Development of local-ingredients-based supplementary food and evaluation of its comparability to standard corn-soy blend plus in treating moderate acute malnutrition among children aged 6 to 59 months in Wolaita, Southern Ethiopia.

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Thesis for the degree of Philosophiae Doctor (PhD)
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Dedication

This thesis is dedicated to the mothers of Damot Pulassa district, who struggle tirelessly to feed their children better while not eating enough for themselves.

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Summary

Background: Acute malnutrition is a severe public health issue in Ethiopia, where the prevalence is among the highest in the world. Acute malnutrition is classified as moderate or severe. Children with moderate acute malnutrition (MAM) have an increased risk of infections and mortality. If children with MAM are not properly managed, MAM can progress to the severe form which is a life-threatening condition. MAM, on the other hand, has not received the attention it deserves and is not commonly recognized as a public health issue. In Ethiopia, children with MAM, who are living in food-insecure districts, are getting corn-soy blend plus (CSB+), which is the standard supplement. In Ethiopia, in districts not classified as chronically food insecure, there are no food supplementation programs. Optimal feeding of locally available, nutrient-dense foods could treat MAM. To our knowledge, few studies in Ethiopia have evaluated the effect of local-ingredients-based supplements (LIBS) compared to conventional supplements for treating MAM.

Objective: The aim of this thesis is to develop local-ingredients-based supplementary food and evaluate if it is comparable to standard corn-soy blend plus in treating moderate acute malnutrition among children aged 6 to 59 months.

Methods: We conducted a descriptive phenomenological qualitative study to assess barriers to management of MAM among children aged 6-59 months in Damot Pulassa, Wolaita, South Ethiopia (Paper I). We used six focus group discussions with mothers or caregivers of children aged 6 to 59 months, and ten in-depth interviews with health service providers, to identify the barriers toward existing management practice for MAM. Thereafter, we developed the LIBS for treating children with MAM aged 6 to 59 months. We developed the LIBS from locally available ingredients such as: pumpkin seed, peanut, amaranth grain, flaxseed and emmer wheat. Collection of ingredients, sorting, soaking, draining, drying, roasting, dehulling or shelling, milling and mixing were done (Paper II). A randomized controlled non-inferiority trial with two arms, involving 324 children with MAM, was conducted to evaluate if the LIBS is similar to CSB+ in treating children with MAM. One hundred and sixty-two children were randomized to each of the two arms. The first arm received 125.2 g of LIBS per day along with 8 ml of refined deodorized and cholesterol-free sunflower oil. The first arm received 150 g CSB+ per day along

with 16 ml of refined deodorized and cholesterol-free sunflower oil. Each child was provided with a daily ration of either LIBS or CSB+ for 12 weeks (Paper III). The study protocol of Paper III was published (Paper IV).

Result: In Paper I, possible reasons for MAM, identification of a child with MAM, management services for MAM, maternal-level barriers, service provider-level barriers, and measures to improve the service were identified as six themes. Maternal-level barriers to managing MAM were: lack of food and money, selling-out of self-produced foods without having sufficient reserves at home, large household size, and shame about having a child with malnutrition. Service provider-level barriers to managing MAM were: occasional house-to-house screening of children, family-initiated counseling, leaving the management responsibility of children with MAM to the family, and lack of repeated follow-up visits by service providers. Mothers or care-givers and service providers perceived as the existing management practice for MAM can be improved through focused, routine and inclusive counseling (including all mothers of children aged below five years and fathers), and the provision of supplementary food.

In Paper II, LIBS1, LIBS2, LIBS3, and LIBS4 were the four food supplements that were developed. The protein content of four developed LIBSs ranged from 20.3 g to 22.5 g, the fat content from 29.3 g to 33.5 g, the kcal content from 510 kcal to 570 kcal, the fiber content from 6.0 g to 8.5 g, the moisture content from 2.8 g to 3.7 g, and the ash content from 2.1 g to 4.3 g. Calcium was 75.6 mg to 115.6 mg, potassium was 473.1 mg to 570.2 mg, sodium was 79.3 mg to 114.4 mg, zinc was 4.1 mg to 5.6 mg, iron was 8.2 mg to 10.2 mg, phosphorous was 442.6 mg to 470.4 mg, and phytate was 2.1 mg to 4.3 mg. LIBS 4 had a significantly higher level of protein, fat, energy, iron, zinc, phosphorous, and potassium compared to LIBS 1, LIBS 2, and LIBS 3. The phytate content of the four LIBS was significantly different. The lowest level of phytate was found in LIBS 4 (Paper II).

LIBS was shown to be non-inferior to CSB+ in both intention-to-treat (ITT) and per-protocol (PP) analyses for recovery rate [ITT risk difference = 4.9% (95% CI: −4.70, 14.50); PP risk difference = 3.7% (95% CI: −5.91, 13.31)]; average weight gain [ITT risk difference = 0.10 g (95% CI: −0.33 g, 0.53 g); PP risk difference = 0.04 g (95% CI: −0.38 g, 0.47 g)]; recovery time [ITT risk difference = −2.64 days (95% CI: −8.40 days, 3.13 days); PP difference −2.17 days

(95% CI: −7.97 days, 3.64 days]. Non-inferiority of LIBS compared with CSB+ was also shown for the MUAC gain and length/height gain (Paper III).

Conclusion: We observed that maternal-level barriers and service provider-level barriers negatively affect the management of MAM among children aged 6 to 59 months. A supplementary feeding that addresses the food shortage of households, in addition to nutrition counseling, is critical in overcoming MAM. We demonstrated that the nutrients of developed LIBSs were within the recommended range of required nutrients for treating children with MAM. We showed that LIBS was similar compared to CSB+ in treating children with MAM aged 6 to 59 months. Therefore, LIBS could be used for the management of children with MAM.

Trial registration: Pan-African Clinical Trial Registration number: PACTR201809662822990, registered on 12 September, 2018.

List of papers

This thesis is based on the following papers, which are indicated by their respective Roman numerals throughout the text.

Paper I: Nane, D., Hatløy, A., Lindtjørn B. Barriers to management of moderate acute malnutrition among children aged 6-59 months in Damot Pulassa, Wolaita, South Ethiopia: a phenomenological study of mothers and health service providers. Accepted for publication in the *Food and Nutrition Bulletin*.

Paper II: Nane, D., Hatløy, A., Lindtjørn B. Development and nutritional evaluations of a local-ingredients-based supplement to treat moderate acute malnutrition among children aged below five years: A descriptive study from rural Wolaita, Southern Ethiopia. *Food Science Nutrition*. 2020; 8: 6287- 6295. https://doi.org/10.1002/fsn3.1927

Paper III: Nane D., Hatløy A., Lindtjørn B. (2021) A local-ingredients-based supplement is an alternative to corn-soy blends plus for treating moderate acute malnutrition among children aged 6 to 59 months: A randomized controlled non-inferiority trial in Wolaita, Southern Ethiopia. *PLoS ONE*. 2020; 16(10): e0258715. https://doi.org/10. 1371/ journal.pone.0258715

