data were collected from an altitude of greater than 2000 meters above sea level. The major produce in these areas are cereals (Teff and barley) and some people are involved in animal husbandry. A community based study was conducted in four kebeles randomly selected from each geographical area (lowland and midland). Data from 162 mother-child pairs were included in this study.

Blood collection, serum separation and micronutrient measurement

Three to five millilitres of venous blood sample from the antecubital vein were taken from each study subject. The samples were taken in the morning (from 8:00 a.m. to 10:00 a.m.) [20] and were aliquoted into tubes without anticoagulants by a trained health professional. Samples were clotted and centrifuged to separate serum. The serum was stored frozen at -20 ^{O}C and transported by plane to the Ethiopian Public Health Institution (EPHI http://www.ephi.gov.et), Addis Ababa. Serum ferritin, an indicator of iron stores, was analysed using an enzyme-linked immunosorbent assay (ELISA) with a fully automated Elecsys 1020 using commercial kits purchased from Boehringer Mannheim, Germany by a senior medical technologist. Serum ferritin (SF) levels were defined as: low serum iron is classified as SF <15 µg/litre as recommended by WHO [21, 22].

A small portion of whole blood from the syringe was used to test haemoglobin level of the mothers and children immediately on site by using portable HemoCue analyser (HemoCue® Hb 301) which is considered to be a gold standard for field work. The cut-off point for anaemia was based on WHO (2011) recommendation for non-pregnant mothers. This procedure was validated elsewhere in resource poor settings [23]. Level of anaemia was classified as: mild anaemia (Hgb 10-11.9 g/dl), moderate anaemia (Hgb 7-9.9 g/dl) and severe anaemia (Hgb less than 7 g/dl). Haemoglobin reading levels were adjusted for altitude [24]. Iron deficiency anaemia was defined as serum ferritin less than 15 µg /L and haemoglobin less than 12 g/dl [24].

To determine zinc, sera derived from the non-fasting blood samples collected in the morning (8.00-10.00 a.m.) were shipped to EPHI in dry ice and polystyrene packaging material. Samples of serum were collected into zinc/metal free vacutainers and gloves were free of talcum powder. The concentration of zinc in serum was determined at the National Food, Medicines, Health Service Administration and Control Authority (FMHACA) laboratory by using Shimadzu Flame Atomic Absorption Spectroscopy (AA 6800 model, Japan). Serum sample (200µL) was added into a trace metal free plastic test tube and diluted with 6% butanol in 1:5 ratios. Calibration of the Atomic Absorption Spectrophotometer (Shimadzu) was carried out using series of zinc standards 0, 0.1, 0.2, 0.3 and 0.4ppm by dilution from stock of 1000 ppm AAS zinc standard. Each series of standards was diluted with 5% glycerol to be equivalent with the viscosity of serum. Zinc concentration was measured using an air-acetylene flame at a wavelength of 213.9 nm and a slit width of 0.7nm. The results were calculated from two runs [25, 26]. To minimize the risk of contamination, all glassware and plastic tubes used were immersed in 10% (v/v) solution of nitric acid for 24 hours, washed with distilled water, and rinsed with deionized water before use. We used a cut-off value for serum zinc of 65 µg/dl, for children and 6665 µg/dl for mothers as recommended by the International Zinc Nutrition Consultative Group (IZincCG) [20].

Socio-demographic status and anthropometric measures

The following information was obtained from mothers during a face-to-face interview and recorded onto a questionnaire: health status of the child, such as age, gender, illness in the 2 weeks prior to the interview; maternal caring capacity, such as age of the mother, literacy (mother being able to read and write), marital status, occupation, parity, birth interval, family size and health services utilization; environmental services, such as owning a latrine and source of drinking water (pipe water vs. water from unprotected spring, river or well). The questionnaire was developed in English, translated into the local language (Tigrigna and Afan Oromo), and pretested in non-study households in a similar community before application. Finally, mothers were given appointments to bring their children to the local clinic for a physical check-up by a medical practitioner. The inclusion criteria for mothers were: biological mother of a child of 6-23 months of age living in the resident area at least for greater than one year, apparently healthy, and reported as non-pregnant by having regular menstrual cycle. The exclusion criteria were children and mothers with current history of acute fever or who reported any infection like malaria, diarrhoeal disease, tuberculosis, and HIV/AIDS.

The anthropometric measurements for children and their mothers were performed using the standardized procedures recommended by WHO [27-29]. The 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. Based on standard anthropometric techniques [30], the heights were measured to the nearest 0.1 cm, using a wooden height-measuring board with a sliding head bar. Mid upper arm circumferences (MUAC) were measured using a non-stretchable MUAC tape (MUAC measuring tape/PAC-50) [30] on the left upper arm of the mothers. The study subjects were barefoot and in light clothes when we measured their weight and height. Children were weighed together with the mother of the child, and the child's weight was calculated by subtracting the respective mother's weight. This was recorded on the form during the fieldwork and the calculations confirmed later on by supervisors. Children's height/length was measured to the nearest one centimetre with locally made portable devices equipped with gauges (SECA 2006 sliding board). To avoid variability among the data collectors, all the anthropometric measurements were taken by two different data collectors and the two measurements were compared. Where there was a difference, the researcher (the first author) himself re-measured for validation. The BMI [weight/height^2 (kg/m^2)] was calculated and the threshold of 18.5 kg/m^2 was used to identify the underweight women.

Dietary intake assessment

Dietary intake was assessed by simple questionnaire that allowed all types of foods consumed during each of the 24 previous hours to be noted and Dietary Diversity Score (DDS) calculated. Methods for this data collection were published elsewhere [31]. The dietary and food frequency assessments were made for both mothers and children. Dietary diversity was calculated from nine food groups for mothers and seven food groups for children. Dietary adequacy was categorised for child as those children who consumed four or more than four food groups from seven; women's dietary adequacy was categorized as mothers who consumed five or more food groups from nine. Consumption of tea/coffee was categorised as mothers or children who consumed tea or coffee four or more times in the previous week and those who consumed tea/coffee less than four times. The zinc bioavailability inhibitor food group score was derived from mothers who consumed from bread, millet, pulses, soybean, and tea in the last 24 hours. The flesh food group was computed from consumption of red meat, organ meat, poultry, and fish. Vitamin A rich food group (pre-Vitamin A carotenoids) was calculated from consumption in the previous 24h of yellow or orange fruits, other vegetables, carrots, other roots.

Variables

The dependent variables were zinc and iron status (micronutrients). The independent variables were the mothers' socio-demographic, economic, health, and sanitation statuses; and health service utilization and feeding style. The nutritional knowledge of the mothers, their dietary diversity score and meal frequency, and the health seeking behavior of the family were also considered.

Data processing and analysis

The data were double entered, by separate data clerks, into EPI Data Version 3.1. Data cleaning and editing were undertaken before the analysis. Descriptive, Pearson's correlation coefficients and chi square tests were performed to determine the association between the infants' and their respective mothers' micronutrient, nutritional and dietary diversity data. P values of 0.05 and below were used as cutting points to determine the statistical significance of the associations between the variables. The statistical analysis was carried out using SPSS (Version 16), Stata (Version 11) and WHO Anthro for children's anthropometric Z score calculation. The magnitude of malnutrition in the infants was assessed by weight-for-length Z-score (WLZ), weight-for-age z-score (WAZ), and length-for-age z-score (LAZ). Based on WHO 2006 reference cut-off points, below negative two Z score is categorized as malnourished.

Ethical consideration

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by

University College Cork, Ireland and Haramaya University College of Health and Medical Sciences Institution, Ethiopia, Research Ethics Review Committees. Subsequently, 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 verbal informed consent was obtained from the caregivers of the children; they were informed that they have 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. Verbal consent was witnessed and formally recorded. Children and women who were found to be under nourished during assessment were referred to the nearest health institution for health care services.

RESULTS

In this study, out of 216 mothers who were interviewed, 202 of them and their children (6-23 months of age) provided blood samples. Of these 202 mother-child pairs, blood samples from 162 mother-children were tested for micronutrients. Forty mother-child samples were not tested due to insufficient blood sample, or sample haemolysis, or 5% of the mothers reported that their children had one or more signs of acute infection (e.g., diarrhoea, cough, nasal discharge, fever) two weeks before the study, which was a condition for exclusion for micronutrient sample, as acute infections affect the serum status of zinc and iron. Thus, 162 samples (mother-child pairs) were retained for this analysis. Of the 162 mothers, 69.8% were illiterate, only 24.7% had their own source of income, 58% had parity greater than or equal to four, only 30.9% completed four focused ante-natal care sessions (ANC), and 42.9% had birth interval of less than two years (Table 1). The number of the lowland mothers whose parity was less than or equal to three (54.8%) was more than that of the midland mother (28.6%; X^2=10.1, P=0.001). A larger percentage of the midland mothers completed four focused ANC sessions (46.2%) compared to the lowland mothers (13.7%; p<0.001); the proportion of contraceptive users was higher among the midland mothers than the lowland ones (70.0% *vs*. 39.0%), and the proportion of the mothers who had their own source of income was higher among the lowland compared to the midland mothers (37.8% vs. 11.2%; Table 1). The mean ages of the mothers and the children were 28.6 (SD $\pm$ 5.72) years and 13.44 (SD $\pm$4.91) months, respectively. Similarly, mean and standard deviation of serum zinc of mothers were 57.0 (22.93) whereas mean (SD) for children were 55.8 (24.54) μg/l, respectively. The correlations between mothers and their children were statistically significant for serum ferritin (p=0.003), zinc (p<0.001) and haemoglobin (p=0.048) (Table 2).

Micronutrient and nutritional status of mothers and children

The overall prevalence of anaemia among the mothers was 19.1%, whereas it was 52.5% among the children. The prevalence was higher among the lowland mothers (30.5%) compared to the midland mothers (7.5%) (p<0.001; Table 3). Prevalence was also higher among the 25-34 years of age mothers and among 12-17 months of age children compared to 15-24 years of age mothers and 18-23 months of age children (Table 4). There is statistically significant association between maternal and child anaemia in this study group (X^2=39.16, p=<0.001) (Table 3).

The overall prevalence of iron deficiency among the mothers was 19.8%. However, the prevalence was higher in lowland mothers (35.4%) than in midland ones (3.8%) and this difference was statistically significant (p=0.000). The prevalence of iron deficiency was higher among 25-34 years of age mothers (68.8%; Table 4). Similarly, overall prevalence of iron deficiency among children was 44.4%, with no marked difference between the agro-ecological zones (46.3% in lowland and 42.5% in midland, Table 3). The 18-23 months children were more iron deficient (37.5%) than 12-17 months children (31.9%; Table 4).

Out of the 162 children, 29.6% had iron deficiency anaemia (IDA) (a combination of iron deficiency and anaemia). The highest prevalence of iron deficiency anaemia was found among the lowland children but was not statistically significant (Table 3).

Of the mothers, 10.5% had iron deficiency anaemia with prevalence of 19.5% in the lowlanders and 1.2% in the midlanders. This difference was statistically significant ($p < 0.001$). Similarly, there was a statistically significant association between the prevalence of iron deficiency anaemia among the mothers and their children (X^2=18.5, p<0.001; Table 3).

Table 4 shows data on iron status of both the lactating mothers and their children by age. Iron deficiency was most common among the children 18-23 months of age (37.5%). As the age of the children increased, the prevalence of iron deficiency increased. However, the level of iron deficiency anaemia was highest (35.4 %) among 12-17 months of age children and lowest among 6-11 months of age. Iron deficiency without anaemia was highest among the children 6-11 months of age (47.2%). Iron deficiencies, both with and without anaemia, were more prevalent among 25-34 years of age of the mothers.

The prevalence of low serum zinc concentration was 67.3% among the children and 72.2% among the mothers. Among children the prevalence in both agro-ecological zones was statistically similar (73.2% in lowland and 61.2% in midland). However, there was a statistically significant difference between the zones in the prevalence of low zinc concentration among the mothers (X^2=43.4, p=0.000), with very high prevalence (95.1%) among lowland mothers (Table 3).

