Child and maternal malnutrition: A cohort study from a drought-prone area in southern Ethiopia

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Thesis for the degree of Philosophiae Doctor (PhD)
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Dedication

To

Father, Son, & Holy Spirit

Scientific Environment

Hawassa University in Ethiopia and the University of Bergen (UiB) in Norway has for many years collaborated on topics such as malnutrition, malaria, tuberculosis, and childhood illnesses.

In 2014, the Norwegian Programme for Capacity Development in Higher Education and Research for Development funded the South Ethiopia Network of Universities in a public health project. This project envisioned enhancing the capacity of universities in southern Ethiopia to train staff to carry out essential research to improve the health of the people living in southern Ethiopia.

I was attached to the joint PhD program at Hawassa University, Ethiopia and the University of Bergen. The training component of this PhD was carried out at the School of Public Health, Hawassa University in Ethiopia and at the Center for International Health, University of Bergen in Norway. This research was conducted in Boricha district, Sidama National Regional State.

The research project was funded by the Norwegian Programme for Capacity Development in Higher Education and Research for Development (NORHED) South Ethiopia Network Universities in Public Health (SENUPH), with the project funding number: ETH-13/0025.

Regarding to my thesis, Professor Bernt Lindtjørn as the main supervisor, and Associate Professor Eskindir Loha as co-supervisor, provided guidance throughout the PhD period.

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I am also indebted to my co-supervisor Associate Professor Eskindir Loha, who was very supportive in my PhD work. I could not have imagined having a better co-supervisor for my PhD study. He treated me as a friend, not as an advisee, and this made the process of my PhD work highly enjoyable.

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Summary

Background: In Ethiopia, child and maternal malnutrition continue to be major public health problems, especially in rural and poor households. The country is far from reaching the global nutrition targets, even though nutritional policies and various interventional programs have been implemented. The possible reason why previous interventions did not achieve the target could be insufficient understanding about the local contexts. To address this issue, it is crucial to understand household characteristics, seasonal patterns of household food insecurity and dietary diversity in relation to child and maternal malnutrition, using a cohort study in a drought-prone area. Moreover, evaluating spatial clustering of malnutrition after controlling for the known risk factors in the local context of high population growth could aid in designing efficient and effective malnutrition interventions for drought-affected areas.

General Objective

The overall aim of the study was to improve our understanding about child and maternal malnutrition through a cohort study in the context of rural drought-prone areas of southern Ethiopia.

The specific objectives were:

1) To evaluate seasonal patterns of household food insecurity, dietary diversity, and household characteristics in relation to wasting and stunting among children in households followed for one year (Paper I);
2) To determine the effects of household characteristics and seasonal variations in food insecurity and food diversity on maternal malnutrition and to assess whether maternal malnutrition is associated with child malnutrition (Paper II);
3) To examine whether child stunting and maternal malnutrition were spatially clustered, after controlling for known risk factors for malnutrition among children and their mothers (Paper III).

Methods: All three studies reported in this thesis are part of a cohort design study that was conducted in the Boricha district of southern Ethiopia. We collected data four times in a year: March 2017, June 2017, September 2017, and December 2017. We measured child and maternal

height and weight, and mid-upper arm circumference. We measured seasonal variation of household food insecurity using the validated tool of the Household Food Insecurity Access Scale (HFIAS) and household dietary diversity using the Household Dietary Diversity Score (HDDS) tool. We measured wealth status and socio-demographic characteristics of the households. Maternal malnutrition was identified using low maternal mid-upper arm circumference and low body mass index. A cohort of 897 households with 935 children, aged between 6 and 47 months, were followed up for one year to measure the patterns and determinants of child stunting and child wasting (Paper I).

The same households with 892 biological mothers were also followed up for the same period to determine the risk factors for maternal malnutrition in the cohort study (Paper II). A multilevel mixed-effect model was used to measure the risk factors for child wasting and child stunting (Paper I), and determine the risk factors for maternal malnutrition (Paper II). Logistic regression model with declaring data to be time-series was employed to identify possible risk factors for spatial clustering of child stunting and maternal malnutrition (Paper III). Meanwhile, Paper III used the identified risk factors from Papers I and II to evaluate spatial clustering of malnutrition, after controlling the known risk factors. In Paper III, we employed Kulldorf's spatial scan statistics to evaluate whether child stunting and maternal malnutrition were spatially clustered in drought-prone areas, after controlling for known risk factors for child and maternal malnutrition. We carried out mapping and visualization of the spatial distribution of child stunting and maternal malnutrition (Paper III).

Results: In Paper I, our cohort study demonstrated that household characteristics such as poverty, education and the household's food insecurity and dietary diversity were associated with wasting or stunting among young children. The highest prevalence of wasting occurred in the same season as the highest prevalence of food insecurity. However, stunting occurred some months after the period with the highest prevalence of food insecurity. In Paper II, the maternal malnutrition was higher in the pre-harvest season, when food insecurity was highest. Moreover, households with malnourished mothers had higher child malnutrition rates. In Paper III, we found that spatial clustering of child stunting and maternal malnutrition among households of

drought-prone area could be due to the non-random distribution of known risk factors for child stunting and maternal malnutrition, such as poverty, and maternal characteristics.

Conclusions: Our findings from the drought-prone district of southern Ethiopia links seasonal variation of household food insecurity and dietary diversity, as indicators of agricultural production, with child wasting, child stunting and maternal malnutrition. The child stunting and maternal malnutrition did not demonstrate spatial variation after we controlled for known risk factors; that implied that spatial clustering before controlling known risk factors for malnutrition could be due the non-random distribution of individual and household characteristics. This occurred under the local context of ecological degradation, high population pressure, and repeated droughts in a rural farming community of southern Ethiopia. These findings could be helpful for designing efficient and effective malnutrition interventions in areas affected with recurrent drought.

List of original papers

This thesis is a synthesis of the following original research papers, which are referred by their respective Roman numerals.

Papers	Title
Paper I	Belayneh M, Loha E, Lindtjørn B. Seasonal variation of household food insecurity and household dietary diversity on wasting and stunting among young children in a drought prone-area in south Ethiopia: A cohort study. Ecology of Food and Nutrition. 2021;60(1):44-69.
Paper II	Belayneh M, Loha E, Lindtjørn B. Maternal malnutrition in a drought-prone area of southern Ethiopia: A cohort study (submitted).
Paper III	Belayneh M, Loha E, Lindtjørn B. Spatial variation of child stunting and maternal malnutrition after controlling for known risk factors in a drought-prone rural community in southern Ethiopia. Annals of Global Health. 2021;87(1):85.

Abbreviations

ACF	Action Contre la Faim
AIDS	Acquired Immune Deficiency Syndrome
BMI	Body Mass Index
95% CI	95% Confidence Interval
CMAM	Community Management of Acute Malnutrition
EDHS	Ethiopian Demographic and Health Survey
EOS	Enhanced Outreach Strategy
FANTA	Food and Nutrition Technical Assistance
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GTPs	Growth and Transformational Plans
HEW	Health Extension Workers
HFIAS	Household Food Insecurity Assessment
HIV	Human Immunodeficiency Virus
HSDP	Health Sector Development Plan
HSTP	Health Sector Transformational Plan
MDG	Millennium Development Goals
MUAC	Mid-Upper Arm Circumference
NNP	National Nutrition Program
OR	Odds Ratio
PHCU	Primary Health Care Unit
PSNP	Productive Safety Net Program
SD	Standard Deviation
SDG	Sustainable Development Goal
SNNPR	Southern Nations, Nationalities, and Peoples' Region
TANDI	Tackling Agriculture and Nutrition Disconnect in India
TSF	Targeted Supplementary Food
UNICEF	United Nations Children's Fund
WHO	World Health Organization

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What is this thesis about?

My thesis focuses on the time relationship between exposure variables such as household characteristics, food insecurity, and food diversity, and outcomes such as child wasting, child stunting and maternal malnutrition, in different seasons of the year in Ethiopia, within a context of ecological degradation, high population pressure, absence of water for irrigation, and repeated droughts. Moreover, we aimed to determine risk factors for malnutrition over a one year follow-up period. Furthermore, the study evaluated the impacts of known risk factors on spatial variation of child and maternal malnutrition in drought-prone areas of southern Ethiopia.

Accordingly, this study aimed to answer the following research questions in the area affected by recurrent drought:

- Are there seasonal differences in child wasting between the post-harvest seasons of September and December, and the pre-harvest seasons of March and June, in drought-prone areas?
- Are there seasonal differences in child stunting between the post-harvest seasons of September and December and the pre-harvest seasons of March and June, in drought-prone areas?
- Are there seasonal differences in maternal malnutrition between the post-harvest seasons of September and December, and the pre-harvest seasons of March and June, in drought prone areas?
- Did the exposure variables such as household characteristics, food insecurity, and dietary diversity, have a time relationship with an outcome variable such as wasting (acute malnutrition), stunting (chronic malnutrition) and maternal malnutrition, in different seasons of the year in Ethiopia?
- What are the risk factors for child and maternal malnutrition through the different seasons of this cohort study?
- Is there spatial clustering of malnutrition after controlling for known risk factors for child and maternal malnutrition?

The study for Paper I of this thesis aimed to obtain information about the time relationship between food security, food availability and diversity, and the subsequent development of acute and chronic malnutrition. More specifically, we evaluated the household characteristics, seasonal patterns of household food insecurity and dietary diversity in relation to child wasting and child stunting among children in households followed for one year in the drought-prone areas of Sidama, Ethiopia.

For Paper II, we aimed to determine the risk factors for maternal malnutrition in drought-prone areas through a cohort study. More specifically, this cohort study evaluated the effects of household characteristics, seasonal variations in food insecurity and food diversity on maternal malnutrition. We also analyzed the correlation between maternal malnutrition and child malnutrition in a drought-prone area of southern Ethiopia.

For Paper III, we investigated child and maternal malnutrition clustering among households of drought-prone areas after we controlled for known risk factors for child stunting and maternal malnutrition. In Ethiopia, several studies have evaluated the spatial distribution of malnutrition. However, these studies did not investigate spatial clustering of malnutrition after controlling for known risk factors for child and maternal malnutrition. Thus, the finding that child and maternal malnutrition were not spatially clustered after controlling for known risk factors for child and maternal malnutrition could improve our understanding of malnutrition in drought-prone areas.

In conclusion, this thesis addresses some important issues regarding child wasting, child stunting, maternal malnutrition, food insecurity, and dietary diversity in drought-prone areas of southern Ethiopia. We documented the time relationship between food insecurity and food diversity with outcomes such as child wasting, child stunting and maternal malnutrition, and also evaluated the impacts of known risk factors on spatial variation of child and maternal malnutrition, within a context of rural drought-prone areas of southern Ethiopia.

Introduction

Understanding malnutrition

Malnutrition is a broad term that includes both under-nutrition and over-nutrition. It represents a condition resulting from insufficient nutrients or surplus nutrients, which do not meet the body's needs for healthy growth and maintenance (1). Moreover, malnutrition could be manifested due to poor biological utilization of the nutrients consumed, as a result of disease or injury (2). Under-nutrition is when an individual manifests underweight, stunting, wasting, or micronutrient deficiencies (3). In most literature, the term under-nutrition such as child wasting and stunting used interchangeably with malnutrition, as in this thesis (4).

The terms child stunting and wasting were first introduced by John Waterlow in the 1970s. He defined stunting as a child who had small height for their age, and wasting as a child who had a low weight in relation to their height (5). According to the 2006 WHO Multi-center Growth Reference study cutoff values, children younger than 5 years are classified as stunted when their height-for-age Z-score is below minus two standard deviations (-2 SD) from the median of the World Health Organization (WHO) reference population, and children below minus three standard deviations (-3 SD) are categorized as severely stunted (6). Stunting is a sign of chronic malnutrition occurring in the most critical periods of growth and development (7). Similarly, the 2006 WHO Multi-center Growth Reference study defines wasting as children whose weight-for-height Z scores were lower than minus two standard deviations (-2 SD) from the World Health Organization Child Growth Standards Median, and children below minus three standard deviations (-3 SD) are categorized as severely wasted (6).

A woman is considered as malnourished if she has one or more conditions, such as underweight, overweight, and/or micronutrient deficiencies (2). Concerning maternal malnutrition in this thesis, I understand maternal under-nutrition as it is commonly defined, as the woman having a body mass index (BMI) <18.5 kg/m^2 or maternal mid-upper arm circumference [MUACs] <23 cm (8).

Malnutrition burden: Globally and in Ethiopia

Global

Malnutrition exists in all countries, and it is a major contributing factor for the global disease burden. About 35% of deaths among children younger than 5 years and 11% of the total global disease burden are attributable to under-nutrition. The vast majority of these children live in south Asia and sub-Saharan Africa, where poverty persists (3, 9, 10).

Globally, it is estimated that the rate of child stunting is declining in most regions. However, about 21% of the world's children (144 million children) were estimated to be stunted in 2019. Despite the steady decline of stunting, the total number of stunted children increased in sub-Saharan Africa due to rapid population growth (11, 12). Thus, the burden of child stunting remains high in the world and causes substantial morbidity and mortality, particularly in sub-Saharan Africa (12).

In 2019, an estimated 7% (47 million) children younger than 59 months were moderately or severely wasted, most living in sub-Saharan Africa and South Asia (11). In the low- and middle-income countries, about 10% of deaths among children younger than 59 months are attributable to severe wasting (13). Moreover, women living in low- and middle-income countries faced numerous biological and socio-economic problems that increase the risk of malnutrition (14). Thus, many women of reproductive age from developing countries are malnourished (10).

Ethiopia

Ethiopia has shown limited progress towards achieving the global nutrition targets; however, the prevalence of child and maternal malnutrition still remains high. In Ethiopia, child wasting is posing a considerable public health challenge, ranking the country with the highest prevalence of wasting in sub-Saharan Africa. The prevalence of wasting has remained at about 10% for the last two decades, according to the consecutive Ethiopian Demographic and Health Survey (EDHS) reports (15-18).

In Ethiopia, the prevalence rate of stunting declined from 52% in 2000 (15) to 37% in 2019 (19). However, the prevalence of stunting is still high, and ranking the country among the top, both in

Africa and the world. Moreover, despite the declining rate, Ethiopia did not achieve the 2020 National Nutrition Program target set to reduce stunting prevalence to 26% (20). Thus, Ethiopia needs great effort to realize the ambitious target of the Seqota Declaration, which aimed to achieve a zero stunting rate among children younger than two years by 2030 (21).

Despite the prevalence rate of maternal under-nutrition in Ethiopia dropping from 30% in 2000 to 22% in 2016, Ethiopia remained one of the countries with the highest rates of maternal under-nutrition (18). In 2019, the Gender Inequality Index ranked Ethiopia 125th among 153 countries for which data are available (22). Rural areas have a higher rate of maternal under-nutrition (25%) than urban areas (15%) (18). About 85% of Ethiopian women are living in rural areas, where inequalities represent a great challenge, with limited access to health services (18, 23).

Impacts of malnutrition

Malnutrition increases the risk of susceptibility to disease by suppressing the immune system, which ultimately increases vulnerability to infectious diseases (24). Malnutrition reduces economic productivity through direct productivity losses and reduced schooling (25, 26). Thus, malnutrition inflicts heavy costs due to loss of productivity and healthcare expenditure (27). Micronutrient deficiencies in low-income Asian countries reduced adult productivity by between 5% and 17% (28). Studies suggest that malnutrition costs Ethiopia, Uganda, Swaziland, and Egypt about 2% to 17% of their national GDP (29).

Wasting is considered as the best indicator of measuring acute malnutrition among children younger than 5 years. Although it is considered as acute malnutrition, the consequences are dire for the long term (30). It is a life-threatening condition for children; particularly severely wasted children have weak functioning of their immune system, development delays, and a higher risk of death (10). Such children require urgent treatment to survive (10).

It has been indicated that poor growth during early childhood is associated with shortness at adulthood, lower educational achievements, lower number of grades of schooling completed, and less productivity in terms of the economy at adulthood (31-34). The association between economic productivity and body stature is mainly true where jobs are labor-intensive. However, the pathway or mechanisms of the long-term consequences of stunting, or faltering in childhood growth, should be further assessed (35).

The most vulnerable people are children and women who share the greatest burden of malnutrition (36). The health impacts of maternal malnutrition are documented in many studies. Malnourished women have less energy to do physical work, a weaker immune system, and are at risk of developing non-communicable diseases (2). Maternal malnutrition increases the risk of poor pregnancy outcomes such as low birth weight, obstructed labor and post-partum hemorrhage (2). Thus, addressing child and maternal malnutrition is important to ensure the overall health and productivity of the world’s population, and this could be considered as a long-term investment in the community (31).

Global recognition of the need to address malnutrition has been growing and the commitments to fight malnutrition are increasing in low- and middle-income countries. However, improvements in nutrition are not sufficient, and the issue represents an unfinished agenda (37). Therefore, countries should maintain the nutritional security of their population in order to break out of poverty or to sustain their economic progress (37).

Risk factors for child and maternal malnutrition

The adopted and modified conceptual framework of under-nutrition was established by the Action Contre la Faim (ACF) in 2012, which itself was adapted from the 1990 malnutrition framework developed by the United Nations International Children’s Emergency Fund (38). This framework considers the concept of seasonal variation of malnutrition. In this conceptual framework, ‘shocks’ indicate natural or human-made disasters such as floods and conflicts that may increase over certain seasons. Trends and seasonality show the seasonal cycles of the year that may contribute to malnutrition. Moreover, to enrich this conceptual framework, we incorporated the potential causal pathway that linked child and maternal malnutrition from the modified TANDI (Tackling Agriculture and Nutrition Disconnect in India) conceptual framework (39). For Paper II of this thesis, we employed this framework to measure maternal malnutrition in drought-prone areas. Accordingly, risk factors that could result in child and maternal malnutrition were broadly categorized as root causes, underlying causes, and immediate causes (see Figure 1).

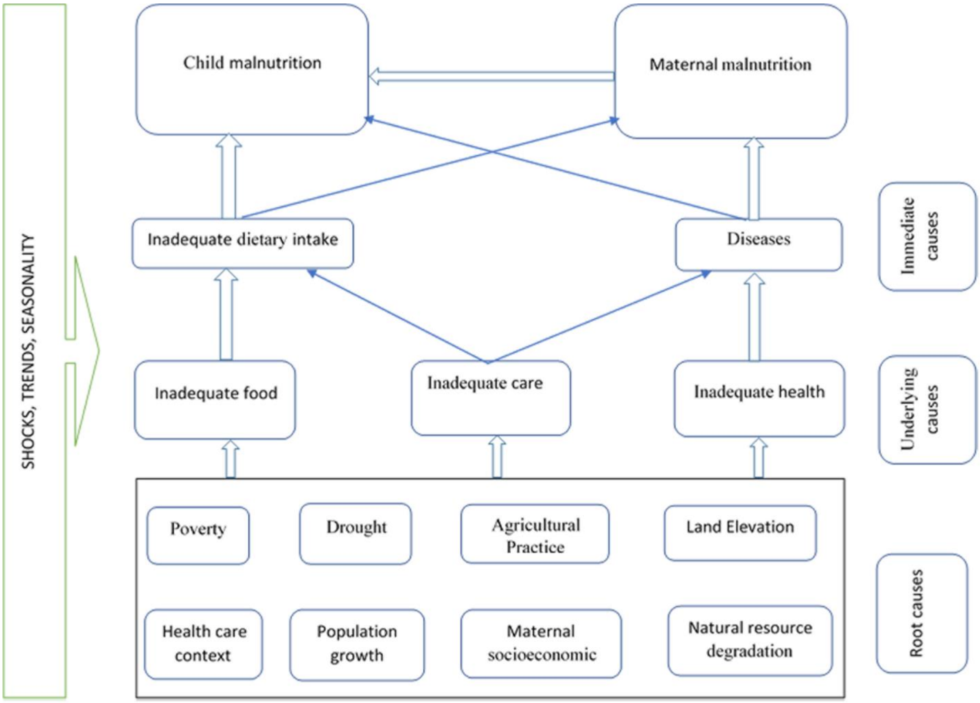

Figure 1: Modified conceptual framework showing the determinants of maternal and child malnutrition for drought-prone areas

Immediate factors

The immediate causes of child and maternal malnutrition work at the individual level. The important immediate causes are inadequate dietary intake and diseases (38, 39). Inadequate dietary intake relates to poor breast-feeding, and complementary feeding practices are the most profound factors for children's nutritional status (10). It is well-documented that infections can contribute to malnutrition, and poor nutrition can increase risk of infection (40). In developing countries, the high prevalence of infectious diseases, such as parasitic and bacterial diseases, is contributing to malnutrition (41). Studies reported that infectious diseases such as pneumonia (42), malaria (43), diarrhea (44), HIV/AIDS (45), and parasitic infections (46) are the main contributing factors to malnutrition. On the other hand, malnutrition compromises the immune system and increases the risk of infection (45). Thus, infection increases the nutrient requirements through increased body metabolism, loss of appetite and poor absorption (2, 47).

Underlying factors

Underlying factors include household food insecurity, inadequate care, and inadequate health (38, 39). It is well-noted that household food insecurity is associated with child and maternal malnutrition (48, 49). Inadequate health in relation to environmental factors such as open defecation, open drainage, and unprotected drinking water may increase the risk of infection, which ultimately may lead to malnutrition (50). Inadequate care is related to the practices concerning caring for vulnerable groups such as children, for example, how they were given breast-feeding. Thus, adequate child care and adequate health are required to attain optimal nutritional status.

Basic/root factors

Root causes include poverty, drought, agricultural practice(s), land elevation, healthcare context, population growth, maternal socio-economic status, and natural resource degradation (38, 39). Studies demonstrated that a better educational status of the mother is an important factor in improving child care and feeding practices (51, 52).

Child and maternal malnutrition

Studies documented that mothers' and their children's nutritional status are associated (53). It is reported that maternal nutritional status is important for child development, and thus, is recommended to be a continued focus in the first 1,000-day window of life (25). Moreover, maternal characteristics, such as women's employment, increase household income and may also increase a woman's preference to spend her earnings on health and nutrition (54). Thus, without improvement to maternal nutrition, child nutrition outcomes will continue to lag (55). Studies have also shown similar risk factors for malnutrition in children and mothers, such as less maternal education (23, 56). Thus, risk factors for maternal malnutrition could also be relevant for child malnutrition.

Famine and drought

Ethiopia has experienced complex political and economic disasters which have manifested as a combination of famines, wars and/or civil strife, as well as mass population migrations, resulting in subsequent public health disasters (57). Furthermore, Ethiopia has a long-time history of famines, and famines are considered as endemic in Ethiopia (58). Famine has occurred recurrently since the ninth century, and there have been ten famines in the last one hundred years, which killed an estimated one-third of the country's population (58, 59). The effects of famine are seen in terms of food shortages that lead to adverse health effects (58). Drought has been the typical cause for Ethiopian famine; nevertheless, famine is caused by multiple factors. The most important underlying causes of Ethiopian famine is poverty, and Ethiopia is ranked among the poorest countries in the world. In early times, drought was most often known to affect the northern part of Ethiopia. In drought-affected areas, women and children were among the high-risk groups (60).

When the farmers experienced drought, they tended to take actions such as sheep and goats being sold to buy food, and men migrating to relatively unaffected areas to look for daily labor. However, as the drought extended and spread, farmers were obliged to sell their farm tools, shelter and clothes; work became harder to find, and grain prices increased while livestock prices decreased (59). When the rains resume, pests in agriculture exacerbate their sufferings. Epidemics often swept together over farmers who had suffered through recurrent years of drought (59).

Nutrition in MDGs, WHA, and SDGs

The Millennium Development Goals (MDGs), World Health Assembly meetings (WHA) and Sustainable Development Goals (SDGs) were the major initiatives and commitments set by international bodies to improve global nutrition status. The eight Millennium Development Goals were international development goals for the year 2015 that were established following the world leaders' assembly at the United Nations Millennium Summit in 2000 (61). Globally, most of the targets of the health MDGs were achieved, although the gains are not so equitable across regions, countries, and between urban and rural areas. However, the progress in hunger reduction has been slow in sub-Saharan Africa. The underweight rate has reduced by only one-third since 1990 in sub-Saharan Africa. Moreover, the number of underweight children has risen in sub-Saharan Africa, due to the region's growing population (61). Thus, a targeted approach might be needed to reach the most vulnerable people (62).

In May 2012, the Sixty-fifth World Health Assembly meeting endorsed a comprehensive implementation plan on maternal, infant and young child nutrition from 2012 to 2025 (63). However, the 2020 global nutrition report indicated that progress in nutrition is too slow. Globally, improvements are unequally distributed, and it is mainly Africa that is experiencing high levels of wasting and stunting. Underweight can be ten times higher in the poorest countries, when compared to wealthier countries. Wasting can be nine times higher in certain communities, and four times higher for stunting. Thus, inequities in nutrition should be addressed to end malnutrition in all its forms (64).

The 2030 Agenda to reach the 17 Sustainable Development Goals was launched in 2015; this represents international cooperation to promote sustainable development. The Sustainable Development Goal that mentions "nutrition" is Sustainable Development Goal 2 ("End hunger, achieve food security and improved nutrition and promote sustainable agriculture"). However, nutrition is a crucial component to achieving several SDGs, and it is noteworthy that there is a need to achieve several SDGs to attain the nutrition goal (65).

The 2020 report on the Sustainable Development Goals showed that food insecurity increased from 22% in 2014 to 26% in 2019, before the occurrence of the Covid-19 pandemic. The Covid-19 pandemic, climate change, conflicts and a locust crisis are additional threats to food systems. Thus, stunting and wasting are likely to worsen among children younger than 5 years of age (66). To achieve the Sustainable Development Goal 2, which is to ensure the world is free from malnutrition by the year 2030, immediate actions are needed (67). However, effective interventions to reduce child stunting remain a challenge (12).

Nutritional interventions

Child and maternal nutritional intervention approaches can be broadly categorized into two, namely, nutrition-specific interventions and nutrition-sensitive interventions. The nutrition-specific interventions are aimed to address immediate determinants of malnutrition, including maternal and child dietary or micronutrient supplementation, promotion of breast-feeding and complementary feeding, delayed cord-cutting, management of acute malnutrition, and anemia treatment (68). The nutrition-sensitive interventions address the underlying determinants of malnutrition, like agriculture and food security, disease prevention and management such as for malaria and diarrhea, social safety nets, women's empowerment, and water, sanitation and hygiene (68).

Evidence regarding the impact of breast-feeding and complementary feeding promotion showed progress in the early initiation of breast-feeding and the promotion of exclusive breast-feeding. However, these interventions had inconclusive findings for the reduction of child stunting and wasting (69). In food-secure populations within developing countries, complementary feeding education alone reduced stunting, but in food-insecure populations, both complementary feeding provision and education reduced stunting. Moreover, there is a limited evidence for effective strategies to support breast-feeding among women, especially in poor settings (70).

Supplementary feeding programs for children younger than 2 years in developing countries did not reduce stunting and wasting. This finding was noted from a systematic review of seven trials (69). However, a Cochrane review among underprivileged children indicated a positive effect on child growth (71). Visser et al. showed that community-based supplementary feeding for food-insecure populations had significant effects on child growth among children younger than 2 years and less nourished (72). Evidence supports the implementation of integrated community-based approaches with the use of locally produced supplementary and therapeutic food to manage children with acute malnutrition (73). Balanced energy and protein supplementation during pregnancy reduced the risk of stillbirth, low birth weight, and small-for-gestational age infants (74). However, the effect of this intervention on maternal weight gain is not documented (70).

The findings from 45 studies on vitamin A, zinc and iron supplementation among apparently healthy children aged 1 to 59 months showed reduction in diarrhea incidence but no effect on the risk of stunting and wasting (75). Multiple-micronutrient supplementation was associated with an increase in height (75). However, concerns remain about the supplementation of iron, which increased the risk of malaria-related health problems in malaria-endemic areas (75). Multiple-micronutrient supplementation during pregnancy reduced risk of maternal anemia, iron deficiency, and low-birth-weight babies in developing countries (76). The evidence on single micronutrient supplementation noted improvements in only a few outcomes; for example, calcium reduced the risk of pre-eclampsia or eclampsia, iron reduced the risk of maternal anemia, and Vitamin D reduced the risk of preterm births (76).

The evidence indicated positive impacts of conditional cash transfers on improving food insecurity (77). Moreover, this intervention has improved the probability of using improved sanitation or water sources. However, the effect of conditional cash transfers on stunting and wasting among children younger than 5 years is inconclusive (77).

In summary, previous nutritional interventions, which had been implemented in developing countries, including Ethiopia, showed limited improvements in child and maternal malnutrition (55, 70). Moreover, it is highlighted that many interventions and frameworks are centrally developed, with little attention paid to data-driven evidence and causal analysis of barriers at the service delivery level (78). The progress of interventions on tackling under-nutrition is slow, and thus, these require more interventional guidance on how to scale up nutrition interventions and to allocate resources to achieve maximum impact (79). Moreover, the delivery of effective interventions requires further scientific evidence in order to address context-specific nutritional gaps; these interventions are needed to support local strategy and to accelerate progress in remediating child and maternal malnutrition (55, 80). Thus, it is needed to acquire enriched evidence to enable targeting of interventions and understanding program outcomes (55).

Ethiopia: The country profile

Without the knowledge of the context in Ethiopia, it is impossible to truly understand either the malnutrition situation in Ethiopia or the implications of the findings in the studies. Ethiopia covers about 1.14 million square kilometers. A projected population size of about 118 million inhabitants (in 2021) makes the country the second most populous in Africa. Nearly half (49.9%) of the population is female, while 15% of the population are children younger than 5 years of age (81). Ethiopia is one of the least urbanized countries in the world, and about 80% of the rural population depend on subsistence, rain-fed agricultural production (82). Studies in Ethiopia indicated that low rainfall can lead to a higher poverty rate, and consecutive years of low rainfall can cause droughts (83, 84).

Climate change affects agricultural production and food security, and thus potentially increases malnutrition (85, 86). Food insecurity and nutritional status are also influenced by seasonal variation (87). Seasonal climate variability could have an impact on disease outbreaks such as malaria and other infectious diseases, during the rainy and dry seasons (88, 89).

In Ethiopia, most parts receive substantial rainfall amounts during Keremt (June to September). However, in the southern part of Ethiopia, including Sidama, the Belg rains, which last from March to May, contribute to most of the crop production. Thus, the climate cycles in Ethiopia vary from one place to another, which fosters different seasonal agricultural cycles. Sidama experiences two rainy seasons: a main season (March-April-May), followed by small rainy seasons that last from June to September and which are interrupted by dry seasons. Thus, following the agricultural cycle, the season of plenty usually comes after the Belg harvest (mid-June to August) and Keremt harvest (October to November) (90).

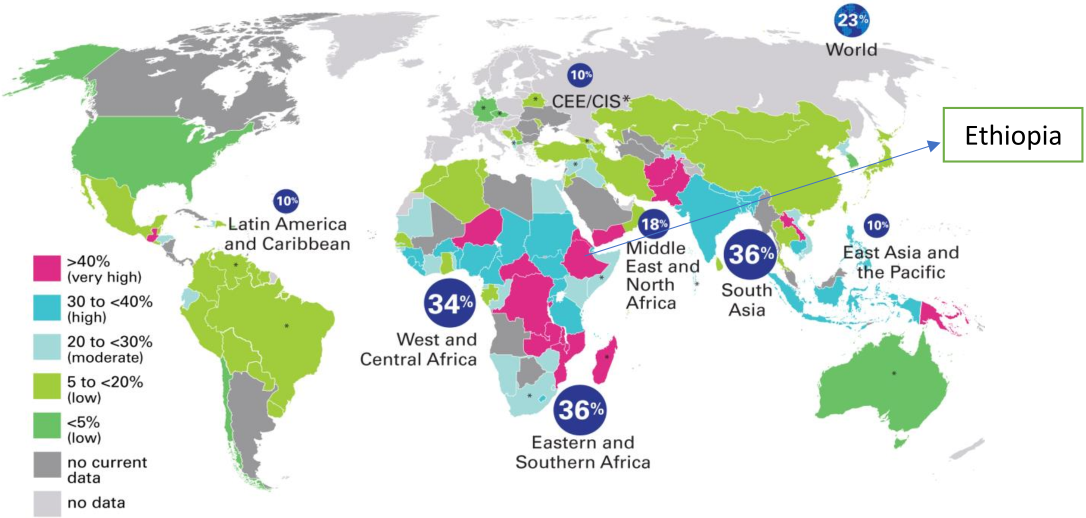

Figure 2: Countries and regions prioritized according to the stunting level among children younger than 5 years (adapted from UNICEF, WHO, World Bank Joint Child Malnutrition dataset, September 2016 update)

In Ethiopia, the Sidama people speak their own Cushitic *Sidama Afoo* language that belongs to the eastern highland Cushitic family of languages. In Sidama society, the elders and the men have absolute power to make decisions. Thus, the children and their mothers are 'voiceless participants', and they are in the lowest stratum in decision-making. Moreover, the consumption of rare and expensive foods such as meat, milk and their products is usually only done during special occasions such as rituals, religious holidays, and social ceremonies and when respected guests are coming to the house. Thus, such foods symbolize social status, and the frequency of getting such a nutrient-rich variety of foods for children younger than 5 years and their mothers is challenging, which might contribute to their malnutrition (91). Child malnutrition contributes about half of all deaths among children younger than 5 years in Ethiopia (92) (Figure 2).