Abbreviation

AEW: Agricultural Extension Worker

ANOVA: Analysis of Variance

CI: Confidence Interval

CMAM: Community-Based Management of Acute Malnutrition

COREQ: Consolidated Criteria for Reporting Qualitative Research

CSB+: Corn-Soy Blended Flour Plus

CTC: Community Therapeutic Care

FAO: Food and Agriculture Organization

FGDs: Focus Group Discussions

GEE: Generalized Estimating Equations

HEWs: Health Extension Workers

HFS: Household Food Security

IDIs: In-depth Interviews

ITT: Intention-To-Treat

LIBS: Local-Ingredients-Based Supplement

MAM: Moderate Acute Malnutrition

MUAC: Mid-Upper Arm Circumference

PACTR: Pan-African Clinical Trial Registry

PHCU: Primary Health Care Unit

PP: Per Protocol

RUSFs: Ready-To-Use Supplementary Foods

SAM: Severe Acute Malnutrition

SURE: Sustainable Undernutrition Reduction in Ethiopia

TEM: Technical Error Measurement

TSFPs: Targeted Supplementary Feeding Programs

UNICEF: United Nations Children's Fund

USDA: United States Department of Agriculture

WDAs: Women Development Army members

WHA: World Health Assembly

WHO: World Health Organization

WHZ: Weight-for-Height Z-score

Table of contents

Introduction

Global burden of malnutrition

Malnutrition is a general term defined as an imbalance of a variety of nutrients that has a measurable negative impact on body composition, function, or clinical outcome [1, 2]. It can be classified into two broad categories: undernutrition and overnutrition [3, 4]. Undernutrition has been classified in two ways since the 1970s: acute malnutrition or wasting (low weight for height or a small mid-upper arm circumference (MUAC)) and chronic malnutrition or stunting (i.e. low height for age). However, many children with borderline measurements who are at risk of undernutrition are missed by this categorical classification. Furthermore, deficiencies in terms of stunting and wasting indicate shared risk factors for undernutrition, and rising levels should be recognized as composite measures of undernutrition [5]. In this thesis, malnutrition refers to undernutrition.

Malnutrition is a significant global public health burden, particularly for children aged below five years [2, 6]. It is not just a public health problem; it is also a barrier to worldwide poverty eradication, productivity, and economic expansion [3]. Various problems are responsible for the child's malnutrition. Among these issues, some basic problems are political insecurity, slow economic growth, and lack of knowledge. Other underlying causes include food insecurity and absence of maternal and childcare services. The third category includes risk factors that are highly specific, like frequent infections and inadequate food intake [7].

Worldwide, malnutrition contributes to nearly half of all deaths among children below five years of age, as well as a significant burden of suboptimal development in children who survive [8, 9]. If malnutrition was appropriately managed, at least one-third of child morbidity and mortality could be prevented [10]. Of 17 Sustainable Development Goals (SDGs), SDG 2 clearly mentions the concept of nutrition with the aim of eradicating hunger, improving food security and nutrition, and promoting sustainable agriculture [11]. To address the global challenge of malnutrition, the World Health Assembly (WHA) has approved six global nutrition goals to be met between 2012 and 2025. The six targets that were included in these goals focused on maternal, infant, and young child nutrition [12, 13]. This commitment included a 40 percent reduction in stunted children, a less than 5 percent prevalence of childhood wasting, reduction of low birth weight by 30 percent, a reduction of anemia in women of reproductive age by 50 percent, ensuring no increase in the number of overweight children, and an increase in exclusively breastfed infants to at least 50 percent [13].

Child malnutrition is most prevalent in developing countries, including sub-Saharan Africa [14]. For children aged below five years, the prevalence of stunting was 39 percent, wasting 10 percent, and underweight 25 percent in this region [15]. Ethiopia has one of the highest rates of malnutrition among children aged below five years in the world. Furthermore, malnutrition is the root cause of death for three-fifths of all children in Ethiopia. In the country, the overall pooled prevalence of stunting was 42 percent, underweight 33 percent, and wasting 15 percent [16]. Over the last decade, Ethiopia has made favorable efforts to minimize rates of undernutrition**.** However, the rates of undernutrition stay so high that the country must decide to engage strongly in nutrition [17]. The eradication of malnutrition in all its types is an absolute necessity for health, ethical, political, economic, and social purposes, with special attention paid to the needs of children and women [18].

Undernutrition is more prevalent in rural areas than in urban areas. Southern Ethiopia was among the most affected areas, with 36 percent of children stunted, 6 percent of children acutely malnourished, and 20 percent of children underweight in 2019 [19]. Even though Ethiopia has already attained a notable improvement in decreasing mortality among children below five years in the last years [20], undernutrition is still a public problem in this country [21, 22].

Acute malnutrition

Acute malnutrition is defined by weight-for-height z-score (WHZ) < -2 or the presence of edema [23, 24]. It is acute and involves severe weight loss over a short period of time because of sudden food deprivation and/or illness [25], resulting in a child being thin for his or her height due to weight loss or failure to gain weight [26]. Acute malnutrition affects 51 million children worldwide: 17 million from severe wasting and 34 million from moderate wasting [27, 28]. It is a major health problem all over the developing world, mainly in settings where extreme poverty exists [29, 30].

Food insecurity, poverty, feeding of diets deficient in important nutrients, inadequate household access to food, inappropriate feeding practices, unaffordable healthcare, high burden of infections, and lack of a sanitary environment, including access to safe water, are the main risk factors for acute malnutrition [31-33].

More than 8 percent of global mortality among children below five years of age was attributed to acute malnutrition [34]. The weakness of immune function, decreased desire for food, increased metabolic rate, and nutrient requirements, and increased susceptibility to infection and illness are considered as potential outcomes of acute malnutrition [25, 35]. Acute malnutrition also has long-term health and developmental concerns, such as impaired cognitive development, increased risk of stunted growth, and a higher chance of developing non-communicable diseases in old age [30, 34, 36]. Acute malnutrition is differentiated as moderate or severe on the basis of severity and the presence of edema [37-39].

Moderate acute malnutrition among children below five years

Moderate acute malnutrition (MAM) is defined by a WHZ between −2 and −3 and/or a mid-upper arm circumference (MUAC) of ≥ 11.5 and < 12.5 cm [40-42]. In developing countries, MAM affects approximately one in ten children below five years of age [43, 44]. MAM has severe public health consequences for child morbidity and mortality [45, 46]. A significantly reduced muscle mass is typical of wasting, and this raises the possibility of death during infections [47].

Children with MAM are more likely to suffer delays in their physical growth and cognitive development, with the consequence of suboptimal adult work capacity, and increased risk of disease in adulthood [48, 49]. They are also at greater risk of death than well-nourished children [35, 50]. Death risk occurring due to MAM is three-fold higher than that of non-malnourished children [36, 51, 52], and incidence and severity of severe acute malnutrition (SAM) can be affected by the prevalence of MAM [53].

Recurrent episodes of MAM in children can result in chronic undernutrition later in life. Chronic undernutrition, in turn, can have an impact on the nutritional status of future generations, tending to result in “inter-generational growth failure”, a cycle of poor diet that continues throughout generations with lifelong implications [54].

Food emergency situations in Ethiopia

Food and nutrition emergencies can lead not only to acute malnutrition and stunting, but also a variety of micronutrient deficiencies, some of which can result in blindness, disability, paralysis, or death. Malnutrition is a common feature of both natural and human-made emergencies. During major emergencies, adequate food provision and intake are among the most critical actions to prevent death and illness caused by malnutrition. The energy and protein requirements needed are a primary concern, and micronutrient needs must also be met [55].

For several decades, Ethiopia has experienced widespread crop and pasture failure, as well as periodic severe humanitarian crises as a result of recurring drought [56]. In the current years, unusually low and irregular rainfall has been increasing the occurrence and effect of droughts [57]. Drought has a significant effect in countries such as Ethiopia, where the economy and livelihood are mainly dependent on rain-fed subsistence agriculture [58]. In addition, Ethiopia is facing numerous natural and man-made disasters, such as floods, earthquakes, wars, internal displacement and communicable disease epidemics, with a substantial influence on the health and nutrition of the affected people [59].