Thirteen percent of children were wasted, 22.8% were underweight, and 35.8% were stunted. There was no statistical difference in these indices between lowland and midland regions (Table 3). In all three anthropometric measurements, the highest malnutrition was recorded at 12-17 months of age (Table 4). Likewise, as measured by BMI (<18.5 kg/m^2), 42.2% of the mothers were chronically malnourished, and the most affected age group was 25-34 years (Table 4). Similarly, based on MUAC, 45.1% of mothers had MUAC less than 22 cm (malnourished, Table 4).

Multiple micronutrient deficiencies of mothers and children

This study showed that 23.5% of the children were deficient in all three micronutrient biomarkers (serum ferritin, zinc, and haemoglobin) whereas 29.0% and 35.8% of children were deficient in two and one of the micronutrient biomarkers, respectively. Multiple micronutrient deficiencies (three and two micronutrients) in children were statistically associated with the mothers' micronutrient status (P<0.001) but not with the agro-ecological zones. Similarly, 9.9, 16.7, and 48.1% of the mothers were deficient in three, two, and one micronutrient biomarkers, respectively, and there were statistically significant associations between the multiple micronutrient deficiencies and the agro-ecological zones among mothers (p=<0.001) (Table 5).

Concurrent micronutrient deficiencies of mothers and children

Among mothers with iron deficiency, 81.2, 56.2 and 68.8% of their children were deficient in zinc, ferritin and anaemic, respectively. Similarly among low zinc status mothers, 75.2, 45.3 and 55.6% of their children had low serum zinc, ferritin and anaemic, respectively. Among undernourished mothers, 41.2% of their children were stunted, 67.6% had low serum zinc, and 60.3% of them were anaemic (Table 6).

Dietary habits of mothers and children

The mean and standard deviation for dietary diversity score was 3.1(0.85) for lactating mothers and 2.6(1.3) for children. Only 6.8% of mothers and 21% of children achieved adequate dietary diversity in the 24h preceding the survey date. Consumption of foods with potential to inhibit zinc bioavailability (bread, millet, pulses, soybean and drinking tea) by both groups was high as 82.1% of mothers and 91.9% of children consumed these foods in the 24h before the survey. Likewise, only 2.5% of mothers and 3.7% of children consumed flesh foods (Table 7).

Factors associated with selected micronutrient deficiencies

Body mass index of the mother, household utilization of iodized salt, family planning utilization, de-worming tablets in the past three months, and maternal and paternal education and occupation did not show statistically significant associations with maternal ferritin in the bivariate models, and thus were removed from the models. Maternal zinc status, drinking water, women dietary diversity score, frequency of drinking coffee/tea in a week and maternal haemoglobin were significantly associated with ferritin status of the mothers and included in the multivariate model.

As the maternal zinc level increase by one unit, maternal ferritin level also increased significantly (β=0.34, p=0.005). Similarly, as maternal haemoglobin level increased, maternal ferritin level also increased (β=3.9, p=0.05). Those mothers who used protected water sources had higher levels of maternal ferritin compared to those who used unprotected water (β=18.4, p=0.001), and mothers who drank coffee/tea more than four times had significantly lower levels of ferritin than those who drank coffee/tea less than four times in a week (β=-15.7, p=0.003) (Table 8).

We found that child ferritin level is associated with child haemoglobin level. Similarly, as maternal ferritin level increases, the ferritin level of the children also significantly increases (β=0.13, p=0.014). As age of the children increased the zinc level tended to decrease but was not statistically significance in multivariate model analysis. Child and maternal zinc status had no association with child ferritin level. In model three, maternal zinc is associated with child zinc status (β=0.38, $p<0.001$), but eating foods that contain zinc bioavailability inhibitors was not significant in multivariate analysis (Table 8).

Maternal zinc is significantly associated with maternal ferritin, source of drinking water, consuming flesh food in the previous 24h, and BMI of the mother. Frequency of drinking tea/coffee in the previous week was not significant. Mothers who consumed flesh food in the 24h preceding the survey had significantly higher zinc status ($\beta=18.0$, $p=0.031$). Maternal ferritin ($\beta=0.15$, $p=0.002$) and protected source of drinking water ($\beta=14.1$, $p<0.001$) show significant association with maternal zinc level (Table 8).

Table 1: Distribution of selected socio-demographic and maternal characteristics of lactating mothers by agro-ecological zone[a] of rural Ethiopia

Variables	Category	Total N (%)	Lowland N (%)	Midland N (%)	X^2	(p-value)
Mother's education	Illiterate	113 (69.8)	63 (76.8)	50 (62.5)	3.94	0.47
	Attended school	49 (30.2)	19 (23.2)	30 (37.5)		
Parity	3 and below	60 (42.0)	40 (54.8)	20 (28.6)	10.1	0.001
	>=4	83 (58.0)	33 (45.2)	50 (71.4)		
ANC[b] follow	<4	112 (69.1)	69 (86.3)	43 (53.8)	17.5	<0.001
	=4	50 (30.9)	13 (13.7)	37 (46.2)		
Family size	1-5	73 (45.1)	41 (50.0)	32 (40.0)	1.64	0.21
	>5	89 (54.9)	41 (50.0)	48 (60.0)		
Number of children <5 years	1 Child	67 (41.4)	25 (30.5)	42 (52.5)	1.00	
	2 Children	85 (52.5)	47 (57.3)	38 (47.5)	4.9	0.03
	3 Children	10 (6.1)	10 (12.2)	0 (0.0)	---	----
Household own toilet	Yes	71 (43.8)	40 (48.8)	31 (38.8)	1.67	0.2
	No	91 (56.2)	42 (51.2)	49 (61.2)		
Ever used contraceptives	Yes	88 (54.3)	32 (39.0)	56 (70.0)	15.7	<0.001
	No	74 (45.7)	50 (61.0)	24 (30.0)		
Birth interval	First birth	12 (8.1)	9 (11.0)	3 (4.6)	1.00	
	1-2 years	63 (42.9)	44 (53.7)	19 (19.2)	0.02	0.9
	≥ 2	72 (49.0)	29 (35.4)	43 (66.2)	1.62	0.2
Have index child vaccination card	Yes	85 (52.8)	15 (18.3)	71 (88.8)	80.7	<0.001
	No	76 (47.2)	67 (81.7)	9 (11.2)		
Mother's occupation	Farmer	150 (92.6)	77 (93.9)	73 (91.2)	0.4	0.5
	Petty trader	12 (7.8)	5 (6.1)	7 (6.2)		
Mother has own source of income	Yes	40 (24.7)	31 (37.8)	9 (11.2)	15.4	<0.001
	No	122 (75.3)	51 (62.2)	71 (88.8)		
Place of delivery of index child	Home	110 (67.9)	65 (79.3)	45 (56.2)	9.8	0.002
	Institution	52 (32.1)	17 (20.7)	35 (43.8)		
Wash salt before use	No	136 (84.0)	75 (91.5)	61 (76.2)	6.96	0.008
	Yes	26 (16.0)	7 (8.5)	19 (23.8)		
Salt utilisation	Add after cooking	37 (22.8)	7 (8.5)	30 (37.5)	19.3	<0.001
	Cook with food	125 (77.2)	75 (91.5)	50 (62.5)		

[a]Lowland agro-ecological zone is represented by Babile District (Woreda) which is 560 km away from Addis Ababa in the eastern part of Ethiopia and midland agro-ecological zone is represented by Hintalo Wajirat and Endreta districts which are 683 km and 773 km away from Addis Ababa in the northern part of Ethiopia. Lowland and midland zones were compared by unpaired t test and p values are show.
[b]Antenatal care

Table 2: Descriptive indicators and correlation of the micronutrient and nutritional status of children (6-23 months) and their lactating mothers in two agro-ecological zones of rural Ethiopia

Variables	Children Mean (SD)	Mothers Mean (SD)	Correlation coefficients	p–values
Serum ferritin (µg/l)	23.2 (24.31)	48.1 (36.25)	0.23	0.003
Haemoglobin (g/dl)	10.6 (1.62)[3]	13.3 (1.27)[3]	0.156	0.048
Serum zinc (µg/l)	55.8 (24.54)	57.0 (22.93)	0.349	<0.001
Under nutrition[1]	-1.57 (1.35)	19.2 (2.15)	0.215	0.006
Age[2]	13.4 (4.91)	28.6 (5.72)	___	___
MUAC (cm)	22.0 (1.58)	12.8 (1.12)	___	___
Height (cm)	71.9 (5.61)	159.7 (5.46)	___	___
Weight (kg)	8.3 (1.44)	48.9 (6.28)	____	___
DDS	2.6 (1.28)	3.1 (0.84)	___	___

[1]Under nutrition is defined as stunting (calculated as Length for age Z score <-2) for children and low BMI (<18.5kg/m2) in mothers
[2]Age is in months for children and in years for mothers
[3]Anaemia was defined as a haemoglobin concentration < 11 g/dl (in children) and < 12 g/dl (in mothers
MUAC, Mid Upper Arm Circumference (cm); DDS, Dietary Diversity Score

Table 3: Micronutrients and nutritional status of mothers and children (6-23 months) by agro-ecological zones in rural Ethiopia

Variables						Children				Mothers			
		Overall Children N (%)	**Overall Mothers N (%)**	**X^2**	**P-value**	**Lowland N (%)**	**Midland N (%)**	**X^2**	**p-value**	**Lowland N (%)**	**Midland N (%)**	**X^2**	**p-value**
Ferritin[a]	non-deficient	90 (55.6)	130 (80.2)	1.00	1.00	44 (53.7)	46 (57.5)	1.0	0.640	53 (64.6)	77 (96.2)	1.0	1.00
	deficient	72 (44.4)	32 (19.8)	22.66	0.000	38 (46.3)	34 (42.5)	0.24		29 (35.4)	3 (3.8)	24.7	0.000
Iron deficiency anaemia[b]	Yes	48 (29.6)	17 (10.5)	18.50	0.000	26 (31.7)	22 (27.5)	0.34	0.608	16 (19.5)	1 (1.2)	14.4	0.000
	No	114 (70.4)	145 (89.5)	1.00	1.00	56 (68.3)	58 (72.5)	1.00		66 (80.5)	79 (98.8)	1.00	
Anaemia[c]	non -anaemic	77 (47.5)	131 (80.9)	1.00	1.00	35 (42.7)	42 (52.5)	1.0		57 (69.5)	74 (92.5)	13.84	0.000
	Anaemic	85 (52.5)	31 (19.1)	39.16	0.000	47 (57.3)	38 (47.5)	1.56	0.2	25 (30.5)	6 (7.5)	1.00	1.00
Normal zinc value		53 (32.7)	45 (27.8)	1.00	1.00	22 (26.8)	31 (38,8)	1.00		4 (4.9)	41 (51.2)	1.00	1.00
Zinc deficiency[d]		109 (67.3)	117 (72.2)	0.94	0.33	60 (73.2)	49 (61.2)	2.61	0.1	78 (95.1)	39 (48.8)	43.4	0.000
Maternal BMI	<18.5	-	68 (42.0)	-	-	-	-	-	-	33 (40.2)	35 (43.8)	0.204	0.750
	>=18.5	-	94 (58.0)	-	-	-	-	-	-	49 (59.8)	45 (56.2)	1.00	1.00
Stunted	LAZ <-2	58 (35.8)	-	-	-	31 (37.8)	27 (33.8)	0.29	0.626	-	-	-	-
	LAZ >-2	104 (64.2)				51 (62.2)	53 (66.2)	1.00					
Wasted	WLZ <-2	21 (13.0)	-	-	-	10 (12.2)	11 (13.8)	0.087	0.818	-	-	-	-
	WLZ >-2	141 (87.0)				72 (87.8)	69 (86.2)	1.00					
Underweight	WAZ <-2	37 (22.8)	-	-	-	18 (22.0)	19 (23.8)	0.74	0.852	-	-	-	-
	WAZ >-2	125 (77.2)	-	-	-	64 (78.0)	61 (76.2)	100		-	-	-	-