Ethiopian health service delivery system

The Ethiopia health service delivery system is organized into three tiers. The first level of the system is the primary health care unit (PHCU) which is composed of a health post, health centers, and district hospital. The general hospital is a second level, and the specialized hospital is the third level, where all the levels are linked through a referral system (see Figure 3).

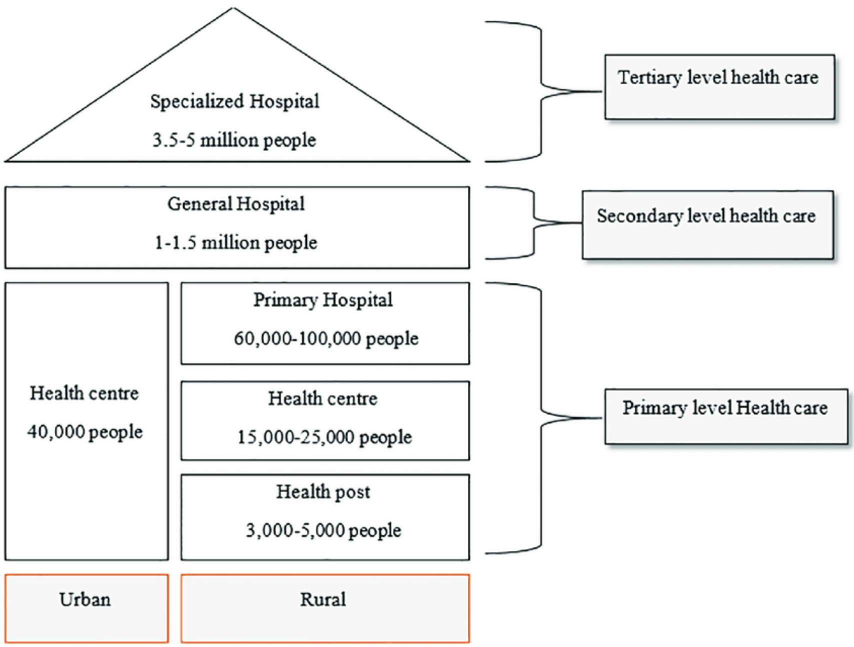

Figure 3: Ethiopian health care delivery system (adopted from the Federal Ministry of Health sector transformational plan, 2015)

In Ethiopia, there are about 311 public and private hospitals, 3,547 health centers, and more than 16,000 health posts. The health extension program is based at the health post level. The health extension program was established in 2003 and has been functioning since 2004. This program is comprised of four main program areas: family health services, disease prevention and control, hygiene and environmental sanitation, and health education and communication (93). Nutrition is one of the five packages under the family health services program area (93). Initially, this program was designed for rural farming communities, and later adapted for urban and pastoralist communities (94).

The health service extension program is an outreach-centered program which is expected to spend 75% of its time in outreach services and 25% on the static health post services. There are about 42,000 government-salaried health extension workers in Ethiopia; at least two female health extension workers are posted to each *kebele* (smallest administrative unit) after completion of a year-long training (94, 95). Health extension workers are supported by unpaid community volunteers called the Health Development Army. The Health Development Army is a group of people, mainly comprised of women, and organized by the Ethiopian government. This group supports health extension workers in liaising with community (96). To enhance agriculture and nutrition linkages, agricultural extension workers also play a role in food and nutrition security at the community level (97). However, the evidence suggests that the health extension program may be reaching a point of diminishing returns (98). As the workloads of health extension workers have continued to expand, the quality of their work is likely to have been negatively affected (99).

Context of the study

The studies reported in this thesis were conducted in the Boricha district of Sidama. In this district, there are swampy stagnant water ponds formed by rainwater, and the dwellers use this water for drinking, household purposes and for their cattle. The rainwater washes waste from the surrounding areas to the swampy areas. The water of the swampy areas dries out within a few weeks of the end of the major rainy season. This district is dependent on rain-fed agriculture, where the main land use is subsistence farming on land owned by smallholder farmers (100, 101). Thus, the study area is exposed to seasonal fluctuation of agricultural production that could result in seasonal variation of malnutrition. This has been addressed in Papers I and II.

The farmers produce annual crops such as sorghum, wheat, teff, maize, haricot bean, potato, and sweet potato in their small-scale rain-fed agriculture. They also produce perennial crops, such as enset, coffee, and bananas. Enset (*Enset ventricosum*) is a traditional staple food in the Boricha district of Sidama. Livestock provide transport, eggs, milk, and meat, though the yield is typically low. Boricha is a drought-prone area categorized as a chronically food in-secured district, and thus included in the Productive Safety Net Program. This area is affected by low levels of rainfalls, inadequate surface water for irrigation, deforestation, land degradation, decreasing soil fertility and high population growth. Moreover, this district has no perennial river, as all the rivers are seasonal (100, 101).

Rationale for this thesis

The overall burden of malnutrition has decreased globally. In 2000, the stunting rate was about 32% (2,000 million) and the wasting rate was about 7% (47 million); by 2019, stunted cases were reduced to 21% (144 million) and wasted cases were reduced to 2% (14 million) among children younger than 5 years. Despite the improvements, the world is still far from the General Health Assembly targets set for 2025 and the Sustainable Development Goals set for 2030 (11, 102).

Ethiopia aimed to reduce malnutrition by improving food availability, access, and consumption of nutritious food by the year 2020 (20). Moreover, Ethiopia adopted the ambitious Sustainable Development Goal of ending malnutrition by the year 2030 (21). Although Ethiopia is among the 20 poorest countries in the world, there has been rapid economic growth, with reductions in rates of poverty. Despite this reduction, there have still been high rates of stunting in rural areas and among the poorest of the population (103). The progress in maternal malnutrition is minimal, and child wasting has not shown any improvement for the last two decades, according to the consecutive Ethiopian Demographic Health Surveys reports (15-18, 104) (see Papers I – III).

To overcome the persisting challenge of malnutrition, we need effective community-based nutrition interventions with a multi-disciplinary approach (51). Moreover, enhanced malnutrition interventions should be deployed to areas with higher malnutrition risk (105). Implementation of community-based nutritional interventions may need better understanding of the local context and the seasonal pattern of rainfall, food security, food diversity, and child wasting and stunting.

Most of the previous studies from Ethiopia that had investigated food security, dietary diversity, and acute and chronic malnutrition used cross-sectional study designs. Thus, they did not document the time relationship between food security, dietary diversity, and the subsequent development of child wasting and stunting. Some of the earlier studies from Ethiopia had reported that there are differences in the prevalence rates of wasting between the post-harvest and pre-harvest seasons (106), and between the dry and wet seasons (107). Previous studies from Sidama, where the present studies were conducted, showed that, where nutrient-poor enset (*Enset ventricosum*) is a major staple diet, children and adults suffered from seasonal energy stress (108-111). However, these studies were from the more fertile area of Sidama compared to the current study, which was conducted in a drought-prone rural subsistence farming community. To fill this knowledge gap, we conducted a study (Paper I) to assess the effects of seasonal patterns of food insecurity and dietary diversity, and household characteristics in relation to subsequent child wasting and child stunting.

Moreover, our study determined the risk factors for child wasting, child stunting and maternal malnutrition through a cohort study that would give stronger evidence about these aspects of malnutrition. In Paper II, we evaluated the determinants of maternal malnutrition through a cohort study, and assessed the association of child and maternal malnutrition in drought-prone areas of Sidama. Thus, our study findings will be helpful for policy-makers at the national and regional levels, and practitioners of nutrition at the community level.

Malnutrition varies across geographic locations, thus understanding its spatial variation at the micro-geographic scale, and the determinants of this heterogeneity, can help target high-risk locations and optimize interventions. In Ethiopia, earlier studies have examined the spatial distribution of malnutrition. However, these studies did not investigate spatial clustering after controlling for the risk factors of malnutrition. To fill this knowledge gap, in Paper III, we examined spatial clustering of child and maternal malnutrition after controlling the known risk factors for malnutrition in drought prone-areas of Sidama.

Objectives

General objective

The overall aim of the thesis is to improve our understanding about child and maternal malnutrition through a cohort study in the context of rural drought-prone areas of southern Ethiopia.

Specific objectives

1. To evaluate seasonal patterns of household food insecurity, dietary diversity, and household characteristics in relation to wasting and stunting among children in households followed for one year (Paper I).

2. To determine the effects of household characteristics and seasonal variations in food insecurity and food diversity on maternal malnutrition, and to assess whether maternal malnutrition is associated with child malnutrition (Paper II).

3. To examine whether child stunting and maternal malnutrition were spatially clustered, after controlling for known risk factors for malnutrition among children and their mothers (Paper III).

Methods

Study locations

The study area was in the Sidama Regional State, which is the newly emerged 10^{th} region in Ethiopia. Sidama Regional State was formed as an autonomous region in June 2020 from the Southern Nations, Nationalities, and Peoples' Region (SNNPR), after the 2019 Sidama Referendum. Administratively, the region has 36 districts and 505 *kebeles*, where each *kebele* comprises about 1,000 to 5,000 dwellers. According to the Sidama Regional Health Bureau report, the region has 16 functional hospitals, 40 health centers and 908 health posts, as of 2020 (112).

All studies in this thesis were conducted in the Boricha district in the North-West part of the Sidama Region. Like many districts in the country, the study area has been affected by irregular rainfall and repeated droughts over the past few decades (113). The district is in the Great Rift Valley, and it is approximately located 34 km south of Hawassa, the capital city of Southern Nations Nationalities of Peoples Region (SNNPR). Boricha is located from 6º46′N and 38º04′E to 7º01′N and 38º24′E, with an altitude range of 1,200-2,076 meters above sea level. The mean annual temperature of the study area varies from 17.6ºC to 22.5ºC, and the mean annual rainfall varies about 801mm to 1,000mm, which peaks during the heavy rainy season in March and April (100, 114). The district population was estimated to be 315,000 people in 2017. It is among the most densely populated areas of Ethiopia, with a population density of 409 persons per square kilometer. The largest ethnic group is the Sidama, most (85%) of whom follow the Christian Protestant religion (100, 101). Currently, Boricha district is further divided into three autonomous districts, named as Boricha district itself, Bilate Zuria district, and Darara district.

Study design and data collection

All three studies in this thesis are a part of community-based cohort design study, which was conducted to evaluate child and maternal malnutrition in the Boricha district of southern Ethiopia from March 2017 to December 2017. A cohort of 897 households with mother-child pairs were recruited from rural communities of Boricha district at the beginning of the study. This cohort included 935 children, aged between 6 and 47 months, and 892 biological mothers, aged between

15 and 49 years. For Paper I, we followed up these children every three months, recording anthropometric measurements. Similarly, for Paper II, we followed up 892 biological mothers every three months, recording anthropometric measurements and exposure variables.

For Paper III, we used data collected every three months among children from 6 to 47 months and their biological mothers (Papers I and II). For Paper III, the identified risk factors from Papers I and II were used as the known risk factors of child stunting and maternal malnutrition in the drought-prone area. Paper III evaluated spatial clustering of child stunting and maternal malnutrition after controlling for the known risk factors for child stunting and maternal malnutrition.

Table 1: Study design, participants, and data collection methods

	Design	**Participants and sample size**	**Data collection**
Paper I: Seasonal variation of household food insecurity and household dietary diversity in relation to wasting and stunting among young children in a drought-prone area in south Ethiopia: A cohort study	Cohort	Children between 6 and 47 months (935 children in 897 households)	Interview with mothers regarding household characteristics, food insecurity, and dietary diversity; measuring anthropometric status of children
Paper II: Maternal malnutrition in a drought-prone area of southern Ethiopia: A cohort study	Cohort	Biological mothers between 15 and 49 years (892 biological mothers in 897 households)	Interview with mothers regarding household characteristics, food insecurity, and dietary diversity; measuring anthropometric status of children and mothers; recording geo-reference data of households
Paper III: Spatial variation of child stunting and maternal malnutrition after controlling for known risk factors in a drought- prone rural community in southern Ethiopia	Cohort	Children between 6 and 47 months and biological mothers between 1 and 49 years (935 children and 892 biological mothers in 897 households)	Interview with mothers regarding household characteristics, food insecurity, and dietary diversity; measuring anthropometric status of children and mothers; recording geo-reference data of households

Data were collected using a pre-tested, semi-structured questionnaire. Training and pre-tests were conducted in an area outside the selected *kebeles* before gathering data from the selected households. A refresher training course was conducted before each data collection season. The questionnaire was translated from English to *Sidamu Afoo*. This questionnaire was used to collect data on child health conditions, socio-demographic characteristics (child's age in months, child's sex, mother's age, mother's educational status, mother's occupation status, father's educational status, father's occupational status, marital status, family size) and socio-economic characteristics (housing conditions, family's household structure, ownership of agricultural land, ownership of improved sanitation, furniture, electricity, watch, radio, television, mobile telephone, house phone, refrigerator, bed type, kerosene lamp, type of cooking fuel, type and number of livestock, and number of sleeping rooms). A detailed account of socio-demographic and socio-economic characteristics was obtained as a baseline.

Moreover, household food security and dietary diversity were measured during the initial and follow-up visits. Household food security was assessed using the Household Food Insecurity Access Scale (HFIAS) developed by the Food and Nutrition Technical Assistance (FANTA) Project which was previously validated for Ethiopia (115-117). Household dietary diversity data were collected using a Household Dietary Diversity Score from a 24-hour recall questionnaire (118).

Anthropometric data, including child weight, child height/length, and child mid-upper arm circumference (MUAC) were measured according to standard techniques developed by the WHO (119). Anthropometric indices of height-for-age, weight-for-height, and weight-for-age Z scores were calculated based on the 2006 WHO reference standard (120). Moreover, maternal weight was measured with a digital SECA scale (SECA GmbH, Germany) and recorded to the nearest 100 g. Maternal height was measured with a locally prepared apparatus to the nearest 0.1 cm. Maternal BMI was calculated in kg/m^2. Maternal MUAC was measured on the left arm, at the midpoint between the olecranon process and the acromion, with 0.1 cm resolution. We validated anthropometric measurements, and thus deleted extreme values with improbable maternal heights and maternal MUACs. Similarly, we deleted outlier cases of child stunting (HAZ score >6 or < -6) and child wasting (WHZ score >5 or < -6). The outliers and missing variables were similar on socio-demographic characteristics, such as age and sex, compared to validated data. Furthermore, the household geo-reference data was measured using a Garmin

GPSMAP60CSx handheld global positioning system device (Garmin International Inc., Olathe, Kansas, USA).

Assessment of exposure and outcome variables

Tables 2 and 3 provide an overview of the outcome and main exposure variables used in this thesis, and their respective definitions.

Table 2: Definitions of outcome variables used in this thesis

Variable name	Definitions	Paper
Stunting	A child with a height-for-age Z-score below 2SD (standard deviation) of the WHO 2006 median growth reference was considered as stunted. In these studies, we have used both continuous and categorized height-for-age (HAZ) to analyze the data.	Papers I and III
Wasting	A child with a weight-for-height Z-score below 2SD (standard deviation) of the WHO 2006 median growth reference was considered as wasted. In these studies, we have used both continuous and categorized weight-for-height (WHZ) to analyze the data.	Paper I
Maternal malnutrition based on MUAC	Maternal mid-upper arm circumference (MUAC) was defined as the circumference of the left arm measured at the midpoint between the olecranon process and the acromion, to the nearest 0.1 cm. The presence of maternal malnutrition was defined based on maternal MUAC; if a mother had a MUAC <23 cm, she was considered as malnourished. In this study, we have used both continuous and categorized MUAC to analyze the data.	Paper II
Maternal malnutrition based on BMI	Maternal body mass index (BMI) was defined as maternal weight in kilograms divided by the square of height in meters. The presence of maternal malnutrition was defined based on BMI; if a mother had BMI <18.5 kg/m^2, she was considered as malnourished. In these studies, we used both continuous and categorized BMI to analyze the data.	Papers II and III
Spatial clustering	The presence of the areas with the highest high rate of cases (child stunting and maternal malnutrition based on BMI) computed by scan statistics.	Paper III
Malnutrition	In our thesis, malnutrition was used interchangeably to refer to under-nutrition such as maternal under-nutrition, child wasting, and child stunting.	Papers II and III

Table 3: Definitions of exposure variables used in this thesis

Variable name	Definitions	Paper
Child age in months	Age of children, measured in months	I, II, and III
Mother's age	Number of years of age for mother.	I, II, and III
Sex	Sex of the child	I, II, and III
Educational status	Assessed based on a question about the father's and mother's highest educational level attained. Then, it was classified as: no formal education; primary; and, secondary and up categories.	I, II, and III
Occupational status	Assessed from the question about the father's and mother's current occupation. Parental occupation could be registered as housewife or farmer, government worker or merchant, daily laborer or home maid, as the main income-generating activity of the household.	I, II, and III
Marital status	Assessed based on a question about the maternal marital status. Marital status was categorized into two: 'married', if the mother was in a marital union at the time of the survey, or 'single or separated or divorced or widowed' category.	I
Family size	The number of persons living per household.	I, II, and III
Household food insecurity level	Food security status was evaluated based on nine occurrence items and nine frequency questions on the household experience of food insecurity that were asked, with a recall period of four weeks preceding the data collection. A follow-up frequency of occurrence question was used to determine the frequency of the experience, based on the HFIAS indicator guide version 3.	I, II, and III
Household dietary diversity level	Food groups consumed according to a household dietary diversity item used the past 24 hours recall. The household dietary consumption habits aggregated into 12 food groups.	I, II, and III
Household wealth index	Wealth index was constructed using principal component analysis using household assets-related variables. The households were then ranked based on percentile groups into five categories: poorest, poor, medium, rich and richest.	I, II, and III
Child's morbidity status	Child morbidity was assessed by a history of the occurrence of diarrhea or cough or a fever in the two weeks preceding the data collection.	I
Exclusive breast-feeding practice	Exclusive breast-feeding practice was evaluated based on a history of breast-feeding practice during the first six months of the child's life.	I
Altitude	Altitude is the household height above sea level in metres. This geo-reference data was measured using a Garmin GPSMAP60CSx handheld global positioning system device (Garmin International Inc., Olathe, Kansas, USA).	II and III

Statistical analysis

Data were double entered using EpiData Version 3.1 (EpiData Association, Odense Denmark), and then exported to the Statistical Package for the Social Sciences 25 (SPSS Inc., Chicago) and Stata 15 (StataCorp, College Station, Texas) for further cleaning and analysis. Principal component analysis was used to construct the relative household wealth index using 11 variables related to household assets and type of materials from which the houses were made (Papers I, II and III). Descriptive statistics, such as means, standard deviations, medians, proportions and rates were used to present data (Papers I, II and III).

The potential risk factors for child and maternal malnutrition, such as household characteristics, seasonal variation of food insecurity, and dietary diversity were considered, based on the conceptual frameworks (38, 39, 121). A multilevel mixed-effect model was fitted to measure the risk factors for child wasting and child stunting for Paper I, and to measure the risk factors for maternal malnutrition based on both MUAC and BMI measurements for Paper II.

The mapping and visualization of the spatial distribution of child stunting and maternal malnutrition were done using ESRI ArcMap 10.4.1 (ESRI, Redlands, CA, USA) software (Paper III). We used SaTScan version 9.7 software (Free software, Kulldorff's spatial scan statistics) to identify locations of statistically significant clusters, after controlling for known risk factors for child and maternal malnutrition (Paper III).

Exposure variables with a p-value less than 0.20 in bivariate analysis were considered for multivariable analysis, to control for confounding variables in Paper I. The level of statistical significance was set at p-value less than 0.05 for all papers with two-tailed statistical tests.

Moreover, in this thesis, we calculated the design effect to quantify the deviation of sampling error in a survey and how this departs from the sampling error that can be expected under simple random sampling. We also calculated the power of the study to evaluate the ability of our study to identify an actual effect.

Table 4: Summarizes the major statistical methods used in this thesis.

Statistical method	**Paper**
Descriptive statistics	I, II, III
Principal component analysis	I, II, III
Multilevel mixed-effect logistic regression model	I
Multilevel mixed-effect linear regression model	II
Logistic regression model with declaring data to be time-series	III
Kulldorf's spatial scan statistics	III

Ethical considerations

Ethical clearance was obtained from the Institutional Review Board (IRB) at Hawassa University (Ref. No: IRB/001/09, Date: 13/09/2016) and the Regional Committee for Medical and Health Research Ethics, Western Norway (ref: 2016/1631/REK Vest) before we started data collection.

Written permission was obtained from the former Sidama Zone Health Department, Boricha district administrators, and selected health institutions. All study participants were informed about the potential benefit and harm from the study, and participants were informed that their participation in the study was voluntary and that they could refuse or withdraw at any time. Informed written consent was obtained from all study participants, and those who could not sign used their thumbprint. For children, consent was obtained from their mothers. Children with malnutrition were treated according to the malnutrition treatment guidelines of the Ethiopian Ministry of Health (122).

Results

Paper I: Seasonal pattern of household food insecurity, dietary diversity, wasting and stunting

For Paper I, we aimed to evaluate seasonal patterns of household food insecurity, dietary diversity, and household characteristics in relation to wasting and stunting among children followed for one year in a drought-prone area in southern Ethiopia.

A cohort of 935 children aged 6 to 47 months from 897 households were followed for one year, with four data collections from March, 2017 to December, 2017. We collected data from 3,449 observations, and the overall prevalence of household food insecurity was 82% (2,816). We observed that household food insecurity had a seasonal pattern: the prevalence of severely food insecure households was higher in March (69%, 608 of 881) and June (76%, 666 of 871), than in September (50%, 433 of 861) and December (38%, 320 of 835). Similarly, the prevalence of the lowest household dietary food diversity (≤ 3) was higher in March (32%, 285 of 879) than in September (22%, 185 of 854) and December (6%, 48 of 830). These findings indicated that the post-harvest seasons were better in terms of food security and dietary diversity than the pre-harvest seasons of March and June.

From 3,312 observations, 43% (1,408) (95% CI: 40.8-44.2) of children were stunted. Stunting showed seasonal variations, with 36% (95% CI: 32.5-39.0) in March and 48% (95% CI: 45.0-51.8) in December. Six percent (95% CI: 4.8-6.3) of children were wasted, with higher prevalence in March (8%) as compared to 3% in September ($p < .001$). Moreover, household characteristics such as poverty level, education, occupation and the household food insecurity and dietary diversity were associated with subsequent wasting or stunting.

Paper II: Maternal malnutrition and its associated risk factors in a cohort study

For Paper II, we aimed to determine the effects of household characteristics and seasonal variations in food insecurity and food diversity on maternal malnutrition, and to assess whether maternal malnutrition is associated with child malnutrition.

We followed 897 households in the pre-harvest (March and June) and post-harvest (September and December) months in 2017. We measured maternal mid-upper arm circumference and/or body mass index, and child stunting and wasting.

In our study, 35% of mothers (1,196 of 3,399 observations) had MUACs less than 23 cm, and 27% (858 of 3,179 observations) had BMIs less than 18.5 kg/m^2. Malnutrition was higher in the pre-harvest month of June (43%; 368/858) than in the post-harvest months of September (35%; 297/853) and December (36%; 300/822). Children's weight-for-height increased when maternal MUACs ($r=0.05$, $p=0.004$) and maternal BMIs ($r=0.14$, $p<0.001$) increased.

The multilevel, mixed-effect, multivariable linear regression model showed that maternal MUAC decreased when the household altitude and food insecurity increased. Maternal MUAC increased when the household dietary diversity, wealth index and maternal age increased. Similarly, maternal BMI decreased when the household altitude and food insecurity increased, and dietary diversity decreased. Moreover, maternal BMI decreased when the number of persons in the household increased.

Paper III: Spatial clustering of child and maternal malnutrition

For this paper, we aimed to assess whether child stunting and maternal malnutrition were spatially clustered in drought-prone areas of southern Ethiopia, after controlling for previously known risk factors for child and maternal malnutrition, such as wealth status, altitude, food insecurity, and maternal characteristics.

We used a community-based cohort study design for a one-year study period. We used SaTScan software to identify high rates of child stunting and maternal malnutrition clustering. The outcome was based on the presence or absence of stunting and maternal malnutrition (BMI <18.5 kg/m^2). We controlled for previously known predictors of child stunting and maternal malnutrition to evaluate the presence of clustering. We used a logistic regression model, declaring data to be time-series, using Stata version 15 for further evaluation of the predictors of spatial clustering.

The crude analysis of SaTScan showed that there were areas (clusters) with a higher risk of stunting and maternal malnutrition than in the underlying at-risk populations. Stunted children within an identified spatial cluster were more likely to be from poor households, have younger and/or illiterate mothers, and often the mothers were farmers and/or housewives. Children identified within the most likely clusters were 1.6 times more at risk of stunting in the unadjusted analysis. Similarly, mothers within the clusters were 2.4 times more at risk of malnutrition in the unadjusted analysis. However, after adjusting for known risk factors such as wealth status, household food insecurity, altitude, maternal age, maternal education, and maternal occupation with SaTScan analysis, we showed that child stunting and maternal malnutrition were not spatially clustered.

Additional results of the thesis

The calculated design effect was 1.04 for stunting (ICC=0.89 and 1.04 average number of sample per cluster), and 1.01 for wasting (ICC= 0.32 and 1.04 average number of sample per cluster), according to our post-hoc data analysis based on the final model intra-class correlation coefficient at the household level (Paper I). Moreover, the post-hoc test of our study showed that the power to measure the effect of the wealth index (poorest versus richest) on child wasting was 5.98% (Paper I). The power calculation by the normal approximation method showed that 26.91% was based on the mean difference of MUAC of mothers between primary and no formal education group (Paper II). Similarly, the power calculation by the normal approximation method showed that 10.71% was based on the mean difference in altitude between cases within the identified spatial cluster and cases outside the cluster (Paper III). See Table 5 for more detailed information.

Table 5: Summarizes the power calculations used in this thesis

Paper I		Child wasting		Power
		Yes	No	
Wealth index	Poorest	38 (5.6%)	646 (94.4%)	5.98%
	Richest	34 (5.0%)	641 (95.0%)	
Paper II		Educational status		Power
		Primary	No formal education	
Maternal MUAC	Mean (cm)	23.7	23.6	26.91%
	Sample size	1,526	1,700	
	Standard deviation	2.17	2.04	
Paper III		Cases within the identified cluster		Power
		Yes	No	
Altitude	Mean (height above sea level in meters)	1925.4	1923.7	10.71%
	Sample size	560	709	
	Standard deviation	33.0	46.4	

Discussion

Methodological discussion

All types of epidemiological study design could introduce errors during the designing of surveys, data collection, processing, and analysis. The main concern in the research is to minimize errors that could lead to incorrect conclusions. Thus, in the following section, we will discuss the possible errors and methodological limitations of the studies in this thesis and the actions taken to minimize errors.

Study design

In this thesis, we employed a prospective cohort study design for all papers (Paper I, II and III). The cohort study design tracks people or groups from exposure to outcome over time (123).

The cohort study is an analytic design of observational studies that has many appealing advantages. These designs measure the incidence rates of diseases and can quantify the associations between the exposure and outcomes in terms of attributable risk, hazard ratio, and relative risk. Cohort study designs are important for studying rare exposure and multiple outcomes by offering a temporal dimension (124). This study design is important when experimental studies are not ethical or feasible (123). They are also less prone to recall and survival bias compared to other observational studies (123).

However, there are limitations involved in the cohort study design. They are more prone to selection bias and cofounding than randomized controlled trials (125). Moreover, cohort studies are prone to loss to follow-up, which can lead to differential losses to follow-up between those exposed and those unexposed that could bias research findings (123). In all three studies in this thesis, we had less than 10% of missed measurements. Thus, the potential influence of loss to follow-up was low in our study.

In our study, a cohort of mother-child pairs was followed for one year. However, detailed data on the socio-economic characteristics was assessed at the first visit to the households. Thus, wealth status of household could have changed during the study period, and this could have influenced the association between wealth and seasonal variation of household food insecurity and dietary diversity, and child and maternal malnutrition.

Moreover, our study lasted for only one year. Longer periods of study could have identified more risk factors for growth faltering in the Paper I and III studies. Thus, seasonal variation of malnutrition could be better understood over longer variation through years in these studies.

Like cohort studies, randomized controlled trials (RCTs) follow a group of people over time. However, in the RCTs, the investigator intervenes to see how a specific intervention changes the outcome, for example, how it affects child and maternal malnutrition. Thus, future studies should consider a RCT study design for establishing causal relations between exposure to outcome in the field of human nutrition (126).

Sample size and sampling

The sample size is a significant feature of studies in order to make inferences about a population from a sample. An adequate sample size is crucial to avoid sampling errors or biases which will affect the credibility of study findings (127).

Type I or alpha error is an incorrect rejection of a null hypothesis that is actually true in the population. Type II or beta error is failing to reject a null hypothesis that is actually false in the population. Although these errors cannot be avoided entirely, it is possible to reduce their likelihood by increasing the sample size (128).

For Papers I and II, the sample size was calculated using OpenEpi 303 version 3.01. Accordingly, the required sample size for the Paper I study was 872 children, and 882 biological mothers for the Paper II study. However, we collected data from a total of 935 children and 892 biological mothers, after excluding non-biological mothers from 897 households. However, the power of our study to measure the effect of the wealth index (poorest versus richest) on child wasting was low for Paper I. Similarly, the power calculation based on the mean difference of altitude among cases in the cluster and cases outside cluster for Paper III was low. Therefore, the sample size might not be adequate for sub-group analysis.

In our study, the sample was obtained using multistage sampling, with two stages, which is among the probability sampling methods. Primarily, nine rural *kebeles* from Boricha district were randomly selected from 39 rural *kebeles* (smallest administrative unit), and secondly, we employed cluster sampling techniques to choose households which had mother-child pairs from each sub-*kebele* ('*gouts*'). This sampling method is preferable when a simple random sampling technique is impractical due to a large and dispersed population. However, the simple random sampling method gives an equal chance for each member of the population to be included in the sample. Thus, this method is less likely to result in a biased sample of study participants compared to a multistage sampling method (129).

Internal validity

Validity refers to the extent to which the study produces accurate results that correspond to the true values (125). The validity of a study can be classified into internal and external validity (125). The internal validity of a study is concerned with the extent to which the study is free from bias, or the study's ability to measure what it sets out to measure for the particular group of people in the study (130). Internal validity is considered to be a prerequisite for external validity. Most violations of internal validity of a research study can be broadly categorized into three types: selection bias, information bias and confounding.

Selection bias

Selection biases are distortions that result from procedures used to select study participants, and which result in significant differences in exposure or outcomes for those who participate and those who do not participate in the study (125). The common element of such biases occurs during the design phase.

Non-response bias is a phenomenon in which there is a systematic difference in characteristics between responders and non-responders (131). The significance of non-response bias was minimal in all three studies (for Papers I, II, and III). Study enumerators and supervisors were residents of the study district, and this probably built trust and relationships with study participants. Moreover, children from 6 to 47 months were recruited to accommodate the age increments due to the follow-up period of one year. Thus, non-inclusion of children aged from 47 to 59 months in the initial visit might have introduced selection bias. However, the ages of the children aged from 6 to 47 months on the initial visit increased by three months for each follow-up visit.

Studies have indicated that the characteristics of volunteer participants are different from non-volunteer participants (132). For all three studies reported in this thesis, we employed a multistage sampling technique to select study participants, and thus we do not have the potential influence of volunteer bias.

Information bias

Information bias is a systematic error that emerges when information collected from study participants is erroneous. Recall bias, measurement errors, and differential and non-differential misclassifications are common types of information bias (125).

In our studies (for Papers I, II, and III), most of the risk factors such as socio-demographic characteristics, maternal characteristics and paternal characteristics were assessed based on the maternal recall, including the age of the children. To reduce maternal recall bias, we used locally memorable events to aid the mothers' recall of their children's age. We also used a short recall period for variables such as household dietary diversity, household food insecurity, and childhood morbidity. Moreover, study participants may have expected possible food or similar support, and they could have given affirmative responses to food insecurity measurement items in order to secure this support. However, the probability of building trust was high, as the study enumerators were residents of the study district. Therefore, the effect of inclination toward affirmative response could be minimized. Furthermore, the affirmative responses were high in the pre-harvest season compared to the post-harvest season, which could indicate that an inclination toward affirmative response was minimal. Lastly, the household dietary diversity was not conducted on specific groups such as mothers or children, and thus the consequences of seasonal variation for these groups could have been underestimated.

Missed information about nutritional intervention such as the safety-net program could also introduce information bias. This might lead to underestimation of the effect of seasonal variation of food insecurity and household dietary diversity on child stunting, child wasting and maternal malnutrition. Thus, we accept that this form of information bias could potentially have influenced our studies' validity in terms of seasonal and spatial pattern.

Studies that ignore the effect of measurement error on the findings can be referred to as naïve studies (133). Accordingly, we acknowledged that our studies were prone to measurement errors during anthropometric recording of height, weight and MUAC. Thus, we deleted measurement errors of child stunting (height-for-age Z-scores greater than six or less than minus six), wasting (weight-for-height Z-scores greater than five or less than minus six) and maternal cases with improbable heights. This reduced the sample size and, therefore, may have affected the findings of the study.