Ethiopia has showed progress in major economic and development indicators; however, child malnutrition is still a concern [58]. Acute malnutrition has been shown to be an important predictor of child mortality. Therefore, it is an ideal indicator of nutritional status in emergencies and an alternative indicator for the overall health and well-being of the total population [36, 58].

Food insecurity in Ethiopia

The intake of adequate quality food, which is a key requirement for a healthy and productive life, ensures household food security (HFS) status. HFS is ensured when all members of the household have consistent physical and economical access to food in sufficient quantity and quality to live a healthy and active life [60, 61]. The access aspect of food insecurity is composed of three main contexts: anxiety and lack of certainty concerning household availability of food, inadequate quality of food, and inadequate dietary intake by household members [62].

Ethiopia is among the world's poorest countries, with a large proportion of its population living in extreme poverty [63]. Poverty is one of the indications of food insecurity that is predominant in Ethiopian rural communities in general, and primarily among children aged below five years. In developing countries such as Ethiopia, food insecurity leads to less socioeconomic development, higher healthcare costs, lower income, and a continued prevalence of child malnutrition [64]. A large proportion of Ethiopia's population is food insecure, both chronically and seasonally. The situation of those who are food insecure has deteriorated. Ethiopia's food security situation is inextricably linked to severe, recurring food shortages and famine brought on by recurring drought. In Ethiopia, there is growing agreement that food insecurity and poverty are inextricably linked. More than half of the population, the majority of whom live in rural areas, does not have access to the daily recommended average requirement of 2100 calories per person per day [63, 65].

Access to adequate food and nutrients is critical for household wealth while also achieving other development goals. Households with inadequate food access commonly experience more challenges associated with food insecurity, such as poor health and lower productivity. These problems can frequently result in a vicious circle in which households may be unable to produce adequate food, even in good seasons, as they are fighting chronic health problems and are unable to work to their full potential [66].

Food insecurity is one of the major challenges in Southern Ethiopia, where 57 percent of the population lives below the poverty line. Wolaita Zone is one of the districts found in the central part of Southern Ethiopia where food insecure households are concentrated and which are known as drought-famine areas [65]. In this zone, 66 percent of household were unable to fulfill the daily recommended minimum calorie intake, and 34 percent were food insecure [67]. In addition, the zone is well known for its fertility and population pressure. A rise in the rural population, notably in the last 30 years, has led to an increase in the number of land-seekers, some of whom have built their homes in forests, steep mountain areas, or grazing land. Many other young people living in rural areas are landless [66]. The size of the usual Wolaita Zone farming area per rural family unit is around 0.45 hectares, which is one of the main causes of serious and chronic food insecurity in the zone [68]. In this area, the soils and vegetation have been severely degraded due to the interaction of environmental and human factors. For example, the area is extremely susceptible to drought [65]. When there is a shortage of food, the term 'green famine' is commonly used to define the condition [66].

Management practice of acute malnutrition

Currently, the WHO and the United Nations Children's Fund (UNICEF) recommend Community-based Management of Acute Malnutrition (CMAM) [69].The primary goal of CMAM is to manage acute malnutrition in children aged 6-59 months. Generally, CMAM is based on four pillars:1) community outreach; 2) supplementary feeding for MAM ; 3) outpatient treatment for children with SAM who have a good appetite and no medical complications; and 4) inpatient treatment for children with SAM who have medical complications and/or no appetite [70].

The CMAM model has been described using various terms, such as community therapeutic care, integrated management of acute malnutrition, community-based therapeutic care, and ambulatory care for managing acute malnutrition [71]. The implementation arrangements for CMAM differ depending on the context or area. While community outreach opens the way, management components of SAM and MAM may collaborate, or outpatient and inpatient treatment may function independently of MAM management [70].

Children with MAM commonly do not receive therapeutic interventions through CMAM, and care to address MAM is not included in CMAM in all countries. Supplementary feeding programs are aimed to prevent a moderately malnourished person from becoming severely malnourished and to rehabilitate them in some situations, typically by delivering supplementary food to an overall ration or the basic diet. In other settings, the consumption of locally grown nutritious foods is encouraged [70, 72].

Management practices for MAM

Generally, the management of MAM can be divided into prevention and treatment approaches [45]. The provision of specialized food products to supplement the diet of susceptible populations, usually for children below five years of age, is one of the interventions to prevent MAM. These strategies are based on the therapeutic program for MAM rather than prevention, and they have not been evaluated in the context of MAM prevention [73]. According to different studies in the literature, the existing preventive approaches for MAM are even more varied, as they include dealing with the basic causes of undernutrition through a combination of food security, behavior change, water and sanitation, and medical, cash-based, and surveillance methods [27, 74]. In general, additional energy- and nutrient-rich supplements should be provided to children with MAM to promote weight gain. This nutrient-dense supplement should cover the daily recommended dietary allowance of all nutrients, in addition to the child's usual diet [29, 75].

The current understanding regarding the management of MAM is debated. Although there has been continued support in recent times to integrate understanding of MAM and its management, conclusions have yet to be reached, particularly in low- and middle-income countries [76]. There is a greater level of agreement around the management of SAM than for the management of MAM [41, 77]. This shows that MAM has not received the consideration it deserves, though it is much more prevalent than SAM and increases the risk of morbidity and mortality on its own [77]. SAM is generally treated with a high-energy ready-to-use therapeutic food, whilst MAM is treated with a combination of strategies, such as nutrition counseling or one of several supplementary foods. Both counseling and supplementary feeding programs (SFPs) have both failed to demonstrate satisfactory recovery rates [78]. There are many guidelines for the management of SAM [75, 76, 79], but there is presently no consistent guideline for the management of MAM [80].

There is inadequate evidence to support the recommended amount of supplementary foods needed to treat children with MAM [81]. The WHO has recognized the current absence of international guiding principles for the management of MAM and called for additional evidence in this area to update related guidelines [82]. In addition, there are inconsistencies in management approaches of MAM at the national level, if any exist at all [83].

Children with MAM who do not receive adequate management can stay moderately wasted for several months, and they may progress towards SAM, which could be a life-threatening condition [53, 84, 85]. Therefore, the management of MAM should be a public health priority [53]. Several national guidelines for MAM treatment recommend the delivery of supplementary foods, while others suggest that mothers/caregivers of children with MAM should be provided with nutrition counseling only [83].

Nutrition counseling

Nutrition counseling emphasises disseminating nutrition-related information, such as proper feeding practices through which dietary diversity can be enhanced and nutritional requirements maintained, as well as recommending that sanitation and hygiene practices should be improved [43]. According to some literature, treating children with MAM only with nutrition counseling has limitations that affect its effectiveness; these include a lack of adherence to the programs [77], and high defaulting from the program compared with treating MAM children with supplementary foods [83]. Treating MAM children with counseling only has a much lower recovery rate than treating them with supplementary food [86]. Especially, counseling interventions for children with MAM alone are not sufficient in areas of food insecurity. The effectiveness of counseling may be affected by the food security status because it relies on domestic sources of food [46, 83].

In Ethiopia, the existing approach for managing MAM is to limit Targeted Supplementary Feeding Programmes (TSFPs) to specific parts of the country defined as chronically food insecure. In districts not nominated as chronically food insecure, food supplementation programs are not available, and as an alternative, current methods are used such as the Enhanced Outreach Strategy which provides nutrition counseling, vitamin A supplementation and deworming, water treatment, and enhanced sanitation [42, 76]. Food supplementation programs for children with MAM are not available in food-secure areas [76]. Even though the recovery rate from MAM is unsatisfactory with nutrition counseling alone, it has been provided for caregivers as an approach for the management of MAM, assuming that caregivers have access to affordable foods, but lack information on how best to use them [45].