[a]Iron deficiency is defined as a serum ferritin concentration < 15 µg/L for mothers and <12 µg/L children.
[b]Iron deficiency anaemia was defined as presence of anaemia and a serum ferritin concentration < 15 µg/L for mothers and <12 µg/L children.
[c]Anaemia was defined as a haemoglobin concentration < 11 g/dl (in children) and < 12 g/dl (in mothers).
[d]Zinc deficiency was defined as serum zinc less than 65 µg/L for children and less than 66 µg/L in mothers
LAZ, Length-for-Age Z score; WAZ, Weight-for-Age Z score; WLZ, Weight-for-Length Z score

Table 4: Micronutrients and nutritional status of mothers and children by age in rural Ethiopia

Variables	Haemoglobin and Ferritin					Zinc	LAZ	WLZ	WAZ
	Iron deficient[a] N (%)	Iron deficiency without anaemia N (%)	Iron deficiency anaemia[b] N (%)	Other causes of anaemia N (%)	Total anaemia N (%)	Zinc deficient[c] N (%)	Z score <-2	Z score <-2	Z score <-2
Children age									
6-11 months	22 (30.6)	17 (47.2)	15 (31.2)	7 (28.0)	32 (37.6)	40 (36.7)	15 (25.9)	1 (4.8)	9 (24.3)
12-17	23 (31.9)	15 (41.7)	17 (35.4)	6 (24.0)	32 (37.6)	42 (38.5)	26 (44.8)	12 (57.1)	17 (45.9)
18-23	27 (37.5)	4 (11.1)	16 (33.3)	12 (48.0)	21 (24.7)	27 (24.8)	17 (29.3)	8 (38.1)	11 (29.7)
Total	72 (44.4)	36 (22.2)	48 (29.6)	25 (15.4)	85 (52.5)	109 (67.3)	58 (35.8)	21 (13.0)	37 (22.8)
Mothers age							BMI<18.5	MUAC<22	
15-24	5 (15.6)	1 (7.1)	3 (17.6)	2 (13.3)	4 (12.9)	21 (63.6)	15 (22.1)	20 (22.5)	-
25-34	22 (68.8)	8 (57.1)	12 (70.6)	10 (66.7)	20 (64.5)	70 (74.5)	40 (58.8)	49 (55.1)	-
35-49	5 (15.6)	5 (35.7)	2 (11.8)	3 (20.0)	7 (22.6)	26 (74.3)	13 (19.1)	20 (22.5)	-
Total	32 (19.8)	14 (8.6)	17 (10.5)	15 (9.3)	31 (19.1)	117 (72.2)	68 (42.2)	89 (45.1)	-

[a]Iron deficiency is defined as a plasma ferritin concentration < 15 µg/L for mothers and <12 µg/L children.
[b]Iron deficiency anaemia was defined as anaemia (haemoglobin concentration < 110 mg/dl in children and < 120 mg/dl in mothers) and a plasma ferritin concentration < 15 µg/L for mothers and <12 µg/L children.
[c]Zinc deficiencies was defined as plasm zinc less than 65 µg/L for children and less than 66 µg/L in mothers
LAZ, Length-for-Age Z score; WAZ, Weight-for-Age Z score; WLZ, Weight-for-Length Z score. BMI, Body Mass Index calculated as weight in kg/height in metre^2 (kg/m^2); MUAC, Mid Upper Arm Circumference in cm.

Table 5: Zinc, iron and haemoglobin deficiencies in combination among lactating mothers and their children (6-23 months) by agro-ecological zones in rural Ethiopia

Variables	Mother and children				Children				Mothers			
	Overall Children N (%)	**Overall Mothers N (%)**	**X^2**	**p-value**	**Lowland N (%)**	**Midland N (%)**	**X^2**	**P-value**	**Lowland N (%)**	**Midland N (%)**	**X^2**	**p-value**
Deficient in all 3	38 (23.5)	16 (9.9)	17.03	<0.001	21 (25.6)	17 (21.2)	0.88	0.35	15 (18.3)	1 (1.2)	43.43	<0.001
Deficient in 2	47 (29.0)	27 (16.7)	13.45	<0.001	29 (35.4)	18 (22.5)	2.11	0.15	22 (26.8)	5 (6.2)	41.83	<0.001
Deficient in 1	58 (35.8)	78 (48.1)	2.1	0.15	24 (29.3)	34 (42.5)	0.00	0.96	43 (52.4)	35 (43.8)	28.86	<0.001
Non-deficient in all 3	19 (11.7)	41 (25.3)	1.00	1.00	8 (9.8)	11 (13.8)	1.00	1.00	2 (2.4)	39 (48.8)	1.00	1.00

Table 6: Concurrent micronutrient deficiencies among lactating mothers and their children (6-23 months) in two agro-ecological zones of rural Ethiopia

	Children deficiencies				
Mother deficiencies	Zinc N/total (%)	IDA[a] N/total (%)	Ferritin N/total (%)	Anaemia N/total (%)	Undernutrition[b] N/total (%)
Iron deficient[c]	26/32 (81.2)	26/31 (81.2)	18/32 (56.2)	22/32 (68.8)	13/32 (40.6)
Anaemia[d]	24/31 (77.4)	13/31 (41.9)	14/31 (45.2)	23/31 (74.2)	8/31 (25.8)
Undernutrition[b]	46/68 (67.6)	26/68 (38.2)	34/68 (50.0)	41/68 (60.3)	28/68 (41.2)
Zinc[e]	88/117 (75.2)	38/117 (32.5)	53/117 (45.3)	65/117 (55.6)	46/117 (39.3)

[a]IDA, Iron deficiency anaemia was defined as anaemia and a serum ferritin concentration < 15 µg/L for mothers and <12 µg/L children

[b]Undernutrition is defined as stunting (calculated as Length for age Z score <-2) for children and low BMI(<18.5kg/m^2) in mothers

[c]Iron deficiency is defined as a plasma ferritin concentration < 15 µg/L for mothers and <12 µg/L children.

[d]Anaemia was defined as a haemoglobin concentration < 110 mg/dl (in children) and < 120 mg/dl (in mothers).

[e]Zinc deficiency was defined as plasma zinc less than 65 µg/L for children and less than 66 µg/L in mother.

Table 7: Dietary diversity of mothers and children in rural Ethiopia

Variables	Mothers	Children
Dietary diversity score (mean and SD)	3.1(0.85)	2.6(1.3)
% achieving adequate dietary diversity	6.8	21
% consumed zinc inhibitors in previous 24h	82.1	91.9
% consumed flesh foods in previous 24h	2.5	3.7
% consumed pre-vit A rich foods in previous 24h	64.8	61.1
% consumed tea/coffee <4 times in a week	24.7	61.1*
% drank milk in previous 24h	29.0	42.6

*In lowland agro-ecological zone there is a behaviour of feeding children with tea or adding tea/Hoja (coffee with added milk) when mashing food.

Table 8: Selected predictors of micronutrient deficiency among mothers and children in rural Ethiopia

Variables	β (95% CI)	p-values
Model 1: Maternal Ferritin		
Maternal zinc	0.34 (0.10,0.57)	0.005
Source of drinking water	18.4(7.4,29.4)	0.001
Women dietary diversity score	3.5(-2.3,9.4)	0.236
Frequency of drinking tea/coffee in week	-15.7(-26.1,-5.4)	0.003
Model 2: Child Ferritin		
Maternal ferritin	0.13(0.026,0.23)	0.014
Child age	-0.6(-1.4,0.13)	0.10
Model 3: Child Zinc		
Maternal zinc	0.38(0.23,0.54)	<0.001
Eat zinc bioavailability inhibitors	-1.2(-10.6,8.1)	0.79
Model 4: Maternal Zinc		
Maternal ferritin	0.15(0.057,0.25)	0.002
Source of drinking water	14.1(7.3,20.8)	<0.001
Flesh food	18.0(1.7,34.4)	0.031
BMI of the mothers	-1.8(-3.2,-0.38)	0.013
Frequency of drinking tea/coffee in week	-3.9(-10.7,2.9)	0.263

DISCUSSION

This study demonstrated significant association between maternal micronutrient status and child nutritional status independent of maternal age, children's age and sex, and socio-demographic conditions. This association may be due to the shared environment which could impact a child's nutritional status through a number of factors including breastfeeding practices, access to quality foods and health care resources. In general, the nutritional status of mothers and their children was poorer in the lowland regions compared to the midland zone of rural Ethiopia.

The significant interrelationship between maternal and child nutritional status is similar to that shown between mothers and their children in earlier studies from Bangladesh, Ethiopia and Brazil [32-35]. The nutrition Collaborative Research Support Program (CRSP) studies reported significant positive correlations between maternal lean mass and infant weight and length, and between maternal BMI and infant length at 3–6 months post-partum [36]. The population in the present study was mainly rural; however both agro-ecological zones have their own traditional habits and diets. The cultural and the traditional feeding habits in the two agro-ecological zones have previously been reported [31].

In this study, 67.3% of the mothers and 72.2% of the children were zinc deficient. This prevalence is lower than studies conducted in Indonesia and Mexico [37, 38]. The prevalence of low zinc status among mothers in our study was similar to a study conducted in Gondar [13], and slightly lower than another study among pregnant women in southern Ethiopia [39].

Anaemia was more prevalent among the children (52.5%) than among their mothers (19.1%) and in the lowland compared to the midland zone. This finding is in contrast to a study conducted in Indonesia where higher prevalence of anaemia was reported in mothers (50%) than in children (17%). There is a statistically significant association between anaemia among mothers and their children ($P<0.001$). Likewise, the prevalence of IDA was also higher among children (29.5%) than the mothers (10.5%). The prevalence of IDA in our study group is lower than reported in other studies in Ethiopia [15, 16, 40].

Another noteworthy finding is the presence of multiple micronutrient deficiencies. When compared to children without anaemia, children with anaemia had a higher prevalence of low zinc status (68.7% vs 87.1%). Similarly, children with low serum ferritin statuses are more deficient in zinc compared to children without ferritin deficiency. Similar findings are apparent in the mothers. The co-occurrence of three deficiencies in micronutrient biomarkers in the children was relatively high, whereas the coexistence of two of these deficiencies was higher, showing that micronutrient deficiency is a serious nutritional issue in the children. This calls for more comprehensive and preventive approaches or interventions–whether food based, supplement based, or fortification based–to alleviate this serious public health issue.

Zinc, iron, and anaemia levels of the mothers were significantly associated with corresponding parameters in their children ($p<0.001$). Likewise, there was a statistically significant association between mothers and their respective children, regarding the co-occurrence of deficiencies of all three or two micronutrient biomarkers ($p<0.001$). This suggests that the nutritional deficiencies of the lactating mothers and their children are highly inter-correlated. An Indonesian study also reports a similar finding [37]. In lactating mothers, there were also statistically significant differences ($P<0.001$) in micronutrient deficiency between the lowland and the midland agro-ecological zones, but these were not observed in children. This may be due to the feeding habits differences in both communities [31].

This analysis adds to the literature on maternal nutritional status in rural communities in low income nations. It demonstrates the presence of acute undernutrition as shown by the low BMI values among mothers in the study's population. It contributes to the understanding of determinants of maternal nutrition in rural Ethiopia. The presence of interrelationship between maternal nutritional measures and child nutritional status stresses the importance of addressing maternal nutritional status with the aim of improving both maternal and child health outcomes.

Dietary diversity of mothers and children 6-23 months old in this study area is very low indicating that there are poor feeding practices in the community. The proportion of children and mothers who consume foods rich in inhibitors of zinc bioavailability (phytates) was very high, which may be one of the root causes of zinc deficiency. Likewise, consumption of flesh food (rich in iron and zinc) was exceptionally low, whereas consumption of foods that can interfere with iron absorption (coffee) was high.

One of the limitations of this study is that it did not assess energy and nutrient intake quantitatively, because it used a qualitative 24 hour recall data. The other possible limitation is recall bias associated with maternal memory and other response variables. We were not able to test creatinine reactive protein (CRP) as a measure of acute infection or inflammation responses due to financial reasons and absence of required reagents at national level during this study. However, bloods were collected from apparently healthy individuals who reported no ill health prior to the study. Two mothers with ferritin concentration greater than 150μg/L were excluded from analysis.