To reduce measurement errors, we intensively trained the data collectors and supervisors on recording and standard operating procedures. Accordingly, we conducted pre-test data collection and evaluated technical error measurements. Moreover, we used a household food insecurity tool, validated in Ethiopia, to reduce misunderstanding and multiple interpretations of the questions (117).

Confounding

Confounding is a central problem for epidemiological study designs which confuses the effects of the findings (125). Confounding bias occurs when the variable in a particular study meets two criteria: firstly, the confounding variables are related with the outcome but not in a causal pathway for the outcome. Secondly, the confounding distribution is different in the groups being compared (125, 134).

In our studies, we included potential confounders in the models which were controlled during that analysis phase. Thus, we conducted a mixed-effect logistic regression to control for confounders such as seasonal variation of household food insecurity and household dietary diversity, and socio-demographic characteristics on child wasting and stunting (Paper I).

Moreover, we controlled for household food insecurity, household dietary diversity, household altitude, family size, wealth index, maternal age, education, and occupation, to investigate risk factors for maternal malnutrition in a mixed-effect linear regression (Paper II). For example, the change of effect measures (crude and adjusted odds ratio) showed a more than 10% difference in the association between morbidity and child wasting (Paper I). Moreover, the change of effect measures (crude and adjusted odds ratio) showed a more than 10% difference, comparing mild food insecurity and severe food insecurity in child stunting (Paper I). The change in effect measures might be due to confounding effects.

Factors such as wealth index, household food insecurity, altitude, maternal age, education, and occupation could be potential sources of bias in spatial clustering of malnutrition. Thus, we included these known risk factors for child and maternal malnutrition in drought-prone areas to control for potential confounders of the malnutrition clustering done with SaTScan version 9.7 software (Paper III). However, unknown confounding factors in our studies and effect modifications could have influenced the findings. Hence, we acknowledge this as a limitation of this study (Papers I, II, and III). However, we believe that our study provides important information for nutrition interventions because child wasting increased when household food insecurity was higher, while child stunting occurred some months later than increased household food insecurity. Moreover, we observed that child stunting and maternal malnutrition were not clustered, after controlling for known risk factors for malnutrition.

Chance

For this thesis, we randomly selected an adequate sample size. The design effect was low which has placed our trust in our sample size.

Chance is a random error that can occur due to sampling variability when we attempt to draw an inference about the population, based on what we found in the sample. Chance or random error may underestimate or overestimate the true effect if the whole population is not included in the study. However, the role of chance can be reduced by increasing the sample size (135). This type of error can also be estimated by performing appropriate tests of statistical significance with confidence intervals around the point estimate (125).

The papers reported in this thesis addressed the possibility of chance for the observed results by using a statistically significance test at a specific cut-off such as a p-value less than 0.05 or 95% confidence interval not crossing the null hypothesis.

External validity

External validity is the generalizability of the study findings to populations not in the study or areas other than the study area (125). Adequate internal validity is a pre-requisite to the external validity of the study (125). The differences observed between the participants group and non-participants group confirms the extent of the study generalizability (136).

The studies reported in this thesis evaluated the impact of seasonal variation of food insecurity, dietary diversity and household characteristics on child stunting, child wasting and maternal malnutrition (Papers I and II) in a typical rural drought-prone area. Compared with many parts of the country's drought-prone areas, the social economics, existing agricultural practices, nutritional interventions, and health services were similar with the study area. Moreover, we had low numbers of loss to follow-up (Papers I and II). Thus, we can conclude that our findings could be extrapolated to other rural drought-prone areas of Ethiopia that exhibit similar conditions to the study area. However, the generalizability of our findings could have been influenced by the study period, which lasted only for one year. Moreover, this study was conducted in a rural community in a drought-prone area, and this could influence generalizability of our findings to an urban setup in a drought-prone area.

Causation

According to Hill's criteria for causation, we may consider that there could be a causal relationship between the risks identified, with child stunting, maternal malnutrition and local spatial clustering of child stunting (137). Our findings that poverty and food insecurity during the pre-harvest season were risk factors for subsequent child wasting and maternal malnutrition seem biologically plausible in Papers I and II. Furthermore, our findings in Papers I and II were consistent with earlier findings on seasonal variations in malnutrition in Ethiopia, and the previous studies were consistent regarding local clustering of child stunting in Paper III.

Moreover, our data suggested a dose-response association; for example, a decrease in the wealth index status led to a lower maternal MUAC in the Paper II study.

Discussions of the main findings

In the present thesis, the main aim was understanding child and maternal malnutrition within a local context with recurrent drought and food shortages in southern Ethiopia. We observed that seasonal variation of household food insecurity and household dietary diversity influenced child wasting, stunting and maternal malnutrition. Household characteristics, such as poverty and illiteracy, were among the root causes of child and maternal malnutrition. Furthermore, the correlation between maternal malnutrition and their child's malnutrition implied that they could share similar risk factors. Moreover, we identified risk factors such as poverty and maternal characteristics for the observed spatial clustering of child stunting and maternal malnutrition.

Seasonality of food insecurity remains under-explored in rural smallholder farmers of Ethiopia (117, 138). A study has shown that food insecurity is high during the pre-harvest season in a rural farming community (117). During this time, males migrate for labor employment, the household food stocks from the last harvest begin to run out, and accumulated debt all combine to force families to sell or consume their agricultural production well before the new harvest (117). Similarly, our findings demonstrated that the number of severely food-insecure households was higher in the pre-harvest seasons of March and June as compared to the post-harvest seasons of September and December. The household food insecurity could occur due to socio-economic variation, education, and occupation; thus, improving such underlying factors could increase household purchasing power and stabilize seasonal fluctuation of food shortages (139, 140). Moreover, our findings demonstrated that the pre-harvest season (March) had the lowest dietary diversity compared to the post-harvest seasons of September and December. Similarly, studies in developing countries indicated that rural communities dependent on agriculture outputs with little access to animal-source foods are more likely to experience seasonal food shortages, with seasonal fluctuation of agricultural production (141).

Similar to household food insecurity and dietary diversity, the rate of child wasting was higher in the pre-harvest season of March compared to post-harvest seasons of September and December.

Similarly, studies from developing countries indicated that the prevalence of child wasting increased with the increased level of food insecurity (142). Studies in Ethiopia showed that child wasting is higher during the pre-harvest season of the year (51). Similarly, maternal malnutrition was highest in the pre-harvest season, when food insecurity was highest and dietary diversity was lowest. Moreover, maternal and child nutritional status showed a relationship which implied that they could share similar risk factors in drought-prone areas. However, we demonstrated that the highest rate of child stunting occurred after some months, with the highest prevalence of food insecurity and lowest dietary diversity. This could be due to the delayed effects of chronic malnutrition.

Poverty could expose households to multidimensional consequences such as food insecurity, malnutrition, and poor health (143). Moreover, poverty disproportionately affects low-income countries, where social protection benefit packages are unacceptably low (143). A multinational cohort study conducted in Vietnam, India, Peru and Ethiopia found children belonging to the lowest quintile households had significantly increased probabilities of being stunted in all four countries (144). Similarly, our findings demonstrated that drought-prone rural farming communities are exposed to child stunting and maternal malnutrition linked to poverty, and there was poverty-explained spatial variation of child stunting and maternal malnutrition. The diminished health and productivity could potentially continue the vicious cycle of poverty (143). Thus, the inter-related causes and consequences of poverty require a multi-sectorial response, including the health, education and social sectors (143).

Ethiopia experiences one of the highest levels of child and maternal malnutrition (145). One of the possible reasons could be inadequate dietary diversity (Paper I). Dietary deficiency is an immediate cause of child and maternal malnutrition, according to the conceptual framework. Our study identified that maternal malnutrition increased when household dietary diversity decreased, consistent with previous studies conducted in Burkina Faso (146, 147). Studies from Kenya and Mali also reported that low dietary diversity was a risk factor for child under-nutrition (148, 149). Moreover, our study showed that the diet consumed by the population mostly came from non-animal-source foods, thus reducing dietary diversity. Thus, poor consumption of animal-source food may have serious consequences for micronutrient adequacy (150-152). Moreover, the dietary diversity score is known to be a proxy indicator of micronutrient intake (153). Thus, low dietary diversity could be a risk factor for both micronutrient and macronutrient deficiency among children and mothers. Thus, we need to consider additional plants for agriculture, as well as new approaches for including animal-source diet items for the rural farming community.

Parental education plays an important role in the nutritional status of children and mothers. Our study showed that higher-status maternal education reduced stunting and higher educational status of fathers reduced wasting among children in drought-prone areas. Moreover, poor maternal education is identified as a risk factor for spatial clustering of stunting. This is in line with previous studies conducted in developing countries, including Ethiopia (54). The possible reasons could be that educated mothers could have better information about child care practices, hygiene practices, child care during illness, and better utilization of health services (154-157). Maternal education could increase women's empowerment to make independent decisions on the use of available resources (158). Moreover, educational status of fathers was identified as an important risk factor for child under-nutrition, similar to maternal education in the previous studies conducted in developing countries (159). In our study, about fifty percent of mothers and more than one-third of fathers had not attended formal education, and thus many children of less-educated parents could be vulnerable to malnutrition.

Sustainable Development Goal 8 aims at fostering productive employment, decent work for all and economic growth. In our findings, we demonstrated that paternal and maternal occupation, especially working outside such as being employed, reduced child stunting. Maternal occupation, especially engaging in agricultural work, increased the rate of maternal malnutrition. However, maternal occupation by being employed or being a merchant had a reduced risk of spatial clustering of child stunting. Similarly, other studies reported that parental occupation, especially working outside in employment, had better nutritional outcomes compared with other occupational categories (160). This could be due to the important link through which occupation status is associated with the household financial income and child care practices (161). Improving maternal financial income and decision-making autonomy could influence child feeding and nutritional status (162).

In our findings we demonstrated that spatial clustering of stunting was higher among younger mothers. This finding is line with previous studies conducted in African countries, including Ethiopia, which documented that children born to younger women had a higher rate of stunting compared to older women (160, 163, 164). This could be because older mothers may have more experience in child care than the younger mothers. Moreover, we identified that maternal malnutrition was higher among younger mothers and larger household family size. Similarly, another study from Ethiopia showed that larger family size increased maternal malnutrition, which could be due to their biological roles of bearing and rearing children (165).

Previous studies documented that highland areas of Ethiopia had a higher rate of malnutrition (166, 167). Similarly, our findings showed that when the household altitude increased, the maternal malnutrition increased significantly. This could be due to higher population pressure in the highland areas, and thus, highland areas could have less farming land and smaller plots for crop production (168, 169). Studies from Ethiopia showed that child under-nutrition decreased with higher crop availability; however, crop availability increased with rainfall, and also rainfall increased with increasing altitude (167). Thus, we speculated that the small size of farming plots could partly explain the association between increased malnutrition and increased household altitude.

Challenges and future direction of nutritional epidemiology research

Nutritional epidemiology has contributed to the development of nutritional policies and strategies. Several findings showed that nutritional epidemiology has contributed to the significant reduction in cardiovascular mortality, which is attributable to improvement in lifestyle and diet-related factors (170). Moreover, nutritional epidemiologists frequently use anthropometric measurements, and thus diagnose and treat malnutrition in resource-poor settings like Ethiopia. Anthropometric measurements are simple and non-invasive techniques to measure the nutritional status of human beings (171).

Recently, however, nutritional epidemiology has not been criticized for its inability to measure dietary intake accurately in individuals and populations. Moreover, its reliance on the observational nature of epidemiologic studies and small randomized controlled trials to address the etiologic questions is not appreciated (172). Nevertheless, substantial deficiencies of key nutrients and/or excessive calories may indeed increase mortality risk, although the dietary intake differences are not perfectly quantified. Human diet is complex, with no perfect method to estimate all aspects of dietary intake, and the ability of nutritional epidemiologic studies is considered to be weak in terms of informing public health policy and guidelines.

The nutritional status assessed by anthropometry could show discrepancies from biochemical markers among older people (173). Child wasting (low weight-for-height) has been interpreted as a condition in which muscle and body fat are reduced. However, malnourished children could have a relative increase in other body proportions, and often present with large abdomens. Thus, a large abdomen could increase the child's weight without affecting height, and the child may still have a normal weight-for-height (174). Moreover, height-for-age Z scores could increase, even though height deficits among children increased (175). Thus, interpretation of anthropometric measurements could be subjected to debate (175). Moreover, conventional approaches of categorizing the prevalence of malnutrition, such as dichotomizing child growth based on Z scores lower than -2 SD of the World Health Organization Child Growth Standards Median, could obscure malnutrition trends (176). Thus, we have used continuous distribution of child and maternal anthropometric measurements (Papers I and II).

Meta-analyzed evidence from observational studies is criticized for using causal language. For instance, one study concluded that optimal consumption of healthy food reduces mortality, and eating of risky foods is associated with higher mortality (177). These implausible findings are often presented by the media as causal (178). Thus, randomized controlled trials (RCTs) are essential to enhance the validity of nutritional studies (178).

Conclusions and Recommendations

Conclusions

We aimed to improve our understanding of child and maternal malnutrition through a cohort study in the context of rural drought-prone areas, and we observed that seasonal variation of household food insecurity and dietary diversity influenced child and maternal malnutrition, whereas the spatial variation of child and maternal malnutrition could be due to risk factors of malnutrition such as poverty, and maternal characteristics. Furthermore, based on the findings of the studies (Papers I, II and III), we conclude with the following more detailed conclusions:

Objective 1: To evaluate seasonal patterns of household food insecurity, dietary diversity, and household characteristics in relation to wasting and stunting among children in households followed for one year. The main conclusions of the findings are presented as follows:

- The risk of child wasting, and child stunting was associated with household food insecurity, household dietary diversity, and household factors such as poverty, parental education and occupation.
- The prevalence of wasting increased in the pre-harvest season, when there was highest prevalence of household food insecurity.
- The highest prevalence of stunting occurred some months after the period with the highest prevalence of food insecurity.

Objective 2: To determine the effects of household characteristics and seasonal variations in food insecurity and food diversity on maternal malnutrition and to assess whether maternal malnutrition is associated with child malnutrition. The main conclusions of the findings are presented as follows:

- The period of prevalence of maternal malnutrition was highest during the pre-harvest season, when food insecurity was highest.
- Households with malnourished mothers often had malnourished children, indicating the presence of shared risk factors.

- The risk of maternal malnutrition was highest among poor households and younger mothers.
- Maternal malnutrition increased with household altitude, probably due to the small farm sizes in highland areas.

Objective 3: To examine whether child stunting and maternal malnutrition were spatially clustered after controlling for known risk factors for malnutrition among children and their mothers. The main conclusion of the findings was as follows:

- Child stunting and maternal malnutrition were not spatially clustered in drought-prone areas after we controlled for known risk factors for malnutrition such as poverty, and maternal characteristics

Recommendations

Based on the findings of this research, we present the operational, policy and further research recommendations, as described in the sections below.

Operational and policy recommendations

Objective 1: To evaluate seasonal patterns of household food insecurity, dietary diversity, and household characteristics in relation to wasting and stunting among children in households followed for one year. The main recommendations of the findings are presented as follows:

- ✓ The national education strategies should give due attention to how universal access to education could be achieved in drought-prone areas in order to improve child malnutrition.
- ✓ Programs working on improving child malnutrition should integrate seasonal weather forecasting, agriculture, health information, and education.
- ✓ Interventions should promote diversity in food production and consumption, and consider including high-quality diet items such as animal-source food and fruits.

Objective 2: To determine the effects of household characteristics and seasonal variations in food insecurity and food diversity on maternal malnutrition and to assess whether maternal malnutrition is associated with child malnutrition.

- ✓ Programs aimed to improve child malnutrition should also aim to improve maternal malnutrition.
- ✓ Nutrition-related program implementers should consider seasonal weather forecasting and an early warning system to enhance agricultural production at the local level.

<u>Objective 3</u>: To examine whether child stunting and maternal malnutrition were spatially clustered after controlling for known risk factors for malnutrition among children and their mothers:

- ✓ Geographically targeted nutritional interventions should be considered in order to improve the various nutrition-related risk factors such as poverty, maternal educational level and occupation.

Recommendations for future research

Based on the findings in the thesis, we recommend the following further research areas:

- ✓ Future implementation research could consider seasonal weather forecasting and an early warning system to enhance agricultural production and food security, and reduce malnutrition.
- ✓ Nutritional implementation studies, including randomized controlled trials, should explore the impacts interventions on child and maternal malnutrition.

References

1. Alemu EA. Malnutrition and Its Implications on Food Security. In: Leal Filho W, Azul AM, Brandli L, Özuyar PG, Wall T, editors. Zero Hunger. Cham: Springer International Publishing; 2019. p. 1-10.

2. Nutrition for Developing Countries, Third ed. Savage King F, Burgess A, Quinn VJ, Osei AK,. Oxford University Press 2015.

3. Webb P, Stordalen GA, Singh S, Wijesinha-Bettoni R, Shetty P, Lartey A. Hunger and malnutrition in the 21st century. BMJ. 2018;361:k2238.

4. Saunders J, Smith T. Malnutrition: Causes and consequences. Clinical Medicine (Lond). 2010;10(6):624-7.

5. Briend A, Khara T, Dolan C. Wasting and Stunting—Similarities and Differences: Policy and programmatic implications. Food and Nutrition Bulletin. 2015;36(1_suppl1):S15-S23.

6. WHO Multicentre Growth Reference Study Group. WHO child growth standards based on length/height, weight and age. Acta Paediatrica Supplement. 2006;450:76-85.

7. Wells JCK, Briend A, Boyd EM, Berkely JA, Hall A, Isanaka S, et al. Beyond wasted and stunted; A major shift to fight child undernutrition. The Lancet Child & Adolescent Health. 2019;3(11):831-4.

8. The Sphere Project. Humanitarian Charter and Minimum Standards in Humanitarian Response, fourth ed. Geneva, Switzerland; 2018. Available from: https://www.spherestandards.org/handbook.

9. Grantham-McGregor S, Cheung YB, Cueto S, Glewwe P, Richter L, Strupp B, et al. Developmental potential in the first 5 years for children in developing countries. The Lancet. 2007;369(9555):60-70.

10. Black RE, Allen LH, Bhutta ZA, Caulfield LE, de Onis M, Ezzati M, et al. Maternal and child undernutrition: Global and regional exposures and health consequences. Lancet. 2008;371(9608):243-60.

11. United Nations Children's Fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank. Levels and Trends in Child Malnutrition: Key Findings of the 2020 Edition of the Joint Child Malnutrition Estimates. Geneva: World Health Organization; 2020. Licence: CC BY-NC-SA 3.0 IGO. 2020.

12. Nabwera HM, Fulford AJ, Moore SE, Prentice AM. Growth faltering in rural Gambian children after four decades of interventions: A retrospective cohort study. The Lancet Global Health. 2017;5(2):e208-16.

13. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. The Lancet. 2013;382(9890):427-51.

14. Ahmed T, Hossain M, Sanin KI. Global burden of maternal and child undernutrition and micronutrient deficiencies. Annals of Nutrition and Metabolism. 2012;61(Suppl. 1):8-17.

15. Central Statistical Authority [Ethiopia] and ORC Macro. Ethiopia Demographic and Health Survey 2000. Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Authority and ORC Macro; 2001.

16. Central Statistical Authority [Ethiopia] and ORC Macro. Ethiopia Demographic and Health Survey 2005. Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Agency and ORC Macro; 2006.

17. Central Statistical Authoritygency [Ethiopia] and ICF International. 2012. Ethiopia Demographic and Health Survey 2011. Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Agency and ICF International; 2012.

18. Central Statistical Authority [Ethiopia] and ICF International. Ethiopia Demographic and Health Survey 2015. Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Agency and ICF International; 2015.

19. Ethiopian Public Health Institute (EPHI) [Ethiopia] and ICF. 2019. Ethiopia Mini Demographic and Health Survey 2019: Key Indicators. Rockville, Maryland, USA: EPHI and ICF; 2019.

20. Government of the Federal Democratic Republic of Ethiopia. National Nutrition Programme 2016-2020, Addis Ababa; Government of the Federal Democratic Republic of Ethiopia (GFDRE); 2016.

21. Government of the Federal Democratic Republic of Ethiopia. Seqota Declaration Implementation Plan (2016-2030), Summary Programme Approach Document, Addis Ababa; Governement of the Federal Democratic Republic of Ethiopia (GFDRE); 2016.

22. United Nations Development Programme. Human Development Reports. Gender Inequality Index. United Nations Development Programme; 2020. Available at: http://hdr.undp.org/en/content/gender-inequality-index-gii.

23. Geda NR. Inequalities in maternal malnutrition in Ethiopia: Evidence from a nationally representative data. BMC Women's Health. 2021;21(1):Article 3.

24. Cegielski JP, McMurray DN. The relationship between malnutrition and tuberculosis: Evidence from studies in humans and experimental animals. The International Journal of Tuberculosis and Lung Disease. 2004;8(3):286-98.

25. Bhutta ZA, Das JK, Rizvi A, Gaffey MF, Walker N, Horton S, et al. Evidence-based interventions for improvement of maternal and child nutrition: What can be done and at what cost? The Lancet. 2013;382(9890):452-77.

26. Horton S, Steckel RH. Malnutrition: Global Economic Losses Attributable to Malnutrition 1900–2000 and Projections to 2050. In: Lomborg B, editor. How Much Have Global Problems Cost the World?: A Scorecard from 1900 to 2050. Cambridge: Cambridge University Press; 2013. p. 247-72.

27. Food and Agriculture Organization of the United Nations. The State of Food and Agriculture: Food Systems for Better Nutrition. Rome: Food and Agriculture Organization of the United Nations; 2013. Available at: http://www.fao.org/docrep/018/i3300e/i3300e.pdf.

28. Horton S. Opportunities for investments in nutrition in low-income Asia. Asian Development Review. 1999;17(1,2):246-73.

29. Campaign on Accelerated Reduction of Maternal Newborn and Child Mortality in Africa. The Socio-economic Impact of Child Malnutrition in Africa. African Union. Available at: http://www.carmma.org/update/socio-economic-impact-child-malnutrition-africa

30. Frison S, Angood C, Khara T, Bahwere P, Black RE, Briend A, et al. Prevention of child wasting: Results of a Child Health & Nutrition Research Initiative (CHNRI) prioritisation exercise. PloS One. 2020;15(2):e0228151.

31. Victora CG, Adair L, Fall C, Hallal PC, Martorell R, Richter L, et al. Maternal and child undernutrition: Consequences for adult health and human capital. The Lancet. 2008;371(9609):340-57.

32. Li H, Stein AD, Barnhart HX, Ramakrishnan U, Martorell R. Associations between prenatal and postnatal growth and adult body size and composition. The American Journal of Clinical Nutrition. 2003;77(6):1498-505.

33. Li H, Barnhart HX, Stein AD, Martorell R. Effects of early childhood supplementation on the educational achievement of women. Pediatrics. 2003;112(5):1156-62.

34. Maluccio JA, Hoddinott J, Behrman JR, Martorell R, Quisumbing AR, Stein AD. The Impact of Improving Nutrition During Early Childhood on Education among Guatemalan Adults*. The Economic Journal. 2009;119(537):734-63.

35. Dewey KG, Begum K. Long-term consequences of stunting in early life. Maternal & Child Nutrition. 2011;7(Suppl 3):5-18.

36. Food and Agriculture Organization of the United Nation, World Food Programme, International Fund for Agricultural Development. The State of Food Insecurity in the World. Meeting the 2015 International Hunger Targets: Taking Stock of Uneven Progress. Rome: Food and Agriculture Organization of the United Nations; 2015. Available at: https://www.fao.org/3/i4671e/i4671e.pdf.

37. Black RE, Alderman H, Bhutta ZA, Gillespie S, Haddad L, Horton S, et al. Maternal and child nutrition: Building momentum for impact. The Lancet. 2013;382(9890):372-5.

38. Action contre la Faim. A Practical Guidebook on Increasing Nutritional Impact through Integration of WASH and Nutrition Programmes for Practitioners in Humanitarian and Development Contexts. https://www.actionagainsthunger.org/sites/default/files/publications/2017_ACF_WASH_Nutrition_Guidebook_BD.pdf. 2012

39. Madan EM, Haas JD, Menon P, Gillespie S. Seasonal variation in the proximal determinants of undernutrition during the first 1000 days of life in rural South Asia: A comprehensive review. Global Food Security. 2018;19:11-23.

40. Dewey KG, Mayers DR. Early child growth: How do nutrition and infection interact? Maternal & Child Nutrition. 2011;7(s3):129-42.

41. Müller O, Krawinkel M. Malnutrition and health in developing countries. CMAJ : Canadian Medical Association Journal 2005;173:279-86.

42. Schlaudecker EP, Steinhoff MC, Moore SR. Interactions of diarrhea, pneumonia, and malnutrition in childhood: Recent evidence from developing countries. Current Opinion in Infectious Diseases. 2011;24(5):496-502.

43. Rowland MGM, Cole TJ, Whitehead RG. A quantitative study into the role of infection in determining nutritional status in Gambian village children. British Journal of Nutrition. 2007;37(3):441-50.

44. World Health Organization: Global Database on the Implementation of Nutrition Action (GINA). Community-based Management of Acute Malnutrition (CMAM) Programme in Niger - Prevention or Treatment of Moderate Malnutrition - MAM child. Available at: https://extranet.who.int/nutrition/gina/en/node/17821.

45. Krawinkel MB. Interaction of nutrition and infections globally: An overview. Annals of Nutrition & Metabolism. 2012;61(Suppl 1):39-45.

46. Erismann S, Knoblauch AM, Diagbouga S, Odermatt P, Gerold J, Shrestha A, et al. Prevalence and risk factors of undernutrition among schoolchildren in the Plateau Central and Centre-Ouest regions of Burkina Faso. Infectious Diseases of Poverty. 2017;6(1):17. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5244543/.

47. Katona P, Katona-Apte J. The interaction between nutrition and infection. Clinical Infectious Diseases. 2008;46(10):1582-8.

48. Motbainor A, Worku A, Kumie A. Household food insecurity is associated with both body mass index and middle-upper-arm circumference of mothers in northwest Ethiopia: A comparative study. International Journal of Women's Health. 2017;9:379-89.

49. Schmeer KK, Piperata BA. Household food insecurity and child health. Maternal & Child Nutrition. 2017;13(2):e12301.

50. Nayak AB, Unnikrishnan B, George A, Shashidhara YN, Suneel C, Mundkur SC, et al. Risk factors for malnutrition among preschool children in rural Karnataka: A case-control study. BMC Public Health. 2018;18(1):283. https:// doi.org/10.1186/s12889-018-5124-3.

51. Egata G, Berhane Y, Worku A. Seasonal variation in the prevalence of acute undernutrition among children under five years of age in east rural Ethiopia: A longitudinal study. BMC Public Health. 2013;13:Article 864.

52. Chirande L, Charwe D, Mbwana H, Victor R, Kimboka S, Issaka AI, et al. Determinants of stunting and severe stunting among under-fives in Tanzania: Evidence from the 2010 cross-sectional household survey. BMC Pediatrics. 2015;15(1):165. https://doi.org/10.1186/s12887-015-0482-9.

53. Farah AM, Endris BS, Gebreyesus SH. Maternal undernutrition as proxy indicators of their offspring's undernutrition: Evidence from 2011 Ethiopia Demographic and Health Survey. BMC Nutrition. 2019;5(1):17. https://doi.org/10.1186/s40795-019-0281-z.

54. Amare ZY, Ahmed ME, Mehari AB. Determinants of nutritional status among children under age 5 in Ethiopia: Further analysis of the 2016 Ethiopia Demographic and Health Survey. Globalization and Health. 2019;15(1):62. https:// doi.org/10.1186/s12992-019-0505-7.

55. Victora CG, Christian P, Vidaletti LP, Gatica-Domínguez G, Menon P, Black RE. Revisiting maternal and child undernutrition in low-income and middle-income countries: Variable progress towards an unfinished agenda. The Lancet (British edition). 2021;397(10282):1388-99.

56. Kabubo-Mariara J, Ndenge GK, Mwabu DK. Determinants of Children's Nutritional Status in Kenya: Evidence from Demographic and Health Surveys. Journal of African Economies. 2009;18(3):363-87.

57. Burkholder BT, Toole MJ. Evolution of complex disasters. The Lancet. 1995;346(8981):1012-5.

58. Taye A, Mariam DH, Murray V. Interim report: Review of evidence of the health impact of famine in Ethiopia. Perspectives in Public Health. 2010;130(5):222-6.

59. USAID/Addis Ababa. Famine Early Warning System Country Report Number 12. Ethiopia; 1987. Available at: https://pdf.usaid.gov/pdf_docs/pnaax386.pdf.

60. Kloos H, Lindtjørn B. Malnutrition during recent famines in Ethiopia. Northeast African Studies. 1994;1:121-36. https://doi.org/10.1353/nas.1994.0000.

61. United Nations. The Millennium Development Goals Report 2015. Available at: https://www.un.org/millenniumgoals/2015_MDG_Report/pdf/MDG%202015%20rev%20(July%201).pdf

62. International Food Policy Research Institute. Global Nutrition Report 2014: Actions and accountability to accelerate the world's progress on nutrition. Washington, DC: International Food Policy Research Institute (IFPRI); 2014. Available at: http://dx.doi.org/10.2499/9780896295643.

63. World Health Assembly. Sixty-fifth World Health Assembly: Geneva, 21-26 May 2012: Resolutions and decisions, annexes. Geneva: World Health Organization; 2012.

64. 2020 Global Nutrition Report: Action on equity to end malnutrition. Bristol, UK: Development Initiatives; 2020. Available at: https://reliefweb.int/report/world/2020-global-nutrition-report-action-equity-end-malnutrition.

65. Grosso G, Mateo A, Rangelov N, Buzeti T, Birt C. Nutrition in the context of the Sustainable Development Goals. European Journal of Public Health. 2020;30(Supplement_1):i19-i23.

66. United Nations. The Sustainable Development Goals Report 2020. Available at: https://unstats.un.org/sdgs/report/2020/The-Sustainable-Development-Goals-Report-2020.pdf

67. Li Z, Kim R, Vollmer S, Subramanian SV. Factors Associated With Child Stunting, Wasting, and Underweight in 35 Low- and Middle-Income Countries. JAMA Network Open. 2020;3(4):e203386.

68. The Lancet. Evaluation of maternal and child under-nutrition: Executive summary of The Lancet Maternal and Child Nutrition Series. 2013. Available from: https://www.ennonline.net/evaluationofmaternalandchildundernutrition.

69. Lassi ZS, Rind F, Irfan O, Hadi R, Das JK, Bhutta ZA. Impact of infant and young child feeding (IYCF) nutrition interventions on breastfeeding practices, growth and mortality in low- and middle-income countries: Systematic review. Nutrients. 2020;12(3):722. https://doi.org/10.3390/nu12030722.

70. Keats EC, Das JK, Salam RA, Lassi ZS, Imdad A, Black RE, et al. Effective interventions to address maternal and child malnutrition: An update of the evidence. The Lancet Child & Adolescent Health. 2021;5(5):367-84.

71. Kristjansson E, Francis DK, Liberato S, Benkhalti Jandu M, Welch V, Batal M, et al. Food supplementation for improving the physical and psychosocial health of socio-economically disadvantaged children aged three months to five years. Cochrane Database Systematic Review. 2015;2015(3):Cd009924.

72. Visser J, McLachlan MH, Maayan N, Garner P. Community-based supplementary feeding for food insecure, vulnerable and malnourished populations - an overview of systematic reviews. Cochrane Database Systematic Reviews. 2018;11(11):Cd010578.

73. Das JK, Salam RA, Saeed M, Kazmi FA, Bhutta ZA. Effectiveness of interventions for managing acute malnutrition in children under five years of age in low-income and middle-

income countries: A systematic review and meta-analysis. Nutrients. 2020;12(1):116. https://doi.org/10.3390/nu12010116.

74. Lassi ZS, Padhani ZA. Impact of dietary interventions during pregnancy on maternal, neonatal, and child outcomes in low- and middle-income countries. Nutrients. 2020;12(2):531. https:// doi.org/10.3390/nu12020531.

75. Tam E, Keats EC, Rind F, Das JK, Bhutta AZA. Micronutrient supplementation and fortification interventions on health and development outcomes among children under-five in low- and middle-income countries: A systematic review and meta-analysis. Nutrients. 2020;12(2):289. https://doi.org/10.3390/nu12020289.

76. Oh C, Keats EC. Vitamin and mineral supplementation during pregnancy on maternal, birth, child health and development outcomes in low- and middle-income countries: A systematic review and meta-analysis. Nutrients. 2020;12(2):491. https:// doi.org/10.3390/nu12020491.

77. de Groot R, Palermo T, Handa S, Ragno LP, Peterman A. Cash transfers and child nutrition: Pathways and impacts. Development Policy Review. 2017;35(5):621-43.

78. Yawson AE, Amoaful EO, Senaya LK, Yawson AO, Aboagye PK, Mahama AB, et al. The Lancet series nutritional interventions in Ghana: A determinants analysis approach to inform nutrition strategic planning. BMC Nutrition. 2017;3(1):27. https:// doi.org/10.1186/s40795-017-0147-1.