Dietary management of MAM

Treating MAM among children with dietary supplementation improves their recovery from MAM, with a reduced risk of morbidity [87]. Studies conducted in low- and middle-income countries suggested the use of nutrient-dense commercially formulated foods, as well as local supplementary foods, for the treatment of MAM [88, 89]. The CMAM Forum echoed recommendations for foods suitable for children with MAM, as well as approaches for counseling caregivers, and a decision-making basis for the selection of appropriate SFP methods [43].

Different researchers noted that the supplementary feeding programs were categorized as TSFP or blanket supplementary feeding programs, depending on the recipients. A blanket method provides supplementary food to all susceptible children within a definite population, regardless of their nutritional status. This method has been used where the prevalence rates of MAM go beyond 20 percent. The objective of a blanket supplementary feeding program is to prevent prevalent malnutrition and to reduce higher mortality rates among susceptible children, through the provision of food supplements and/or micronutrients for at-risk populations [31, 43]. TSFP offers supplemental provisions only for MAM children and is the most commonly used approach for treating MAM [41, 76]. It is frequently used when MAM and SAM prevalence rates are from 10-14 percent. In this program, fortified blended flours as ready-to-use supplementary food are included as therapeutic products [41]. The guidance for the recommended nutrient composition of these supplements has been issued by the WHO [75].

Specialized foods used for supplementary feeding

Currently, a variety of specially formulated food supplements are used to treat children with MAM [90, 91]. These food supplements are corn-soy blend (CSB), prepared as a porridge [91, 92], super cereal/corn-soy blend plus (CSB+), super cereal plus/corn-soy blend plus with milk and oil (CSB++) [92, 93], lipid-based nutrient products [94], and BP5 biscuits [90]. Among these, CSBs are most commonly used [91, 95]. In various situations, these supplements are culturally and organoleptically acceptable [96]. Super cereal and super cereal plus are the most common CBSs currently used for managing MAM [43, 97]. These cereal and soya bean mixtures have been refined, combined, and precooked (by roasting) for children with MAM who are below five years of age [98].

The CSB+ (super cereal) comprises heat-treated maize (64 percent), whole soya beans (24 percent), sugar (10 percent), vegetable oil, and a vitamin and mineral premix. CSB++ (super cereal plus) is made from heat-treated maize (58 percent), dehulled soya beans (20 percent), dried skimmed milk powder (8 percent), sugar (10 percent), vegetable oil, and a vitamin and mineral premix. CSB++ is used as a complement to breast milk [43]. Most of the time, these supplements are provided to children with MAM for at least three months [83]. These standard food supplements are effective in treating MAM, though such management is short-term and not sustainable for the treatment of persistent malnutrition considering the high commodity cost in poverty-hit countries [93, 99].

Nutritional requirements of children with MAM

Children with MAM have nutritional requirements that differ from non-malnourished children [100]. They need increased consumption of energy, proteins, and all other important nutrients above and beyond those needed by healthy children [75]. It is known that wasted children have an increased energy need for catch-up growth. The fat content is an essential factor affecting energy density since the energy density of fat is 9 kcal/g, according to the Atwater factors. It is more than twice that of protein and carbohydrate (4 kcal/g) [101]. The Atwater factors have been used to compute the calorie value shown on most food labels [102]. Assuming the high energy requirements of acutely malnourished children and the positive outcomes achieved with diets with a high amount of fat in the management of SAM, aiming at a fat intake close to the upper limit of the range (25-65 g/1,000 kcal; 45 energy percent [E%]) looks useful in the management of MAM [75, 101]. Intake of the optimal protein content of a diet (26 g/1,000 kcal) has major importance in the treatment of children with MAM [100].

Protein digestibility can be affected by anti-nutrients mostly found in plant-based foods. In addition, anti-nutrients can affect mineral absorption [103, 104]. Among anti-nutrients, phytate is widely present in plant-based diets [105]. Phytate contents in cereals and legumes can be reduced by soaking of grains, dehulling, and germination during food processing [106, 107]. In addition, most anti-nutrients are destroyed by heating through the processing of diets for children [106, 108]. Phytate content is estimated as molar ratios to minerals (iron, zinc, and calcium). To efficiently reduce the inhibition of mineral absorption, the molar ratios for phytate: Fe should be below 1.0 [105]; phytate: Zn molar ratio should be below 15 [106]; and phytate: Ca molar ratio should be below 0.24 [109].

Currently, little is recognized about the nutrient requirements for children with MAM [110]; however, some recommendations have been suggested [43, 100]. These proposed recommendations are about the minimum nutrient requirements when using a variety of properly developed locally-available foods and the optimum requirements proposed for the formulation of specialized foods for children with MAM [111]. The food choice for the management of MAM should consider efficacy in promoting recovery as well as accessibility [46].

Ethiopia: Country profile

Ethiopia is in the northeastern part of the African continent having a total size of 1.1 million square kilometers. Its topography varies from mountains as high as Ras Dashen at 4550 meters above sea level to the Afar Depression, which is 110 meters below sea level [112]. The projected population size of Ethiopia (as of 2020) was 114 million, making it Africa's second-most populous country. About half (49.9 percent) of the population is female, and the proportion of population consisting of children aged below five years is 15%. Most people (79%) reside in rural areas [113]. Ethiopia is classified into administrative regions; the regions are subdivided into zones which are then subdivided into administrative units called districts (*woreda*). Each district is further divided into *kebeles*, the smallest administrative unit [112].

Over the last decade, Ethiopia's health sector has seen progress in terms of various health, nutrition, and population indicators [114]. The citizens' life expectancy continued to increase from 45 years in 1990 to 64 years in 2014 [115]; the maternal mortality rate has decreased from 1,250 deaths per 100,000 live births to 353 in 2015 [116], and the mortality rate among children below five years has decreased from 204 deaths per 1000 live births in 1990 to 74 deaths per 1,000 births in 2015 [117]. Despite these achievements, the government emphasizes the need to maintain progress and address the still high rates of maternal and neonatal mortality [118].

In Ethiopia, there has been some improvement in reducing stunting and wasting and in reaching exclusive breastfeeding targets. However, Ethiopia is lagging behind in meeting the WHA Global Nutrition Targets. According to the sub-national analysis, Addis Ababa, Ethiopia's capital, is the only state on track to attain a 40 percent reduction of stunting by 2025 [13].

Ethiopia, like many other developing countries, is focusing on improving its health systems by introducing several strategies and initiatives from the WHO's six recommended building blocks: service delivery; health workforce; information; medical products, vaccines, and technologies; financing; and leadership and governance [118]. Currently, Ethiopia is implementing a health sector development plan with a three-tiered health-delivery system. Primary healthcare units (one health center and five community health posts) that supported by are primary hospitals are at the bottom of the tier system; secondary level services are delivered by general hospitals which serve as referral centers for primary healthcare units (PHCUs), and tertiary (top-tier) level services are provided by specialized hospitals which serve as referral centers for general hospitals [119].

Ethiopia began the health extension project in 2004 to address a human resource shortage in the healthcare sector. It was carried out by establishing a health post in each *kebele* and assigning health extension workers (HEWs) to each *kebele* [120]. HEWs work on the front line of primary health care systems in Ethiopia. They are mostly female secondary school graduates who are chosen from their local communities and complete a year of health service-delivery training. The introduction of HEWs raised health service coverage and offered an essential source of health improvement skills and guidance [121]. Two HEWs are assigned at a health post to service a *kebele* with a population of around 5,000 people [122]. Improved child and maternal nutrition, disease prevention, and health education are among HEWs' key responsibilities [121].