Conclusion

This study showed that anaemia, low serum iron and zinc statuses are very prevalent micronutrient deficiencies among lactating mothers and their children <24 months in rural Ethiopia. Deficiencies among the lactating mothers correlated significantly with deficiencies in their children suggesting that micronutrient deficiency is intergenerational, even though the mechanisms involved have not yet been explained adequately. Many of the low iron status mothers and children were also had low zinc status, suggesting that there is an association between iron and zinc status. The fact that we found multiple micronutrient deficiencies within this study population suggests a need to establish effective preventive public health nutrition programs.

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Chapter 6

Infant and Young Child Feeding (IYCF) practices among mothers of children aged 6–23 months in two agro-ecological zones of rural Ethiopia

Abstract

Background: It is estimated that 6% of all deaths of under 5 years old children in developing countries can be prevented by appropriate complementary feeding, in particular good dietary diversity and meal frequency. The aim of this paper is to assess infant and young child feeding practices among mothers of children aged 6-23 months in rural Ethiopia.

Methods: A community based cross-sectional study design was employed among mothers living in two agro-ecological zones. Trained data collectors conducted the interviews, anthropometric measurements, and the blood test for anaemia. To determine the predictors of minimum meal frequency, multivariable logistic regression models were used with 95% confidence intervals.

Results: We found that 95.4% of the children were breastfed, of whom 59.7% were initially breastfed within one hour after their birth, 83.3% fed on colostrum, 22.2% received pre-lacteal feeds and 50.9% of the children received complementary feedings by 6 months of age. In the 24 hours preceding the survey date, 39.8% of the children were fed using bottle; 4.6% and 1.9% of them consumed vitamin A-rich and iron-rich foods, respectively. Likewise 50.5%, 22.2%, and 12.0% of the children achieved minimum meal frequency, good dietary diversity and minimum acceptable diet, respectively. There are associations between the agro-ecological zones and dietary diversity, meal frequency, initiation of breast feeding, pre-lacteal feeds, bottle and colostrum feeding. The predictors of poor minimum meal frequency were age of the child, being anaemic, stunting. A significantly lower percentage of children achieved minimum meal frequency in the lowland agro-ecological zone compared to midland (p=0.01).

Conclusions: One out of nine children received appropriate diet for their age, which was very low. Mothers of child bearing age should be educated on the importance of infant and young child feeding.

KEYWORDS: Complementary feeding, dietary diversity, minimum acceptable diet, minimum meal frequency

Introduction

Adequate and quality complementary food during infancy and early childhood is essential for full growth and development. Poor child feeding practice and high rate of infection reduces cognitive development, educational achievement, productivity [1-3], and growth [4]. WHO recommends the introduction of complementary foods at six months of age, as breast milk alone is not enough to meet the nutritional requirements of 6-23 months of age children. After 6 months of age and with only optimum breastfeeding, children will become malnourished if they do not achieve appropriate dietary diversity and meal frequency [4-6]. Thus, the transition period from exclusive breastfeeding to two years is critical for optimal growth and development of children who need appropriate, safe, adequate amounts of complementary food [7], whereas suboptimal infant feeding results in under nutrition. Out of the 10.9 million under-five-year deaths that occur worldwide annually, malnutrition is, directly or indirectly, responsible for 60.0% of them. Over 3.4 million children less than five die each year due to inappropriate feeding practices [8].

In many developing countries, inadequate complementary feeding of 6-23 month old children is a major problem. Only 50% of children receive the minimum number of meals, less than one-third achieve minimum dietary diversity, and only 21% meet the criteria for the minimum acceptable diet [9]. In a study conducted in northern Ethiopia, only 10.8% of children achieved adequate dietary diversity and only 44.7% received the minimum meal frequency [10]. According to Alive and Thrive Ethiopia and the Ethiopian Demographic and Health Survey (EDHS) 2011, the extent of achievement of the minimum dietary diversity in the country was 4.8% and the proportion of children who received the minimum acceptable diet was 4.1% [11, 12]. Decreased dietary diversity is associated with stunting [1, 13]. It is estimated that 6% of all under-five-year deaths in developing countries can be prevented by appropriate complementary feeding, in respect of which dietary diversity and meal frequency are the most important issues [1, 14-16].

Understanding the importance of Infant and Young Child Feeding (IYCF) on the nutritional status of children less than two years of age, WHO established and validated a set of core indicators to measure IYCF practices [17]. A particular challenge related to age-appropriate complementary feeding is ensuring acceptable diet quality through an appropriately diverse diet [18]. So updated information on infant feeding practices from community based studies will help the Ethiopian National Nutrition Program to better monitor the changes in feeding practices and design interventions to increase the recommended feeding practices and thereby contribute to reducing undernutrition in the country. Thus, the aim of this paper was to assess IYCF practices and factors association with children feeding practices in two agro-ecological zones of rural Ethiopia.

Materials and Methods

Study area

This study was conducted in Babile, Enderta and Hintalowajirat districts of Ethiopia from January to February 2014. Babile, which is in eastern Ethiopia and 560 km away from Addis Ababa, is 950 to 2000 meters above sea level, and in this study it represents a lowland agro-ecology zone. In the district, data were collected from 1000-1500 meters above sea level. The major agricultural product for consumption is sorghum and oil seeds; and groundnuts are used as a cash crop. Khat (*Catula edulis*) is also grown extensively as a cash crop. Hintalo Wajirat and Endreta districts (683 km and 773 km away from Addis Ababa) in the northern part of Ethiopia represent midland agro-ecological zones. Data were collected from an altitude of greater than 2000 meters above sea level, where the inhabitants produce cereals (Teff and barley) and are involved in animal husbandry.

Study design, population and sampling

A community based cross sectional survey was conducted on 216 mother-child pairs from 4 randomly selected kebeles between January and February 2014. After we obtained the number of mothers who had children 6-23 months of age from the lists available to health extension workers, we allocated the sample size in each kebele based on the number of mothers in each kebele. Finally, the required number of mothers in each kebele was selected randomly.

Data collection

Data were collected using a structured questionnaire that is based on standardized tools developed by FANTA [19], which is a published operational guideline for measuring dietary diversity. The questionnaire inquires of each of the mothers the type of foods she ate and fed to her index child at home and outside the compound in the last 24 hours. The exact composition of all these foods was also noted. It also asks the kind of foods she fed her child in the last seven days.

The information collected on dietary consumption was used to calculate the dietary diversity score (DDS), the minimum meal frequency (MMF), and minimum acceptable diet (MAD) classification, which were defined at a workshop on dietary diversity [20, 21]. During the data collection, the frequency of consumption and the amount of food consumed was taken into consideration. Since the qualitative recall was conducted over 24 distinguishable hours, the DDS could be calculated over a 24 hours period. Dietary diversity was calculated on the basis seven food groups – see Table 4 [22]. The recall was randomly made on weekdays or on weekend days, since weekends do not have any special significance in the context of our study. We took care not to include atypical days (local feasts or celebrations) in the recall.

Minimum meal frequency, dietary diversity and minimum acceptable diet were defined and calculated according to WHO guidelines [19]. In addition, early initiation of breastfeeding**,** introduction of solid, semi-solid or soft foods**,** continued breastfeeding at 1 year, consumption of iron-rich or iron-fortified foods, children ever breastfed and bottle feeding were assessed. The anthropometric measurements conducted for both mothers and children were performed using the standardized procedures recommended by WHO [23, 24] after completing the interviews. Haemoglobin levels of the mothers and children were measured immediately on site by using portable HemoCue analyser. Anaemia is defined as haemoglobin less than 11 g/dl for children and less than 12 g/dl for mothers after adjustment is made for altitude [25].

Data collectors and data quality control

The data were collected by nurses and laboratory technologists, who had experience in collecting data in rural settings, who were native speakers of the local languages, and whom we trained intensively for the purposes of this study. To control the quality of the data, the questionnaire was prepared first in English and then translated into Tigrigna and Afan Oromo languages, which are the local languages in the different zones. The process of data collection was supervised by the principal investigator (KTR). A pre-test survey was conducted on 5% of the total sample size in other rural areas which have similar characteristics. Before the actual survey, solutions to the errors and problems identified during the pre-test survey were integrated into the final version of questionnaire. Two different measurements were taken for anthropometric parameters by different measurers for each study subject. If variation between measurements was observed, the principal investigator (KTR) checked the measurement.

Variables

The dependent variable was IYCF. The independent variables were socio-demographic and economic factors, food intake pattern, agro-ecological zone, maternal and children haemoglobin values, antenatal care, place of delivery of index child, history of illness in the past and nutritional status of mother and children.

Data processing and analysis

Data were double entered into EPI data Version 3.1 by different data clerks. Before the analysis, the data were cleaned and edited by KTR using SPSS version 16 and Stata 11. WHO Anthro 2005 was used for calculating the z-scores. For the analysis, the data were transferred to SPSS Version 16.0. IYCF indicators, initiation of breastfeeding within one hour after delivery, DDS, MMF and MAD, proportion of children exclusively breastfed, and number who started complementary feeding at six months were reported in this study. The variables associated with MMF were analysed via univariate and multivariate analysis. P-values of less than 0.1 were used as cutting point to include in multivariable analysis model. Chi-square test was used to determine the associations between feeding practices and agro-ecological zones.

Ethical consideration

Ethical clearance was obtained from University College Cork and Haramaya University College of Health and Medical Sciences Institutional Research Ethics Review Committee. The Ethiopian National Ministry of Science and Technology Ethical Review Committee granted the final approval of the protocol. Informed consent was obtained from the caregivers/mothers of the children.

Results

Out of the 220 mothers interviewed, 216 (98.2) completed the survey. The four dropouts were due to fear of needles and thus did not provide a blood sample for the haemoglobin test. All of the mothers were biological mothers with 31.5% in age range of 30-34 years. 55.6% of the children were female children, 68.5% of the mothers did not have formal education, 87% were married, and 91.2% were farmers (Table 1).

Maternal and children health service utilization

Most of the mothers (82.8%) had antenatal care follow up at least once during their last pregnancy. More than half of them (53.7%) attended four focused ANC as recommended. Only 31.9% of the mothers gave birth to their index child at a health institution. Many of them (61.1%) had more than one child who was less than five years (Table 1).

Infant and Young Child Feeding (IYCF) Practices by agro-ecology

In this study, 95.4% of the mothers had ever practiced breastfeeding, 50.9% of them introduced timely complementary feeding at 6 months, 59.7% had initiated breastfeeding within 1 hour after birth, 22.2% used pre lacteal feeds, and 95.3% continued breast feeding at one year. Only 1.9% of the mothers fed their babies iron-rich food, and the day before the survey only 39.8% had not bottle fed their children. The mean and standard deviation of dietary diversity for the day preceding the survey were 2.6 ± 0.085 (with 95% CI of 2.48, 2.83). The overall prevalence of children achieving minimum dietary diversity was 22.2% (95% CI =17.0, 28.4). Half of the children (50.5%) received the minimum meal frequency, but only 12% (95% CI =8.0, 17.0) of them received the minimum acceptable diet (combination of dietary diversity and meal frequency). Only 6.2% of the non-breastfed children and 13% of their counterparts were provided with the minimum acceptable diet. There are statistically significant differences between the agro-ecological zones and the initiation of breastfeeding, colostrum feeding, children ever breastfed, use of pre-lacteal feed, bottle feeding, minimum dietary diversity, and minimum meal frequency (Table 2).

Table 3 showed that 58.8% of the children aged 6-11 months inclusive initiated breastfeeding within one hour after birth and 41.3% were fed using bottle. 15%, 40%, and 8.8% received minimum dietary diversity, minimum meal frequency, and minimum acceptable diet, respectively. As the age of the children increased, the proportion of children received minimum meal frequency and dietary diversity increased proportionally.

Grain, roots and tubers were the most common food items consumed by the children in the last 24 hours (86.6%). 55.6% of them consumed legumes and nuts, 47.2% drank milk, but only 4.6% ate vitamin-A rich fruit and vegetables, and 1.9% ate flesh foods. The extent of consuming diverse food groups in the 24 hours was low among all age groups and it was lower among the 6–11 month olds than among other groups (Table 4).