79. Shekar M, Condo J, Pate MA, Nishtar S. Maternal and child undernutrition: Progress hinges on supporting women and more implementation research. The Lancet. 2021;397(10282):1329-31.

80. Heidkamp RA, Piwoz E, Gillespie S, Keats EC, D'Alimonte MR, Menon P, et al. Mobilising evidence, data, and resources to achieve global maternal and child undernutrition targets and the Sustainable Development Goals: An agenda for action. The Lancet. 2021;397(10282):1400-18.

81. United Nations. World Population Prospects. United Nations, Department of Economic and Social Affairs, Population Division; 2020. Available from: http://population.un.org/wpp/Download/Standard/Population/.

82. Food and Agriculture Organization. AQUASTAT Country Profile – Ethiopia. Rome: Food and Agriculture Organization of the United Nations (FAO). Rome, Italy; 2016. Available from: https://www.fao.org/aquastat/statistics/query/index.html?lang=en

83. Dercon S, Krishnan P. Vulnerability, seasonality and poverty in Ethiopia. Journal of Development Studies. 2000;36(6):25-53.

84. Webb P, von Braun J, Yohannes Y. Famine in Ethiopia: Policy implications of coping failure at national and household levels. Food and Nutrition Bulletin. 1992;15. https://doi.org/10.1177/156482659401500107.

85. Myers SS, Smith MR, Guth S, Golden CD, Vaitla B, Mueller ND, et al. Climate change and global food systems: Potential impacts on food security and undernutrition. Annual Review of Public Health. 2017;38:259-77.

86. Lloyd SJ, Kovats RS, Chalabi Z. Climate change, crop yields, and undernutrition: Development of a model to quantify the impact of climate scenarios on child undernutrition. Environmental Health Perspectives. 2011;119(12):1817-23.

87. Hillbruner C, Egan R. Seasonality, household food security, and nutritional status in Dinajpur, Bangladesh. Food and Nutrition Bulletin. 2008;29(3):221-31.

88. Thomson MC, Mason SJ, Phindela T, Connor SJ. Use of rainfall and sea surface temperature monitoring for malaria early warning in Botswana. American Journal of Tropical Medicine and Hygiene. 2005;73(1):214-21.

89. Abeku TA, van Oortmarssen GJ, Borsboom G, de Vlas SJ, Habbema JD. Spatial and temporal variations of malaria epidemic risk in Ethiopia: Factors involved and implications. Acta Tropica 2003;87(3):331-40.

90. Dadi DK. Characterizing the predictability of seasonal climate in Ethiopia. Dissertation for the degree philosophiae doctor (PhD), University of Bergen, Norway, University of Bergen, Norway; 2013. https://malaria.w.uib.no/files/2014/06/DiribaPhD.pdf

91. Mengesha AD, Ayele TT. The Impact of Culture on the Nutritional Status of Children and Mothers During Recurring Food Insecurity: The case of Boricha Woreda (SNNPRS). American Journal of Educational Research. 2015;3(7):849-67.

92. UNICEF World Bank and WHO. Joint child malnutrition dataset. Available at: https://data.unicef.org/resources/joint-child-malnutrition-estimates-2016-edition/.

93. Federal Ministry of Health (FMOH). Health Sector Strategic Plan (HSDP-III) 2005/6-2009/10 FMOH; 2005 . Available from: https://extranet.who.int/countryplanningcycles/search/site/HSDP%20III.

94. Assefa Y, Gelaw YA, Hill PS, Taye BW, Van Damme W. Community health extension program of Ethiopia, 2003–2018: Successes and challenges toward universal coverage for primary healthcare services. Globalization and Health. 2019;15(1):24. https:// doi.org/10.1186/s12992-019-0470-1.

95. Netsanet W. Workie, Gandham NV Ramana. The Health Extension Program in Ethiopia; 2013. Available from: https://openknowledge.worldbank.org/handle/10986/13280

96. Kok MC, Kea AZ, Datiko DG, Broerse JE, Dieleman M, Taegtmeyer M, et al. A qualitative assessment of health extension workers' relationships with the community and health sector in Ethiopia: Opportunities for enhancing maternal health performance. Human Resources for Health. 2015;13(1):Article 80.

97. Hailu T, Tessema M, Fofanah M, Lema Z. Nutrition training manual for health and agriculture workers at community level in Ethiopia. Integrating nutrition into crop and livestock farming systems of the Ethiopian highlands for improved nutrition outcomes. In: Ethiopian Public Health Institute (EPHI), International Potato Center (CIP), and International Livestock Research Institute (ILRI), editors.: International Livestock Research Institute (ILRI); 2016.

98. Tekle MG, Wolde HM, Medhin G, Teklu AM, Alemayehu YK, Gebre EG, et al. Understanding the factors affecting attrition and intention to leave of health extension workers: A mixed methods study in Ethiopia. Human Resources for Health. 2022;20(1):Article 20.

99. Kitila KM, Wodajo DA, Debela TF, Ereso BM. Turnover intention and its associated factors among health extension workers in Illubabora Zone, South West Ethiopia. Journal of Multidisciplinary Healthcare. 2021;14:1609-21.

100. Tesfaye B. Rural household food security situation anaylsis: The case of Boricha Wereda, Sidama Zone. Thesis for Degree of Master of Science in Development Studies, Addis Ababa University; 2011Available from: http://etd.aau.edu.et/bitstream/handle/123456789/7233/Bechaye%20tesfaye.pdf?sequence=1&isAllowed=y

101. Boricha Woreda Agricultural Office Report, Boricha, Sidama Zone, Ethiopia. 2020.

102. NCD Risk Factor Collaboration. Worldwide trends in body-mass index, underweight, overweight, and obesity from 1975 to 2016: A pooled analysis of 2,416 population-based measurement studies in 128.9 million children, adolescents, and adults. The Lancet. 2017;390(10113):2627-42.

103. Hirvonen K, Headey DD, Golan J, Hoddinot JF. Changes in child undernutriton in Ethiopia (2000 - 2016). In: Cheru F, Cramer C, Oqubay A, editors. The Oxford Handbook of Ethiopian Economy. New York: Oxford University Press; 2019, p. 399-411.

104. Global Nutrition Report. Country Nutrition Profiles. Global Nutrition Report; 2020. Available at: https://globalnutritionreport.org/resources/nutrition-profiles/africa/eastern-africa/ethiopia/.

105. Hagos S, Hailemariam D, WoldeHanna T, Lindtjørn B. Spatial heterogeneity and risk factors for stunting among children under age five in Ethiopia: A Bayesian geo-statistical model. PloS One. 2017;12(2):e0170785.

106. Roba KT, O'Connor TP, Belachew T, O'Brien NM. Variations between post- and pre-harvest seasons in stunting, wasting, and infant and young child feeding (IYCF) practices among children 6-23 months of age in lowland and midland agro-ecological zones of rural Ethiopia. The Pan African Medical Journal. 2016;24:163. https:// doi.org/10.11604/pamj.2016.24.163.938.

107. Kinyoki DK, Berkley JA, Moloney GM, Odundo EO, Kandala NB, Noor AM. Space-time mapping of wasting among children under the age of five years in Somalia from 2007 to 2010. Spatial and Spatio-Temporal Epidemiology. 2016;16:77-87.

108. Abebe Y, Stoecker BJ, Hinds MJ, Gates GE. Nutritive value and sensory acceptability of corn- and kocho-based foods supplemented with legumes for infant feeding in Southern Ethiopia. African Journal of Food, Agriculture, Nutrition and Development. 2006;6(1). https://agris.fao.org/agris-search/search.do?recordID=AJ2013001698.

109. Bosha T, Lambert C, Riedel S, Melesse A, Biesalski HK. Dietary diversity and anthropometric status of mother-child pairs from enset (false banana) staple areas: A panel evidence from Southern Ethiopia. International Journal of Environmental Research and Public Health. 2019;16(12):2170. https:// doi.org/10.3390/ijerph16122170.

110. Ferro-Luzzi A, Morris SS, Taffesse S, Demissie T, D'Amato M. Seasonal undernutrition in rural Ethiopia: Magnitude, correlates, and functional significance. Food and Nutrition Bulletin. 2002;23(4):421-2.

111. Branca F, Pastore G, Demissie T, Ferro-Luzzi A. The nutritional impact of seasonality in children and adults of rural Ethiopia. European Journal of Clinical Nutrition. 1993;47(12):840-50.

112. Sidama Regional Health Bureau Report, Hawassa, Sidama National Region State, Ethiopia. 2020.

113. Adane A. Assessment of food security situation of the rural households: The case of Boricha Woreda of Sidama Zone, Ethiopia. GeoJournal. 2021;86(2):711-27.

114. Dabaro D, Birhanu Z, Negash A, Hawaria D, Yewhalaw D. Effects of rainfall, temperature and topography on malaria incidence in elimination targeted district of Ethiopia. Malaria Journal. 2021;20(1):Article 104.

115. Hagos SG, Lunde T, Mariam Dh, Woldehanna T, Lindtjørn B. Is the adapted Household Food Insecurity Access Scale (HFIAS) developed internationally to measure food insecurity valid in urban and rural households of Ethiopia? BMC Nutrition. 2015;1(1):Article 2.

116. Coates J, Swindale A, Bilinsky P. Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide. Washington, D.C. 20009-57212007. Available from: https://www.fantaproject.org/sites/default/files/resources/HFIAS_ENG_v3_Aug07.pdf.

117. Kabalo BY, Gebreyesus EH, Loha E, Lindtjørn B. Performance of an adapted household food insecurity access scale in measuring seasonality in household food insecurity in rural Ethiopia: A cohort analysis. BMC Nutrition. 2019;5(54). https://doi.org/10.1186/s40795-019-0323-6.

118. Swindale A, Bilinsky. P. Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide (v.2).Washington, D.C.: FHI 360/FANTA. 2006. Available from: https://www.fantaproject.org/sites/default/files/resources/HDDS_v2_Sep06_0.pdf.

119. WHO. Physical status: The use and interpretation of anthropometry. Report of a WHO Expert Committee. World Health Organization Technical Report Series. 1995;854:1-452.

120. WHO Multicentre Growth Reference Study Group. WHO Child Growth Standards: Length/height-for-age, weight-forage, weight-for-length, weight-for-height and body mass index-for-age: Methods and Development. World Health Organization, 2006.

121. Beal T, Tumilowicz A. A review of child stunting determinants in Indonesia. Maternal and Child Nutrition. 2018;14(4):e12617.

122. Ethiopian Federal Ministry of Health. Protocol for the Management of Severe Acute Malnutrition; March 2007, p. 6-7. Available from: https://www.ennonline.net/attachments/897/ethiopia-sam-guideline-march-2007.pdf.

123. Grimes DA, Schulz KF. Cohort studies: Marching towards outcomes. The Lancet. 2002;359(9303):341-5.

124. Song JW, Chung KC. Observational studies: Ccohort and case-control studies. Plastic and Reconstructive Surgery. 2010;126(6):2234-42. .

125. Rothman KJ, Greenland S, Lash TL. Modern Epidemiology. Lippincott Williams & Wilkins; 2008.

126. Lichtenstein AH, Petersen K, Barger K, Hansen KE, Anderson CAM, Baer DJ, et al. Perspective: Design and Conduct of Human Nutrition Randomized Controlled Trials. Advances in Nutrition. 2021;12(1):4-20.

127. Taherdoost H. Determining sample size: How to calculate survey sample size. International Journal of Economics and Management Systems. 2017;2:237-9.

128. Banerjee A, Chitnis UB, Jadhav SL, Bhawalkar JS, Chaudhury S. Hypothesis testing, type I and type II errors. Indian Psychiatry Journal. 2009;18(2):127-31.

129. Sedgwick P. Multistage sampling. BMJ. 2015;351:h4155.

130. Grimes DA, Schulz KF. Bias and causal associations in observational research. The Lancet. 2002;359(9302):248-52.

131. Sedgwick P. Non-response bias versus response bias. BMJ. 2014;348:g2573. https://doi.org/10.1136/bmj.g2573.

132. Remington RD, Taylor HL, Buskirk ER. A method for assessing volunteer bias and its application to a cardiovascular disease prevention progamme involving physical activity. Journal of Epidemiology and Community Health. 1978;32(4):250-5.

133. Althubaiti A. Information bias in health research: Definition, pitfalls, and adjustment methods. Journal of Multidisciplinary Healthcare. 2016;9:211-7.

134. Mamdani M, Sykora K, Li P, Normand S-LT, Streiner DL, Austin PC, et al. Reader's guide to critical appraisal of cohort studies: 2. Assessing potential for confounding. BMJ (Clinical Research Edition). 2005;330(7497):960-2.

135. Zaccai JH. How to assess epidemiological studies. Postgraduate Medical Journal. 2004;80(941):140-7.

136. David M, Ware R, Donald M, Alati R. Assessing generalisability through the use of disease registers: Findings from a diabetes cohort study. BMJ Open. 2011;1(1):e000078.

137. Fedak KM, Bernal A, Capshaw ZA, Gross S. Applying the Bradford Hill criteria in the 21st century: How data integration has changed causal inference in molecular epidemiology. Emerging Themes in Epidemiology. 2015;12:14. https:// doi.org/10.1186/s12982-015-0037-4.

138. Sibhatu KT, Qaim M. Rural food security, subsistence agriculture, and seasonality. PloS One. 2017;12(10):e0186406.

139. Obayelu AE. Households' food security status and its determinants in the North-Central Nigeria. Food Economics. 2012;9(4):241-56.

140. Becquey E, Delpeuch F, Konaté AM, Delsol H, Lange M, Zoungrana M, et al. Seasonality of the dietary dimension of household food security in urban Burkina Faso. British Journal of Nutrition. 2012;107(12):1860-70.

141. Abizari A-R, Azupogo F, Nagasu M, Creemers N, Brouwer ID. Seasonality affects dietary diversity of school-age children in northern Ghana. PloS One. 2017;12(8):e0183206.

142. Nepali S, Simkhada P, Davies IG. Association between wasting and food insecurity among children under five years: Findings from Nepal demographic health survey 2016. BMC Public Health. 2020;20(1):Article 1027.

143. The Lancet Child & Adolescent Health (Editorial). Tackling the multidimensionality of child poverty. The Lancet Child & Adolescent Health. 2019;3(4):199. https:// doi.org/10.1016/S2352-4642(19)30067-7.

144. Petrou S, Kupek E. Poverty and childhood undernutrition in developing countries: A multi-national cohort study. Social Science & Medicine. 2010;71(7):1366-73.

145. Forsido SF, Tadesse F, Belachew T, Hensel O. Maternal dietary practices, dietary diversity, and nutrient composition of diets of lactating mothers in Jimma Zone, Southwest Ethiopia. PloS One. 2021;16(7):e0254259.

146. Savy M, Martin-Prével Y, Traissac P, Delpeuch F. Measuring dietary diversity in rural Burkina Faso: Comparison of a 1-day and a 3-day dietary recall. Public Health Nutrition. 2007;10(1):71-8.

147. Savy M, Martin-Prével Y, Sawadogo P, Kameli Y, Delpeuch F. Use of variety/diversity scores for diet quality measurement: Relation with nutritional status of women in a rural area in Burkina Faso. European Journal of Clinical Nutrition. 2005;59(5):703-16.

148. Hatløy A, Hallund J, Diarra MM, Oshaug A. Food variety, socioeconomic status and nutritional status in urban and rural areas in Koutiala (Mali). Public Health Nutrition. 2000;3(1):57-65.

149. Onyango A, Koski KG, Tucker KL. Food diversity versus breastfeeding choice in determining anthropometric status in rural Kenyan toddlers. International Journal of Epidemiology. 1998;27(3):484-9.

150. Pelto GH, Armar-Klemesu M, Siekmann J, Schofield D. The focused ethnographic study 'Assessing the behavioral and local market environment for improving the diets of infants and young children 6 to 23 months old' and its use in three countries. Maternal & Child Nutrition. 2013;9 Suppl 1:35-46.

151. Cleghorn G. Role of red meat in the diet for children and adolescents. Nutrition & Dietetics. 2007;64(S4):S143-S6.

152. Muslimatun S, Wiradnyani LA. Dietary diversity, animal source food consumption and linear growth among children aged 1-5 years in Bandung, Indonesia: A longitudinal observational study. British Journal of Nutrition. 2016;116 Suppl 1:S27-S35.

153. Zhao W, Yu K, Tan S, Zheng Y, Zhao A, Wang P, et al. Dietary diversity scores: An indicator of micronutrient inadequacy instead of obesity for Chinese children. BMC Public Health. 2017;17(1):440. https:// doi.org/10.1186/s12889-017-4381-x.

154. Oyekale A, editor. Factors Explaining Acute Malnutrition Among Under-Five Children in Sub-Sahara Africa (SSA). 2012. Available at: file:///C:/Users/user/Downloads/Documents/314_11976life0904_2101_2107.pdf.

155. Keats A. Women's schooling, fertility, and child health outcomes: Evidence from Uganda's free primary education program. Journal of Development Economics. 2018;135:142-59.

156. Sunguya BF, Poudel KC, Mlunde LB, Urassa DP, Yasuoka J, Jimba M. Poor nutrition status and associated feeding practices among HIV-positive children in a food secure region in Tanzania: A call for tailored nutrition training. PloS One. 2014;9(5):e98308

157. Bhutta ZA, Ahmed T, Black RE, Cousens S, Dewey K, Giugliani E, et al. What works? Interventions for maternal and child undernutrition and survival. The Lancet. 2008;371(9610):417-40.

158. Girma W, Genebo T. Determinants of nutritional status of women and children in Ethiopia. Addis Ababa, Ethiopia, Ethiopia Health and Nutrition Research Institute, ORC Macro, Calverton; 2002. https://dhsprogram.com/pubs/pdf/fa39/02-nutrition.pdf.

159. Vollmer S, Bommer C, Krishna A, Harttgen K, Subramanian SV. The association of parental education with childhood undernutrition in low- and middle-income countries: Comparing the role of paternal and maternal education. International Journal of Epidemiology. 2017;46(1):312-23.

160. Nankinga O, Kwagala B, Walakira EJ. Maternal employment and child nutritional status in Uganda. PloS One. 2019;14(12):e0226720.

161. Ukwuani FA, Suchindran CM. Implications of women's work for child nutritional status in sub-Saharan Africa: A case study of Nigeria. Social Science & Medicine. 2003;56(10):2109-21.

162. Shroff MR, Griffiths PL, Suchindran C, Nagalla B, Vazir S, Bentley ME. Does maternal autonomy influence feeding practices and infant growth in rural India? Social Science & Medicine. 2011;73(3):447-55.

163. Nigatu G, Assefa Woreta S, Akalu TY, Yenit MK. Prevalence and associated factors of underweight among children 6-59 months of age in Takusa district, Northwest Ethiopia. International Journal for Equity in Health. 2018;17(1):Article 106.

164. Fentahun W, Wubshet M, Tariku A. Undernutrition and associated factors among children aged 6-59 months in East Belesa District, northwest Ethiopia: A community based cross-sectional study. BMC Public Health. 2016;16(1):Article 506.

165. Ersino G, Zello GA, Henry CJ, Regassa N. Gender and household structure factors associated with maternal and child undernutrition in rural communities in Ethiopia. PloS One. 2018;13(10):e0203914.

166. Díaz-Gutiérrez J, Martínez-González MÁ, Pons Izquierdo JJ, González-Muniesa P, Martínez JA, Bes-Rastrollo M. Living at higher altitude and incidence of overweight/obesity: Prospective analysis of the SUN cohort. PloS One. 2016;11(11):e0164483-e.

167. Hagos S, Lunde T, Mariam DH, Woldehanna T, Lindtjørn B. Climate change, crop production and child undernutrition in Ethiopia: A longitudinal panel study. BMC Public Health. 2014;14(1):884. https:// doi.org/10.1186/1471-2458-14-884.

168. Mohammed SH, Habtewold T, Alizadeh S, Larijani B, Esmaillzadeh A. The relationship between residential altitude and stunting: Evidence from >26,000 children living in highlands and lowlands of Ethiopia. British Journal of Nutrition. 2020;123(8):934-941.

169. Headey D, Dereje M, Taffesse AS. Land constraints and agricultural intensification in Ethiopia: A village-level analysis of high-potential areas. Food Policy. 2014;48:129-41.

170. Hu FB, Willett WC. Current and Future Landscape of Nutritional Epidemiologic Research. JAMA. 2018;320(20):2073-4.

171. UKEssays. Anthropometric Measurements and the Limitations of Assessment of Nutritional Status. Available from: https://www.ukessays.com/essays/nutrition/anthropometric-measurements-and-the-limitations-of-assessment-of-nutritional-status.php?vref=1.

172. Satija A, Yu E, Willett WC, Hu FB. Understanding nutritional epidemiology and its role in policy. Advances in Nutrition. 2015;6(1):5-18.

173. Lemonnier D, Acher S, Boukaïba N, Flament C, Doucet C, Piau A, et al. Discrepancy between anthropometry and biochemistry in the assessment of the nutritional status of the elderly. European Journal of Clinical Nutrition. 1991;45(6):281-6.

174. Post CLA, Victora CG. The Low Prevalence of Weight-for-Height Deficits in Brazilian Children Is Related to Body Proportions. The Journal of Nutrition. 2001;131(4):1290-6.

175. Lundeen EA, Stein AD, Adair LS, Behrman JR, Bhargava SK, Dearden KA, et al. Height-for-age z scores increase despite increasing height deficits among children in 5 developing countries. The American Journal of Clinical Nutrition. 2014;100(3):821-5.

176. Fitzgerald R, Manguerra H, Arndt Michael B, Gardner William M, Chang Y-Y, Zigler B, et al. Current dichotomous metrics obscure trends in severe and extreme child growth failure. Science Advances. 2022;8(20). https://www.science.org/doi/10.1126/sciadv.abm8954.

177. Schwingshackl L, Schwedhelm C, Hoffmann G, Lampousi AM, Knüppel S, Iqbal K, et al. Food groups and risk of all-cause mortality: A systematic review and meta-analysis of prospective studies. American Journal of Clinical Nutrition. 2017;105(6):1462-73.

178. Ioannidis JPA. The challenge of reforming nutritional epidemiologic research. JAMA. 2018;320(10):969-70.

Appendices

Paper I

Ecology of Food and Nutrition

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Seasonal Variation of Household Food Insecurity and Household Dietary Diversity on Wasting and Stunting among Young Children in A Drought Prone Area in South Ethiopia: A Cohort Study

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Seasonal Variation of Household Food Insecurity and Household Dietary Diversity on Wasting and Stunting among Young Children in A Drought Prone Area in South Ethiopia: A Cohort Study

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ABSTRACT
This study was conducted to evaluate seasonal patterns of household food insecurity, dietary diversity, and household characteristics on wasting and stunting among children in households followed for 1 year in the drought-prone areas of Sidama, Ethiopia. A cohort study design was employed. Data were collected on the pre-harvest season (March and June) and post-harvest season (September and December) of 2017. We studied 935 children aged 6 to 47 months. At four seasons over a year, we had 3,449 observations from 897 households and 82% (2,816) (95% CI: 80.3–82.9) were food in-secured households. Severe food insecurity was higher in the pre-harvest (March; food scarcity season) which was 69% as compared to 50% of September ($P < .001$). From 3,312 observations, 43% (1,408) (95% CI: 40.8-44.2) of children were stunted. Stunting showed seasonal variations with 36% (95% CI: 32.5-39.0) in March and 48% (95% CI: 45.0-51.8) in December. Six percent (95% CI: 4.8-6.3) of children were wasted, with higher prevalence in March (8%) as compared to 3% of September ($P < .001$). Moreover, household characteristics such as poverty level, education, occupation and the household food insecurity and dietary diversity were associated with subsequent wasting or stunting.

KEYWORDS
Seasonal variation; food insecurity; dietary diversity; wasting; stunting; Ethiopia

Introduction

Globally, about 800 million people are food unsecured and 2 billion people experience micronutrient deficiencies (Pérez-Escamilla 2017). Food insecurity is a public health problem, especially in the African Sahel and in the lowlands in Ethiopia which has often been affected by drought and famines (Graves et al. 2019; Lindtjørn 1990; Regassa and Stoecker 2012). Food insecurity emerges as a predictor of child wasting and stunting. Although governments and international organizations developed nutrition policies and use

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interventional programs to reduce the burden of malnutrition (Tumilowicz et al. 2018), one possible reason why they did not achieve the target was that previous interventions did not sufficiently address the local contexts (Tumilowicz et al. 2018).

Although Ethiopia remains among the 20 poorest countries in the world (UNDP 2019), there has during the last 20 years been a rapid economic growth with increased per capita gross domestic product (GDP) with reductions in rates of poverty and stunting (Golan et al. 2019). According to four consecutive demographic and health surveys, the prevalence of stunting was 52% in 2000 (CSA 2001), 47% in 2005 (CSA 2006), 44% in 2011 (CSA 2012), and 38% in 2016 (CSA 2016). This shows that stunting has fallen by 2.5% per year. However, stunting still remains high, especially in rural areas and among the poorest (Golan et al. 2019). The prevalence of wasting has remained fairly constant and high at about 10% from 2000 to 2016, according to several Ethiopian Demographic Health Surveys (CSA 2001, 2006, 2012, 2016)

There are multiple risk factors of stunting according to the WHO conceptual framework (Beal et al. 2018). Previously conducted cross-sectional studies in Ethiopia revealed that there are numerous factors responsible for child wasting and stunting. These can broadly be classified into basic factors like child characteristics (Woldeamanuel and Tesfaye 2019), parental characteristics (Kahssay et al. 2020), and household characteristics (Woldeamanuel and Tesfaye 2019). Moreover, underlying factors like food insecurity (Mulu and Mengistie 2017) and sanitation (Girma et al. 2019; Kahssay et al. 2020; Woldeamanuel and Tesfaye 2019) and immediate factors such as inadequate dietary intake (Girma et al. 2019) and infections (Mulu and Mengistie 2017; Woldeamanuel and Tesfaye 2019) were associated with child wasting and stunting. However, there is a lack of information about risk factors of child wasting and stunting evaluated through cohort study in drought-prone areas of Sidama.

Ethiopia is committed to reducing child malnutrition by improving food availability, access, and consumption of nutritious food (Governement of the Federal Democratic Republic of Ethiopia 2016a), and adopted the “Seqota Declaration of 2015” with its ambitious goal of ending child malnutrition by the year 2030 (Governement of the Federal Democratic Republic of Ethiopia 2016b).

Malnutrition rates are highly sensitive to agricultural practice (Ruel and Alderman 2013) which is the main economic source of income for rural Ethiopian communities (Dadi 2013). Ethiopian farmers practice subsistence farming, which depends on rainfall (Abreha 2007), and in such communities, inadequate rain often leads to food shortages. If severe, such shortages lead to famines (Dadi 2013).

Boricha in Sidama in southern Ethiopia, where this study was conducted, has repeatedly been affected by famines. It is an area with high population growth (Tesfaye 2011), a chronically food-insecure area, and a large part of the population are supported by the Productive Safety Net Program (PSNP) (Tesfaye 2011). An earlier study from Boricha has shown that about 80% of households were food in-secured (Regassa and Stoecker 2012), and in 2017, about 12,100 households received such support (Boricha Woreda Agricultural Office Report 2017). Even in years with good rains, many households do not produce enough food for the whole year (Tesfaye 2011)

Most of the earlier studies conducted in Ethiopia were cross-sectional, and thus do not tell about the time relationship between food security, food availability and diversity, and the subsequent development of acute and chronic malnutrition. Some studies show that there are differences in wasting prevalence rates between the dry and wet seasons (Kinyoki et al. 2016) and between post-harvest and pre-harvest seasons (Roba et al. 2016). Earlier research from Sidama, where the current study was done showed seasonal wasting where nutrient-poor enset *(Ensete ventricosum)* is the major staple crop (Abebe et al. 2006; Bosha et al. 2019; Ferro-Luzzi et al. 2001). These studies were from the more fertile area of Sidama than the current study which was carried out in a drought-prone population, and also showed that children and adults both suffered from exposure to seasonal energy stress. Changes in weight-for-height Z-score were greater in individuals of low socioeconomic status (Branca et al. 1993).

Ethiopia requires effective community-based nutrition interventions with a multi-disciplinary approach to curb childhood malnutrition (Egata, Berhane, and Worku 2013). Implementation of community nutrition programs may require improved understanding of the local context and seasonality between the food diversity, rainfall pattern, occurrence of food security, wasting and stunting. Moreover, determining risk factors of child-undernutrition through cohort study would give stronger evidence about childhood wasting and stunting. Such information is not only important for policymakers at the national and regional levels but also for the practitioners of local public health and nutrition in the communities.

To our knowledge, few studies have evaluated the time relationship between exposure variables such as household characteristics, food insecurity, food diversity, on outcomes such as wasting (acute malnutrition) and stunting (chronic malnutrition) in different seasons of the year in Ethiopia. Such an understanding is important for public health and nutrition when implementing community-based nutrition interventions. Hence, the aim of this paper is to evaluate seasonal patterns of household food insecurity, dietary diversity, and household characteristics on wasting and stunting among children in households followed for 1 year in the drought-prone areas of Sidama, Ethiopia.

Methods and materials

Study design, period, and setting

We used a cohort study design to conduct a community-based follow-up study. We visited each selected household repeatedly over the course of 1 year to assess the risks of child wasting and stunting in different seasons.

Boricha is located in the Sidama Zone in the Southern Nation Nationalities and the Regional State of Ethiopia. It covers about 588 square km, and it is about 330 km from the capital city of Ethiopia. Located at 6° 46′N and 38° 04′E to 7° 01′N and 38° 24′E, its altitude is 1200–1800 mm above sea level. Most of its 315,000 people, 14% of whom are children aged 6–59 months, belong to the Sidama ethnic group and speak Sidamu Afoo. Most (95%) of the population live in rural areas, and most (95%) are subsistence farmers, though a few (4.5%) are merchants. The average family has five members, and the population density is 409 persons per square kilometer (Tesfaye 2011).

Boricha's subsistence agriculture system comprises mostly small, rain-fed farms that produce maize, enset (*Enset ventricosum*), potatoes, haricot beans, sweet potatoes, and teff. Some farmers grow cash crops like coffee, chat, spices, and eucalyptus. Livestock provide transport, milk, meat, and eggs, which are important income sources, though yield is typically low.

High population growth, absence of adequate surface water for irrigation, inaccessibility of underground water, decreasing soil fertility, low rainfalls, land degradation, and deforestation are important contributors to food insecurity in the area (Tesfaye 2011). Figure 1 shows a map of the Boricha district.

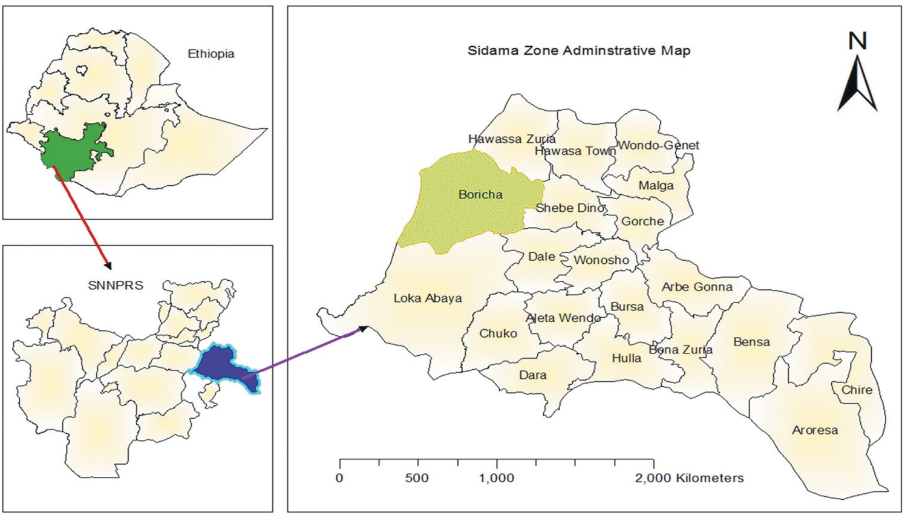

Figure 1. Boricha district map, Sidama, Southern Ethiopia, Ethiopia, 2017.

The rainy seasons in Sidama are biannual, and the *Belg* rains which last from March to Maycontribute to most of the crop production. The *Keremt* rains usually last from June to September and are smaller (Dadi 2013). Thus, following the agricultural cycle, the season of plenty usually occurs after the *Belg* harvest (mid-June to August) and Keremt harvest (October to November).

Outcome and exposure variables

We used the WHO conceptual framework (Beal et al. 2018) and analyzed our cohort study data using possible exposures of child malnutrition such as household characteristics, food access, food utilization, and seasonal variations of food security on our main outcome variables stunting and wasting.

The main outcomes of the study were the prevalence of stunting and wasting among children aged less than 5 years. The main exposure variables were season, wealth, household food insecurity access, household dietary diversity, child morbidity in the past 2 weeks, mother's marital status, family size, maternal age, maternal education, maternal occupation, child sex, child age in month, paternal education, paternal occupation, child's place of birth order, and if the child had been exclusively breastfed. Parental occupation was registered as the main economic activity of mothers and fathers, and could be housewife, daily laborer, government worker, farmer or merchant. In rural areas, for example, a father who works as a daily laborer could have farmland. A merchant husband usually has agriculture in addition to his business and his land size could even be large than that of an ordinary farmer. This may indirectly inform about different income-generating activities in addition to agricultural production. Even government workers have agricultural land in the rural part of Ethiopia. Therefore, we believe that occupation is an indicator of main income-generating activities of the household.