In 2010, six years after inception of the health extension program, a new strategy called the Women's Development Army (WDA) was linked with the health extension program [120]. The WDA concept involves a strategically organized mobilization of nearby households [119]. Under the supervision of the HEWs, one woman from every five households, who knows the packages of the health extension program and practices them, would become a WDA leader, in charge of improving the health of five neighboring households [120]. WDA unpaid volunteers are placed to assist with immunization campaigns, track pregnancies and illnesses, and pass messages and data between households and HEWs. They are supposed to meet with their members once a week to discuss topics including nutrition, children's health, antenatal care, hygiene, birth, and so on [123].

Ethiopia has health and agriculture sector platforms that distribute government programming to all districts and *kebele* across the country. HEWs handle routine health post and community-based health and nutrition services [124]. Agriculture extension workers (AEWs) provide training for farmers, and transfer essential knowledge and skills that would help the farmers to increase crop production [125, 126]. They cultivate demonstration gardens in communities, focusing on dietary diversity and nutrition-sensitive gardening. AEWs are mostly men and are deployed at a ratio of about 1:167 families [127].

In the rural households of Wolaita, agriculture is practiced, along with other activities (non-/off-farm), as a coping strategy for food insecurity and poverty. Many farmers choose non-farm and off-farm activities over agriculture as their major source of income to generate better income for survival and livelihood improvement [126].

In Ethiopia, malnutrition, poverty and food insecurity are occurring concomitantly [128]. Food insecurity is one of the risk factors for undernutrition [129]. Sustainable Undernutrition Reduction in Ethiopia (SURE) is a multi-sectoral government-led program that integrates health and agriculture sector service delivery for nutrition outcomes. It incorporates and improves the existing community-based nutrition program. In Ethiopia, SURE is focused on four agrarian regions (Amhara, Oromo, Afar, and Southern Nations, Nationalities and Peoples). The main components of of the SURE program are: (i) community-based nutrition services that are delivered by HEWs; (ii) enhanced nutrition services that are delivered by HEWs and AEWs; (iii) systems strengthening through integrated monitoring and training of HEWs and AEWs; and (iv) multi-sectoral coordination done by the district and region [127].

The context of this thesis was Damot Pulassa, Wolaita Zone, Southern Ethiopia. Wolaita Zone has 16 *woredas* and six town administrations [130]. The zonal health department report showed that there were 419 health facilities, including 8 hospitals, 69 health centers, and 342 health posts in Wolaita Zone. There were 681 HEWs and 1,195 agriculture extension workers in the zone [131, 132]. Children with MAM who are in a food-insecure district are recruited under the TSFP, whereas children with MAM who are living in the food-secure districts have no food supplementation; rather, their mothers or caregivers are getting nutrition counseling as a management strategy for MAM.

Rationale of the study

Acute malnutrition is a significant public health problem. When compared to well-nourished children, children with MAM are more likely to die [133]. MAM is a common and persistent problem in Ethiopia [54]. The management of MAM is either supplementary feeding or nutrition counseling. TSFPs are restricted to particular districts of the country defined as chronically food insecure [76]. In the area claimed as food secure, nutrition counseling is used for the management of MAM. This strategy is based on the perception that nutrient-dense food is accessible and that caregivers have poor awareness of how to make foods into appropriate diets for malnourished children [45, 75]. Understanding the community's and health care workers' opinions, attitudes, experiences, and preferences towards the existing management practice for MAM is a key step toward better future programs and policies. Such insight is important in developing recommendations that can be implemented at the local level. Thus, we assessed community perceptions of the existing management practices for MAM in Ethiopia, particularly among the service providers and beneficiaries (Paper I)

Several studies from low- and middle-income countries recommend the use of nutrient-dense ready-to-use foods and local supplementary foods [41, 45, 89]. The WHO recommends providing locally available nutrient-dense foods to improve the nutritional status of children with MAM and thereby avoid SAM [75]. In the dietary management of MAM, optimal feeding of locally available nutrient-dense foods has been revealed to be effective at the household level in improving the nutritional status of children [75, 134].

MAM is more prevalent than SAM and there is a need to develop supplementary foods from local food items [103]. These supplementary foods can be formulated from locally available ingredients that are accessible to all the persons, cheap, and can deliver the required amounts of nutrients essential for the effective recovery of children with MAM [87]. It is known that supplementary foods, developed from locally available, nutritionally dense foods, have a positive effect on the recovery of children with MAM, and are better accepted and desirable [135]. As far as our knowledge is concerned, there is no supplementary food from local ingredients for the treatment of MAM in Ethiopia.

According to different studies, the recovery rates after supplementation with ready-to-use supplementary foods (RUSFs) versus CSB+ resulted in similar recovery rates among children with MAM and were relatively successful in treating MAM [90, 93, 136]. The similar effects that CSB+ compared to other RUSFs prepared for the management of MAM made the differences too narrow to feasibly conduct a superiority trial. To the best of our knowledge, there is no study done in Ethiopia developing local-ingredients-based supplement (LIBS) and testing its effect compared with the standard supplement for the treatment of MAM in Ethiopia. We, therefore, aimed to develop LIBS and evaluate if it is at least as effective as CSB+ in treating MAM.

Objectives

General objective

The overall aim was to develop local-ingredients-based supplementary food and evaluate if it is comparable to standard corn-soy blend plus in treating moderate acute malnutrition among children aged 6 to 59 months

Specific objectives

1. To explore the perceptions of mothers and health service providers towards barriers to existing management practices for MAM among children aged 6 to 59 months in Wolaita, Southern Ethiopia (Paper I)
2. To develop a local-ingredients-based supplement for treating MAM among children in Wolaita, Southern Ethiopia (Paper II).
3. To evaluate if the local-ingredients-based supplement is as effective as standard corn-soy blend plus in treating moderate acute malnutrition among children aged 6 to 59 months in Wolaita, Ethiopia (Paper III).

Methods

Study setting

Wolaita Zone is one of the zones found in the southern part of Ethiopia, and it covers an area of 4,471.3 km^2. The zone has a total population of 2,067,163, with 312,141 children aged below five years [137]. In terms of land use in the zone, 261,000 hectares (ha) are used for crop production, 5,318 ha for grazing and 8,261 ha for other reasons. Undernutrition is common in Wolaita Zone among children below five years of age. Thirty-four percent of children below five years of age were stunted, while 6.9 percent were wasted and 11.9 percent were underweight in 2020 [138].

The study location of this thesis research, Damot Pulassa District, is situated in Wolaita Zone, bordered in the east and south by Damot Gale, in the west by Boloso Sore, and in the north by the Hadiya Zone (Figure 1). Damot Pulassa District is located at a distance of 365 km away from Addis Ababa, the capital city of Ethiopia. Damot Pulassa District is sub-divided into 22 rural *kebeles* (the lowest government administrative unit) and one urban *kebele* [139]. In 2014, the estimated population of the district was more than 130,000 people [131]. The district has the highest population densities, reaching up to 600 persons per square kilometer in some *kebeles*. The discrepancy between population and land balance has continued by far to be the primary cause for the endemic food insecurity in the area [140].

Damot Pulassa District is served by five health centers and 23 health posts. These health posts are staffed by HEWs and provide nutrition-related services like counseling on feeding practices, screening for nutritional status of young children and nutritional management of the malnourished ones. Damot Pulassa District is categorized as a maize and root crop livelihood area as these are the key crops produced in the district. This district was selected based on a consideration of the high level of food insecurity, high level of child malnutrition, good geographical location and access to transportation.