Factors associated with not receiving minimum meal frequency

The factors that do not show statistically significant association with receiving minimum meal frequency in the bivariate models, and thus removed from the models, were sex of children, household utilization of iodized salt, family planning utilization, taking deworming tablets in the past three months for mothers, maternal dietary diversity, maternal/child sickness within 15 days before the survey, maternal and paternal education and occupation.

In the bivariate logistic regression model, the age of the children, age at starting complementary feeding, children being stunted and anaemic, source of drinking water were identified as significantly associated with the risk of not meeting the minimum meal frequency and they were included in the multivariable analysis. In the final model (multiple variable logistic regression analysis), it was found that the infants who were born in lowland area (AOR = 3.56; 95% CI: 1.35-9.40), who were anaemic (AOR = 3.46; 95% CI: 1.81-6.63), and who were less than 12 months of age (AOR = 2.54; 95% CI: 1.24–5.09) had significantly higher risk of not meeting the minimum meal frequency (Table 5).

Table 1: Descriptive socio-demographic and obstetrics history of mothers in rural Ethiopia

Variables/ Characteristics	***Categories***	***Number***	***Percent***
Sex of the children	Male	96	44.4
	Female	120	55.6
Age of the children (months)	6-11 inclusive	80	37.0
	12-17 inclusive	106	49.1
	18-23 inclusive	30	13.9
Agro-ecological zone	Lowland	111	51.4
	Midland	105	48.6
Mother age (years)	<24	51	23.6
	25-29	52	24.1
	30-34	68	31.5
	≥ 35	45	20.8
Marital status of mother	Married	188	87
	Others	28	13
Educational status of the mothers	Illiterate	148	68.5
	Attend school	68	31.5
Occupation of father	Farmer	183	84.8
	Merchant	7	3.2
	Others	26	12
Occupation of mothers	Farmer	197	91.2
	Merchant	10	4.6
	Others	9	4.2
Number of children	1	84	38.9
under five	≥ 2	132	61.1
Parity	3 and below	74	34.3
	≥ 4	142	65.7
Ever used contraceptive	No	105	48.6
	Yes	111	51.4
Ante Natal Care follow up	<4	116	53.7
	≥ 4	63	29.2
	Not attended	37	17.1

Place of delivery of	Home	147	68.1
index child	Health institution	69	31.9
Anaemia status	Anaemic	116	53.7
of the children	Non anaemic	100	46.3
Anaemia status	Anaemic	47	21.8
of the mother	Non anaemic	169	78.2
MUAC of the mothers	≤ 22	123	56.9
	>22	93	43.1

Table 2: Feeding practices of children by agro-ecological zone in rural Ethiopia

Variables/ characteristics	Categories	Overall N(%)	Lowland N (%)	Midland N(%)	X^2	P-value
Mother told to put baby on breast immediately after birth	Yes	180(83.7)	95(85.6)	85(81.7)	0.59	0.44
	No	35(16.3)	16(14.4)	19(18.3)		
Initiation of breast feeding	Within 1 hrs	129(59.7)	59(53.2)	70(66.7)	1.00	1.00
	Within 24 hrs	61(28.2)	31(27.9)	30(28.6)	0.43	0.51
	Within 3 days	10(4.6)	8(7.2)	2(1.9)	4.36	0.036
	Not given at all	16(7.4)	13(11.7)	3(2.9)	6.31	0.02
Children ever breast fed	Yes	206(95.4)	103(92.8)	103(98.1)	3.44	0.06
	No	10(4.6)	8(7.2)	2(1.9)		
Child fed on colostrum	Yes	180(83.3)	106(95.5)	74(70.5)	24.3	0.0001
	No	36(16.7)	5(4.5)	31(29.5)	2	
Pre-lacteal food	Not given	168(77.8)	68(61.3)	100(95.2)	36.0	<0.001
	Given	48(22.2)	43(38.7)	5(4.8)	4	
Bottle fed yesterday	Yes	130(60.2)	50(45.0)	80(76.2)	21.8	<0.001
	No	86(39.8)	61(55.0)	25(23.8)	4	
Age of starting complementary feeding	<6 months	59(27.3)	36(32.4)	23(21.9)	3.30	0.069
	At 6 months	110(50.9)	51(45.9)	59(56.2)	1.00	1.00
	>6 months	31(14.4)	17(15.3)	14(13.3)	0.7	0.40
	Not started	16(7.4)	7(6.3)	9(8.6)	0.04	0.84
Currently breastfed	No	16(7.4)	10(9.0)	6(5.7)	0.85	0.35
	Yes	200(92.6)	101(91.0)	99(94.3)		
Timely complementary feeding (6-9 months)	No	13(23.6)	5(20.0)	8(26.7)	0.33	0.75
	Yes	42(76.4)	20(80.0)	22(73.3)		
Receive solid, semi-solid or soft foods (6-8 months)	No	12(33.3)	4(28.6)	8(36.4)	0.23	0.73
	Yes	24(66.7)	10(71.4)	14(63.6)	4	

Continued breast feeding at 1 year	No	3(4.7)	3(7.5)	0(0.0)	NA	NA
	Yes	64(95.3)	37(92.5)	24(100)		
Consumption of iron-rich or iron-fortified foods	No	212(98.1)	110(99.1)	102(97.1)	1.14	0.34
	Yes	4(1.9)	1(0.9)	3(2.9)		
Minimum dietary* diversity	No	168(77.8)	80(72.1)	88(83.8)	4.3	0.038
	Yes	48(22.2)	31(27.9)	17(16.2)		
Minimum meal frequency*	No	107(49.5)	73(65.8)	34(32.4)	24.0	<0.001
	Yes	109(50.5)	38(34.2)	71(67.6)	5	
Minimum acceptable diet*	No	190(88.0)	97(87.4)	93(88.6)	0.07	0.789
	Yes	26(12.0)	14(12.6)	12(11.4)		

*It is calculated for children 6-23 months of age; NA, not available

Table 3: Infant and Young Child feeding practices disaggregated by age in rural Ethiopia

Children feeding practices	Provided	% (95% CI)
Initiated breasting after birth within 1 hour 6-11 month olds (n=80)	47	58.8(47.2, 69.6)
Initiated breasting after birth within 1hour 12-23 month olds (n=136)	82	60.3(51.5,68.6)
Initiated breasting after birth within 1 hour (all) (n=216)	129	59.7(52.8,66.3)
Currently breast fed 6-11 months(n=80)	75	93.8(86.0,97.9)
Currently breast fed 12-23 months(n=136)	125	91.9(86.0, 96.0)
Bottle feeding children 6-11 months (n=80)	33	41.3(30.3,52.8)
Bottle feeding children 12-23 months(n=136)	53	39.0(30.7,47.7)
Bottle feeding (all) (n=216)	86	39.8(33.3,46.7)
Minimum dietary diversity		
Minimum dietary diversity for 6–11 months (n=80)	12	15.0(8,24.7)
Minimum dietary diversity for 12–17 months (n=106)	26	24.5(16.8,34)
Minimum dietary diversity for 18–23 months (n=30)	10	33.3(17.3,52.8)
Minimum dietary diversity for 6–23 months (N= 216)	**48**	**22.2(17,28.4)**
Minimum meal frequency		
Minimum meal frequency for 6–23 months non breastfed (n=32)	16	50.0(31,68)
Minimum meal frequency for 6–23 months breastfed (n=184)	93	50.5(43,58)
Minimum meal frequency for 6–11 months (all) (n=80)	32	40.0(29,51.5)
Minimum meal frequency for 12–17 months (all) (n= 106)	59	55.7(46,65)
Minimum meal frequency for 18–23 months (all) (n=30)	18	60.0(40.6,77)
Minimum meal frequency for 6–23 months all (N=216)	**109**	**50.5(43.6,57)**
Minimum acceptable diet		
Minimum acceptable diet for breastfed children (all)(n=184)	24	13.0(8.5,18.7)
Minimum acceptable diet for non-breastfed children(all) (n=32)	2	6.2(N/A)
Minimum acceptable diet 6–11 months (all) (n=80)	7	8.8(3.6,17.2)
Minimum acceptable diet 12–17 months (all) (n=106)	16	15.2(9,23.5)
Minimum acceptable diet 18–23 months (all) (n=30)	3	10.0(N/A)
Minimum acceptable diet for all children (6–23 months) (N=216)	**26**	**12.0(8,17)**

Table 4: Food groups given in past 24 hours to children aged 6–23 months

Food groups	**Overall 6-23 months (n=216)**		**Age groups (months)**		
			6-11 (n=80)	**12-17 (n=105)**	**18-23 (n=32)**
	Yes (%)	**No (%)**	**Yes (%)**	**Yes (%)**	**Yes (%)**
Grain, root and tubers	187(86.6)	29(13.4)	59(73.8)	99(93.4)	29(96.7)
Legumes and nuts	120(55.6)	96(44.4)	36(45)	61(57.5)	23(76.7)
Dairy products	102(47.2)	114(52.8)	34(42.5)	54(50.9)	14(46.7)
Vit A rich fruit & veg	10(4.6)	206(95.4)	2(2.5)	7(6.6)	1(3.3)
Other fruits & vegetables	133(61.6)	83(38.4)	32(40)	80(75.5)	21(70.0)
Flesh foods	4(1.9)	212(98.1)	2(2.5)	1(0.9)	1(3.3)
Egg	11(5.1)	205(94.9)	4(5.0)	6(5.7)	1(3.3)

Table 5: Factors associated with not meeting minimum meal frequency (MMF) among 6–23 months of age children in Rural Ethiopia

	MMF		**COR (95% C.I)**	**AOR (95% C.I)**	P-values
	No (n)	Yes(n)			
Age of the children					
< 12 months	48	32	1.96(1.07,3.57)	2.54(1.24,5.09)	<0.09
>=12 months	59	77	1.00	1.00	
Age of starting complementary feeding					
Less than 6 months	27	14	1.13(0.57,2.24)	1.4(0.63,2.92)	0.001
At 6 months	47	32	1.00	1.00	1.00
≥ six months	33	63	0.31(0.14,0.69)	0.34(0.14,0.80)	0.013
Children stunted			1.00	1.00	
Yes Haz ≤ -2	48	38	0.66(0.38,1.13)	0.58(0.29,1.16)	0.12
No Haz >-2	59	71			
Anaemia status of the children					
Anaemic	74	41	3.66(2.0,6.7)	3.46(1.81,6.63)	<0.000
Non anaemic	33	67	1.00	1.00	
Family have toilet					
No	54	41	1.68(0.95,3.0)	0.68(0.35,1.339)	0.269
Yes	53	68	1.00	1.00	
Agro-ecological zones					
Low land	73	38	4.01(2.28,7.07)	3.56(1.35,9.40)	0.01
Midland	34	71		1.00	

COR = Crude Odds Ratio, AOR = Adjusted Odds Ratio

Discussion

In order to reduce malnutrition in a developing country like Ethiopia, adequate, safe and acceptable child feeding practice is crucial. For this reason, WHO and UNICEF have recommended eight core infant feeding practices [19, 21]. In this study we found that 51% of the mothers initiated complementary feeding at six month, and 59.7% had initiated breastfeeding within 1 hour after birth. About half (50.5%) of the children received the minimum meal frequency, 22.2% achieved minimum dietary diversity and 12% of them received the minimum acceptable diet.

The number of the mothers who initiated breastfeeding within one hour after birth in this study (59.7%) is less than reported in a study conducted in Enderta zone of northern Ethiopia (68.3%) [26], but it is more than the number reported by EDHS [12]. It is recommended that a neonate should be breastfed immediately after birth and should be exclusively breastfed up to six months of age. But this is a rare phenomenon in Ethiopia. In our study, for example, about four in ten mothers did not initiate breastfeeding on time, which is a clear manifestation of the severity of the feeding problem in the community.

According to WHO, complementary food is important to prevent malnutrition and it should be introduced at 6 months of age, when the infant's stomach is ready to digest other foods. In this study, 51% of the mothers had initiated complementary feeding by the sixth month of the child's age, which is less than the percentage of mothers reported in similar studies in northern Ethiopia (79.7%), Mekelle (62.8%), Harar (54.4%) [26-28], and nationally (61%) [29]. Nearly half of the mothers in our survey did not begin providing their infants with additional foods on time. This suggests that families in this community need further education regarding appropriate child feeding practices.