Study population and sampling

A two-stage sampling technique was employed. First, nine rural kebeles were randomly selected from the 39 rural kebeles (smallest administrative unit) in Boricha. Secondly, a cluster sampling technique was used to choose households from each sub-kebele's ("*gouts*") of the selected kebeles. Households with mothers who had children aged 6–47 months were included. The final sample included 897 households with 935 children, and all eligible children were included in our study. Respondents at interviews were biological mothers unless they had died or were divorced.

The sample size was calculated using OpenEpi 303 software (Dean, Sullivan, and Soe 2013). The sample size was estimated based on the following assumption: 95% level of confidence, 80% power, proportion of wasting in the lowland region of Ethiopia at the post-harvest season 12.6%, proportion of wasting in the lowland region of Ethiopia at the pre-harvest season 6.6% (Roba et al. 2016)., and 15% non-response rate yielding a total of 872. However, we collected data from a total of 935 children. Figure 2 provides a detailed description of the study population.

Data collection procedures

Pretested and structured questionnaires were used to gather information about the household conditions, child health and nutrition characteristics, household dietary diversity, and household food security.

The data collectors had completed grades 10, 11, or 12, and were fluent speakers of the local *Sidamu Afoo* language and were familiar with the local area. The 18 data collectors and three supervisors were trained outside of the selected kebeles to conduct pretests using a structured questionnaire. Data collectors were assigned in pairs to maintain the quality of data collection. The questionnaire was prepared in English and then translated to *Sidamu Afoo* by the principal investigator (MB) and scrutinized by an experienced translator.

We used four season categories for data collection, based on the area's agricultural cycle: *Tsedey* (September, October, and November), *Bega* (December, January, and February), *Belg* (March, April, and May), and *Keremt* (June, July, and August). Data were collected in 2017 at the end of each seasonal month and beginning of each new season; that is, in December, March, June, and September. The questionnaires were checked for completeness, and households with incomplete questionnaires were re-visited, and all mistakes were corrected.

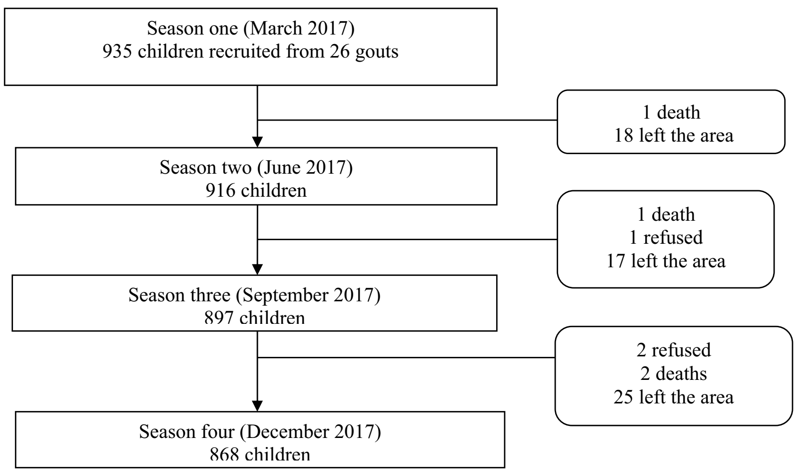

Figure 2. Study profile of children, Boricha district, Sidama, South Ethiopia, March through December 2017.

Child morbidity

Childhood diarrhea was defined as the passage of loose or liquid stools more frequently (three or more times per day) within 2 weeks period preceding to survey (WHO 2005). Fever was defined as an abnormally high body temperature assessed by asking mothers "Does the child's body feel hot" and cough was assessed by asking mothers "Did the child have cough in the 2 weeks„ preceding survey period (WHO 2005). The alternative response for the occurrence of diarrhea, fever, and cough was categorized as "Yes" or "No". Thus, child morbidity was the occurrence of diarrhea or cough or a fever in the 2 weeks preceding the data collection.

Food insecurity

Food security status was assessed using nine occurrence items and nine frequency questions of the Household Food Insecurity Access Scale (HFIAS), validated for Ethiopia, including measurements at different seasons (Coates, Swindale, and Bilinsky 2007; Hagos et al. 2015; Kabalo et al. 2019). The nine occurrence items were as follows: 1. worry about food, 2. unable to eat preferred food, 3. eat just a few kinds of food, 4. eat foods they really did not want to eat, 5. eat a smaller meal, 6. eat fewer meals in a day, 7. no food of any kind in the household, 8. go to sleep hungry, and 9. go a whole day and night without eating. The three major domains included anxiety and uncertainty about household food, insufficient quality, and insufficient food intake (Coates, Swindale, and Bilinsky 2007). The nine frequency follow-up questions measured the occurrence of the event in the previous 4 weeks. Food insecurity was classified as secure, mild, moderate, and severe, based on the HFIAS indicator guide version 3 (Coates, Swindale, and Bilinsky 2007). A food-secure household did not experience any or only rare food insecurity conditions, whereas severely food-insecure households often experienced insufficient food intake (Coates, Swindale, and Bilinsky 2007). Detailed information about the food insecurity classification is available in the HFIAS indicator guide (Coates, Swindale, and Bilinsky 2007).

Dietary diversity

Household Dietary Diversity Score of 24 hours recall measurements was utilized to measure household dietary diversity. A household dietary diversity used the past 24 hours recall for 12 food-groups and include cereals, roots or tubers, vegetables, fruits, meat or poultry, eggs, fish and seafood, pulses or legumes or nuts, milk and milk products, oil or fats, sugar or honey, and miscellaneous (Swindale and Bilinsky 2006).

Wealth index

Principal component analysis was used to construct the wealth index using household assets (Rutstein and Staveteig 2014). From the 28 initial variables, 11 were included in the analysis. Variables with 95% and above similar responses were dropped. Included were variables such as type and number of livestock (cow/oxen, chickens, goat, sheep, and horses); ownership of improved sanitation (latrine) facility; type of cooking fuel; housing condition (main construction of house wall, floor, and roof); number of sleeping rooms; ownership of chair; and ownership of a working mobile telephone. The principal component analysis revealed a Kaiser-Meyer-Olkin sampling adequacy of 0.67 and a significance level below 0.001. Finally, of the 11 components, four exceeded an initial eigenvalue of 1. Household wealth status was ranked based on percentile groups into five groups that had approximately the same number of cases: poorest, poor, medium, rich, and richest (Rutstein and Staveteig 2014).

Anthropometric measurements

Measurements were evaluated on children's weight, height, recorded age, and mid-upper arm circumference, using Emergency Nutrition Assessment for Standardized Monitoring and Assessment of Relief and Transitions software version 2011 (Erhardt, Golden, and Seaman 2011). Repeated evaluations were conducted until the coefficient of reliability reached 90% during the pretest. For children less than 24 months of age, height was measured in a recumbent position, using a length board, to the nearest 0.1 cm. Children older than 2 years were measured in the standing position to the nearest 0.1 cm. Weight was measured with light clothes and recorded to the nearest 100 g using a digital SECA scale (SECA GmbH, Germany). Child age was assessed using mothers' recall and using memorable events to aid in the recall.

Wasting and stunting were calculated based on the 2006 WHO Multi-center Growth Reference study cutoff values. Children whose weight-for-height Z (WHZ) scores were lower than −2 were classified as wasted, and children whose height-for-age Z (HAZ) scores were lower than −2 were categorized as stunted (WHO 2006).

Data analysis

Data were double entered using EpiData version 3.1 (Christiansen and Lauritsen 2010) and exported for further analysis to STATA version 15 (StataCorp, Texas, USA). The anthropometric data were analyzed using the

WHO Anthro version 3.2.2 (World Health Organization, Geneva, Switzerland).

The natural sequence of data presentation was done following the World Health Organization conceptual framework for childhood stunting (Beal et al. 2018). Thus, first, we analyzed the correlation between continuous background variables such as wealth, age of mother, education level on intermediary variables such as household food insecurity and household dietary diversity. After that, we analyzed how both the background variables and household food insecurity and household dietary diversity were associated with subsequent measures of wasting and stunting. For this, we both used correlation and multivariate analysis.

To analyze data collected over a period of 1 year on the same households, we used longitudinal, binary outcome, mixed-effect logistic regression statistical analysis to analyze wasting and stunting. Thus, the anthropometric measurement in one season was controlled for in the subsequent season. Household level was included to Kebele level (smallest administrative unit) hierarchy due to the presence of more than one child in one household for wasting and stunting outcome analyses. The model construction used Kebele level and household level for random effect equations and exchangeable variance-covariance structure of specifications for random effects. Time setting of the model used season as time variable and child code as a panel ID variable. Robust standard-error estimator and the main effect of independent variables were used. The model reports *P*-value, test statistics, fixed effects coefficients as odds ratio, and confidence interval with 95% confidence.

Bivariate analysis for all important independent variables was conducted, and associations with *P*-value less than 0.20 were considered for multivariate analysis to control for confounding. We have used Pearson's chi-squared test to compare categorical data. Maternal age, maternal education, and maternal occupation variables were considered for multivariate analysis of wasting and child age was considered for multivariate analysis of stunting even if *P*-value is greater than 0.20. The final model intra-class correlation coefficient for wasting was 7% at Kebele level and 32% at the household level. The final model intra-class correlation coefficient for stunting was 13% at the kebele level and 89% at the household level. We have utilized Akaike information criterion to compare models and we found the final models of wasting and stunting had smaller Akaike information criterion (AIC) that indicates for a better-fitting model. However, this model does not account for our few time-varying covariates as if this model has no clearly identified way of managing time-varying covariates.

Ethical consideration

The institutional review board at Hawassa University, College of Medicine and Health Sciences (Ref. No: IRB/001/09, Date: 13/09/2016) and the Regional

Committee for Medical and Health Research Ethics, Western Norway (ref: 2016/1631/REK Vest) approved this research proposal. Written permission was obtained from the Sidama Zone health department, Woreda administrators and selected health institutions. Informed written consent was obtained from all participating mothers or caregivers before interview. Mothers who were unable to sign used their thumb prints.

Results

Baseline characteristics

The study included 935 children (505 boys and 427 girls) from 897 households. More than 99% (892 of 897) of respondents were the biological mothers of the children. Among the households, 92% (809 of 897) of household heads were men. The family size ranged from 3 to 12 members, with a mean of 5. The age of mothers ranged from 18 to 46, with a mean age of 28 years. About 50% (448 of 897) of mothers were illiterate, and 98% (872of 897) were married. Most (83%; 727 households) were Protestant Christians, and 98% (876 of 897) of mothers belonged to the Sidama ethnic group. Most (87%; 773) mothers were housewives who also worked on their farms. More than half of husbands (561; 63%) were farmers, and 37% (332 of 897) were illiterate. Table 1 lists detailed background information.

The following analysis is based on correlation analysis of different variables (correlation matrix).

Households characteristics at baseline and subsequent HFI and FD

Table 2 indicates that poverty at baseline was associated with household food insecurity at all seasons. Similarly, mothers with low education had increased household food insecurity at all seasons. Richer households also had increased food diversity. Larger family size and also increasing maternal age were associated with higher household food insecurity and lower food diversity.

We also found that household characteristics such as wealth status, child age, and maternal age were associated with stunting and wasting: Both lower education of the mother at the baseline and increasing child age were associated with increasing stunting at most of the seasons. Household food insecurity at the baseline was associated with increasing rates of wasting at all seasons. Similarly, food diversity at the baseline was also associated at most of the seasons for increasing stunting measurements. It also demonstrated that household food insecurity was associated with stunting and food diversity and further with wasting.

Thus, as described above, our univariate correlation analyses indicate that household characteristics were associated with household food insecurity and

Table 1. Baseline information about socioeconomic characteristics in Boricha district of Southern Ethiopia; March 2017.

Child Variables	March 2017 (n = 935)	
Child sex	Frequency	Percentage
Male	505	54.2%
Female	427	45.8%
Child age in months		
6–23 months	274	29.8%
24 month and above	645	70.2%
Household Variables	**March 2017 (n = 897)**	
Mother's age		
19 and below	2	0.2%
20–29	503	56.5%
30–39	361	40.6%
40 and above	24	2.7%
Mother's education		
Primary	402	45.1%
Secondary	42	4.7%
No formal education	448	50.2%
Mother's occupation		
Housewife & farmer	773	86.5%
Merchant/employed	98	11%
Other	23	2.6%
Father's education		
Primary	453	50.8%
Secondary and up	107	12%
No formal education	332	37.2%
Father's occupation		
Farmer	561	62.9%
Merchant/employed	237	26.6%
Other	94	10.5%
Family size		
5 and below	513	60.8%
Greater than 5	331	39.2%
Wealth status		
Poorest	179	20.1%
Poor	186	20.9%
Medium	169	18.9%
Rich	178	20%
Richest	180	20.2%
Religion		
Protestant	727	83.1%
Catholic	88	10.1%
Muslim	60	6.9%

dietary diversity, and household food insecurity and dietary diversity were associated with wasting and stunting of the children.

Household food insecurity

From 3,449 observations, 82% (2,816) reported being food insecure (95% CI: 80.3–82.9). Household food insecurity showed seasonal variations: the number of severely food-insecure households was higher in March (69%, 608 of 881) than in September (50%, 433 of 861) and December (38%, 320 of 835). Similarly, the number of severely food-insecure households was higher in June (76%, 666 of 871) than in September (50%, 433 of 861) and December (38%, 320 of 835). These findings indicate that the post-harvest seasons (September

Table 2. Correlation matrix of continuous variables to assess an association between baseline characteristics, household food insecurity, household dietary diversity, wasting, and stunting in four different seasons.

Variable	HFI 1	HFI 2	HFI 3	HFI 4	FD 1	FD 3	FD 4	WHZ1	WHZ2	WHZ3	WHZ4	HAZ 1	HAZ2	HAZ3	HAZ4
Increased Wealth	–0.43 (0.00)	–0.37 (0.00)	–0.29 (0.00)	–0.09 (0.004)	0.23 (0.00)	0.16 (0.00)	0.03 (0.45)	0.035 (0.31)	–0.017 (0.61)	0.08 (0.03)	0.001 (0.98)	0.06 (0.09)	0.04 (0.26)	0.04 (0.22)	0.12 (0.001)
Increased Mother education	20.24 (0.00)	–0.28 (0.00)	–0.10 (0.003)	–0.20 (0.00)	0.13 (0.00)	0.06 (0.07)	0.07 (0.05)	0.02 (0.54)	0.01 (0.81)	0.025 (0.48)	–0.001 (0.97)	0.09 (0.005)	0.08 (0.02)	0.07 (0.07)	0.11 (0.001)
Increased Family size	0.09 (0.004)	0.11 (0.001)	0.02 (0.63)	0.06 (0.10)	–0.07 (0.04)	–0.02 (0.49)	0.02 (0.64)	–0.06 (0.11)	–0.07 (0.03)	–0.06 (0.11)	–0.012 (0.74)	–0.04 (0.24)	–0.008 (0.82)	–0.002 (0.95)	–0.02 (0.56)
Increased Maternal age	0.19 (0.00)	0.08 (0.02)	0.06 (0.07)	–0.11 (0.002)	–0.09 (0.01)	0.05 (0.13)	–0.01 (0.71)	–0.01 (0.78)	0.02 (0.53)	0.03 (0.45)	0.08 (0.03)	–0.03 (0.36)	–0.06 (0.078)	–0.09 (0.01)	–0.13 (0.0004)
Increased Child age								0.05 (0.19)	0.02 (0.63)	–0.11 (0.002)	–0.18 (0.00)	–0.20 (0.00)	–0.13 (0.00)	–0.05 (0.18)	–0.02 (0.53)
Child sex								0.03 (0.36)	0.005 (0.89)	0.06 (0.10)	0.04 (0.28)	0.04 (0.21)	0.001 (0.78)	0.026 (0.46)	0.007 (0.84)
HFI1					–0.31 (0.00)	–0.37 (0.00)	–0.17 (0.00)	–0.13 (0.00)	–0.09 (0.01)	–0.11 (0.002)	–0.13 (0.00)	0.04 (0.29)	0.002 (0.95)	–0.04 (0.25)	–0.01 (0.85)
HFI2						–0.27 (0.00)	–0.19 (0.00)	–	–0.09 (0.006)	–0.09 (0.01)	–0.11 (0.002)	–	–0.06 (0.07)	–0.07 (0.06)	–0.05 (0.13)
HFI3						–0.42 (0.00)	–0.08 (0.02)	–	–	–0.18 (0.00)	–0.11 (0.002)	–	–	–0.02 (0.67)	–0.01 (0.75)
HFI4							–0.28 (0.00)	–	–	–	–0.19 (0.00)	–	–	–	0.09 (0.013)
FD1								–0.04 (0.23)	0.004 (0.90)	–0.006 (0.85)	–0.01 (0.83)	0.08 (0.02)	0.09 (0.01)	0.09 (0.01)	0.06 (0.08)
FD3								–		0.13 (0.00)	0.15 (0.00)	–		–0.03 (0.45)	–0.05 (0.17)
FD4								–	–	–	0.07 (0.06)	–	–	–	–0.005 (0.90)

HFI1 = Household food insecurity score in season 1, FD1 = Food diversity score in season1, WHZ1 = weight-for-height Z scores in season 1, HAZ 1 = Height-for-age Z score in season 1; Numbers next to acronyms indicated for seasons. For example, 1 = season 1, 2 = season 2, 3 = season3 and 4 = season 4 and December) were better than the food-scarce, pre-harvest seasons (March and June). Seasonal variation was observed for food insecurity, acute malnutrition (wasting), and chronic malnutrition (stunting). Acute malnutrition (wasting) decreased as the household food insecurity decreased. The prevalence of stunting increased one season later than the increase in household food insecurity prevalence. See Figure 3 for information.

Household dietary diversity

The mean household dietary diversity score was 5 food groups per day. The household's consumption of food groups showed seasonal variations: the number of households who had lowest food diversity (≤3) was higher in March (32%, 285 of 879) than in September (22%, 185 of 854) and December (6%, 48 of 830). These findings indicate that the pre-harvest season (season of scarcity) of March had the least diet diversity as compared to post-harvest seasons (September and December). See the table for the overall dietary diversity across three seasons (Table 3).

Regarding responses to household dietary diversity items (Figure 4), the highest consumed food group was condiments that accounted for 2,493 (97%) followed by food groups such as of cereals which was 2,330 (90%). The least consumed food group was fish and eggs, and they accounted for 3%. In

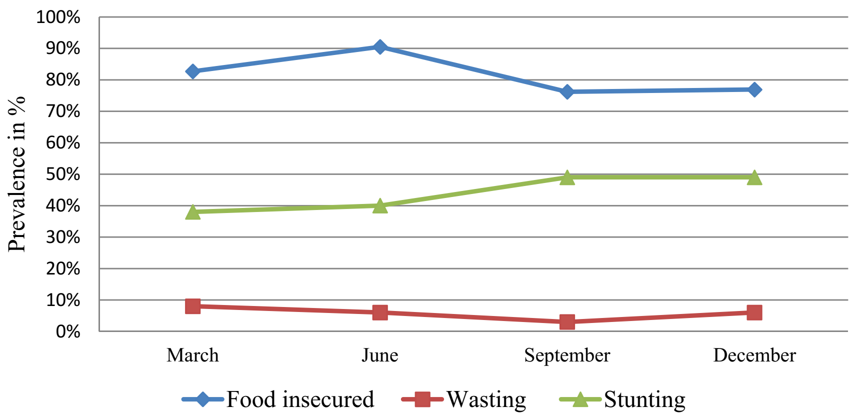

Figure 3. Seasonal variation trend line of food insecurity, wasting, and stunting among children under age five years, Boricha, South Ethiopia, 2017.

Table 3. The overall seasonal pattern of household food consumption, Boricha, Southern Ethiopia, 2017.

Season	Lowest (≤ 3) food groups	Above 4 food groups	X^2	P-value	Odds ratio	95% confidence limit
March	285 (32.2%)	599 (67.8%)	Ref	Ref	Ref	Ref
September	185 (21.5%)	675 (78.5)	25	< 0.001	0.58	0.46–0.71
December	48 (5.8%)	785 (94.2%)	191	< 0.001	0.13	0.09–0.18

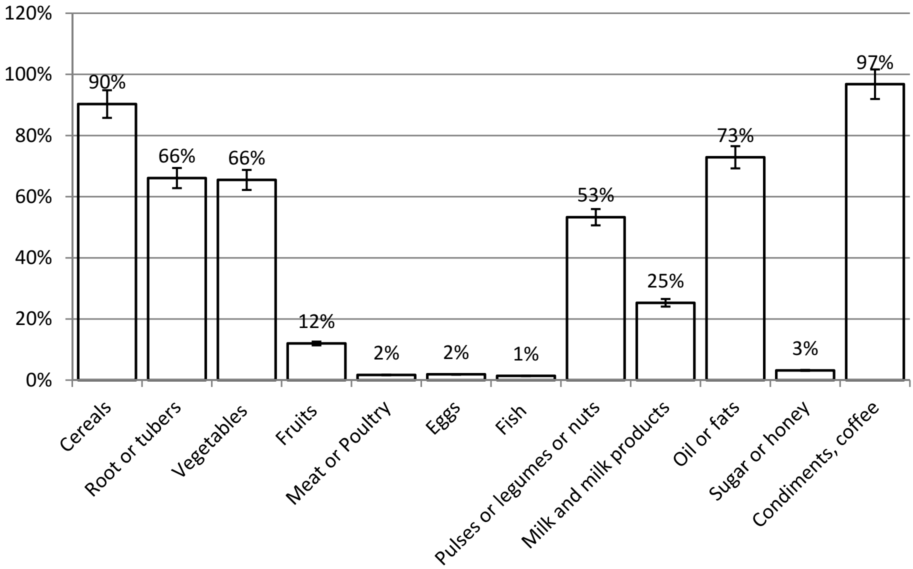

Figure 4. Frequency of utilizing twelve food groups in the past 24 hours, Boricha, South Ethiopia, 2017. Bar with 95% confidence level.

general, animal source foods such as meat, eggs, and fish were less frequently consumed.

Evaluation of seasonal pattern for the food groups shows that, except for roots or tubers and fish, there was a significant variation across the different seasons. The pre-harvest season of March had significantly lower use of foods such as cereals, vegetables, fruits, meat or poultry, eggs, sugar compared to post-harvest season of September. Similarly, the pre-harvest season of March had a significantly lower proportion of consumption to most of the dietary diversity food group as compared to the post-harvest season of December. The consumption of animal source foods (meat, egg, and fish) contributed less than 5% for household dietary diversity across the different seasons. The overall association of each food group across different seasons is listed in Table 4.

Wasting

From 3,438 observations in Boricha, about 6% (191 of 3,438 children; 95% CI: 4.8-6.3) of children were wasted. The wasting prevalence was highest among children aged less than 1 year, which was about 12% (17 out of 136 children). Wasting prevalence was 5% (35 out of 713) among children aged between 12 and 23 months, 5% (43 out of 826) children aged between 24 and 35 months, and 5% (89 out of 1,659) children aged greater than 36 months.

Table 4. Seasonal patterns in household dietary diversity (HDDS) items, Boricha, Southern Ethiopia, 2017.

S.No	Items	March, 2017	September, 2017	December, 2017	X^2	P-value
1	Cereals	697 (78.2%)	808 (94.3%)	825 (99.0%)	236	P < .001
2	Root or tubers	583 (65.6%)	560 (65.1%)	562 (67.6%)	1	P > .05
3	Vegetables	244 (27.4%)	687 (79.9%)	759 (91.3%)	895	P < .001
4	Fruits	100 (11.4%)	141 (16.5%)	67 (8.1%)	29	P < .001
5	Meat or poultry	9 (1.0%)	33 (3.8%)	3 (0.4%)	34	P < .001
6	Eggs	15 (1.7%)	32 (3.73)	3 (0.36%)	26	P < .001
7	Fish	11 (1.2%)	13 (1.5%)	13 (1.6%)	0.4	P > .05
8	Pulses or legumes	374 (42.1%)	369 (43.0%)	631 (76.0%)	254	P < .001
9	Milk and milk product	250 (28.3%)	258 (30.1%)	140 (17.0%)	45	P < .001
10	Oil or fats	607 (68.1%)	599 (70.2)	667 (80.8%)	40	P < .001
11	Sugar or honey	23 (2.6%)	45 (5.3%)	13 (1.6%)	20	P < .001
12	Condiments, coffee	840 (94.2%)	837 (98.0%)	816 (98.3%)	30	P < .001

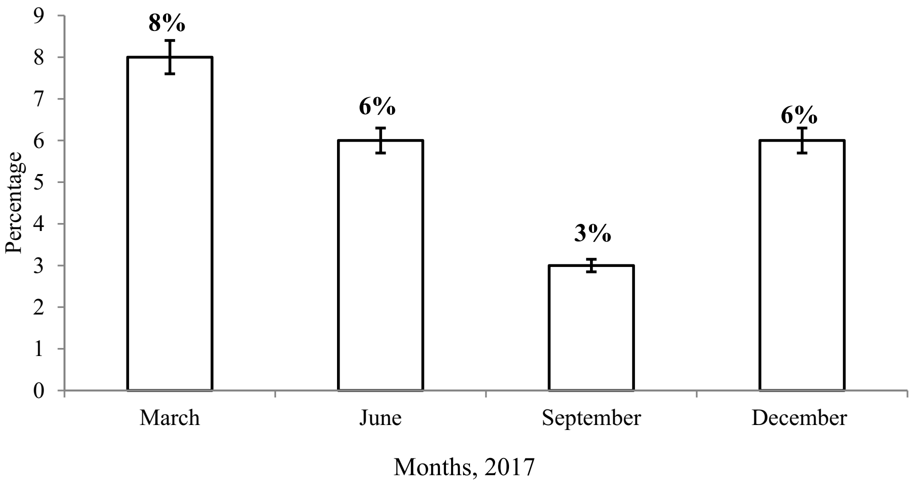

Figure 5. Seasonal variation of wasting among children under age five in Boricha, South Ethiopia, 2017. Bar with 95% confidence level.

The prevalence of wasting increased in the pre-harvest season: As shown in Figure 5, the prevalence of wasting showed seasonal variations: 8% (70 of 880 persons) in March 2017 (95% CI: 6.2-9.7) and 3% (26) in September 2017 (95% CI: 2.0-4.4).

Bivariate risk analysis showed that the risk of child wasting was highest among households with less educated fathers, among food-insecure households, among households with child sickness in the past 2 weeks, and in March.

Multivariate risk assessment showed that the risk of child wasting increased among households with less educated fathers, food-insecure households, and in March. See Table 5 for more information.

Stunting

From 3,312 observations, about 43% (1,408 of 3,312) of children were stunted (95% CI: 40.8–44.2). Stunting prevalence increased with age, with higher prevalence among children older than 36 months of age. Stunting prevalence was 25% (35 out of 139) among children aged less than 12 months, 43% (316 out of 723) children aged between 12 and 23 months, 40% (328 out of 827) children aged between 24 and 35 months, and 45% (729 out of 1,623) children aged 36 months and older.

Stunting occurred some months after the period with the highest prevalence of food insecurity and showed significant seasonal variations: 36% (303 of 848 persons) in March (95% CI: 32.5–39.0) and 48% (396 of 818 persons) in December (95% CI: 45.0–51.8), as shown in Figure 6.

Bivariate analysis showed that the risk of child stunting was highest among poor households and among households with parents who did not have formal education, parents who had other occupations (e.g., daily laborer, maid), household dietary diversity, and non-exclusively breastfed children. The risk peaked in December.

Multivariate analysis showed an increased risk of child stunting in December 2017, as well as among poor households, among households that had less educated mothers, and whose parents had other occupations. See Table 6 for detailed information.

Discussion

Our cohort study demonstrates that some of the possible underlying causes of child wasting and stunting were lack of food access, low food utilization, and marked seasonal variations of food security. Household food insecurity and prevalence of wasting increased in the pre-harvest season, with the highest prevalence of wasting occurring in the same season as the highest prevalence of food insecurity. However, stunting occurred some months after the period with the highest prevalence of food insecurity. This took place in an area of ecological degradation, high population pressure, and repeated droughts. As background information, we demonstrate that basic household factors such as poverty and education were associated with both stunting and wasting.

The prevalence rates of wasting were similar to consecutive Ethiopian Demographic Health Surveys (CSA 2016, 2012, 2001, 2006). The highest prevalence of stunting was recorded during the post-harvest period, similar to the 45% to 51% prevalence rates described for a drought-prone area in the Rift Valley in Central Ethiopia (Gari et al. 2018) and the 51% rate recorded in the Ethiopian Demographic Health Survey 2005 (CSA 2006). Previous studies show that rates of childhood stunting have decreased in Ethiopia, primarily among the more wealthy segments of the population (Golan et al. 2019; Wirth

Table 5. Multivariate risk factor of wasting under the age of 5 years in nine Kebele, Boricha, Southern Ethiopia, 2017.

Variables		Cases among participants				Crude OR (95% CI)		Adjusted OR (95%CI)	
		Yes (N)	**%**	**No (N)**	**%**	**OR**	**95% CI**	**OR**	**95% CI**
Wealth quintile	Poorest	38	5.6	646	94.4	1.42	0.64–3.12	1.01	0.45–2.26
	Poor	42	5.9	676	94.2	1.21	0.83–1.77	1.11	0.78–1.58
	Medium	44	6.9	591	93.1	1.32	0.97–1.80	1.23	0.95–1.60
	Rich	30	4.4	653	95.6	0.83	0.49–1.41	0.75	0.44–1.27
	Richest	34	5.0	641	94.9	1	Ref	1	Ref
Food security	Secure	19	3.2	573	96.8	0.50	0.31–0.80**	0.56	0.37–0.83**
	Mild	10	3.8	255	96.2	0.60	0.27–1.31	0.78	0.36–1.67
	Moderate	27	5.0	511	94.9	0.66	0.46–0.96*	0.82	0.48–1.39
	Severe	134	6.6	1,890	93.4	1	Ref	1	Ref
Season	Wasting in March 2017	70	7.9	810	92.1	1	Ref	1	Ref
	Wasting in June 2017	49	5.5	842	94.5	0.64	0.36–1.14	0.64	0.37–1.09
	Wasting in September 2017	26	3.2	795	96.8	0.34	0.18–0.62***	0.42	0.24–0.72**
	Wasting in December 2017	46	5.4	800	94.6	0.63	0.32–1.24	0.73	0.39–1.37
Mother's age		186	5.5	3,199	94.5	0.99	0.95–1.03	0.99	0.95–1.03
Mother's occupation	Housewife and farmer	164	5.6	2,770	94.4	0.76	0.34–1.71	0.77	0.29–2.04
	Employed/merchant	17	4.4	373	95.6	0.50	0.15–1.65	0.48	0.11–2.08
	Others	7	8.6	74	91.4	1	Ref	1	Ref
Mother's educational status	Primary	87	5.8	1,420	94.2	1.08	0.79–1.48	1.39	0.97–1.99
	Secondary and above	7	4.5	149	95.5	0.67	0.25–1.82	0.89	0.23–3.39
	No formal education	95	5.5	1,638	94.5	1	Ref	1	Ref
Father's educational status	Primary	86	5.0	1,628	95.0	0.69	0.48–0.97*	0.68	0.48–0.95*
	Secondary and above	21	5.2	387	94.9	0.69	0.39–1.18	0.68	0.29–1.59
	No formal education	82	6.5	1,190	93.6	1	Ref	1	Ref
Father's occupation	Farmer	110	5.1	2,028	94.9	0.74	0.45–1.20	0.68	0.41–1.14
	Merchant	51	5.6	857	94.4	0.73	0.37–1.42	0.76	0.38–1.51
	Others	26	7.4	325	92.6	1	Ref	1	Ref
Child sex	Male	113	6.0	1,758	94.0	1.18	0.93–1.50	1.16	0.92–1.46
	Female	78	5.0	1,489	95.0	1	Ref	1	Ref
Morbidity	No	156	5.2	2,859	94.8	0.52	0.28–0.96**	0.79	0.40–1.54
	Yes	35	8.3	388	91.7	1	Ref	1	Ref

*p <.05, **p <.01, and ***p <.001

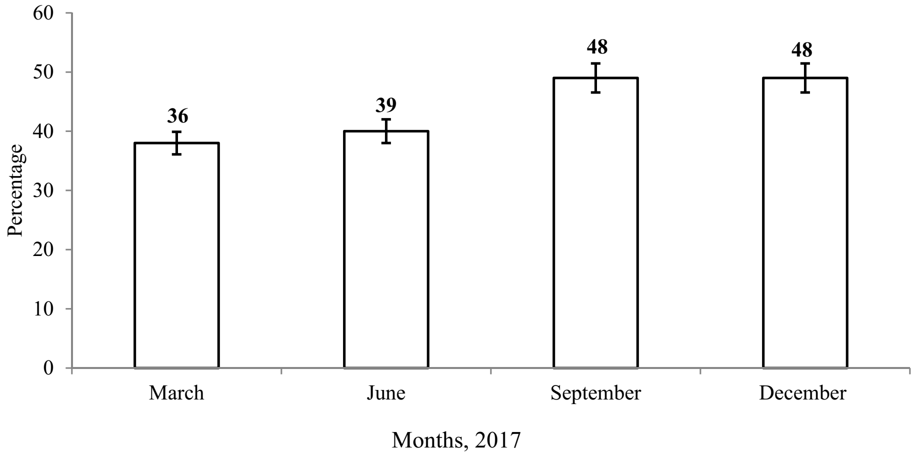

Figure 6. Seasonal variation in stunting among children under age five, Boricha, South Ethiopia, 2017. Bar with 95% confidence level.

et al. 2017). The possible reason for the constant trend of wasting and stunting in Ethiopia could be due to persistent low socio-economic status of the country (UNDP 2019) and inequalities between rural and urban (Tranvåg, Ali, and Norheim 2013)

Regarding household food insecurity, more than two thirds of households had manifested food insecurity in all seasons. Similarly, cross-sectional studies conducted in Boricha in 2012 (Regassa and Stoecker 2012) and elsewhere in South Ethiopia (Asesefa Kisi et al. 2018; Betebo et al. 2017; Hagos et al. 2015) had high prevalence rates of food insecurity. Moreover, our finding was higher than the national survey (35% of household food insecurity) (Humphries et al. 2015). Thus, our study shows that there was no improvement in the household food security situation in this part of the country.