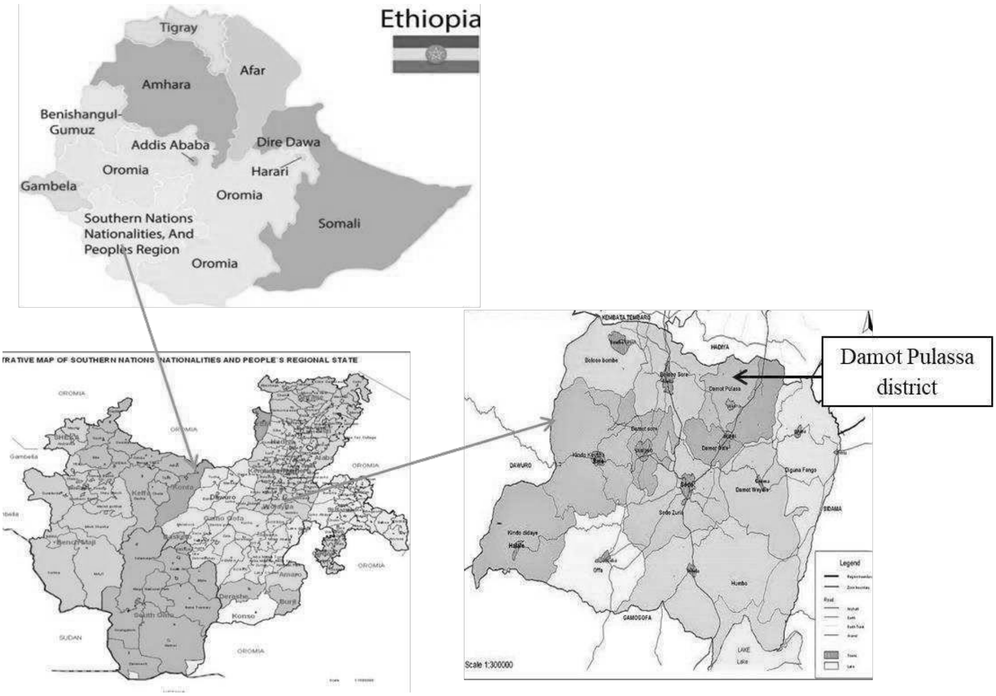

Figure 1: Geographic location of study area, the Damot Pulassa District, Ethiopia

A summary of the study design, population, total sampling and data of this thesis is presented in Table 1.

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

Papers	**Design**	**Participant**	**Sampling/ sample size**	**Data**
Paper I: Barriers to management of moderate acute malnutrition among children aged 6-59 months in Damot Pulassa, Wolaita, South Ethiopia	A phenomenological study	Mothers/care givers of children with MAM aged 6 to 59 months and service-providers.	Purposive sampling of 55 mothers or caregivers and ten service providers	Six focus group discussions with mothers or caregivers of children aged 6 to 59 months and ten in-depth interviews with health workers
Paper II: Development and nutritional evaluation of local-ingredients-based supplements to treat moderate acute malnutrition among children aged below five years in rural Wolaita, Southern Ethiopia	Descriptive			Selection of food ingredients, processing of ingredients, nutrient analysis and supplement formulation
Paper III: A local-ingredients-based supplement is an alternative to corn-soy blends plus for treating moderate acute malnutrition among children aged 6 to 59 months in Wolaita, Southern Ethiopia	Randomized controlled non-inferiority trial	Children with MAM aged 6 to 59 months	Randomizati on of 324 children aged 6 to 59 months	Interviews with caregivers and anthropometric measurements

MAM: moderate acute malnutrition

Study population

In Paper I, the main study population was mothers or caregivers of children with MAM. In addition, HEWs and WDA members were included.

In Paper III, the study population was children with MAM aged 6 to 59 months living in selected *kebeles* of Damot Pulassa District. We excluded children with SAM (based on the WHO 2009 child growth standards), and/or with bilateral pitting edema [141]. Children who had any disease or other medical problems that prohibited the children from safely consuming supplementary food were excluded. We also excluded children who were simultaneously involved in another supplementary feeding program.

Study design

In Paper I, we used a qualitative, descriptive phenomenological design. Focus group discussions (FGDs) and in-depth interviews (IDIs) were done. The opinions and understandings of mothers/caregivers of children aged 6 to 59 months with MAM and health service providers, toward barriers to current management practices for MAM, were captured.

For Paper II, we used a descriptive study design to develop a LIBS for the treatment of children with MAM aged 6 to 59 months. Selection of food ingredients, processing of ingredients, nutrient analysis, and supplement formulation were described in this study.

In Paper III, we used an individual randomized controlled non-inferiority trial design with two arms. In this study, we tested if children aged 6 to 59 months with MAM, treated with 125.2 g of LIBS with 8 ml of refined deodorized and cholesterol-free sunflower oil/day, for a period of 12 weeks, would not have an inferior recovery rate compared to similar children treated with 150 g CSB+ flour and 16 ml of refined deodorized and cholesterol-free sunflower oil/day (with a 7 percent margin of non-inferiority).

Outcome

The primary outcome was a recovery rate defined as the percentage of children who attained a MUAC $\geq$ 12.5 cm and/or WHZ ≥ -2, without bipedal edema, at the end of 12 weeks. The mean recovery time (the duration within 12 weeks in which the child recovered from MAM), average weight gain, average height or length gain and average MUAC gain were the secondary outcomes (Table 2). Children who progressed to SAM during the study and/or continued as moderately malnourished at the end of the 12-week follow-up were considered to have failed management for MAM. The selection of outcome measures was based on similar studies [93, 94, 96].

Table 2: Definitions of outcome variables used in this thesis

Variable name	Definition or measurement	Paper
Protein	g/100g of LIBS	II
Fat	g/100g of LIBS	II
Carbohydrate	g/100g of LIBS	II
Energy	Kcal/100g of LIBS	II
Fiber	g/100g of LIBS	II
Moisture	g/100g of LIBS	II
Ash	g/100g of LIBS	II
Calcium	mg/100g of LIBS	II
Potassium	mg/100g of LIBS	II
Sodium	mg/100g of LIBS	II
Zinc	mg/100g of LIBS	II
Iron	mg/100g of LIBS	II
Phosphorous	mg/100g of LIBS	II
Pytate	mg/100g of LIBS	II
Recovery rate	Recovery rate indicates the percentage of children who attained a MUAC ≥ 12.5 cm and/or WHZ ≥ −2, without bipedal edema, at the end of the 12 weeks of intervention	III
Mean recovery time	The mean duration of recovery from MAM within the 12 weeks of intervention among children aged 6 to 59 months.	III
Average weight gain	The average weight gain is defined as the average gain in weight per day attained by the children aged 6 to 59 months within the 12 weeks of intervention. It was expressed as g/kg/day	III
Average height or length gain	The average height or length gain among children aged 6 to 59 months who received LIBS and CSB+ for 12 weeks. It was expressed in mm/day.	III
Average MUAC gain	Average MUAC gain is defined as average gain in MUAC among children aged 6 to 59 months who received LIBS and CSB+ for 12 weeks. It was expressed in mm/day.	III
Failed management for MAM in ITT analysis	Failed management of MAM in ITT analysis, defined as children who progressed to SAM during the study, persisted as moderately malnourished at the end of the 12-week follow-up, or were lost to follow-up without recovering from MAM during the 12-week intervention.	III
Failed management for MAM in PP analysis	Failed management of MAM in PP analysis, defined as children who progressed to SAM during the study and persisted as moderately malnourished at the end of the 12-week follow-up. The loss to follow-up was excluded from the analysis.	III