This study revealed that a majority of children in the 6-23 month age group were not exclusively breastfed during their first 6 months of life, used pre-lacteal food, were bottle fed, and did not consume adequate micronutrients based on their poor dietary diversity scores. It is reported that lack of exclusive breastfeeding, inappropriate complementary feeding, food scarcity, and micronutrient deficiencies lead to malnutrition [30]. Similarly it is found that deprivation of colostrum, duration of breastfeeding, use of pre-lacteal feeds, age of introduction of complementary feeding and method of feeding are the main factors contributing to under-five stunting [1, 4, 7, 26]**.** The most identified reasons for malnutrition were short duration of breastfeeding, low prevalence of exclusive breastfeeding, continued breastfeeding to 1 year, and insufficient dietary diversity [1, 9, 31]. To decrease probability of malnutrition and its consequences, in addition to appropriate breastfeeding, children need to receive complementary foods including at least four of the seven food groups after six months of age [14, 16]. Prevalence of achieving the minimum dietary diversity was 22.2%, with higher prevalence in lowland (27.9%) compared to midland (16.2%). Although this is higher than reported by DHS (4.8%) [12], in Tigray (17.8%) [28], and Ethiopia overall (10.8%) [10], it is hardly promising that so few of these children received adequate dietary diversity. In this study, a majority of the children received a diet primarily based on staple foods (grain, roots and tubers), very few of the children received vitamin-A rich fruit and vegetables, egg, and flesh foods. Legumes and nuts were more consumed by the 18-23 months age group compared to the other age groups, while other fruit and vegetables were more commonly consumed among 12-17 months age groups. When poor dietary diversity is prevalent, it negatively affects minimum dietary diversity score and acceptable diet which, in turn, affect growth and development of the children. Generally, the dietary diversity during the previous 24 hours was very poor in the 6–11 months age group, with the lowest intakes reported for vitamin A rich fruit and vegetables and flesh foods (Table 4). These data indicate that children in this age group start with complementary feeding that is inadequate to meet their daily micronutrient requirements during their transitions from exclusive breastfeeding [7].

The percentage of children in our study who achieved minimum meal frequency (50.5%), is less than the magnitude reported from Sri Lanka (88.3%), Bangladesh (81.1%), and Nepal (76.6) [32-34]. Children should achieve minimum meal frequency to increase the probability of reaching the required levels of energy and micronutrient intakes in developing countries with low or average levels of breast milk intake. Studies show that achievement of minimum meal frequency is associated with improved height for age in children [29].

The proportion of the children who received the minimum acceptable diet was 12%. This is similar to the number reported by Mekbib *et al* (11.9%) [28], but higher than reported by EDHS (5.2%) [12]. This clearly shows that children in the study area are not getting adequate nutrient and energy intakes. The minimum acceptable diet is an indicator of standards of dietary diversity (a proxy for nutrient density) and feeding frequency (a proxy for energy density) and hence is a useful method to track progress of the children feeding.

With respect to dietary diversity, our study indicates that diversity of different food groups offered during the past 24 hours was low, with the lowest rates reported for vitamin A rich fruit and vegetables and flesh foods (Table 4). Children in the 6–23 months of age group go through a reasonably rapid dietary transition from exclusive breastfeeding to complementary feeding. Additionally, during this dietary change, they are also prone to some diseases like diarrhoea [35, 36]. During this period, children need more nutritious food to overcome the adverse effects of such diseases. Unfortunately, the current findings show that the children in this age group were not receiving appropriate complementary foods as recommended by the WHO. Our findings are similar to a national study and another study in the northern part of Ethiopia [12, 28].

Our data also indicate that anaemic children are at higher risk of not achieving the minimum meal frequency compared to the non-anaemic children. This suggests that food shortage and/or inappropriate meal frequency led to anaemia in these children. This finding is also reinforced by the very small percentage of children who were fed iron-rich food (only 1.9%). This percentage is less than previously documented in Ethiopia [29]. There is no association between antenatal care (ANC) and meeting minimum meal frequency. This may be due to the fact that health professionals providing antenatal care were more focused on the mothers' pregnancy-related information than on child health care practices [28], and a relatively small percentage (29.2%) of mothers attended ANC during pregnancy of this index child. Most mothers in rural Ethiopia do not have adequate knowledge on the importance of feeding frequency, so most families prefer to give to their children a large amounts of food at once (which children may have difficulty consuming) rather than feeding smaller amounts more frequently [28].

To our knowledge, there are no previous studies that investigated the association between minimum meal frequency and agro-ecological zones in Ethiopia. However, there is a report of regional variations in Nepal [32]. Our study showed that a large proportion of children in lowland zone do not receive minimum meal frequency compared to those from the midland zone even though the reasons for the difference should be further explored.

We found that very few of the children were fed foods rich in vitamin A and iron. These micronutrients are a prerequisite for healthy growth and development in early life and also have great impact on adult health and wellbeing [37]. It is recommended that children from 6-23 months should consume 7-11 mg/day iron as their iron stores at birth are depleted after six months [38]. Unfortunately, our data demonstrate that this age group is at high risk of iron deficiency as most of the children do not fed on iron-rich animals foods.

Conclusion

Poor infant and young child feeding (IYCF) practices are reported in the present study, apart from the high proportion of children who were breastfed. Even though dietary diversity of the lowland community is better than midland community in this assessment during pre-harvest season, both are far below the WHO recommendations for IYCF practices. Appropriate IYCF should be a high priority to build the health of future generations in both agro-ecological zones. Health 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 lowland agro-ecological zones.

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Chapter 7

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

Abstract
Food availability and access are strongly affected by seasonality in Ethiopia. However, there are little data on seasonal variation in Infant and Young Child Feeding (IYCF) practices and malnutrition among 6-23 months old children in different agro-ecological zones of rural Ethiopia.

Design*:* Socio-demographic, anthropometry and IYCF indicators were assessed in post- and pre-harvest seasons among children aged 6–23 months of age randomly selected from rural villages of lowland and midland agro-ecological zones.

Results*:* Child stunting and underweight increased from prevalence of 39.8% and 26.9% in post-harvest to 46.0% and 31.8% in pre-harvest seasons, respectively. The biggest increase in prevalence of stunting and underweight between post- and pre-harvest seasons was noted in the midland zone. In contrast to children from the midland region, children from the lowland region had higher rates of stunting and underweight in both the post- and pre-harvest seasons. Wasting decreased from 11.6% post-harvest to 8.5% pre-harvest, with the biggest decline recorded in the lowland zone. Minimum meal frequency, minimum acceptable diet and poor dietary diversity increased considerably in pre-harvest compared to post-harvest season in the lowland zone, while there were sharp decreases in these indices in pre-harvest period in the midland zone. Feeding practices and maternal age were predictors of wasting, while women's dietary diversity was a persistent predictor of child dietary diversity in both seasons.

Conclusions*:* There is seasonal variation in malnutrition and IYCF practices among children 6-23 months of age. A major contributing factor for child malnutrition may be poor feeding practices. Seasonal effects on indices of malnutrition and IYCF practices were more pronounced in children from the midland agro-ecological zone. However, the prevalence of malnutrition and IYCF practices were very poor in the lowland region irrespective of season. Health information strategies focused on both IYCF practices and dietary diversity of mothers could be a sensible approach to reduce the burden of child malnutrition in rural Ethiopia.

Keywords: IYCF; lowland; midland, season, dietary diversity

Introduction

Poor Infant and Young Child Feeding (IYCF) practices are a major cause of child malnutrition. It is estimated that more than one third of child mortality in developing countries could be prevented by appropriate complementary feeding practices [1]. It is also recognized that malnutrition has short and long term adverse effects on child growth and development [2]. About one-third of deaths in children less than five years of age are due to underlying malnutrition, which includes stunting, severe wasting, deficiencies of vitamin A, zinc and iron [3]. In this study, the term malnutrition is used to refer to under nutrition.

In less developed countries, 19.4% of children less than five years of age were underweight and about 29.9% were stunted in the year 2011 [4]. By 2014 prevalence of stunting in children had declined to 23.8% [5]. In 2015 in Sub Saharan Africa (SSA), 220 million people are food insecure, up to 40% of children are stunted and more than 3.4 million children less than five die each year [6, 7]. More than one-third of child deaths in Ethiopia are typically from increased severity of disease associated with malnutrition [8]. Studies in Ethiopia demonstrate that stunting is a common health problem among children less than two and ranges from 16.3 to 43% [9, 10], while wasting ranges from 1.8 to 6.8% in recently published studies [9, 11].

While many studies conducted in developing countries, including Ethiopia, indicate that the prevalence of child malnutrition is unacceptably high, few studies have investigated the seasonal effect on prevalence of child malnutrition. Studies have indicated that there is seasonal change in the prevalence of acute child malnutrition at the beginning of the dry season (October) compared to the beginning of the rainy season (May/June) [12, 13]. Similarly, high level of acute malnutrition was reported among children under 5 in Chad during the rainy season [14].

In Ethiopia it is established that food availability and access are strongly affected by seasonality; most of the households are only able to produce enough food to meet their food needs for less than six months of the year and they face food scarcities during the lean season [15, 16]. However, it is not known if variations in IYCF and child malnutrition follow similar patterns to that of food availability. Such information would help to identify appropriate interventions that are required to tackle child malnutrition in the country. A single study conducted among children 6-

36 months of age in the eastern part of Ethiopia found that the prevalence of wasting was lower in rainy (pre-harvest season) compared to dry season (7.4 vs 11.2%) [16]. Our recent study reported significant variations in nutritional status of lactating mothers in two agro-ecological zones of rural Ethiopia [17]. This chapter reports on seasonal variation in IYCF and malnutrition among 6-23 months of age children of those lactating mothers in different agro-ecological zones of rural Ethiopia.

Materials and Methods

Study area

This study was conducted in the Babile, Enderta and Hintalowajirat districts of Ethiopia from January to February 2014 and July to August 2014. Babile District (Woreda), which is 560 km away from Addis Ababa in the eastern part of Ethiopia, represents lowland agro-ecological area. The altitude of Babile Woreda ranges from 950 to 2000 meters above sea level and data were collected from 1000-1500 meters above sea level. The major agricultural product for consumption is sorghum and oil seeds; and groundnuts are used as cash crop. Khat (*Catha edulis*) is also a major cash crop in this region. Hintalo Wajirat and Enderta districts (683 km and 773 km away from Addis Ababa in the northern part of Ethiopia, respectively) represent midland agro-ecological areas. Data were collected from altitudes 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 eight kebeles (smallest administrative unit of Ethiopia) randomly selected from each geographical area from January to February 2014 (post-harvest season which is dry) and from July to August 2014 (pre-harvest season which is rainy). Two hundred sixteen mother/child pairs were included in the study and the ages of children were 6-23 months old during post-harvest, of which 206 were surveyed again during pre-harvest season.

Mothers with children 6-23 months of age were selected randomly from a registration list available in each kebele and used by researchers to verify maternal and child age. The number mother/child pairs selected in each kebele was proportional to population size in each kebele.

Dietary data

Dietary diversity was calculated in a standardized way using a tool developed by FANTA [18, 19]. A simple questionnaire allowed all foods eaten during the 24 previous hours to be noted. Each woman involved in the study was asked to recall all the communal dishes she had eaten and given to her child in the compound during this period. Information collected allowed us to calculate a Dietary Diversity Score (DDS) using seven food groups for infants [18]: cereals/roots/tubers; pulses/nuts; vitamin A rich fruits/vegetables; other vegetables and fruits; flesh foods; eggs; milk/dairy products. A nine food group classification was used for women. Women who consumed five or more than five food groups were considered as adequate while four or greater than four food groups was considered as adequate for children. 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 to not include atypical days (local feasts or celebrations) in the recall. Minimum meal frequency and minimum acceptable diet were defined and calculated according to WHO guidelines [19].