The intake of animal source food and fruits were low, and this is similar to findings from other developing countries (Bosha et al. 2019; Campbell et al. 2014; Hirvonen, Taffesse, and Worku Hassen 2016). However, we found a high intake of carbohydrate source foods which indicates the monotonous nature of the diet (Table 6). This indicates for most of the rural households are unable to afford the high price of animal source food (Hirvonen and Wolle 2019), and thus suggests inadequate micronutrient intake (Arimond et al. 2010).

Furthermore, our study confirmed the risk factors for stunting and wasting in Ethiopia found in other studies. For example, the risk of child stunting increased with decreasing the wealth status of households (Greffeuille et al. 2016). This finding suggests that reducing poverty with a pro-poor economic growth policy could reduce malnutrition. Stunting and wasting also were higher among parents who did not have formal education, and children of

Table 6. Multivariate risk factor for stunting among children younger than 5 years in nine kebele in Boricha, Southern Ethiopia, 2017.

Variables		Cases among participants				Crude OR (95% CI)		Adjusted OR (95% CI)	
		Yes (N)	**%**	**No (N)**	**%**	**OR**	**95% CI**	**OR**	**95% CI**
Wealth quintile	Poorest	331	50.2	329	49.9	4.99	1.80–13.82**	4.01	1.33–12.08*
	Poor	293	42.5	396	57.5	3.01	1.21–7.44*	2.47	0.96–6.35
	Middle	258	40.9	373	59.1	1.75	0.65–4.69	1.81	0.62–5.25
	Rich	290	42.8	387	57.2	1.39	0.89–2.19	1.65	1.11–2.46*
	Richest	224	35.3	411	64.7	1	Ref	1	Ref
Food security	Secure	229	40.2	341	59.8	1.92	0.99–3.74	1.28	0.72–2.26
	Mild	140	55.6	112	44.4	2.94	1.18–7.31*	1.35	0.78–2.35
	Moderate	218	41.8	303	58.2	1.56	1.02–2.39*	1.01	0.71–1.45
	Severe	816	41.6	1,134	58.2	1	Ref	1	Ref
Season	Stunting in March 2017	303	35.7	545	64.3	0.24	0.08–0.71*	0.23	0.08–0.68**
	Stunting in June 2017	330	38.7	522	61.3	0.31	0.12–0.82*	0.44	0.16–1.21
	Stunting in September 2017	379	47.7	415	52.3	0.98	0.20–3.31	0.98	0.27–3.54
	Stunting in December 2017	396	48.4	422	51.6	1	Ref	1	Ref
Mother's education	Primary	581	39.1	906	60.9	0.47	0.27–0.84**	0.43	0.19–0.96*
	Secondary and above	39	26.2	110	73.8	0.18	0.09–0.35***	0.36	0.16–0.83*
	No formal education	780	47.1	876	52.9	1	Ref	1	Ref
Mother's occupation	Farmer and housewife	1,233	43.5	1,600	56.5	0.36	0.18–0.69**	0.09	0.02–0.34***
	Employed/merchant	136	35.1	252	64.9	0.14	0.05–0.43***	0.05	0.01–0.25***
	Others	38	47.5	42	52.5	1	Ref	1	Ref
Mother's age		1,385	42.2	1,899	57.8	1.03	0.99–1.07	0.97	0.92–1.02
Child sex	Male	791	44.1	1,004	55.9	1.45	0.85–2.49	1.52	0.77–2.98
	Female	617	40.1	900	59.3	1	Ref	1	Ref
Child age	6–23 months	351	40.7	511	59.3	0.80	0.41–1.57	1.43	0.57–3.57
	>=24 months	1,057	43.1	1,393	56.9	1	Ref	1	Ref
Father's educational status	Primary	692	41.5	975	58.5	0.72	0.41–1.23	1.08	0.63–1.84
	Secondary and above	120	30.2	277	69.8	0.24	0.12–0.47***	0.41	0.14–1.17
	No formal education	581	47.4	645	52.6	1	Ref	1	Ref
Father's occupational status	Farmer	923	44.9	1,133	55.1	0.71	0.29–1.69	0.55	0.22–1.39
	Merchant	318	35.6	576	64.4	0.32	0.15–0.69**	0.22	0.08–0.61**
	Others	159	46.4	184	53.6	1	Ref	1	Ref
Exclusive breastfeeding practice	Only breast milk	1,259	41.24	1,794	58.8	0.09	0.01–0.86*	0.05	0.002–1.18
	Breast and other food items	129	67.5	62	32.5	1	Ref	1	Ref
Household dietary diversity score		1,067	43.7	1,377	56.3	1.16	1.07–1.26***	1.07	0.97–1.18

*p <.05, **p <.01, and ***p <.001

uneducated parents were at higher risk for malnutrition (Hasan et al. 2016; Makoka and Masibo 2015; Victora et al. 1986). Thus, education might improve child care and child feeding practices (Kalanda, Verhoeff, and Brabin 2006), which in turn improves child nutritional status (Saha et al. 2008). Hence, improving child nutritional status will require multi-sector approaches. Programs to improve child malnutrition among rural subsistence farming communities should integrate agricultural, educational, and health information. Practically at the local level, our study suggests that the district (Woreda) health office and health extension workers should identify households in need of food, advise them on ways to improve their food diversity and intake and if possible, and refer them to the Productive safety net program.

Strengths of the study

Our study area is typical in Ethiopia with recurrent droughts and food shortages. The population was representative of the area, as we randomly selected the kebeles and households. Furthermore, to assess the outcome variables, we conducted a cohort study using four repeated assessments of the same households in four different seasons over a year. The sample size was large and adequate, and the loss to follow-up was small. We also used a multilevel, mixed-effect model to account for both hierarchical effect of response correlation at the kebele level and household level, and longitudinal response of repeated measurements at individual level.

Limitations

The effect of seasonal variations on food insecurity, stunting, and wasting were significant when controlling for confounders. However, our study lasted for only 1 year. Thus, it would be advisable to conduct future studies over longer periods (Lindtjorn and Alemu 2002). Also, our study included only households from rural populations, and hence future studies could include urban households. Most risk factors were assessed from maternal recall, which may have introduced recall bias, although we used a short recall period to reduce such bias. As the study participants may have expected possible aid, they may incline toward affirmative responses of household food insecurity access scale measurement items. Household dietary diversity was not conducted on specific groups, and the consequences of seasonal variation may be higher in specific groups such as mothers or children.

Conclusions and recommendations

Our study suggests that household food insecurity increased the risk of child wasting during the period of highest food scarcity (pre-harvest season; table 8 and Figure 6). Similarly, the risk of low household food consumption increased in the period of the highest food insecurity. Moreover, household characteristics such as poverty level, education, occupation, and the household food insecurity and dietary diversity were associated with subsequent wasting or stunting. Thus, our study links poverty, household food insecurity, and household dietary diversity as indicators of agricultural production, with stunting or wasting in this drought-prone rural farming community. However, our data suggest that household food insecurity was a more pronounced predictor for stunting and wasting than household dietary diversity, as had been suggested by others (Ali et al. 2013). Our research findings could have implications for both designing and evaluating interventions to reduce the state of nutrition in the affected communities.

Possible future knowledge gaps and interventions could focus on increasing household wealth and agricultural production. Crop production capacity of the areas and weather variations from year to year could influence malnutrition, indicating a need to integrate studies on rainfall trends, agriculture, and health, as well as climate change in Ethiopia (Simane et al. 2016). Our study on seasonal changes on food insecurity and dietary diversity underscores increasing challenges in agricultural production in a drought-affected area in Ethiopia. These challenges will continue to erode nutrition security, as has been the case for decades, and it may undermine sustainable livelihood and development efforts in the area (Niang et al. 2014). One potential intervention in food security and diet diversity is to combine the need for improved seasonal forecasting and early warning systems for farmers. Programs working in improving child malnutrition among rural subsistence farming communities could integrate seasonal weather forecasting, health information, and improved education of all, but especially women (Persson, Rasmussen, and Yang 2019). Interventions should consider including high-quality diet such as animal source food and fruits (Hawkes et al. 2020). Moreover, interventions should promote diversity in food production and consumption among poor households living in drought-prone areas. Such an intervention could support decision-making among farmers to reduce societal vulnerabilities and enhance adaptation and resilience to the impacts of climate change (Vaughan and Dessai 2014).

Authorship

M.B., E.L., and B.L. designed the study. All authors participated in the data analysis, drafting of the manuscript, and writing the final article.

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Disclosure statement

The authors declare that they have no competing interests.

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References

Abebe, Y., B. J. Stoecker, M. J. Hinds, and G. E. Gates. 2006. Nutritive value and sensory acceptability of corn- and kocho-based foods supplemented with legumes for infant feeding in Southern Ethiopia. *African Journal of Food, Agriculture, Nutrition and Development* 6 (1).

Abreha, N. H. 2007. An economic analysis of farmers' risk attitudes and farm households' responses to rainfall risk in tigray Northern Ethiopia.Ph.D. Thesis, Wageningen University.

Ali, D., K. K. Saha, P. H. Nguyen, M. T. Diressie, M. T. Ruel, P. Menon, and R. Rawat. 2013. Household food insecurity is associated with higher child undernutrition in Bangladesh, Ethiopia, and Vietnam, but the effect is not mediated by child dietary diversity. *The Journal of Nutrition* 143 (12):2015–21. doi:10.3945/jn.113.175182.

Arimond, M., D. Wiesmann, E. Becquey, A. Carriquiry, M. C. Daniels, M. Deitchler, N. Fanou-Fogny, M. L. Joseph, G. Kennedy, Y. Martin-Prevel, et al. 2010. Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse, resource-poor settings. *The Journal of Nutrition* 140 (11):2059S–69S. doi:10.3945/jn.110.123414.

Asesefa Kisi, M., D. Tamiru, M. S. Teshome, M. Tamiru, and G. T. Feyissa. 2018. Household food insecurity and coping strategies among pensioners in Jimma Town, South West Ethiopia. *BMC Public Health* 18 (1):1373. doi:10.1186/s12889-018-6291-y.

Beal, T., A. Tumilowicz, A. Sutrisna, D. Izwardy, and L. M. Neufeld. 2018. A review of child stunting determinants in Indonesia. *Maternal & Child Nutrition* 14 (4):e12617. doi:10.1111/mcn.12617.

Betebo, B., T. Ejajo, F. Alemseged, and D. Massa. 2017. Household food insecurity and its association with nutritional status of children 6–59 months of age in East Badawacho District, South Ethiopia. *Journal of Environmental and Public Health* 2017:6373595. doi:10.1155/2017/6373595.

Boricha Woreda Agricultural Office Report. 2017. Boricha, Sidama Zone, Ethiopia.

Bosha, T., C. Lambert, S. Riedel, A. Melesse, and H. K. Biesalski. 2019. Dietary diversity and anthropometric status of mother-child pairs from enset (False Banana) staple areas: A panel evidence from Southern Ethiopia. *International Journal of Environmental Research and Public Health* 16:12. doi:10.3390/ijerph16122170.

Branca, F., G. Pastore, T. Demissie, and A. Ferro-Luzzi. 1993. The nutritional impact of seasonality in children and adults of rural Ethiopia. *European Journal of Clinical Nutrition* 47:840–50.

Campbell, R. K., S. A. Talegawkar, P. Christian, S. C. LeClerq, S. K. Khatry, L. S. Wu, and K. P. West Jr. 2014. Seasonal dietary intakes and socioeconomic status among women in the Terai of Nepal. *Journal of Health, Population, and Nutrition* 32 (2):198–216.

Christiansen, T. B., and J. M. Lauritsen (Ed.). 2010. EpiData - Comprehensive Data Management and Basic Statistical Analysis System. Odense Denmark, EpiData Association, 2010. Http://www.epidata.dk

Coates, J., A. Swindale, and P. Bilinsky. 2007. *Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide*, 20009–5721. Washington, D.C.: Food and Nutrition Technical Assistance Project, Academy for Educational Development.

CSA. 2001. *Ethiopian demographic health survey 2000*. Addis Abeba and Calverton: Central Statistical Agency.

CSA. 2006. *Ethiopian demographic health survey 2005*. Addis Abeba and Calverton: Central Statistical Agency.

CSA. 2012. *Ethiopia demographic and health survey 2011*, 155–56. Ethiopia and Calverton Addis Ababa: Central Statistical Agency and ICF International.

CSA. 2016. *Ethiopia demographic and health survey report 2016*. Addis Ababa, Ethiopia: Central Statistical Agency and ICF International.

Dadi, D. K. 2013. Characterizing the predictability of seasonal climate in Ethiopia. Dissertation for the degree philosophiae doctor (PhD) in Meteorology, University of Bergen, Norway.

Dean, A. G., K. M. Sullivan, and M. M. Soe. 06 April 2013. *OpenEpi: Open source epidemiologic statistics for public health, Version*. www.OpenEpi.com

Derso, T., A. Tariku, G. A. Biks, and M. M. Wassie. 2017. Stunting, wasting and associated factors among children aged 6–24 months in Dabat health and demographic surveillance system site: A community based cross-sectional study in Ethiopia. *BMC Pediatrics* 17 (1):96. doi:10.1186/s12887-017-0848-2.

Egata, G., Y. Berhane, and A. Worku. 2013. Seasonal variation in the prevalence of acute undernutrition among children under five years of age in east rural Ethiopia: A longitudinal study. *BMC Public Health* 13:864. doi:10.1186/1471-2458-13-864.

Erhardt, J., M. Golden, and J. Seaman. 2011. Inventors Emergency nutrition assessment for SMART software 2011. *Action Against Hunger*. Toronto, Canada.

Ferro-Luzzi, A., S. S. Morris, S. Taffesse, T. Demissie, and M. D'Amato. 2001. *Seasonal undernutrition in Rural Ethiopia: Magnitude,correlates, and functional significance*. Addis Ababa: International Food Policy Research Institute Washington, D.C. and Istituto Nazionale della Nutrizione, Rome in collaboration with Ethiopian Health and Nutrition Research Institute.

Gari, T., E. Loha, W. Deressa, T. Solomon, and B. Lindtjorn. 2018. Malaria increased the risk of stunting and wasting among young children in Ethiopia: Results of a cohort study. *PloS One* 13 (1):e0190983. doi:10.1371/journal.pone.0190983.

Girma, A., H. Woldie, F. A. Mekonnen, K. A. Gonete, and M. Sisay. 2019. Undernutrition and associated factors among urban children aged 24–59 months in Northwest Ethiopia: A community based cross sectional study. *BMC Pediatrics* 19 (1):214. doi:10.1186/s12887-019-1595-3.

Golan, J., D. Heacdey, K. Hirvonen, and Hoddinot. 2019. The Oxford handbook of Ethiopian economy. In *Changes in child undernutriton in Ethiopia, 2000–2016*, ed. C. Cramer, A. Oqubay, and F. Cheru, 399–411. New York: Oxford University Press.

Governement of the Federal Democratic Republic of Ethiopia. 2016a. *National nutrition programme 2016–2020*. Addis Ababa: Governement of the Federal Democratic Republic of Ethiopia (GFDRE).

Governement of the Federal Democratic Republic of Ethiopia. 2016b. *Seqota declaration implementation plan (2016–2030), summary programme approach DOCUMENT*. Addis Ababa: Governement of the Federal Democratic Republic of Ethiopia (GFDRE).

Graves, A., L. Rosa, A. M. Nouhou, F. Maina, and D. Adoum. 2019. Avert catastrophe now in Africa's Sahel. *Nature* 575 (7782):282–86. doi:10.1038/d41586-019-03445-z.

Greffeuille, V., P. Sophonneary, A. Laillou, L. Gauthier, R. Hong, R. Hong, E. Poirot, M. Dijkhuizen, F. Wieringa, and J. Berger. 2016. Persistent inequalities in child undernutrition in Cambodia from 2000 until Today. *Nutrients* 8 (5):297. doi:10.3390/nu8050297.

Hagos, S. G., T. F. Lunde, M. Damen, T. Woldehanna, and B. Lindtjørn. 2015. Is the adapted Household Food Insecurity Access Scale (HFIAS) developed internationally to measure food insecurity valid in urban and rural households of Ethiopia? *BMC Nutrition* 1 (1):2. doi:10.1186/2055-0928-1-2.

Hasan, M. T., R. J. Soares Magalhaes, G. M. Williams, and A. A. Mamun. 2016. The role of maternal education in the 15-year trajectory of malnutrition in children under 5 years of age in Bangladesh. *Maternal & Child Nutrition* 12 (4):929–39. doi:10.1111/mcn.12178.

Hawkes, C., M. T. Ruel, L. Salm, B. Sinclair, and F. Branca. 2020. Double-duty actions: Seizing programme and policy opportunities to address malnutrition in all its forms. *The Lancet* 395 (10218):142–55. doi:10.1016/S0140-6736(19)32506-1.

Hirvonen, K., and A. Wolle. 2019. *Consumption, production, market access and affordability of nutritious foods in the Oromia Region of Ethiopia*. Addis Ababa, Ethiopia: Alive & Thrive and International Food Policy Research Institute.

Hirvonen, K., A. S. Taffesse, and I. Worku Hassen. 2016. Seasonality and household diets in Ethiopia. *Public Health Nutrition* 19 (10):1723–30. doi:10.1017/S1368980015003237.

Humphries, D. L., K. A. Dearden, B. T. Crookston, L. C. Fernald, A. D. Stein, T. Woldehanna, M. E. Penny, and J. R. Behrman, Determinants Young Lives, and Team Consequences of Child Growth Project. 2015. Cross-sectional and longitudinal associations between household Food security and child anthropometry at ages 5 and 8 years in Ethiopia, India, Peru, and Vietnam. *The Journal of Nutrition*. 145 (8):1924–33. doi:10.3945/jn.115.210229.

Kabalo, B. Y., E. H. Gebreyesus, E. Loha, and B. Lindtjørn. 2019. Performance of an adapted household food insecurity access scale in measuring seasonality in household food insecurity in rural Ethiopia: A cohort analysis. *BMC Nutrition* 5 (54). doi:10.1186/s40795-019-0323-6.

Kahssay, M., E. Woldu, A. Gebre, and S. Reddy. 2020. Determinants of stunting among children aged 6 to 59 months in pastoral community, Afar region, North East Ethiopia: Unmatched case control study. *BMC Nutrition* 6 (1):9. doi:10.1186/s40795-020-00332-z.

Kalanda, B. F., F. H. Verhoeff, and B. J. Brabin. 2006. Breast and complementary feeding practices in relation to morbidity and growth in Malawian infants. *European Journal of Clinical Nutrition* 60 (3):401–07. doi:10.1038/sj.ejcn.1602330.

Kinyoki, D. K., J. A. Berkley, G. M. Moloney, E. O. Odundo, N. B. Kandala, and A. M. Noor. 2016. Space-time mapping of wasting among children under the age of five years in Somalia from 2007 to 2010. *Spatial and Spatio-temporal Epidemiology* 16:77–87. doi:10.1016/j.sste.2015.12.002.

Lindtjørn, B. 1990. Famine in southern Ethiopia 1985-6: Population structure, nutritional state, and incidence of death among children. *BMJ* 301 (6761):1123–27. doi:10.1136/bmj.301.6761.1123.

Lindtjorn, B., and T. Alemu. 2002. Year-to-year and seasonal variations in stunting among preschool children in Ethiopia. *Journal of Health, Population, and Nutrition* 20 (4):326–33.

Makoka, D., and P. K. Masibo. 2015. Is there a threshold level of maternal education sufficient to reduce child undernutrition? Evidence from Malawi, Tanzania and Zimbabwe. *BMC Pediatrics* 15:96. doi:10.1186/s12887-015-0406-8.

Mulu, E., and B. Mengistie. 2017. Household food insecurity and its association with nutritional status of under five children in Sekela District, Western Ethiopia: A comparative cross-sectional study. *BMC Nutrition* 3:35. doi:10.1186/s40795-017-0149-z.

Niang, I., O. C. Ruppel, M. A. Abdrabo, A. Essel, C. Lennard, J. Padgham, and P. Urquhart. 2014. Africa. In *Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of Working Group II to the fifth assessment report of the intergovernmental panel on climate change*, ed. V. R. Barros, C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, et al., 1199–265. Cambridge: Cambridge University Press.

Pérez-Escamilla, R. 2017. Food security and the 2015–2030 sustainable development goals: From human to planetary health: Perspectives and opinions. *Current Developments in Nutrition* 1 (7):e000513. doi:10.3945/cdn.117.000513.

Persson, L. A., K. M. Rasmussen, and H. Yang. 2019. Nutrition for women and children-Are we doing the right things in the right way? *PLoS Medicine* 16 (8):e1002906. doi:10.1371/journal.pmed.1002906.

Regassa, N., and B. J. Stoecker. 2012. Household food insecurity and hunger among households in Sidama district, southern Ethiopia. *Public Health Nutrition* 15 (7):1276–83. doi:10.1017/s1368980011003119.

Roba, K. T., T. P. O'Connor, T. Belachew, and N. M. O'Brien. 2016. Variations between post- and pre-harvest seasons in stunting, wasting, and Infant and Young Child Feeding (IYCF) practices among children 6–23 months of age in lowland and midland agro-ecological zones of rural Ethiopia. *The Pan African Medical Journal* 24:163. doi:10.11604/pamj.2016.24.163.9387.

Ruel, M. T., and H. Alderman, Maternal, and Group Child Nutrition Study. 2013. Nutrition-sensitive interventions and programmes: How can they help to accelerate progress in improving maternal and child nutrition? *The Lancet*. 382 (9891):536–51. doi:10.1016/S0140-6736(13)60843-0.

Rutstein, S., and S. Staveteig. February 2014. Making the demographic and health surveys wealth index comparable. DHS Methodological Reports No. 9. Rockville, Maryland, USA: ICF International.

Saha, K. K., E. A. Frongillo, D. S. Alam, S. E. Arifeen, L. A. Persson, and K. M. Rasmussen. 2008. Appropriate infant feeding practices result in better growth of infants and young children in rural Bangladesh. *The American Journal of Clinical Nutrition* 87 (6):1852–59. doi:10.1093/ajcn/87.6.1852.

Simane, B., H. Beyene, W. Deressa, A. Kumie, K. Berhane, and J. Samet. 2016. Review of climate change and health in Ethiopia: Status and gap analysis. *Ethiopian Journal of Health Development* 30 (1 Spec Iss):28–41.

Swindale, A., and P. Bilinsky. 2006. Household Dietary Diversity Score (HDDS) for measurement of household food access: Indicator guide (v.2).Washington, D.C.: FHI 360/FANTA. https://www.fantaproject.org/sites/default/files/resources/HDDS_v2_Sep06_0.pdf

Tesfaye, B. 2011. Rural household food security situation anaylsis: The case of Boricha Wereda, Sidama Zone. A Thesis Presented to the School of Graduate studies of the Addis Ababa.

Tranvåg, E. J., M. Ali, and O. F. Norheim. 2013. Health inequalities in Ethiopia: Modeling inequalities in length of life within and between population groups. *International Journal for Equity in Health* 12 (1):52. doi:10.1186/1475-9276-12-52.

Tumilowicz, A., M. T. Ruel, G. Pelto, D. Pelletier, E. C. Monterrosa, K. Lapping, K. Kraemer, L. M. De Regil, G. Bergeron, M. Arabi, et al. 2018. Implementation science in nutrition: Concepts and frameworks for an emerging field of science and practice. *Current Developments in Nutrition* 3 (3). doi: 10.1093/cdn/nzy080.

UNDP. 2019. Human development report 2019. http://hdr.undp.org/sites/default/files/hdr2019.pdf

Vaughan, C., and S. Dessai. 2014. Climate services for society: Origins, institutional arrangements, and design elements for an evaluation framework. *Wiley Interdisciplinary Reviews. Climate Change* 5 (5):587–603. doi:10.1002/wcc.290.

Victora, C. G., J. P. Vaughan, B. R. Kirkwood, J. C. Martines, and L. B. Barcelos. 1986. Risk factors for malnutrition in Brazilian children: The role of social and environmental variables. *Bulletin of the World Health Organization* 64 (2):299–309.

WHO. 2005. *Handbook: IMCI Integrated management of childhood illness*. Geneva: World Health Organization. https://apps.who.int/iris/handle/10665/42939

WHO. 2006. WHO child growth standards based on length/height, weight and age: WHO multicenter growth references study group. *Acta Pñdiatrica* Suppl 450: 76Á/85.

Wirth, J. P., J. Matji, B. A. Woodruff, S. Chamois, Z. Getahun, J. M. White, and F. Rohner. 2017. Scale up of nutrition and health programs in Ethiopia and their overlap with reductions in child stunting. *Maternal & Child Nutrition* 13 (2):e12318. doi:10.1111/mcn.12318.

Woldeamanuel, B. T., and T. T. Tesfaye. 2019. Risk factors associated with under-five stunting, wasting, and underweight based on Ethiopian demographic health survey datasets in tigray region, Ethiopia. *Journal of Nutrition and Metabolism* 2019:6967170. doi:10.1155/2019/6967170.

Paper III

Spatial Variation of Child Stunting and Maternal Malnutrition after Controlling for Known Risk Factors in a Drought-Prone Rural Community in Southern Ethiopia

Annals of Global Health

ORIGINAL RESEARCH

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ABSTRACT

Background: Globally, understanding spatial analysis of malnutrition is increasingly recognized. However, our knowledge on spatial clustering of malnutrition after controlling for known risk factors of malnutrition such as wealth status, food insecurity, altitude and maternal characteristics is limited from Ethiopia. Previous studies from southern Ethiopia have shown seasonal patterns of malnutrition, yet they did not evaluate spatial clustering of malnutrition.

Objective: The aim of this study was to assess whether child stunting and maternal malnutrition were spatially clustered in drought-prone areas after controlling for previously known risk factors of malnutrition.

Methods: We used a community-based cohort study design for a one-year study period. We used SaTScan software to identify high rates of child stunting and maternal malnutrition clustering. The outcome based was the presence or absence of stunting and maternal malnutrition ([BMI] <18.5 kg/m^2). We controlled for previously known predictors of child stunting and maternal malnutrition to evaluate the presence of clustering. We did a logistic regression model with declaring data to be time-series using Stata version 15 for further evaluation of the predictors of spatial clustering.

Results: The crude analysis of SaTScan showed that there were areas (clusters) with a higher risk of stunting and maternal malnutrition than in the underlying at risk populations. Stunted children within an identified spatial cluster were more likely to be from poor households, had younger and illiterate mothers, and often the mothers were farmers and housewives. Children identified within the most likely clusters were 1.6 times more at risk of stunting in the unadjusted analysis. Similarly, mothers within the clusters were 2.4 times more at risk of malnutrition in the unadjusted analysis. However, after adjusting for known risk factors such as wealth status, household food insecurity, altitude, maternal age, maternal education, and maternal occupation with SaTScan analysis, we show that child stunting and maternal malnutrition were not spatially clustered.

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Conclusion: The observed spatial clustering of child stunting and maternal malnutrition before controlling for known risk factors for child stunting and maternal malnutrition could be due to non-random distribution of risk factors such as poverty and maternal characteristics. Moreover, our results indicated the need for geographically targeted nutritional interventions in a drought-prone area.

INTRODUCTION

Child and maternal malnutrition remain a persistent problem, resulting in substantial increases in overall morbidity and mortality in developing countries [1]. Globally, maternal and child malnutrition related factors contribute to approximately 35% of child deaths and 11% of the total global disease burden [1]. Thus, the global efforts to avert malnutrition continued through the Millennium Development Goals (MDGs) era, and the Sustainable Development Goals (SDGs) set targets with the aim of eliminating malnutrition by 2030 [2]. Similarly, policy and national nutrition programmatic efforts have been made in Ethiopia to tackle the continuing challenge of malnutrition [3]. Despite concerted efforts, the prevalence of malnutrition remains high in low and middle income countries, and the progress to reduce malnutrition remains slow [4]. The issue of malnutrition is a complex phenomenon and it is the result of a dynamic interaction between factors such as illness and insufficient intake of dietary energy, underlying causes such as food insecurity and lack of health services access, and basic causes such as household economy, education, occupation, political and environmental reasons [5, 6].

To reduce health disparities, an understanding of the geographical distribution of health problems is increasingly recognized by the global health community. Accordingly, researchers are more often using spatial analysis of malnutrition as it is helpful to understand the complex nature of the geographical distribution of malnutrition [7, 8]. Knowledge about spatial distribution of malnutrition can provide information about how to allocate resources to vulnerable areas, and to plan effective interventions [8].

Earlier studies on spatial analysis of malnutrition conducted in Ethiopia showed spatial clustering [9, 10]. However, they did not evaluate the occurrence of spatial variation of malnutrition after controlling for known risk factors. To fill this knowledge gap, we designed this study to evaluate whether child stunting and maternal undernutrition were clustered or not, after controlling for known risk factors for malnutrition in the area. This study was a part of a large cohort study where we found that the risk of child malnutrition was associated with household characteristics such as poverty, education, occupation, household food insecurity and the risk of maternal malnutrition was higher among poor households and among older mothers. The households with malnourished mothers often had malnourished children. Moreover, the findings link both maternal malnutrition and child malnutrition with seasonal variation of household food insecurity among drought-prone rural farming communities [11, 12].

The aim of this study was to assess whether child stunting and maternal malnutrition were spatially clustered in drought prone areas after controlling for known risk factors of malnutrition among children and their mothers.

METHODS AND MATERIALS

STUDY AREA

This study was conducted in Boricha, which is geographically located at 6° 46’N and 38° 04’E to 7° 01’N and 38° 24’E in southern Ethiopia. Boricha district is a drought prone area, approximately located 34 km south of Hawassa, the capital city of Southern Nations Nationalities of Peoples Region (SNNPR).

Sidama is the largest ethnic group in the district and more than 90% of the population lives in rural areas. Protestant Christianity is the main religion in the district and most of people make their living directly from subsistence farming and livestock rearing. Based on the 2007 national census, approximately 315,000 people lived in the district in 2017. The district has 39 rural kebeles (smallest administrative units), each with an average population of 1,000 to 6,000 people. In 2017, there was one government hospital, five public health centres, 39 health posts in the district. Each kebele has at least one health post staffed by two health extension workers who report to the health centre.

As Boricha is the drought prone area, malnutrition is the major health problem. Highest peak of acute malnutrition cases occurs between March and June during Belg rainy season, and the lowest occurrence of acute malnutrition occurs between September and December, following rains in March and June [11]. Moreover, the absence of rivers and far to reach to underground water serve as potential malnutrition sites. Thus, study area is known for drought prone and included in Safety Net Programme.

STUDY DESIGN AND PERIOD

This study is a part of a community-based cohort study conducted to evaluate child and maternal malnutrition at the community level. During 2017, all households were visited four times. The aim of our study was to measure the patterns and determinants of child stunting and child wasting, determine the risk factors of maternal malnutrition, and evaluate spatial clustering of child and maternal malnutrition.

Outcome and exposure variables

The main outcomes of the study were the spatial clustering of child stunting and maternal malnutrition. The main exposure variables were wealth, altitude, household food insecurity access, maternal education, maternal occupation, and maternal age. The aforementioned covariates were related to child and maternal malnutrition according to their significance level in the previous studies conducted in Boricha district and they are assumed to be non-randomly distributed geographically [11, 12]. Thus, we want to find clusters that cannot be explained by these covariates.

STUDY POPULATION AND SAMPLING

We employed two-stage sampling technique to select mother-child pairs. First, nine rural kebeles (smallest administrative unit) were randomly selected from 39 rural kebeles of Boricha district. Secondly, out of the nine rural kebeles, we recruited study subjects from gouts (villages) through cluster sampling technique.