Abbreviations: g: gram; Kcal: Kilocalorie; mg: milligram; MUAC: mid-upper arm circumference; WHZ: weight-for-height z-score; MAM: moderate acute malnutrition; LIBS: local-ingredients-based supplement; CSB+: corn-soya blend plus; ITT: intention to treat; PP: per protocol

Exposures

Table 3 summarizes the exposure variables used in this thesis. Table 4 also summarizes the nutrient contents of exposure supplements given to the children with MAM aged 6 to 59 months. For 12 weeks, we provided a daily ration of 125.2 g of LIBS with 8 ml of refined deodorized and cholesterol-free sunflower oil for subjects in the intervention group. The composition of LIBS was: 30 g of pumpkin seed, 25 g of peanut grain, 20 g of amaranth grain, 15 g of flaxseed, 10 g of emmer wheat, 25.2 g of cane sugar and 8 ml of refined deodorized and cholesterol-free sunflower oil; this yielded 699 kcal, 22.7 g protein, 59.9 g carbohydrate, and 40.9 g fat. The cane sugar was added to LIBS, which improved the taste of the LIBS and increased the amount of calories that should come from carbohydrates, but it was still lower than the carbohydrate level found in the CSB+ (conventional food provided for children with MAM in the control group). Similarly, children in the control group were provided with CSB+ in the amount of 150 g CSB+ per day with 16 ml of refined deodorized and cholesterol-free sunflower oil daily for 12 weeks. This supplement yielded 751 kcal, 21.25 g protein, 95 g carbohydrate, and 30.76 g fat. Due to the higher amount of carbohydrate in the CSB+, the amount of calories is higher than the amount of calories found in LIBS. In the trial protocol of Paper III, the nutrient compositions of both supplements were described [109].

Table 3: Definitions of exposure variables used in this thesis

Variable name	Level	Definition	Paper
LIBS 1		Local-ingredients-based supplement 1	II
LIBS 2		Local-ingredients-based supplement 2	II
LIBS 3		Local-ingredients-based supplement 3	II
LIBS 4		Local-ingredients-based supplement 4	II
Sex	Individual	Sex of the child	III
Age	Individual	Age of the child in months based on birth certificate and/or actual age reported by the mother	III
Maternal age	Individual	Age of the mother in years based on birthdate reported by the mother	III
Marital status	Individual	Marital status of the mother	III
Maternal MUAC	Individual	MUAC measurement of the mother	III
Education	Individual	Educational level of the mother	III
Mother's occupation	Individual	The occupation of mother	III
Household head	Individual	The household head is the person who responsible for making decisions and earning money	III
Occupation	Individual	Occupation of the household head	III
Household size	Individual	The numbers of household members	III
Caretaker	Individual	Primary caretaker of the child	III
Morbidity	Individual	History of any sickness in the two weeks before data collection	III
Use of bednet	Individual	History of bed net use by the child	III
MUAC	Individual	MUAC measurement of the child	III
Weight	Individual	Weight of the child in kg	III
Length/height	Individual	Length/height measurements of the child in cm	III

Abbreviations: LIBS: local-ingredients-based supplement; MUAC: mid-upper arm circumference; Kg: kilogram; cm: centimeter

Table 4: Nutrient composition of the supplementary foods

Nutrient	125 gm of LIBS with 8 ml of sunflower oil*	150 gm of CSB+ with 16 ml of sunflower oil**
Energy (kcal)	698.5	750.84
Protein (g)	22.7	21.25
Carbohydrate (g)	59.9	95.0
Fat (g)	40.9	31.76
Ash (g)	2.1	4.3
Iron (mg)	8.1	6.00
Zinc (mg)	5.6	7.5
Calcium (mg)	100.00	195.00
Phosphorous (mg)	470.55	300.00
Potassium (mg)	666.14	600.00
Magnesium (mg)	394.7	107.75
Sodium (mg)	84.6	41.25
Folic acid(µg)	49.4	90.00

Abbreviations: LIBS: local-ingredients-based supplement; CSB+: corn-soy blend plus; kcal: kilocalorie; g: gram; mg: milligram; µg: microgram.

**Nutrient values for LIBS ration calculated by using the United States Department of Agriculture (USDA) food composition database and NutriSurvey software* [142, 143].

***Nutrient values for the CSB+ were adapted from Amegovu et al. 2013* [87].

Sampling

Recruitment of study participants

In Paper I, the mothers or caregivers were selected with the help of HEWs who know the local population involved in the management program for MAM. The enrollment criteria for mothers or caregivers were that they had children aged 6 to 59 months, presently with MAM, who had been admitted to the management program for MAM. The HEWs and WDAs were purposely selected based on their relevant experience (i.e. they function in a role detecting and/or managing children with MAM). The study was carried out between June 3 and July 5, 2018 (Paper I).

In Paper III, the recruitment process was done by the trained data collectors, together with HEWs who had the list of households with children aged 6 to 59 months. They visited all such households found in selected *kebeles* (Waribira Golo, Bibiso Olola, Waribira Suke, Shanto, Tomtome, and Lera) in Damot Pulassa District. Data collectors and HEWs assessed if all children in the household aged 6 to 59 months were eligible by measuring the MUAC. The recruitment process was carried out from August 27 to September 20, 2018.

Children with a MUAC of < 12.5 cm were recorded and brought to the actual screening site with their mother/caregiver, where their MUAC was re-measured and their weight, and height or length were measured. The WHZ or weight-for-height z-score (i.e. WHZ: between −3 and −2 Z-scores) values were used in addition to the values of the MUAC (i.e. between ≥ 11.5 cm and < 12.5 cm). When the child was not identified as moderately malnourished according to the values of weight-for-height/length z-scores but identified on the MUAC value, we recruited them according to their MUAC values. Edematous malnutrition was examined by using the bilateral pitting edema criterion. When the child was identified as severely malnourished, referral to the SAM clinic was made. The screening for MAM was continued until the sample size was met. (Paper III)

Randomization and blinding

In Paper III, using random allocation software, a computer-generated randomization list containing codes was created. The allocation ratio was one-to-one. Mothers chose an envelope with coded numbers that corresponded to one of the two supplementary foods. The research assistant, who was not otherwise involved with the study, carried out the randomization process. Following randomization, the investigator divided the children into sub-groups with an equal number of subjects based on their neighborhood. This was done to make it easier to assign one food distributor per sub-group, as food distributors only needed to access households with a specific child. The research assistant, who was aware of which number corresponded to which food, organized the food distribution process.

This study was double-blinded, i.e. caregivers, data collectors, and food distributors were blinded for the intervention. The supplements were similar in color and texture, and they were prepared and distributed in the same way. Both supplements were packed in the same plastic packs. Before packing, the sugar provided for the intervention group was blended with the flour. Both intervention and control groups were provided with refined deodorized and cholesterol-free sunflower oil. Food distributors were assigned to support caregivers in cooking the porridge with 8 ml of refined deodorized and cholesterol-free sunflower oil for the intervention group and with 16 ml of refined deodorized and cholesterol-free sunflower oil for the CSB+ group. We distributed the refined deodorized and cholesterol-free sunflower oil with colored plastic cups that did not reveal the amount of oil. A person other than the assessor analyzed the data.