Anthropometric data

The anthropometric measurements for mothers and children were performed using the standardized procedures recommended by WHO [20]. The study participants were weighed to the nearest 100 g on electronic scales (SECA, Germany) with a weighing capacity of 0 to 140 kg with minimal (light) clothing and removed their shoes and hats during the measurement. Children were weighed together with the mother of the child, and the child's weight was calculated by subtracting the respective mother's weight, and this was recorded on the form during the fieldwork and confirmed later on by supervisors. Their length/height was measured to the nearest one centimetre with locally made portable devices (SECA 2006 sliding board). The BMI was calculated by dividing weight by height in meters squared [weight/height^2 (kg/m^2)]. The mid-upper arm circumference (MUAC) of the left arm was measured to the nearest mm with a non-stretch measuring tape (MUAC 12.5 measuring tape/PAC-50).

Data collectors and quality control

Data collectors were nurses holding diploma level or above qualifications. They were recruited and trained intensively on the data collection procedures, the context of specific questions across the questionnaire and anthropometric measurement procedures to be used. The questionnaire was prepared first in English then translated to Tigrigna and Afan Oromo languages as both agro-ecological zones have their own local languages. The process of data collection was overseen by supervisors and principal investigators.

A pre-test survey was conducted on 5% of the total sample size in another rural area which has similar characteristics. Problems identified during the pre-test survey were corrected before the start of the actual survey. Two different measurements were taken by separate data collectors for height and weight of every study subject. In case of variation among the data collectors, the principal investigator took the measurement again for validation. Finally, the principal investigator was responsible for co-ordination and supervision of the overall data collection process. All children were apparently healthy during data collection and children with apparent sign of fever, diarrhoea, or any acute illness were excluded from the survey.

Dependent variables were IYCF and nutritional status (malnutrition). The independent variables were the socio-demographic and household level characteristics of the family, health status of mothers and children, breastfeeding, housing, water and sanitation, health services utilization and cultural/social characteristics related to feeding style. Frequency of complementary feeding, dietary diversity and child illness and health seeking behaviour of the family were also assessed.

Data processing and analysis

The data were double entered by separate data clerks into EPI Data version 3.1. Data cleaning and editing were undertaken before analyses. For analyses, data were transferred to SPSS (v 16.0) and Stata (v 11). Frequency, mean and standard deviation were computed for the variables of interest. Normality was checked graphically using different plots (P-P and/or Q-Q-plot). Assumptions including normality, homoscedasticity and linearity were checked. The WHO Anthro 2005 and ENA software of the WHO were used for calculating the Z-scores (WAZ, WLZ, LAZ, and MUACZ) and cut-off points of -2 standard deviations were used to define undernutrition. IYCF practices and women's dietary diversity were assessed based on the UNICEF guidelines [21]. Multivariable linear regressions were applied to isolate independent effects of predictors of weight-for-height z-score, weight-for-length z-score and infant dietary diversity score and paired t-test was used to determine if significant differences existed between post- and pre-harvest seasons.

Results

Anthropometric status of children

Out of 216 children aged between 6 and 23 months recruited during post-harvest season, 206 (95.4%) were reassessed during pre-harvest. Reasons for loss were migration and absences from home during survey time. The mean and standard deviations of LAZ, WAZ and WLZ for the children were -1.67 (1.4), -1.3 (1.2), and -0.49 (1.4) in post-harvest and changed to -1.94 (1.48), -1.4 (1.2), -0.52 (1.3) in pre-harvest season, respectively. The main differences between pre- and post-harvest season were significantly decreased LAZ (p=0.006) and women dietary diversity score, while child weight and length were significantly increased in pre-harvest season (P<0.001). The mean infant dietary diversity score increased from 2.66 in post-harvest to 2.68 in pre-harvest season.

Prevalence of child malnutrition

For the children in this study 11.6% were wasted, 26.9% were underweight, and 39.8% were stunted in post-harvest season. In pre-harvest (lean) season, the prevalence changed to 8.5%, 31.8% and 46.0%, respectively (Table 2). Regarding the change in prevalence across agro-ecological zones, a greater change in stunting was recorded in the midland agro-ecological zone (from 36.2% post-harvest to 46.9% pre-harvest) compared to lowland (from 43.2% post-harvest to 45.3% pre-harvest) (Table 3). On the other hand, the prevalence of acute malnutrition (wasting) declined by half in lowland region (from 12.6% post-harvest to 6.6% pre-harvest) with no seasonal change in their midland counterparts (Table 3).

Child feeding practices

Grains, roots and tubers were the most common food items consumed by the children in the previous 24 hours in both seasons, followed by legumes and other fruit and vegetables. It was found that consumption of grains, legumes and pre-vitamin A rich fruit and vegetables increased in pre-harvest season, while consumption of egg, milk and other fruits and vegetables declined in pre-harvest compared to post-harvest season (Table 2). The majority of mothers were breastfeeding their children beyond one year of age as 89.3% of the mothers still breastfed their child during the second round of the survey (lean season). The proportion of bottle-fed children decreased in the pre-harvest season (Table 2).

Dietary diversity

The proportion of children overall who received minimum dietary diversity ($\geq$ 4 food groups) was 22.2% in post-harvest and increased to 24.1% in the pre-harvest season (Table 2). Similarly, the proportion of children overall who received minimum meal frequency and minimum acceptable diet were slightly increased in the pre-harvest season (Table 2). However, when one examines the data by agro-ecological zones, the proportion of children who received minimum dietary diversity in the midland region declined from 16.2% post-harvest to 2.9% pre-harvest while it significantly increased in the lowland region from 27.9% post-harvest to 44.5% pre-harvest (Table 3). This variation between agro-ecological zones was significant ($P<0.05$) (Table 3). Variation in infants dietary diversity between agro-ecological zones was significant in pre-harvest season (OR=0.049). The percentages of children who received minimum meal frequency and minimum acceptable diet were significantly higher in the lowland zone compared to midland in the pre-harvest season and female children had higher percentages than male (Table 3).

There was a slightly higher rate of wasting, underweight and stunting among male compared to female children in both seasons. There was a statistically significant difference in stunting between male and female children during the post-harvest season ($p<0.05$). Likewise, there were slightly higher rates in measures of IYCF practices among female compared to male children with the exception of drinking milk, where the rate was higher among male children (Table 3).

Predictors of malnutrition and dietary diversity

Maternal age, minimum meal frequency, height of the mother and age of the children were predictors of child weight for length Z-score (WLZ) in post-harvest season. Children who received minimum meal frequency were less likely to be wasted

compared to counterparts (p=0.092). As the age of the mothers increased by one year, the risk of the child WLZ decreased by 0.047(β=-0.047, P=0.001). Similarly, as the height of the mothers increased by one centimetre, the risk of the child being wasted decreased (β=-0.048, P=0.002). Those children aged greater than 12 months had lower WLZ compared to children aged less than 12 months of age (β=-0.057, P=0.002). In model four, age of mother and infant dietary diversity score were independent predictors of WLZ in pre-harvest season (Table 4). It was found that infant feeding practice is a significant predictor of wasting in both seasons (Table 4).
In model two, infant dietary diversity score in the post-harvest season was significantly associated with women dietary diversity score and child age. As dietary diversity of women increased by one unit, the dietary diversity of the child also increased (β=0.2 P=0.042). Similarly, as the age of the child increased by one month, the dietary diversity score of the children increased by 0.84 units (β=0.84,P<0.001). In model five, women's dietary diversity is a predictor of infant dietary diversity score. In general, women dietary diversity score is an independent predictor of infant dietary diversity score in both seasons, while agro-ecological region does not show significant association with child dietary diversity in multivariable analysis (p=0.27) (Table 4).

Table 1: Descriptive statistics and paired t-test between post- and pre-harvest seasons for children aged 6-23 months in rural Ethiopia

Variables	Mean and SD		Paired t-test	
	Post-harvest	Pre harvest	Mean difference	t(p-value)
Child weight (kg)	8.21(1.4)	9.7 (4.5)	1.5 (4.3)	4.9 (<0.001)
Child length (cm)	71.4 (5.5)	77.4 (5.1)	5.8 (3.7)	22.2 (<0.001)
LAZ	-1.67 (1.4)	-1.94 (1.48)	-0.3 (1.4)	-2.8 (0.006)
WAZ	-1.30 (1.2)	-1.4 (1.2)	-0.11 (1.2)	-1.3 (0.2)
WLZ	-0.49 (1.4)	-0.52 (1.3)	-0.4 (1.6)	-0.3 (0.7)
Child MUAC (cm)	12.8 (1.4)	13.3 (4.0)	0.5 (3.9)	1.9 (0.56)
IDDS	2.66 (1.2)	2.68 (1.3)	0.01 (1.8)	0.8 (0.9)
WDDS	3.1 (0.8)	2.8 (1.6)	-0.28 (1.9)	-2.1 (0.039)

LAZ, Length-for-Age Z-score; WAZ, Weight-for-Age Z-score; WLZ, Weight-for-Length Z-score; MUAC, Mid upper arm circumferences, IDDS, Infant Dietary Diversity score; WDDS, Women dietary diversity score; SD, Standard deviation.

Table 2: Seasonal variation in malnutrition and Infant and Young Child Feeding (IYCF) practices among children 6-23 months of age in rural Ethiopia

Variables	Post-Harvest		Pre- Harvest		X^2
	No	**%**	**No**	**%**	**(P-Value)**
Wasted	25	11.6	17	8.5	5.4(0.020)
Underweight	58	26.9	64	31.8	15.1(<0.001)
Stunted	86	39.8	93	46.0	48.9(<0.001)
Received minimum meal frequency	109	50.5	107	51.9	0.26(0.61)
Infant Dietary Diversity (≥ 4 food groups)	48	22.2	52	24.1	5.9(0.015)
Received minimum acceptable diet	26	12.0	34	16.6	1.95(0.16)
Women dietary diversity (≥ 5 food groups)	13	6.0	32	16.7	0.48(0.001)
Currently breastfed	200	92.6	184	89.3	0.32(0.57)
Bottle fed yesterday	130	60.2	86	39.8	13(0.0003)
Group 1, grains, roots and tubers	187	86.6	206	95.4	1.6(0.20)
Group 2, legumes	120	55.6	139	64.4	0.049(0.89)
Group 3, dairy products	102	47.2	51	23.6	20.3(<0.001)
Group 4, flesh food	4	1.9	16	7.4	1.8(0.18)
Group 5, egg	11	5.1	8	3.7	0.44(0.50)
Group 6, pre-vitamin A rich fruit and veg	10	4.6	70	32.4	3.64(0.56)
Group 7, other fruits and vegetables	133	61.6	95	44.0	2.3(0.13)

Table 3: Malnutrition and Infant and Young Child Feeding (IYCF) practices among children 6-23 months of age by agro-ecology and sex in rural Ethiopia