This cohort had included 935 children between 6 months to 47 months and 892 biological mothers between 15–49 years old from the total of 897 households at the beginning of the study. Children from 6 months to 47 months were recruited to accommodate age increment due to a one-year follow-up period of time. See earlier publication for detailed description of the study population [11].

DATA COLLECTION

We utilized eighteen data collectors and three supervisors for data collection, who were familiar with the local context and fluent speakers of the local language (*Sidamu Afoo*). They were trained and conducted pre-test outside of the selected kebeles that had similar socio-economic characteristics. We collected on socio-demographic data such as maternal age, educational status of mothers and occupational status of mothers.

Each household had a unique code and geo-referenced using a handheld global positioning system (GPS) device (Garmin's GPSMAP60CSx, Garmin International Inc., Olathe, Kansas, USA).

FOOD INSECURITY AND DIETARY DIVERSITY

Household food insecurity was assessed by using the Household Food Insecurity Access Scale (HFIAS) tool developed by the FANTA project and validated in different seasons of Ethiopia [13–15]. Food consumption was assessed by Household Dietary Diversity Score (HDDS) of 24 hours recall measurements. Twelve food groups were measured: Meat or Poultry, Eggs, Fish, Cereals, Root or tubers, Vegetables, Fruits, Pulses or legumes or nuts, milk and milk products, oil or fats, sugar or honey, and miscellaneous [13]. See earlier publication for detailed information [11].

WEALTH INDEX

We constructed wealth index using principal component analysis [6]. Household assets-related variables such as type and number of herds, ownership of improved sanitation, type of fuel used for cooking food, materials used for construction of house wall, floor and roof, number of sleeping rooms, ownership of chair and mobile telephone. The principal component analysis Kaiser-Meyer-Olkin measure of sampling adequacy was 67% and significance level of below 0.001. The households were then ranked into five categories such as poorest, poor, medium, rich and richest.

CHILD AND MATERNAL MALNUTRITION

The term malnutrition denotes both to undernutrition and over-nutrition. It is a condition that results from eating a diet in which various nutrients are either an insufficient or excessive. However, this paper focuses on the maternal and child undernutrition aspect such as child stunting and maternal undernutrition based on BMI measurements.

Child anthropometric measurements were evaluated based on children's height and recorded using Emergency Nutrition Assessment for Standardized Monitoring and Assessment of Relief and Transitions software (NutriSurvey for SMART, version 2011). Children up to 24 months of age were measured in a recumbent position using a length board to the nearest 0.1cm. Children who are able to stand unassisted measured in the standing position to the nearest 0.1cm. We used mother's recall and memorable events to assess child age. Child stunting was defined as height-for-age Z-score of less than two standard deviation of the World Health Organization Child Growth Standards Median [16].

The presence of maternal malnutrition was defined as a body mass index [BMI] <18.5 kg/m^2 [17]. The weight was recorded to the nearest 100 g using a digital SECA scale (SECA GmbH, Germany) and the height was measured with a locally prepared apparatus that had a 0.1 cm resolution.

DATA ANALYSIS

Data were double-entered and checked using EpiData v. 3.1 (Odense, Denmark), and transferred to STATA 15 (StataCorp, College Station, TX) for further cleaning and analysis. Descriptive statistics such as frequency counts, percentages, means and 95% CI were used to summarize the data. For the anthropometric measurements we deleted extreme values of child stunting (height-for-age Z-scores greater than six or less than minus six) which represented 4.9% of the measurements. Similarly, we deleted cases with improbable heights (about 1%).

Data visualization was done using ESRI ArcMap 10.4.1 (ESRI, Redlands, CA, USA) software. The coordinates' projection was defined using Universal Transverse Mercator Zone 37°N and World Geodetic system 1984. We used SaTScan version 9.7 software (Free software, Kulldorff's spatial scan statistics) and specified three Microsoft Excel files (case, population, and coordinates) as an input data to identify locations of statistically significant clusters after controlling for risk factors. Kulldorff's spatial scan statistics was used to identify statistically significant clusters (purely spatial) of high stunting and maternal malnutrition ([BMI] <18.5 kg/m^2) rates using a discrete scan statistics of Poisson probability model [18]. Scan statistics computed data across space through a circle for space and covered the entire period [18].

Spatial analysis used a circular window shape that was performed with maximum spatial cluster size as a 50% of the population at risk; 50% was the upper limit for SaTScan clusters and did not account SaTScan clusters of the population greater than 50%. The circular window with the maximum log likelihood was considered as the most likely cluster area if P-value < 0.05 and the remaining clusters were reported as secondary cluster if they are geographically non-overlapping windows with the P-value < 0.05 [18]. The maximum number of Monte Carlo replications was 999 and the minimum number of two cases was required for high rates of clusters. SaTScan Version 9.7 calculated the P-values by using the combination of Monte Carlo, sequential Monte Carlo, and Gumbel approximation [18].

To evaluate whether there is clustering or not when the known risk factors for clustering in the study area are controlled, we compared crude analysis of SaTScan with the adjusted analysis after including covariates in the SaTScan Version 9.7. The dependent variable was a binary outcome (yes/no) based on the presence or absence of stunting and maternal malnutrition [BMI] <18.5 kg/m^2. We considered the known predictor variables such as wealth index, food insecurity, altitude, maternal education, maternal occupation and maternal age. These covariates were selected based on their significant association with child stunting and maternal malnutrition ([BMI] <18.5 kg/m^2) according to previous research conducted in Boricha district [11, 12].

Although identifying the presence of clustering after controlling for known risk factors is the primary objective, we also identified the effects of the risk factors for the observed clustering [19]. Hence, we did a logistic regression model with declaring data to be time-series using Stata version 15 for further evaluation of the predictors of spatial clustering. The time setting of the model used season of the year as time variable, and child code was considered as panel ID variable. The model construction used an exchangeable correlation matrix, and a main effect term builder. The stunted children identified within the spatial cluster were compared with stunted children outside the cluster. The presence or absence of differences of risk factors between the groups (stunted children in the cluster versus stunted children outside the cluster) could give information about the underlying risk factors that may be responsible for the observed clustering. The potential risk factors considered were wealth status, altitude, household food insecurity, maternal age, maternal education, and maternal occupation. However, because of the very wide cluster radius size in the spatial cluster of maternal malnutrition, we limited our analysis only for stunting [20].

ETHICAL CONSIDERATION

We had secured ethical approval from Institutional Review Board (IRB) at Hawassa University (Ref. No: IRB/001/09, Date: 13/09/2016) and the Regional Committee for Medical and Health Research Ethics, Western Norway (ref: 2016/1631/REK Vest) before we had started data collection. All study participants were informed about the benefit and harm of the study, and then informed written consent was obtained from all study participants. Those who could not sign on used their thumb print.

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RESULTS

CHARACTERISTICS OF THE STUDY POPULATION

A total of 935 children residing in 897 households were visited for the four-consecutive time for the study. About 505 (54%) were boys and 427 (46%) were females. Most of our respondents (99%; 892 of 897) were biological mothers of children. The mean age of respondents was 28 years. About 50% (445 of 887) of mothers were illiterate. Occupationally, 770 of 889 (87%) of mothers were housewives and farmers. The average family size of the study households was five persons. See ***Table 1*** describes the characteristics of the study population by the nutritional status.

BASELINE CHARACTERISTICS	CHILD MALNUTRITION (N = 935 CHILDREN: 3312 MEASUREMENTS)		MATERNAL MALNUTRITION (N = 892 MOTHERS: 3179 MEASUREMENTS)	
		STUNTING		THINNESS
	MEAN (95% CI)	% WITH Z-SCORE < –2	MEAN (95%CI)	BMI <18.5 KG/M²
Child age (in months)				
6–11	–0.9 (–1.21, –0.64)	35 (25.2%)	19.9 (19.48, 20.34)	40 (30.8%)
12–23	–1.5 (–1.63, –1.34)	316 (43.5%)	19.6 (19.47, 19.80)	214 (31.2%)
24–35	–1.6 (–1.72, –1.47)	328 (39.7%)	19.85 (19.67, 20.03)	226 (28.3%)
36 and above	–1.8 (–1.93, –1.76)	729 (44.9%)	20.3 (20.19, 20.44)	351 (23.5%)
Child sex				
Male	–1.7 (–1.79, –1.62)	791 (44.1%)	20.1 (19.97, 20.20)	443 (25.5%)
Female	–1.6 (–1.71, –1.53)	617 (40.6%)	20.0 (19.84, 20.10)	410 (28.5%)
Mother's age (in years)				
19 and below	–1.3 (–1.98, –0.65)	2 (33.3%)	24.7 (23.17, 26.23)	0
20–29	–1.6 (–1.65, –1.49)	742 (39.3%)	20.4 (20.30, 20.52)	374 (20.8%)
30–39	–1.8 (–1.86, –1.66)	607 (46.3%)	19.5 (19.35, 19.62)	447 (35.4%)
40 and above	–1.9 (–2.19, –1.52)	34 (42.0%)	19.8 (19.16, 20.42)	28 (33.3%)
Household food insecurity				
Food secured	–1.7 (–1.83, –1.52)	229 (40.2%)	20.5 (20.25, 20.69)	124 (21.7%)
Food in-secure	–1.7 (–1.74, –1.60)	1,174 (43.1%)	19.9 (19.84, 20.03)	729 (28.1%)
Household dietary diversity				
<=3	–1.5 (–1.64, –1.29)	189 (39.5%)	20.2 (19.98, 20.42)	116 (24.5%)
>4	–1.8 (–1.84, –1.69)	878 (44.6%)	20.0 (19.86, 20.10)	536 (27.4%)
Wealth quantiles				
Poorest	–1.9 (–2.03, –1.72)	331 (50.2%)	19.7 (19.48, 19.85)	216 (31.5%)
Poor	–1.6 (–1.78, –1.51)	293 (42.5%)	20.0 (19.79, 20.17)	186 (28.8%)
Medium	–1.7 (–1.79, –1.51)	258 (40.8%)	20.3 (20.14, 20.53)	120 (20.6%)
Rich	–1.7 (–1.81, –1.55)	290 (42.8%)	20.0 (19.77, 20.18)	180 (29.3%)
Richest	–1.4 (–1.57, –1.32)	224 (35.2%)	20.2 (20.03, 20.41)	155 (24.6%)
Family size				
<=5	–1.7 (–1.73, –1.57)	804 (41.9%)	20.1 (20.01, 20.23)	447 (24.5%)
>5	–1.7 (–1.81, –1.61)	532 (44.1%)	19.9 (19.78, 20.08)	355 (30.6%)
Mother's education				
Primary	–1.6 (–1.67, –1.49)	581 (39.1%)	20.0 (19.84, 20.11)	417 (29.1%)
Secondary	–1.0 (–1.27, –0.78)	39 (26.0%)	20.7 (20.35, 21.14)	20 (14.4%)
Non formal education	–1.8 (–1.88, –1.70)	780 (47.1%)	20.0 (19.91, 20.14)	415 (26.2%)
Occupational status of mother				
Housewife & farmer	–1.7 (–1.77, –1.63)	1233 (43.5%)	20.0 (19.88, 20.07)	764 (27.8%)
Merchant/employed	–1.4 (–1.56, –1.25)	136 (35.1%)	20.4 (20.18, 20.70)	76 (22.1%)
Other	–1.9 (–2.32, –1.48)	38 (47.0)	20.4 (19.92, 20.82)	12 (15.4%)

(Contd.)

BASELINE CHARACTERISTICS	CHILD MALNUTRITION (N = 935 CHILDREN: 3312 MEASUREMENTS)		MATERNAL MALNUTRITION (N = 892 MOTHERS: 3179 MEASUREMENTS)	
		STUNTING		THINNESS
	MEAN (95% CI)	% WITH Z-SCORE < –2	MEAN (95%CI)	BMI <18.5 KG/M^2
Father's educational status				
Primary	–1.7 (–1.75, –1.59)	692 (41.5%)	20.0 (19.83, 20.07)	456 (28.4%)
Secondary and above	–1.3 (–1.45, –1.12)	120 (30.2%)	20.3 (20.00, 20.53)	80 (22.3%)
No formal education	–1.8 (–1.87, –1.65)	581 (47.4%)	20.1 (19.93, 20.22)	313 (26.2%)
Father's occupational status				
Farmer	–1.8 (–1.85, –1.69)	923 (44.8%)	20.0 (19.92, 20.15)	538 (27.6%)
Merchant	–1.4 (–1.51, –1.30)	318 (35.6%)	19.8 (19.68, 20.02)	257 (29.4%)
Others	–1.8 (–1.96, –1.58)	159 (46.4%)	20.5 (20.26, 20.75)	54 (16.3%)
Residency				
Sadamo Dikicha	–1.6 (–1.81, –1.45)	142 (40.1%)	18.6 (18.35, 18.93)	199 (52.0%)
Alawo Siso	–1.0 (–1.16, –0.84)	93 (25.9%)	20.1 (19.89, 20.39)	78 (25.9%)
Fulasa Aldaada	–2.3 (–2.62, –2.06)	177 (61.5%)	22.0 (21.73, 22.24)	27 (7.6%)
Aldaada Deela	–1.6 (–1.81, –1.46)	137 (37.9%)	20.0 (19.76, 20.25)	89 (25.7%)
Kitawo Dambie	–2.2 (–2.38 –2.06)	198 (54.3%)	18.8 (18.56, 19.01)	170 (50.0%)
Gonowa Bulano	–2.2 (–2.37, –2.06)	233 (59.3%)	20.1 (19.85, 20.33)	66 (22.3%)
Sadamo Challa	–1.4 (–1.57, –1.32)	122 (30.1%)	19.9 (19.69, 20.08)	80 (20.8%)
Qonsore haranja	–0.9 (–1.11, –0.78)	108 (26.1%)	21.3 (21.05, 21.49)	35 (9.0%)
Hanja Gooro	–1.8 (–1.97, –1.55)	198 (52.9%)	19.5 (19.31, 19.68)	114 (29.6%)

Table 1 The nutritional status by the selected baseline study characteristics, among children and their mothers in the Boricha district of Southern Ethiopia; March 2017.

NUTRITIONAL STATUS OF CHILD AND THEIR MOTHERS

We found that the prevalence of stunting and maternal malnutrition varied among the nine kebeles. The highest prevalence of stunting (62%) and was recorded in Fulasa-Aldaada kebele. The highest prevalence of maternal malnutrition (52%) recorded in Sadamo-Dikicha kebele. The prevalence of stunting increased as the age of the child increased. See ***Table 1*** describes the characteristics of the study population by the nutritional status.

SPATIAL CLUSTERING OF STUNTING

The crude analysis of SaTScan showed that, there were areas with higher risk of stunting than in the underlying at-risk populations. The most likely and secondary significant spatial clusters for stunting were identified in the north and north-eastern part of the study area.

Children identified within the most likely clusters were 1.6 times more at risk of stunting than in the underlying at-risk populations in the unadjusted analysis. However, covariate adjusted SaTScan analysis showed that clustering disappeared. See ***Table 2*** for more information.

SPATIAL CLUSTERING OF MATERNAL MALNUTRITION BASED ON MATERNAL BMI

The crude analysis of SaTScan showed that, there were areas with higher risk of maternal malnutrition than in the underlying at-risk populations. Mothers within the most likely clusters were 2.4 times more at risk of malnutrition in the crude analysis. However, covariate adjusted SaTScan analysis did not show spatial variation of maternal malnutrition. See ***Table 3*** for more information.

	MOST LIKELY CLUSTERS	
	UNADJUSTED SATSCAN ANALYSIS	ADJUSTED SATSCAN ANALYSIS
Number of locations	166	–
Coordinates	6.989467 N, 38.286050 E	7.001650 N, 38.279983 E
Radius (km)	4.71 km	0 km
Population (No. of children)	614	4
Number of cases	361	3
Expected cases	258.67	2.00
Annual cases per 100,000	70 177.6	75 426.1
Observed/expected cases	1.40	1.50
Relative risk	1.55	1.50
Log likelihood ratio	23.36	0.216786
P-value	P < 0.001	P = 1.00
	SECONDARY CLUSTERS	
	UNADJUSTED	ADJUSTED
Number of locations	99	–
Coordinates	6.938250 N, 38.358983 E	–
Radius (km)	2.96 km	–
Population (No. of children)	318	–
Number of cases	201	–
Expected cases	133.97	–
Annual cases per 100,000	75 444.7	–
Observed/expected cases	1.51	–
Relative risk	1.60	–
Log likelihood ratio	16.531033	–
P-value	P < 0.001	–

Table 2 Purely spatial scan statistics of the significant clusters for stunting among children under the age of five years, Boricha, Southern Ethiopia, 2017.

	MOST LIKELY CLUSTERS	
	UNADJUSTED SATSCAN ANALYSIS	ADJUSTED SATSCAN ANALYSIS
Number of locations	84	–
Coordinates	6.930917 N, 38.936267 E	6.923550 N, 38.288100 E
Radius (km)	62.16 km	0 km
Population (No. of children)	329	4
Number of cases	182	3
Expected cases	87.21	1.80
Annual cases per 100,000	66,029.1	52,731.9
Observed/expected cases	2.09	1.67
Relative risk	2.41	1.67
Log likelihood ratio	45.837737	0.333394
P-value	P < 0.001	P = 1.00

(Contd.)

	MOST LIKELY CLUSTERS	
	UNADJUSTED SATSCAN ANALYSIS	ADJUSTED SATSCAN ANALYSIS
	SECONDARY CLUSTER	
	UNADJUSTED	ADJUSTED
Number of locations	56	–
Coordinates	6.913650 N, 38.295950 E	–
Radius (km)	1.57 km	–
Population (No. of children)	215	–
Number of cases	121	–
Expected cases	56.99	–
Annual cases per 100,000	67 174.9	–
Observed/expected cases	2.12	–
Relative risk	2.33	–
Log likelihood ratio	29.984131	–
P-value	P < 0.001	–

Table 3 Purely spatial scan statistics of the significant clusters for maternal BMI in the Boricha, Southern Ethiopia, 2017.

RISK FACTORS IDENTIFICATION FOR SPATIAL CLUSTERING

In this analysis we aimed to provide further insights into risk factors for the clustering of stunting and to evaluate the effects of risk factors for the observed crude spatial clustering. Accordingly, we found significant differences with regard to factors such as poverty, maternal age, maternal education, and maternal occupation between stunting cases found within a crude spatial cluster and cases outside the cluster (***Table 4***).

Table 4 Risk factor for clustering of stunting among children under the age of five years in nine kebele, Boricha, Southern Ethiopia, 2017.

VARIABLES		CASES WITHIN IDENTIFIED SPATIAL CLUSTER		UNADJUSTED OR		ADJUSTED OR	
		YES (%)	NO (%)	OR	95% CI	OR	95% CI
Food insecurity	Secured	95 (48.2)	102 (51.8%)	1	Ref	1	Ref
	Mild food insecurity	90 (75.0%)	30 (25.0%)	3.22	1.96–5.31	2.89	1.72–4.89
	Moderate food insecurity	101 (50.5%)	99 (49.5%)	1.10	0.74–1.62	0.97	0.63–1.49
	Severe food insecurity	274 (36.4%)	478 (63.6%)	0.62	0.45–0.84	0.42	0.30–0.60
Wealth index	Poorest	173 (53.6%)	150 (46.4%)	1	Ref	1	Ref
	Poor	88 (35.6%)	159 (64.4%)	0.48	0.34–0.67	0.37	0.25–0.54
	Medium	65 (27.9%)	168 (72.1%)	0.34	0.23–0.48	0.25	0.17–0.37
	Rich	138 (52.7%)	124 (47.3%)	0.96	0.69–1.34	0.74	0.51–1.06
	Richest	96 (47.1%)	108 (52.9%)	0.77	0.54–1.09	0.60	0.40–0.91
Mother's age (in years)		560 (44.1%)	709 (55.9%)	0.99	0.97–1.01	0.94	0.92–0.96
Mother's education	Illiterate	356 (48.9%)	372 (51.1%)	1	Ref	1	Re
	Primary	196 (38.7%)	311 (61.3%)	0.66	0.52–0.83	0.39	0.29–0.53
	Secondary and above	8 (23.5%)	26 (76.5%)	0.32	0.14–0.72	0.18	0.07–0.48
Mother's occupation	Farmers and housewife	501 (45.3%)	605 (54.7%)	1	Ref	1	Ref
	Employed/merchant	49 (38.0%)	80 (62.0%)	0.74	0.51–1.08	0.59	0.39–0.90
	Others	10 (29.4%)	24 (70.6%)	0.50	0.24–1.06	0.50	0.18–1.42
Altitude		560 (44.1%)	709 (55.9%)	1.00	0.99–1.003	1.00	0.99–1.003

Stunted children within an identified spatial cluster were about four times more likely to be from poorest households than those outside a cluster. Stunted children within an identified spatial cluster were more likely to be from younger and illiterate mothers, and often the mothers were farmers and housewives. These findings suggest that these factors are non-randomly distributed, and varies across cases identified within the cluster and cases identified outside the cluster.

DISCUSSION

We found that child stunting and maternal malnutrition were not spatially clustered in drought prone areas after we controlled for known risk factors of malnutrition. The spatial clustering of child stunting and maternal malnutrition could be due to non-random distribution of risk factors of malnutrition such as poverty, maternal age, maternal education, and maternal occupation.

Our unadjusted scan statistics demonstrated that, the spatial distribution of child and maternal malnutrition was non-random process, as has also been demonstrated by other countries [21, 22], including Ethiopia [9, 10]. Some of these findings assumed that the basis for area-level spatial variation in malnutrition is due to individual or household level characteristics, which is similar to our findings [22, 23]. Thus, the absence of clustering after controlling for known risk factors of child and maternal malnutrition could improve our understanding of possible factors of malnutrition clustering. Moreover, this could have implication for targeting nutritional interventions, and to consider type of nutrition related interventions such as educational, agricultural or health care services.

However, there could be more risk factors that might be associated with both child and maternal malnutrition, and that could influence the spatial heterogeneity of child and maternal malnutrition. For example, maternal depression and malnutrition could influence child malnutrition [24, 25]. Micronutrient deficiencies such as zinc, iron, iodine and vitamins are prevalent among women and children due to higher physiological demands, and again these deficiencies could lead to higher risk of infections [26–28]. The occurrence of infectious diseases such as respiratory illnesses, malaria and diarrhoea can affect child and maternal malnutrition [29–34]. Furthermore, complementary feeding practices, multiple births, premature births, short birth length, maternal care, low birth weight are associated with increased risk of childhood malnutrition [35–40]. Contextual factors such as beliefs and norms could also be risk factors for malnutrition [41]. Moreover, our cohort study only lasted for one-year, and it is well-documented that the stunting process could start in prenatal period. Thus, it is advisable to conduct studies over longer periods to identify more risk factors of growth faltering during prenatal and early life [42].

STRENGTHS OF THE STUDY

Among some of the strengths of the study, the risk factor like food insecurity was collected in four different seasons along with the child and maternal malnutrition measurements. We used non-aggregated (individual data points) which could increase the spatial resolution of cluster detection [20]. Moreover, our study identified some risk factors of spatial clustering of child and maternal malnutrition in the drought prone area.

We had less than 10% of missed measurements (height-for-age Z-score and body mass index) due to loss to follow-up and outliers, which indicated that the impact of loss to follow and outliers was low. Moreover, our study population is a representative sample of the population, and the non-response bias was low. We performed a cohort study design, and thus our study can establish temporal associations. Moreover, our study had consistency with the previous studies regarding to local clustering of child stunting [10].

LIMITATIONS OF THE STUDY

The non-random distribution of risk factors not evaluated in our study could influence the spatial clustering of child and maternal malnutrition. However, we included the most common risk factors of child and maternal malnutrition. We opted to use a circular window in the spatial scan statistics rather than other windows to identify the significant clusters; however, the true clusters may be elliptic or rectangular. Scan statistics using circular windows cannot detect these shapes, unless all possible angles are considered, which is difficult to compute [18].

Nutritional epidemiology has been criticized for its inaccurate survey measurements of food consumption and reliance on observational associations [43–45]. Thus, one method of enhancing the validity of nutritional studies is to conduct randomized controlled trials [44]. Moreover, it is recommended to apply new technologies such as biomarkers and digital technologies for nutritional epidemiology studies [45].

In this study, measurement errors could be originated from the anthropometric recordings, recall bias, and social desirability bias. However, to minimize such biases, we trained data collectors and supervisors, conducted pre-tests, evaluated technical error measurements, and calibrated instruments. Moreover, we used memorable events to aid the mother's recall of their children's age and we also used short recall periods for variables related to household food consumption. Missed information regarding government support such as the safety-net programme could influence the findings of our study.

CONCLUSIONS AND RECOMMENDATIONS OF THE STUDY

In conclusion, child stunting and maternal malnutrition were not spatially clustered after we controlled for known risk factors for child stunting and maternal malnutrition, and these risk factors are probably not randomly distributed. The results of this study would be helpful for geographically targeting nutritional interventions and to consider type of nutrition related interventions such as educational, agricultural or health care services in a drought prone area.

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR CONTRIBUTIONS

M.B., E.L., and B.L. designed the study. M.B. and B.L. participated in the data analysis, and drafting of the manuscript. All authors approved the final article.

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REFERENCES

1. **Black RE, Allen LH, Bhutta ZA,** et al. Maternal and child undernutrition: Global and regional exposures and health consequences. *Lancet*. 19 January 2008; 371(9608): 243–60. DOI: *https://doi.org/10.1016/S0140-6736(07)61690-0*
2. **United Nations Department of Economic and Social Affairs.** Sustainable development goal 2. 2019. *https://sustainabledevelopment.un.org/sdg2*.
3. **Kennedy E, Fekadu H, Ghosh S,** et al. Implementing Multisector Nutrition Programs in Ethiopia and Nepal: Challenges and Opportunities From a Stakeholder Perspective. *Food and Nutrition Bulletin*. 2016; 37. DOI: *https://doi.org/10.1177/0379572116674552*
4. **Development Initiatives.** Global nutrition report: Shining a light to Spur action on nutrition; 2018. *https://reliefweb.int/report/world/2018-global-nutrition-report-shining-light-spur-action-nutrition*.
5. **Marx S, Phalkey R, Aranda-Jan CB, Profe J, Sauerborn R, Hofle B.** Geographic information analysis and web-based geoportals to explore malnutrition in Sub-Saharan Africa: A systematic review of approaches. *Article. BMC public health*. 20 November 2014; 14. DOI: *https://doi.org/10.1186/1471-2458-14-1189*
6. **Blössner M, de Onis M.** Malnutrition: Quantifying the health impact at national and local levels. *WHO Environmental Burden of Disease Series*. 2005; 12.
7. **Osgood-Zimmerman A, Millear AI, Stubbs RW,** et al. Mapping child growth failure in Africa between 2000 and 2015. *Nature*. 28 February 2018; 555(7694): 41–47. DOI: *https://doi.org/10.1038/nature25760*
8. **Miller HJ.** Tobler's First Law and Spatial Analysis. *Annals of the Association of American Geographers*. 1 June 2004; 94(2): 284–289. DOI: *https://doi.org/10.1111/j.1467-8306.2004.09402005.x*
9. **Alemu ZA, Ahmed AA, Yalew AW, Birhanu BS.** Non random distribution of child undernutrition in Ethiopia: spatial analysis from the 2011 Ethiopia demographic and health survey. *International journal for equity in health*. 3 December 2016; 15(1): 198. DOI: *https://doi.org/10.1186/s12939-016-0480-z*
10. **Gebreyesus SH, Mariam DH, Woldehanna T, Lindtjørn B.** Local spatial clustering of stunting and wasting among children under the age of 5 years: Implications for intervention strategies. *Public health nutrition*. 2015; 19(8): 1417–1427. DOI: *https://doi.org/10.1017/S1368980015003377*
11. **Belayneh M, Loha E, Lindtjorn B.** Seasonal Variation of Household Food Insecurity and Household Dietary Diversity on Wasting and Stunting among Young Children in A Drought Prone Area in South Ethiopia: A Cohort Study. *Ecology of food and nutrition*. 16 July 2020; 1–26. DOI: *https://doi.org/10.1080/03670244.2020.1789865*
12. **Belayneh M, Loha E, Lindtjørn B.** Maternal malnutrition in drought-prone areas of Southern Ethiopia: A cohort study (Unpublished work); 2021.
13. **Coates J, Swindale A, Bilinsky P.** Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide. Washington, DC. 20009-57212007.
14. **Hagos SG, Lunde T, Damen M, Woldehanna T, Lindtjørn B.** Is the adapted Household Food Insecurity Access Scale (HFIAS) developed internationally to measure food insecurity valid in urban and rural households of Ethiopia? *BMC nutrition*. 2015; 1(1): 2. DOI: *https://doi.org/10.1186/2055-0928-1-2*
15. **Kabalo BY, Gebreyesus SH, Loha E, Lindtjorn B.** Performance of an adapted household food insecurity access scale in measuring seasonality in household food insecurity in rural Ethiopia: A cohort analysis. *BMC nutrition*. 2019; 5: 54. DOI: *https://doi.org/10.1186/s40795-019-0323-6*
16. **World Health Orgaization.** WHO Child Growth Standards based on length/height, weight and age. *Acta paediatrica (Oslo, Norway: 1992) Supplement*. April 2006; 450: 76–85. DOI: *https://doi.org/10.1111/j.1651-2227.2006.tb02378.x*
17. **The Sphere Project.** Humanitarian Charter and Minimum Standards in Humanitarian Response, fourth edition, Geneva, Switzerland; 2018. *https://www.spherestandards.org/handbook*. 2018.
18. **Kulldorff M.** SaTScan User Guide for version 9. 6.1; 2020. *https://www.satscan.org/*.
19. **Tobler WR.** A Computer Movie Simulating Urban Growth in the Detroit Region. *Economic Geography*. 1970; 46: 234–240. DOI: *https://doi.org/10.2307/143141*
20. **Ozonoff A, Jeffery C, Manjourides J, White LF, Pagano M.** Effect of spatial resolution on cluster detection: A simulation study. *International Journal of Health Geographics*. 27 November 2007; 6(1): 52. DOI: *https://doi.org/10.1186/1476-072X-6-52*
21. **Morris SS.** Targeting urban malnutrition: A multi-city analysis of the spatial distribution of childhood nutritional status. *Food Policy*. 1 Feburary 2001; 26(1): 49–64. DOI: *https://doi.org/10.1016/S0306-9192(00)00029-4*
22. **Fenn B, Morris SS, Frost C.** Do childhood growth indicators in developing countries cluster? Implications for intervention strategies. *Public health nutrition*. October 2004; 7(7): 829–34. DOI: *https://doi.org/10.1079/PHN2004632*

23. **Adekanmbi VT, Uthman OA, Mudasiru OM.** Exploring variations in childhood stunting in Nigeria using league table, control chart and spatial analysis. *BMC public health*. 18 April 2013; 13: 361. DOI: *https://doi.org/10.1186/1471-2458-13-361*
24. **Anoop S, Saravanan B, Joseph A, Cherian A, Jacob KS.** Maternal depression and low maternal intelligence as risk factors for malnutrition in children: A community based case-control study from South India. *Arch Dis Child*. 2004; 89(4): 325–329. DOI: *https://doi.org/10.1136/adc.2002.009738*
25. **Kang Y, Kim J.** Risk factors for undernutrition among children 0-59 months of age in Myanmar. *Maternal & child nutrition*. October 2019; 15(4): e12821. DOI: *https://doi.org/10.1111/mcn.12821*
26. **Katona P, Katona-Apte J.** The Interaction between Nutrition and Infection. *Clinical Infectious Diseases*. 2008; 46(10): 1582–1588. DOI: *https://doi.org/10.1086/587658*
27. **Bailey RL, West KP, Jr., Black RE.** The Epidemiology of Global Micronutrient Deficiencies. *Annals of Nutrition and Metabolism*. 2015; 66(suppl 2): 22–33. DOI: *https://doi.org/10.1159/000371618*
28. **Maggini S, Wintergerst ES, Beveridge S, Hornig DH.** Selected vitamins and trace elements support immune function by strengthening epithelial barriers and cellular and humoral immune responses. *British Journal of Nutrition*. 2007; 98(S1): S29–S35. DOI: *https://doi.org/10.1017/S0007114507832971*
29. **Scrimshaw NS, Taylor CE, Gordon JE.** Interactions of nutrition and infection; prepared in consultation with seventeen specialists in various countries. 1968; 329. World Health Organization monograph series; no 57. 9241400579. *https://apps.who.int/iris/handle/10665/41782*.
30. **Rowland MG, Rowland SG, Cole TJ.** Impact of infection on the growth of children from 0 to 2 years in an urban West African community. *The American Journal of Clinical Nutrition*. 1988; 47(1): 134–138. DOI: *https://doi.org/10.1093/ajcn/47.1.134*
31. **Rowland MGM, Cole TJ, Whitehead RG.** A quantitative study into the role of infection in determining nutritional status in Gambian village children. *British Journal of Nutrition*. 2007; 37(3): 441–450. DOI: *https://doi.org/10.1079/BJN19770047*
32. **Checkley W, Epstein L, Gilman R, Cabrera L, Black R.** Effects of acute diarrhea on linear growth in Peruvian children. *American journal of epidemiology*. 2003; 157(2): 166–75. DOI: *https://doi.org/10.1093/aje/kwf179*
33. **Walker CF, Black RE.** Zinc and the risk for infectious disease. *Annual Review of Nutrition*. 2004; 24(1): 255–275. DOI: *https://doi.org/10.1146/annurev.nutr.23.011702.073054*
34. **Gari T, Loha E, Deressa W, Solomon T, Lindtjørn B.** Malaria increased the risk of stunting and wasting among young children in Ethiopia: Results of a cohort study. *PloS one*. 2018; 13(1): e0190983–e0190983. DOI: *https://doi.org/10.1371/journal.pone.0190983*
35. **Umeta M, West CE, Verhoef H, Haidar J, Hautvast JGAJ.** Factors Associated with Stunting in Infants Aged 5–11 Months in the Dodota-Sire District, Rural Ethiopia. *The Journal of Nutrition*. 2003; 133(4): 1064–1069. DOI: *https://doi.org/10.1093/jn/133.4.1064*
36. **Beal T, Tumilowicz A, Sutrisna A, Izwardy D, Neufeld LM.** A review of child stunting determinants in Indonesia. *Maternal & child nutrition*. October 2018; 14(4): e12617. DOI: *https://doi.org/10.1111/mcn.12617*
37. **Stewart CP, Iannotti L, Dewey KG, Michaelsen KF, Onyango AW.** Contextualising complementary feeding in a broader framework for stunting prevention. *Maternal & child nutrition*. September 2013; 9(suppl 2): 27-45. DOI: *https://doi.org/10.1111/mcn.12088*
38. **Hamel C, Enne J, Omer K,** et al. Childhood Malnutrition is Associated with Maternal Care During Pregnancy and Childbirth: A Cross-Sectional Study in Bauchi and Cross River States, Nigeria. *J Public Health Res*. 2015; 4(1): 408–408. DOI: *https://doi.org/10.4081/jphr.2015.408*
39. **Ntenda PAM.** Association of low birth weight with undernutrition in preschool-aged children in Malawi. *Nutrition journal*. 2 September 2019; 18(1): 51. DOI: *https://doi.org/10.1186/s12937-019-0477-8*
40. **Hailu BA, Bogale GG, Beyene J.** Spatial heterogeneity and factors influencing stunting and severe stunting among under-5 children in Ethiopia: Spatial and multilevel analysis. *Sci Rep*. 2 October 2020; 10(1): 16427. DOI: *https://doi.org/10.1038/s41598-020-73572-5*
41. **Morales R, Aguilar AM, Calzadilla A.** Geography and culture matter for malnutrition in Bolivia. *Economics & Human Biology*. 1 December 2004; 2(3): 373–389. DOI: *https://doi.org/10.1016/j.ehb.2004.10.007*
42. **Shrimpton R, Victora CG, de Onis M, Lima RC, Blossner M, Clugston G.** Worldwide timing of growth faltering: Implications for nutritional interventions. *Pediatrics*. May 2001; 107(5): E75. DOI: *https://doi.org/10.1542/peds.107.5.e75*
43. **Ioannidis JPA.** Implausible results in human nutrition research. *BMJ: British Medical Journal*. 2013; 347: f6698. DOI: *https://doi.org/10.1136/bmj.f6698*

44. **Ioannidis JPA.** The Challenge of Reforming Nutritional Epidemiologic Research. *JAMA*. 2018; 320(10): 969–970. DOI: *https://doi.org/10.1001/jama.2018.11025*
45. **Hu FB, Willett WC.** Current and Future Landscape of Nutritional Epidemiologic Research. *JAMA*. 27 November 2018; 320(20): 2073–2074. DOI: *https://doi.org/10.1001/jama.2018.16166*

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Data Collection Instruments

&

Ethical Approvals

Quest ID: |__|__|__|__|__|

Seasonality and Spatial Distribution of Malnutrition

INTERVIEW INFORMATION

DATE OF INTERVIEW	|__|__| Day |__|__| Month |__|__||__|__| Year
TIME STARTED	|__|__| Hour |__|__| Minutes
TIME ENDED	|__|__| Hour |__|__| Minutes
INTERVIEWER NAME	______________________________________
SUPERVISOR	______________________________________
CHECKED BY	______________________________________
ENTERED BY	1) ____________________________________
	2) ____________________________________

NAME OF THE KEBELE	__________/___________
NAME OF VILLAGE	__________/___________
Name of HAD	|__|__|
NAME OF THE HOUSEHOLD HEAD	__________/___________

INTERVIEWER: INTRODUCTION AND CONSENT. May I begin the interview now?