Seasons	Category	Agro-ecology: Lowland[1] N (%)	Agro-ecology: Midland[2] N (%)	OR (95%CI)	Child Sex: Male N (%)	Child Sex: Female N (%)	OR (95%CI)
Post-harvest	Wasted	14(12.6)	11(10.5)	0.73(0.28,1.85)	13(13.5)	12(10.0)	1.4(0.6,3.25)
	Underweight	32(28.8)	26(24.8)	0.65(0.25,1.65)	28(29.2)	30(25.0)	1.2(0.67,2.26)
	Stunted	48(43.2)	38(36.2)	0.74(0.41,1.33)	46(47.9)	40(33.3)*	1.8(1.1,3.2)*
	Received minimum meal frequency	38(34.2)	71(67.6)	4.01(2.2,7.36)*	46(47.9)	63(52.5)	1.2(0.7,2.06)
	IDDS (≥ 4 food groups)	31(27.9)	17(16.2)	0.49(0.24,1.01)	19(19.8)	29(24.2)	1.3(0.67,2.5)
	Received minimum acceptable diet	14(12.6)	12(11.4)	0.9(0.36,2.23)	10(10.4)	16(13.3)	1.0(0.8,1.3)
	WDDS (≥ 5 food groups)	12(10.8)	1(1.0)	0.07(0.001,0.55)*	____	____	____
	Child drank milk in previous 24 h	78(70.3)	24(22.9)	0.12(0.06,0.24)*	49(51.0)	53(44.2)	0.75(0.42,1.3)
	Child ate food rich in iron	1(0.9)	3(2.9)	3.2(0.25,171.3)	3(3.1)	1(0.8)	0.26(0.005,3.3)
Pre-harvest	Wasted	7(6.6)	10(10.5)	0.6(0.22,1.65)	9(10.2)	8(7.1)	1.5(0.55,4.05)
	Underweight	30(28.3)	34(35.8)	0.71(.39,1.3)	30(34.1)	34(30.1)	1.2(0.66,2.2)
	Stunted	48(45.3)	45(46.9)	0.94(.54,1.63)	46(51.7)	47(46.0)	1.5(0.86,2.6)
	Received minimum meal frequency	66(59.9)	41(39.6)	0.45(0.24,0.82)*	37(42.0)	70(61.9)	5.0(2.6,9.6)*
	IDDS (≥ 4 food groups)	49(44.5)	3(2.9)	0.049(0.01,0.17)*	25(26.3)	27(22.5)	1.0(0.5,1.9)
	Received minimum acceptable diet	31(28.2)	3(2.9)	0.078(0.015,0.27)*	14(15.9)	31(27.4)	3.2(1.5,7.0)*
	WDDS(≥ 5 food groups)	32(36.8)	0(0.0)	___	___	___	____
	Child drank milk in previous 24 h	51(46.4)	0(0.00)	___	27(28.4)	24(20.0)	0.63(0.33,1.18)
	Child ate food rich in iron	12(10.8)	4(3.8)	0.34(0.08,1.2)	8(8.3)	8(6.7)	1.1(0.34,3.6)

IDDS; infant dietary diversity calculated from seven food group: WDDS; Women dietary diversity score calculated from nine food group. [1]Babile District (Woreda) which is 560 km away from Addis Ababa in the eastern part of Ethiopia is representing a lowland agro-ecological zone. [2]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: Selected predictors of malnutrition and dietary diversity among children 6-23 months of age in rural Ethiopia, multivariate regression

Variables	β(95% CI)	P values
Model 1: Post-harvest WLZ		
Child received minimum meal frequency	-0.029(-0.63,-0.05)	0.092
Age of mothers (years)	-0.047(-0.07, -0.019)	0.001
Height of mothers	-0.048(-0.08,-0.019)	0.002
Age of child as greater or less than 12 months	-0.057(-0.93,-0.023)	0.002
Model 2: Post-harvest IDDS		
Women dietary diversity score (WDDS)	0.2(0.01 0.37)	0.042
Age of the child (months)	0.84(0.52, 1.2)	<0.001
Model 3: Pre-harvest LAZ		
Child MUACZ score	0.37(0.21,0.52)	<0.001
Age of the child (months)	-0.042(-0.08,0.001)	0.47
IDDS	0.13(-0.022,0.28)	0.093
Region	0.13(-0.28,0.54)	0.5
Model 4: Pre-harvest WLZ		
Age of mothers (years)	-0.033(-0.06,-0.01)	0.02
Child MUACZ score	0.36(0.22,0.49)	<0.001
Region	-0.067(-0.44,0.31)	0.71
IDDS	0.42(-0.03,0.86)	0.068
Model 5: Pre-harvest IDDS		
WDDS	0.44(0.33,0.55)	<0.001
Age of mothers (years)	0.023(-0.004, 0.05)	0.092
Region	0.21(-0.16,0.58)	0.27

LAZ, Length-for-Age Z-score; β, coefficient for the predictor value; MUACZ, Mid Upper Arm Circumference for Age Z-score; WLZ; Weight-for-Length Z-score. IDDS, Infant Dietary Diversity Score; WDDS, Women Dietary Diversity Score

Discussion

Investigation of effects of seasonal variation on nutritional status of children is more complicated than for lactating mothers who, as adults, have stopped growing. This is because groups of children living in underprivileged environments consistently show an evolution of malnutrition over time, even in the total absence of seasonality effects. In resource poor settings, children after six months of age tend to show a marked decline in nutritional status due to changes in diet and morbidity and this deterioration probably occurs regardless of season. The post-harvest and pre-harvest sampling periods in this study were separated by an interval of six months, which is long enough for age-related dynamic effects in children to manifest themselves. Since the same children were assessed at both time points, and all of these children naturally grew between the data collection periods, interpretation of the data must take care not to attribute all changes solely to seasonality.

In this study we found that 39.8% of children were stunted, 11.6% wasted and 26.9% were underweight in the post-harvest season while these prevalences were changed to 46.0%, 8.5% and 31.8%, respectively, in the pre-harvest season. These findings highlight the magnitude of malnutrition as a major public health problem among children aged 6-23 months of age in rural Ethiopia. Prevalence of stunting increased but wasting declined from post- to pre-harvest seasons. Malnutrition can start very early in life and progressively increase during the child's growth. The major change in stunting from post- to pre-harvest seasons was seen in the midland compared to the lowland region (increased from 36.2% to 46.9% in midland, and from 43.2% to 45.3% in lowland). The proportion of children who were wasted was decreased by nearly half from 12.6% post-harvest to 6.6% pre-harvest in lowland region. There was no change in the prevalence of wasting between seasons in children from the midland region. The reasons for the variation between agro-ecological zones with respect to stunting and wasting were not clear. The proportion of children who had adequate dietary diversity was 2.9% in midland zone in the lean (pre-harvest) season whereas 44.5% of children in lowland received adequate dietary diversity in the lean season. In the midland region it was noted that most mothers participated in weeding of cereals and this may lead to less time available to care for their children, while in the lowland region, Khat production requires less weeding than cereal crops and, additionally, Khat production was primarily handled by males (data not shown).

The community in the lowland zone relies primarily on cash crop production (Khat, *Catha edulis*) and this activity increased during the rainy season (pre-harvest). This product is sold to market and monies obtained may be used to purchase foodstuff and hence help to bridge the gap in food availability between seasons. This community also produce vegetables and fruit which, to some extent, are consumed at household level. The same seasonal changes in rates of acute under nutrition were reported in a previous study from a similar setting of eastern Ethiopia [16]. Additionally, our investigations among mothers of children in this study also found that women from the midland region were more affected by lean season (pre-harvest) compared to their counterparts in the lowland region [17].

Stunting is an indicator of chronic malnutrition and is a hindrance to linear growth, which is the product of a cumulative history of stressful episodes that may be compensated by catch-up growth during more favourable periods. The prevalence of stunting in our study was greater than reported in some other studies [9, 23, 24], and lower than the EDHS in post-harvest season but higher than EDHS in pre-harvest season [25]. These variations in stunting could be attributed to different socio-demographic and economic situations in the study areas. We found that infant dietary diversity score is weakly associated with child stunting in the pre-harvest season, indicating there is a possible association between stunting and feeding practice unlike another study reported from Ethiopia [10].

Similarly, the overall proportion of children underweight was increased in pre-compared to post-harvest season with higher change in the midland agro-ecological zone and no significant change in the lowland zone. The proportion of underweight children in our study is larger than reported in other recent studies [9, 11, 24], and similar to EDHS in post-harvest season [25]. The main contributor to the rise in underweight children in the midland agro-ecological zone may be partly attributed to poor feeding practices during the lean season compared to the post-harvest season.

We found that shorter stature mothers are more likely to have wasted children which suggests that malnutrition is intergenerational from mother to child, a finding that is also supported by other studies [26]. Similarly, children from mothers with lower dietary diversity score are more likely to have lower dietary diversity score themselves persistently in both seasons. These data indicate that children born in households with inadequate feeding practices tend to have poor dietary practices also. This may be associated with household food insecurity or poor knowledge about the importance of household dietary diversity. The association between maternal and infant dietary scores was also identified in studies in Bangladesh, Vietnam, and elsewhere in Ethiopia, which indicated that, as the dietary diversity of the mothers increases by one unit, the dietary diversity of infants increases by 0.24 dietary group [27]. Therefore, interventions that focus on infant feeding practices should also consider in parallel maternal nutrition and dietary diversity practices.

This study also revealed that low weight-for-length Z-score (WLZ) in children was associated with low dietary diversity and low minimum meal frequency. This indicates that poor feeding practices are a key cause of wasting in both seasons which needs urgent intervention. Likewise, as the age of the mothers increases, the risk of the child being wasted decreases.

Nearly all mothers in Ethiopia breastfeed their children. However, the proportion exclusively breastfeeding before 6 months and providing appropriate complementary feeding thereafter was very low compared to WHO recommendations [22]. This study found that the vast majority of the mothers were breastfeeding their children and about 89.3% of them continued breastfeeding beyond one year of age, which is similar to findings in a study conducted by Regassa, who reported that 87% of mothers continued breastfeeding beyond the first year in southern Ethiopia [28]. It is accepted that continued and frequent breastfeeding is important for a child's health and decreases the risk of morbidity and mortality in underprivileged populations [29]. Despite the fact that a large proportion of mothers had long duration of breastfeeding, complementary feeding practices are poor in our study areas. As indicated above, the proportion of children who receive appropriate complementary feeding was very low. Studies in Ethiopia showed that even mothers who had knowledge on the timing and importance of complementary feeding do not give appropriate complementary feeding to their children [11, 24]. This may be associated with cultural and traditional backgrounds of the family.

The 24 hour dietary diversity score measured in this survey indicated that most of the children do not achieve appropriate dietary diversity as recommended by WHO [22], as less than 25% of children received four or greater food groups in the 24 hours preceding the survey in both seasons. This finding is similar to previous studies indicating that children in this age category received less than four food groups. The exceptions are studies conducted by Negash *et al*. [11] and Regassa [28] who reported that 32.5% and 42.4%, respectively, of children received ≥ four food groups. Regarding seasonal variation, there was a slight increase in pre- compared to post-harvest season in dietary diversity. Our findings indicate that there was disproportional decline in the measures of IYCF practices such as dietary diversity, minimum meal frequency and minimum acceptable diet in midland agro-ecological zones between post- and pre-harvest seasons while these indicators increased in the lowland zone over the same period. Thus, children in the midland zone were more affected by the lean season than their counterparts in the lowland zone.

The most commonly consumed food groups by children were grains, roots and tubers, followed by legumes, and other fruit and vegetables in both seasons with slight decrease in other fruit and vegetables in the lean season. Higher consumption of grains, roots and tubers and other fruit and vegetables are typical characteristics of the Ethiopian diet [9, 24]. But higher rate of legume consumption is more typical of the northern Ethiopian regions [30]. Consumption of milk is significantly decreased during lean season in both agro-ecological zones. However, our data indicate that all children did drink milk in the midland region in the 24 hours preceding the survey. The consumption of milk in these study areas is higher than reported in others studies [9, 30] and lower than reported by Regessa and Mesfin *et al*. [24, 28]. Similarly, consumption of meat and egg were low in this study as most communities in rural parts of Ethiopia do not consume meat regularly [9]. Consumption of meat and egg by our study participants was lower than studies in similar setting [24, 30].

The strong point of this study is its design (longitudinal study design). We were able to investigate IYCF practices and anthropometric indices in this transition period from breastfeeding/predominately breastfeeding to complementary food. This age group is at high risk for many infectious diseases, and inappropriate feeding practices particularly in a developing country, as well as being in the window period where the effects of malnutrition are not adequately averted at later age of development.

There are limitations in our study that might affect our findings. Most of the risk factors were determined from maternal reports as there was no other means of obtaining that information for the children, this may introduce recall bias. Nonetheless, the duration prior to recall was short and we included some double checking in the questionnaire for validation of results. Thus, maternal recall bias is unlikely to have affected the observed relationships.

Conclusions

In conclusion, this study showed that malnutrition and poor IYCF practices among children aged 6-23 months of age are major public health concerns in rural Ethiopia. Poor IYCF practices among children in both seasons may be the major underlining causes of malnutrition. Results suggest that the lean season affects children of the midland agro-ecological zone more than the lowland region. 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. Interventions focusing on improving appropriate IYCF practices at an early age should be in place to prevent malnutrition and its devastating impact with special focus on agro-ecological zones.

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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^2), 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.