NO	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
Section One: I would like to start the interview asking a few questions about you, your partner and the household condition.			
101.	Date of interview	Monday ....1 Tuesday ....2 Wednesday ....3 Thursday ....4 Friday ....5 Saturday....................6 Sunday....................7	
102.	Respondent's relationship/status	Head....................1 Spouse of head ....2 Other adult male....................3 Other adult female....................4 Other (specify) ....5 ________________________	
103.	Sex of the household head?	Male ....1 Female 2	
104.	What is your family size?	________________ persons	
105.	How old are you now?	____________years	
106.	What is the highest level of school you attended?	Primary (1-8) ....1 Secondary(9-12) ....2 College/university....................3 Read and write ....4 Illiterate 5	
107.	What is your marital status?	Currently married ....1 Separated ....2 Divorced ....3 Widowed ....4 Never married 5	
108.	What is your religion?	Protestant....................1 Orthodox Christian ....2 Catholic ....3 Islam ....4 Other (specify) ....5 ________________________	

109.	To which ethnic group do you belong?	Sidama ....1 Amhara ....2 Wolayita ....3 Oromo ....4 Silte ....5 Other (specify) ....6 ______________________	
110.	What is your occupation?	Farmer and housewife....................................1 Housewife ....2 Employee/private ....3 Student....................................4 Merchant ....5 Maid servant....................................6 Daily laborer ....7 Other (specify) ....8 ______________________	
111.	What is your partner/husband occupation?	Farmer ....1 employee/private ....2 Student....................................3 Merchant ....4 Daily laborer ....5 Unemployed ....6 Other (specify) ....7 ______________________	
112.	What is your partner/husband educational status? (highest level of school attended)	Primary (1-8) ....1 Secondary(9-12) ....2 College/university....................................3 Read and write ....4 Illiterate 5	
113.	Who usually decides how the money you earn will be used: you, your husband/partner, you and your husband/partner jointly?	Respondent ....1 Husband/partner ....2 Respondent and Husband/partner jointly…..3 Other (specify) ....4 ______________________	
114.	Who usually makes decisions about health care for yourself?	Respondent ....1 Husband/partner ....2 Respondent and Husband/partner jointly …3 Other (specify) 4	
115.	Who usually makes decisions about making major household purchases?	Respondent ....1 Husband/partner ....2 Respondent and Husband/partner jointly ....3 Other (specify) 4	
116.	Does your husband help you with household chores like looking after the children, cooking, cleaning the house, and doing other work around the house?	Yes....................................1 No....................................0	
INTERVIEWER: PLEASE SUPPLY THE FOLLOWING INFORMATION ABOUT RESPONDENT'S HOME			
117.	Main construction material used for the floor:	Natural floor Earth /sand 11	

	CIRCLE ALL THAT APPLY	dung ....12 Rudimentary floor Wood planks ....21 Bamboo....22 Finished floor Polished wood or parquet....31 Ceramic tiles ....33 Cement ....34 Other (specify)....36 ______________________________	
118.	Main construction material used for the roof: CIRCLE ALL THAT APPLY	Natural roofing No roof ....11 Thatch/leaf/mud ....12 Rudimentary roofing Rustic mat/plastic sheet ....21 Reed/Bamboo ....22 Wood planks ....23 Finished roofing Corrugated iron/metal....31 Wood ....32 Other (specify)....33 ______________________________	
119.	Main construction material used in exterior walls: CIRCLE ALL THAT APPLY	Natural walls No walls ....11 Cane/Trunks/Bamboo/Reed ....12 Dirt ....13 Rudimentary walls Bamboo/wood with Mud ....21 Stone with mud ....22 Plywood ....23 Card board ....24 Reused wood ....25 Finished walls Cement ....31 Stone with lime/cement ....32 Bricks ....33 Covered adobe....34 Wood planks/shingles ....35 Other (specify)....36 ______________________________	
120.	Will you describe your family's household structure, please?	We live in a rented a house.... 1 We live in a house that we own by purchase...... 2 We live in a house that we inherited from family.... 3 We live in a house that we constructed by ourselves....4 Others (specify).... 5	
121.	How many rooms in this household are used for sleeping	……………………………………………	
122.	Does any member of the household own any agricultural land?	Yes....1 No....0	**Q124**
123.	How many (LOCAL UNITS) of agricultural land do members of this household own?	Local units(*Timad*) |__|__|	

	LOCAL UNITS ____________ (SPECIFY) IF 95 OR MORE CIRCLE 'B'	Don't know 98	
124.	Does the household own any livestock, herds, other farm animals, or poultry?	Yes ....1 No..0	Q126
125.	How many of the following animals do you keep? (INTERVIEWER: IF HOUSEHOLD DOES NOT OWN A PARTICULAR ITEM, RECORD "00" AGAINST THAT ITEM.)	1) Milk cows, oxen or bulls .... |__|__| 2) Chickens .... |__|__| 3) Goats .... |__|__| 4) Sheep...................................... |__|__| 5) Horses ,donkey, or mule .... |__|__| 6) Beehives .... |__|__|	
126.	Does any member of the hold have a bank or microfinance saving account	Yes ....1 No..0	
127.	What is the main source of water used by your household for drinking? [INTERVIEWER: BE SURE OF THE SOURCE OF "PIPED WATER". IF THE ANSWER IS "PIPED WATER" CHECK THE SOURCE AND CIRCLE THE APPROPRIATE CODE]	<u>Piped water/supply water</u> Piped inside dwelling .... 11 Piped to yard/plot .... 12 Public tap .... 13 <u>Water from spring</u> Protected well/spring .... 21 Unprotected well/spring .... 22 <u>Water from Dug well</u> Protected well .... 31 Unprotected well .... 32 <u>Water from borehole</u> Borehole in yard/plot .... 41 Public borehole .... 42 <u>Surface water</u> Pond/lake/River/stream/spring/Dam . 51 <u>Rain water</u>.. 61 <u>Tanker truck</u> .... 71 <u>Bottled water</u> .... 81 Other (specify) .... 82 ________________________	
128.	How long does it take to go there, get water, and come back?	Minutes …………………………………….. I don't know …………………………………. 88	
129.	Do you treat water to make safer to drink??	Yes ....1 No..0	Q131
130.	What do you usually do to make the water safer to drink? Anything else?	Boil……………………………………………… 1 Add blench/chlorine/Water guard/pure/Bishan gari/Aqua tab…………………………………… 2 Strain through cloth…………………..…………3 Bio sand/composite/ceramic/Pot filters……… 4	

		Solar disinfection……………………………… 5 Let it stand and settle………………………… 6 I don't know………………………………….. 7 Others (specify)……………………………… 8	
131.	What is the main source of water used by your household for other purposes such as cooking and hand washing? [INTERVIEWER: BE SURE OF THE SOURCE OF "PIPED WATER". IF THE ANSWER IS "PIPED WATER" CHECK THE SOURCE AND CIRCLE THE APPROPRIATE CODE]	<u>Piped water/supply water</u> Piped inside dwelling .... 11 Piped to yard/plot .... 12 Public tap .... 13 <u>Water from spring</u> Protected well/spring .... 21 Unprotected well/spring .... 22 <u>Water from Dug well</u> Protected well .... 31 Unprotected well .... 32 <u>Water form borehole</u> Borehole in yard/plot .... 41 Public borehole .... 42 <u>Surface water</u> Pond/lake/River/stream/spring/Dam . 51 <u>Rain water</u> .... 61 <u>Tanker truck</u> .... 71 <u>Bottled water</u> .... 81 Other (specify) 82	
132.	What kind of toilet facility does your household have? [INTERVIEWER: LIMIT TO ONE RESPONSE; IF TWO TYPES ARE MENTIONED, RECORD THE TYPE CLOSEST TO THE TOP OF THE LIST]	<u>Pit latrine</u> Pit latrine without slab ....1 Pit latrine with slab/cement........................2 Ventilated Improved pit latrine...................3 Open pit..4 No facility/bush/field ....5 Other (specify)..6 ________________________________	
133.	Do you have hand washing facilities in the toilet?	Yes ....1 No...0	
134.	Do you share this toilet facility with other households?	Yes ....1 No...0	→ **Q136**
135.	How many households use this toilet facility?	………………………………………………	
136.	Tell me, please, if your home has: [INTERVIEWER: CIRCLE ALL THAT APPLY]	Electricity..1 Watch/clock..2 Radio...3 Television ....4 Mobile Telephone..5 House Phone ....6 Refrigerator ....7 Chair..8 A bed with cotton/Sponge/Spring mattress .9 Electric Mitad...10	

		Kerosene Lamp/pressure 11	
137.	What type of fuel does your household mainly use for cooking?	fire wood………………………………………1 Charcoal………………………………………2 Animal dung…………………………………..3 Kerosene…………….……………………….4 Biogas………………………………………...5 Straw/shrubs/Grass/Agricultural crop……...6 Electricity…………………………….……..7 No cooked food in household…….….……..8 Specify other …….…………………….…..98	
138.	Where do you cook food usually?	In the house…………………………….….. 1 In separate building…………..……………. 2 Outdoors……………………...………….. 3 Specify others……………………………… 4	
139.	Does any member of household own (INTERVIEWER: IF HOUSEHOLD DOES NOT OWN A PARTICULAR ITEM, RECORD “00” AGAINST THAT ITEM.)	Bicycle………………………………………|__|__| Moto bike……………………………………|__|__| An animal draw cart………………………..|__|__| A car trunk………………………………….|__|__|	
140.	What is your household budget for?	Items 1. Food and supplies. Per day.......................….. 2. Electricity. Per month................................... 3. Water. Per month.. 4. Telephone. Per month…...............................… 5. Kerosene per day... 6. Fertilizer per year.. 7. ``Eder`` per month .... 8. ``Equb`` per month .... 9. Savings per month	

Section Two: Household Food Insecurity Access Scale (HFIAS) Measurement: Now I would like to ask you few questions regarding your household food security situation in the past four weeks.			
NO	**QUESTIONS AND FILTERS**	**CODING CATEGORIES**	**SKIP**
201.	In the past four weeks, did you worry that your household would not have enough food?	Yes ....1 No............0	Q203
202.	How often did this happen in the past four weeks?	Rarely (once or twice in the past four weeks) ....1 Sometimes (three to ten times in the past four weeks) ....2 Often (more than ten times in the past four weeks) 3	
203.	In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	Yes ....1 No............0	Q205
204.	How often did this happen in the past four weeks?	Rarely (once or twice in the past four weeks) ....1 Sometimes (three to ten times in the past four weeks) ....2 Often (more than ten times in the past four weeks) 3	
205.	In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?	Yes ....1 No............0	Q207
206.	How often did this happen in the past four weeks?	Rarely (once or twice in the past four weeks) ....1 Sometimes (three to ten times in the past four weeks) ....2 Often (more than ten times in the past four weeks) 3	
207.	In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	Yes ....1 No............0	Q209
208.	How often did this happen in the past four weeks?	Rarely (once or twice in the past four weeks) ....1 Sometimes (three to ten times in the past four weeks) ....2 Often (more than ten times in the past four weeks) 3	
209.	In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	Yes ....1 No 0	Q211
210.	How often did this happen in the past four weeks?	Rarely (once or twice in the past four weeks) ....1 Sometimes (three to ten times in the past four weeks) 2	

		Often (more than ten times in the past four weeks) 3	
211.	In the past four weeks, did you or any other household member have to eat fewer meals in a day because there was not enough food?	Yes ....1 No..0	Q213
212.	How often did this happen in the past four weeks?	Rarely (once or twice in the past four weeks) ....1 Sometimes (three to ten times in the past four weeks) ....2 Often (more than ten times in the past four weeks) 3	
213.	In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?	Yes ....1 No..0	Q215
214.	How often did this happen in the past four weeks?	Rarely (once or twice in the past four weeks) ....1 Sometimes (three to ten times in the past four weeks) ....2 Often (more than ten times in the past four weeks) 3	
215.	In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?	Yes ....1 No..0	Q217
216.	How often did this happen in the past four weeks?	Rarely (once or twice in the past four weeks) ....1 Sometimes (three to ten times in the past four weeks) ....2 Often (more than ten times in the past four weeks) 3	
217.	In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?	Yes ....1 No..0	Q219
218.	How often did this happen in the past four weeks?	Rarely (once or twice in the past four weeks) ....1 Sometimes (three to ten times in the past four weeks) ....2 Often (more than ten times in the past four weeks) 3	
219.	Have you received any food support in the past month?	Yes ....1 No..0	

220.	How do you cope at times when you are running out of food in the house?	Reduce number of meals……………………1 Reduce meal size……………………………2 Borrowing……………………………………..3 Petty trade ……………………………………4 Consume stored food (seed) ……………….5 Migration for labor……………….………...6 Sell of farm tools………………………………7 Sale charcoal/fire wood………………………8 Daily labor ……………………………………9 Safety Net……………………………………10 Sell of farm animals…………………………11 Other(specify) ……………….………………98	

Section Three: (a)Household dietary diversity

Now I would like to ask you about the types of foods that you or anyone else in your household ate ***yesterday during the day and at night*** *either separately or combined with other foods.* ***Ask this question for 2 years and above only.***

301.	Could you tell me the types of foods that were prepared in the house and that you or anyone else in your household ate?	Breakfast……………………………….…. 1 Lunch………………………………………. 2 Dinner………………………………………3 Others………………………………………4	
302.	Were there any foods that were not prepared in the house because it was a fasting day?	Yes...1 No 0	
303.	Any bread, rice, pasta, biscuits, or any other foods made from millet, sorghum, maize, wheat?	Yes...1 No 0	
304.	Any potatoes, sweet potato, bulla, *kocho* or any other food made from roots or tubers?	Yes...1 No 0	
305.	Any vegetables?	Yes...1 No 0	
306.	Any fruits?	Yes...1 No 0	
307.	Any beef, pork, lamb, goat, rabbit wild game, chicken, duck, or other birds, liver, kidney, heart, or other organ meats?	Yes...1 No 0	
308.	Any eggs?	Yes...1 No 0	
309.	Any fresh or dried fish or shellfish?	Yes...1 No 0	
310.	Any foods made from beans, peas, lentils, or nuts?	Yes...1 No 0	
311.	Any cheese, yogurt, milk or other milk products?	Yes...1 No 0	
312.	Any foods made with oil, fat, or butter?	Yes...1 No 0	
313.	Any sugar or honey?	Yes...1 No 0	
314.	Any other foods, such as condiments, coffee, tea?	Yes...1 No 0	

(b) Child's dietary diversity: N*ow I would like to ask you about the types of foods that your child ate* ***yesterday during the day and at night*** *either separately or combined with other foods.* ***Ask this question for children 6 month to 2 year only.***			
315.	Was the food that your child ate yesterday during the day and at night from foods prepared to the family?	Yes.......1 No.......0	 **Q401**
316.	Were there any foods that were not prepared for the child because it was a fasting day?	Yes.......1 No.......0	
317.	Before I ask what foods your child ________________ (name) ate yesterday. Was yesterday a usual day? For example was he sick? etc	Yes.......1 No.......0	
318.	Could you tell me the types of foods that were prepared in the house and that the child________________ (name) ate yesterday?	Breakfast.......1 Lunch.......2 Dinner.......3 Others.......4	
319.	Any bread, rice, pasta, biscuits, or any other foods made from millet, sorghum, maize, rice, wheat?	Yes.......1 No.......0	
320.	Any potatoes, bulla, *kocho* or any other food made from roots or tubers?	Yes.......1 No.......0	
321.	Any vegetables?	Yes.......1 No.......0	
322.	Any fruits?	Yes.......1 No.......0	
323.	Any beef, pork, lamb, goat, rabbit wild game, chicken, duck, or other birds, liver, kidney, heart, or other organ meats?	Yes.......1 No.......0	
324.	Any eggs?	Yes.......1 No.......0	
325.	Any fresh or dried fish or shellfish?	Yes.......1 No.......0	
326.	Any foods made from beans, peas, lentils, or nuts?	Yes.......1 No.......0	
327.	Any cheese, yogurt, milk or other milk products?	Yes.......1 No.......0	
328.	Any foods made with oil, fat, or butter?	Yes.......1 No.......0	
329.	Any sugar or honey?	Yes.......1 No.......0	
330.	Any other foods, such as condiments, coffee, tea?	Yes.......1 No.......0	

Section Four: Child health and nutrition conditions
(INTERVIEWER: ASK ABOUT ALL LIVING CHILDREN UNDER 5 YEARS OF AGE LIVING IN THE HOUSEHOLD;
Now I would like to ask your few questions about your children's health.

NO	QUESTIONS AND FILTERS	CODING CATEGORIES	SKIP
401.	How many times were you pregnant? (including those that did not end with a live births), record "00" if none	|__|__| times Don't know …….88	
402.	Now I would like to ask about all the births you have had during your life. How many times have you given live birth? [I mean, to a child who ever breathed or cried or showed other signs of life – even if he or she lived only a few minutes or hours], record "00" if none	|__|__| times Don't know …….88	
403.	How many sons or daughters do you have?	|__|__| Sons |__|__| Daughters |__|__| Total	

404.	**QUESTIONS AND FILTERS**	**Last birth/CHILD** **Child name ______________**	**Second-to-last CHILD** **Child name______________**
405.	How old is [name]?	______________ months	______________ months
406.	Sex of [name]?	Male……………………...1 Female …………………2	Male……………………...1 Female …………………2
407.	How long (months) was the interval between the last child and second-to-last birth?	______________ months	______________ months
408.	Where did you give birth? PROBE TO IDENTIFY THE PLACE OF DELIVERY	Hospital ....….1 Health center.............….2 Health post................….3 Home ....….4 TBA home ....….5 Other (specify)____________________ Don't remember…………….8	Hospital.................. …..1 Health center .... …..2 Health post............ …..3 Home .... …..4 TBA home............. …..5 Other (specify)_________________ Don't remember……….8
409.	Did you get antenatal service?	Yes............... 1 No .... 0 Don't remember…………….8	Yes .... 1 No .... 0 Don't remember…………….8
410.	Did you get post natal service?	Yes............... 1 No .... 0 Don't remember…………….8	Yes .... 1 No .... 0 Don't remember…………….8
411.	Did you get food from government while you were pregnant?	Yes............... 1 No .... 0 Don't know 8	Yes .... 1 No .... 0 Don't know 8
412.	Did you give colostrum to [name]?	Yes............... 1 No .... 0 Don't know 8	Yes .... 1 No .... 0 Don't know 8
413.	How long after birth did you first put [name] to the	Within one hour ………..1	Within one hour ………..1

	breast?	Within a day…………2 After a day..............3 Don't know………...8	Within a day…………2 After a day ....3 Don't know………...8
414.	For how long did you breastfeed [name]?	___________Weeks/months/*Years* Currently breastfeeding…….95 Don't know………..8	___________Weeks/months/*Years* Currently breastfeeding…….95 Don't know……… ..8
415.	During this time (or until the baby was 6 months of age), what did you give the baby to eat or drink?	Only breast milk…………..1 Mostly breast milk………..2 Milk other than breast Milk………………………...3 Infant formula……………....4 Local semi-solid food…...5 Don't remember………....8	Only breast milk…………..1 Mostly breast milk………..2 Milk other than breast Milk………………………...3 Infant formula……………....4 Local semi-solid food…...5 Don't remember………....8
416.	How old was [child name] when he/she got anything else other than breast milk to eat or drink?	___________Weeks/months/*Years* Still on breast milk…….95 Don't know………..8	___________Weeks/months/*Years* Still on breast milk…….95 Don't know……… ..8
417.	Did (NAME) eat any solid, semi-solid, or soft foods yesterday during the day or at night?	Yes............... 1 No 0	Yes .... 1 No 0
418.	How many times did (NAME) eat solid, semisolid, or soft foods yesterday during the day or at night?	___________(times) Don't know………8	___________(times) Don't know………8
419.	Do you have a card where [name]'s vaccinations are written down?	Yes............... 1 No .... 0 Don't know…..8	Yes .... 1 No .... 0 Don't know…..8
420.	**INTERVIEWER: ASK FOR THE CARD FOR EACH CHILD; RECORD VACCINATION DATE FOR EACH VACCINE FROM THE CARD; WRITE "44" IN "DAY" COLUMN IF CARD SHOWS THAT VACCINATION WAS GIVEN BUT NO DATE IS RECORDED. WRITE "99" IN "DAY" COLUMN IF CARD IS NOT SHOWNBUT VACCINATION IS GIVEN.**		
	Immunizations	Day Month Year	Day Month Year
	BCG	|__|__| |__|__| |__|__|	|__|__| |__|__| |__|__|
	Polio 0 (at birth)	|__|__| |__|__| |__|__|	|__|__| |__|__| |__|__|
	Polio 1 (OPV)	|__|__| |__|__| |__|__|	|__|__| |__|__| |__|__|
	Polio 2 (OPV)	|__|__| |__|__| |__|__|	|__|__| |__|__| |__|__|
	Polio 3 (OPV)	|__|__| |__|__| |__|__|	|__|__| |__|__| |__|__|
	Pentavalent 1	|__|__| |__|__| |__|__|	|__|__| |__|__| |__|__|
	Pentavalent 2	|__|__| |__|__| |__|__|	|__|__| |__|__| |__|__|
	Pentavalent 3	|__|__| |__|__| |__|__|	|__|__| |__|__| |__|__|
	Measles	|__|__| |__|__| |__|__|	|__|__| |__|__| |__|__|
421.	Has [name] had diarrhea in the last 2 weeks?	Yes..………………1 No ……………… 0 **→Q422** Don't know ……8 **→Q422**	Yes..………………1 No ……………… 0 **→Q422** Don't know ……8 **→Q422**
422.	Now I would like to know how much [name] was given to drink during the diarrhea (including breast milk)? Was he/she given less than usual to drink, about the same amount, more than usual to drink or nothing?	Much less...................1 Somewhat less...........2 About the same..........3 More...........................4 Nothing........................5	Much less....................1 Somewhat less ....2 About the same...........3 More ....4 Nothing 5

	IF LESS, PROBE: Was he/she given much less than usual to drink or somewhat less?	Don't know……………..8	Don't know……………..8
423.	Has [name] been ill with a fever at any time in the last 2 weeks?	Yes............... …………1 No .... …………..0 Don't know ....……8	Yes .... …………1 No .... …………0 Don't know ....……8
424.	Has [name] had an illness with a cough at any time in the last 2 weeks?	Yes............... …………1 No .... …………..0 Don't know ....……8	Yes .... …………..1 No .... …………..0 Don't know ....……8
425.	Have you heard of or do you know about the health extension worker?	Yes............... 1 No 0	
426.	Did the HEW visit your household during the past 6 months to talk about health related issues?	Yes............... 1 No 0	
427.	What are the services provided by the health extension workers? (Multiple Responses Possible)	Yes No a)Message on Immunization……………… 1 2 b)Information on child feeding……………..1 2 c) Message on diarrhea treatment………..1 2 d)Information on pregnancy care……...….1 2 e) Information on Breastfeeding …………1 2 f) Information on hygiene……….................1 2 g) Promotion of pit latrine construction….…1 2 h) promote latrine use…………………..….1 2 i)promote safe water use…………….……..1 2 j) Information/discussion on Family planning ……………………..……..…1 2 Other, specify__________________	
428.	Have you heard about a Model family	Yes............... 1 No 0	
429.	Is this family graduated as a Model Family?	Yes, graduated (Certificate seen)…………………..…1 Yes, graduated (Certificate not seen)……………..2 No, working towards………………………………...3 Not at all……………………………………………...4	

Section five: Child and mother's anthropometric measurement, and Household's GPS data				
501.	-- Name : Last Child MUAC__________________	Child mother pair ☐☐ . ☐ K.g	Child weight ☐☐ . ☐ K.g	Child's height/length ☐☐☐ . ☐
502.	-- Name : Second to - Last Child MUAC__________________	Child mother pair ☐☐ . ☐ K.g	Child weight ☐☐ . ☐ K.g	Child's height/length ☐☐☐ . ☐
503.	-- Mother's name	Weight ☐☐ . ☐ K.g	Height(cm) ☐☐☐ . ☐	MUAC (cm) ☐☐☐ . ☐
504.	Longitude and latitude	N ☐☐ . ☐☐☐☐☐	E ☐☐☐ . ☐☐☐☐☐	
505.	Altitude (elevation)	☐☐☐☐		

REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	our date:	reference:
REC Western Norway	11.11.2016	2016/1631/REK vest
	your date:	
	20.09.2016	

Bernt Lindtjørn
University of Bergen

2016/1631 Seasonality and spatial distribution of malnutrition and treatment outcome of acute malnutrition among children aged 6-59 months in Boricha, Southern Ethiopia 2016-2018

Institution responsible for the research: University of Bergen
Project manager: Bernt Lindtjørn

With reference to your application, the Regional Committee for Medical and Health Research Ethics (REC Western Norway) reviewed the application in the meeting 27.October 2016, pursuant to The Health Research Act § 10.

Project summary
Sidama in South Ethiopia is a densely populated area that has experienced repeated droughts and food insecurity. Recently, the government decentralised the management of severe malnutrition to community health workers and health centres. Using community-based observational study design, the main aim of this study is to assess the seasonality and spatial distribution of malnutrition, and evaluate treatment outcome of acute malnutrition among children aged 6-59 months. The specific objectives are 1/ To measure the seasonality and spatial distribution of malnutrition 2/ To measure the treatment outcome of children with severe and moderate acute malnutrition 3/ To evaluate the long-term treatment outcomes of children with severe malnutrition after discharge from health institutions. This study will generate knowledge that will help to improve the management of severe malnutrition not only in Sidama, but also in other parts of Ethiopia.

Ethical review
Committee emphasizes that the study has an ethical approval from the Institutional Review Board (IRB) at Hawassa University.

Consent and Responsible conduct
According to the application *«For the children who were malnourished, this study would provide an opportunity for closer follow-up of the individual child. Thus, if we find a severely malnourished child during our community based survey and this child has not been included in the ongoing food safety programme, we will refer the child to the community institutions».* The Committee presumes that all children receive necessary assistance and further follow-up, if need for this is revealed by the researchers, regardless of whether they have been included in the food safety programme or not.

The information sheet and consent form

- The information sheet must inform that participation includes interview (explaining what kind of questions), and that height, weight, age and Mid Upper Arm Circumference will be recorded.

Besøksadresse:
Armauer Hansens Hus (AHH), Tverrfløy Nord, 2 etasje. Rom 281. Haukelandsveien 28

Telefon: 55975000
E-post: rek-vest@uib.no
Web: http://helseforskning.etikkom.no/

- The sheet must inform about measures to care for and protect the participants in the project (i.e. further follow-up and assistance).

Data processing after project conclusion
The Committee presumes that the data is anonymized by project end date 30.09.2018.

Conditions

- If the researchers reveal that referral and further follow-up is required, the study must ensure/facilitate that the child receive necessary assistance (including transportation to local health care if this is required).
- The information sheet and consent form must be audited according to the remarks and must be sent to REC.

Decision
REC Western Norway approves the project in accordance with the submitted application as long as the conditions are met.

Final Report and Amendments
The approval is based on the grounds that the project is implemented as described in the application and the protocol, as well as the guidelines stated in the Health Research Act. If amendments need to be made to the study, the project manager is required to submit these amendments for approval by REC via the amendment form. The Project Manager must submit a final report to the REC Western Norway no later than 31.03.2019, according to Health Research Act § 12.

Appeal
The decision of the committee may be appealed to the National Committee for Research Ethics in Norway. The appeal should be sent to the Regional Committee for Research Ethics in Norway, West. The deadline for appeals is three weeks from the date on which you receive this letter.

Sincerely yours

Ansgar Berg
Prof. Dr.med
Chairman

Camilla Gjerstad
Committee Secretary

copy: postmottak@uib.no

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HAWASSA UNIVERSITY
COLLEGE OF MEDICINE AND HEALTH SCIENCES
Institutional Review Board

Ref. No: IRB/001/09
Date: 13/09/2016

Name of Researcher(s): *Mehretu Belayneh, Bernt Lindtjorn, Eskindir Loha*

Topic of Proposal: ***Seasonality and spatial distribution of malnutrition and treatment outcome of acute malnutrition among children aged 6-59 months in Boricha, southern Ethiopia.***

Dear researcher(s),

The Institutional Review Board (IRB) at the College of Medicine and Health Sciences of Hawassa University has reviewed the aforementioned research protocol with special emphasis on the following points:

1. Are all principles considered?
   - 1.1. Respect for persons: Yes ☑ No ☐
   - 1.2. Beneficence: Yes ☑ No ☐
   - 1.3. Justice: Yes ☑ No ☐
2. Are the objectives of the study ethically achievable? Yes ☑ No ☐
3. Are the proposed research methods ethically sound? Yes ☑ No ☐

Based on the aforementioned ethical assessment, the IRB has:

A. Approved the proposal for implementation ☑
B. Conditionally Approved ☐
C. Not Approved ☐

Yours faithfully,

Ayalew Astatkie (PhD),
Institutional Review Board Chairperson.

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