Sample size

In the six FGDs, 55 mothers/caregivers of children aged 6 to 59 months with MAM, with eight to ten mothers/caregivers in each group, purposively recruited from the community, were included. Four HEWs and six WDAs were recruited for in-depth interviews. (Paper I)

Paper III involved 324 children aged 6 to 59 months. One hundred and sixty-two children were randomly assigned to each of the two arms. In this paper, the sample size was calculated to examine if LIBS was not inferior to CSB+ in terms of the recovery rate among children aged 6 to 59 months suffering from MAM. To calculate the sample size, we based the calculation on assumptions such as: 80 percent power of the test, 7 percent margin of non-inferiority, 5 percent level of significance, and assuming a recovery rate with CSB+ of 67 percent. The total required sample size for the study was 324 subjects with 162 subjects per study group, allowing for a 10 percent withdrawal rate. The anticipated 10 percent dropout rate was used based on the observed dropout rate reported in two studies [93, 94].

The non-inferiority margin was fixed based on the stated recovery rates of children who received CSB (67 percent) [92] and children with MAM without any treatment was (54 percent) [76]. The absolute difference between the two recovery rates was 13 percent. The average of the absolute difference of the two recovery rates (7 percent) was specified as a non-inferiority margin. Thus, to demonstrate non-inferiority, the new intervention (LIBS) should not be more than 7 percent worse than the standard treatment (CSB). This was based on the recommendations for selecting a non-inferiority margin [144, 145]. We used the stated recovery rates of children who received CSB (67 percent) to reduce the non-inferiority margin and to increase the sample size. For this sample size calculation, we used the PharmaSchool sample size calculator for non-inferiority trials.

Research instrument

Measurements and standardization

In the qualitative survey, the FGD and IDI guides were developed following extensive review of the relevant literature. The FGD and IDI guides were developed in English and translated into the local language, Wolaitato. This was followed by back-translation into English to ensure internal validity. Before the commencement of the data collection interviews, we carried out a pilot study comprising one FGD and one IDI among respondents who were not included in the study samples. This was useful and identified the gaps in the interview guides. Adjustment of questions for their flow, content, and terminology was done, based on the pilot study.

The pre-tested, semi-structured, open-ended interview guide (see Appendix I) included aspects such as asking participants to describe the current management practice for MAM and to reflect on barriers with existing management practice for MAM. The interview began with demographic data collection. Participants were then asked to describe the current management program for MAM, accessibility of the existing management service for MAM, the role of current MAM management practices in affecting the children's condition, and barriers concerning the children's weight gain, feeding practice, dietary diversity, growth, recovery from MAM, and implementation of the MAM management program.

For paper III, we did pilot-testing of the questionnaire (see Appendix 1) and refined it for clarity and correctness before commencing the interviews. The selected caregivers of children with MAM aged 6 to 59 months were interviewed for collection of baseline information such as socio-demographic and economic status, child's age, dietary habits, breastfeeding practices, and history of child and maternal illness. We used a Seca weight scale to the nearest 0.1 kg to measure the child's weight. The data collectors confirmed that the weight scale was located on a flat, firm surface, and weighing was done with light clothing.

Before measuring the child's height for children above two years of age, the data collectors ensured that the height board was on level ground and that the child was barefoot; the collector knelt down to get to the child's level and encouraged the caregiver to support the child. For children below two years of age, the data collectors measured the length with the child lying down, being sure that the length board was positioned on a flat and stable surface.

In this paper, we calculated the technical error measurement (TEM) and reliability coefficient for weight, height or length and MUAC. Each participant was measured twice by each observer; once each day, on two consecutive days. Generally, TEM is used to estimate the imprecision of intra-observer error (measurements taken by different observers on the same subject) or inter-observer error (between repeated measures performed on different occasions of the same subject by the same observer) [146, 147]. Intra-observer TEM is estimated from the difference between repeated measures performed on different occasions of the same subject by the same observer. Inter-observer TEM is estimated from single measurements taken by different observers on the same subject, with the reliability coefficient estimating the proportion of total measurement variance that is not because of measurement error [147].The actual anthropometric measurement was started after the reliability coefficient fell within a range of acceptable cut-off points [146, 147].

Data management

Data collection

In Paper I, the principal investigator and research assistants (two facilitators and one note-taker), who trained on the study objectives and methodology, carried out the FGDs. The participants were informed about the objectives and procedure of the study before starting the data collection. They were then questioned about their willingness to continue and to offer oral as well as written informed consent. The FGDs were done using Wolaitato, the local language spoken by the mothers/caregivers. We did the FGDs in privacy at sites which were reachable by participants (i.e. health posts and health centers). To get detailed information, probing was done.

The principal investigator conducted the IDIs through face-to-face interviews. The interviews were conducted in Wolaitato, the local language spoken by the HEWs and WDAs. All of the IDIs were done privately at the workplace of each health worker, and confidentiality was maintained. FGDs and IDIs were continued till saturation of information was reached; this takes place when extra interviews do not offer new evidence to data already collected and they become redundant [148]. Permission from the participants was obtained for audio-recording of data collected from FGDs and IDIs; at the same time, an assistant facilitator was taking notes. The FGDs lasted between 50 and 70 minutes, and IDIs between 60 and 80 minutes.

Based on four dimension criteria, we kept the data collection scientifically rigorous and trustworthy [149]. Credibility: To achieve this, we spent time in the field, conducted peer debriefing, and conducted a member check. These practices were maintained throughout data collection, observation, and interviewing to gain a thorough understanding of the data. Dependability: The research team created a data audit with the help of the supervisor to ensure that the data and findings were rich, thick, consistent, and stable over time. Confirmability: Using data audit and triangulation, we were able to assess the accuracy of the results and the truthfulness of the participants' perspectives. Transferability: We did purposive sampling to get specific data relative to the context. We also included detailed descriptions to assist readers in determining whether the findings could be applied to their own situation. Following such processes, we attempted to avoid our personal motivations, perceptions, experiences, contexts, and prior assumptions from affecting interpretation of data.

For Paper II, selection of food ingredients was the first step. We prepared an overview of all food items which are frequently consumed in the study area, based on the experience and knowledge of the research team. To determine the nutritive value of ingredients, we reviewed different international nutrient databases, such as the United States Department of Agriculture (USDA), the Food and Agriculture Organization (FAO), as well as national food databases (Ethiopian food composition table).

During the final selection of candidate food items that have the potential to be developed into a supplement, we considered physical availability and nutritional value. We defined availability as being when the community can easily get the food item from either the garden or local open-air markets. The macronutrient and micronutrient density of food items were compared, to select densely nutritious food. All selected ingredients (pumpkin seeds, peanuts, amaranth grain, flaxseeds, and emmer wheat) were bought from the local markets found in the Wolaita Zone.

After purchasing the selected ingredients, we processed all the ingredients (Fig. 2). We hand-sorted the ingredients to remove damaged seeds, foreign matter, and small, shriveled and/or discolored seeds. Perforated shakers were used to sieve the small-sized debris. The cleaned pumpkin seed, peanut, amaranth grain, and emmer wheat were washed exhaustively with tap water and soaked in salty water. Pumpkin seed was soaked for 12 hours, with draining every four hours. Amaranth grain and emmer wheat were soaked for 12 hours, with draining every six hours. Peanut was soaked for 6 hours. To make the ingredients crispy, we spread the drained ingredients in the sunlight to dry. The flaxseed was wiped before roasting. Each ingredient was roasted separately at approximately 150°C for about 20 minutes, with constant stirring, waiting until it developed an aroma and then they were cooled. After cooling, the peanuts were skinned and skins separated from seeds by winnowing. Finally, the milling of individual ingredients was done using a flour miller.

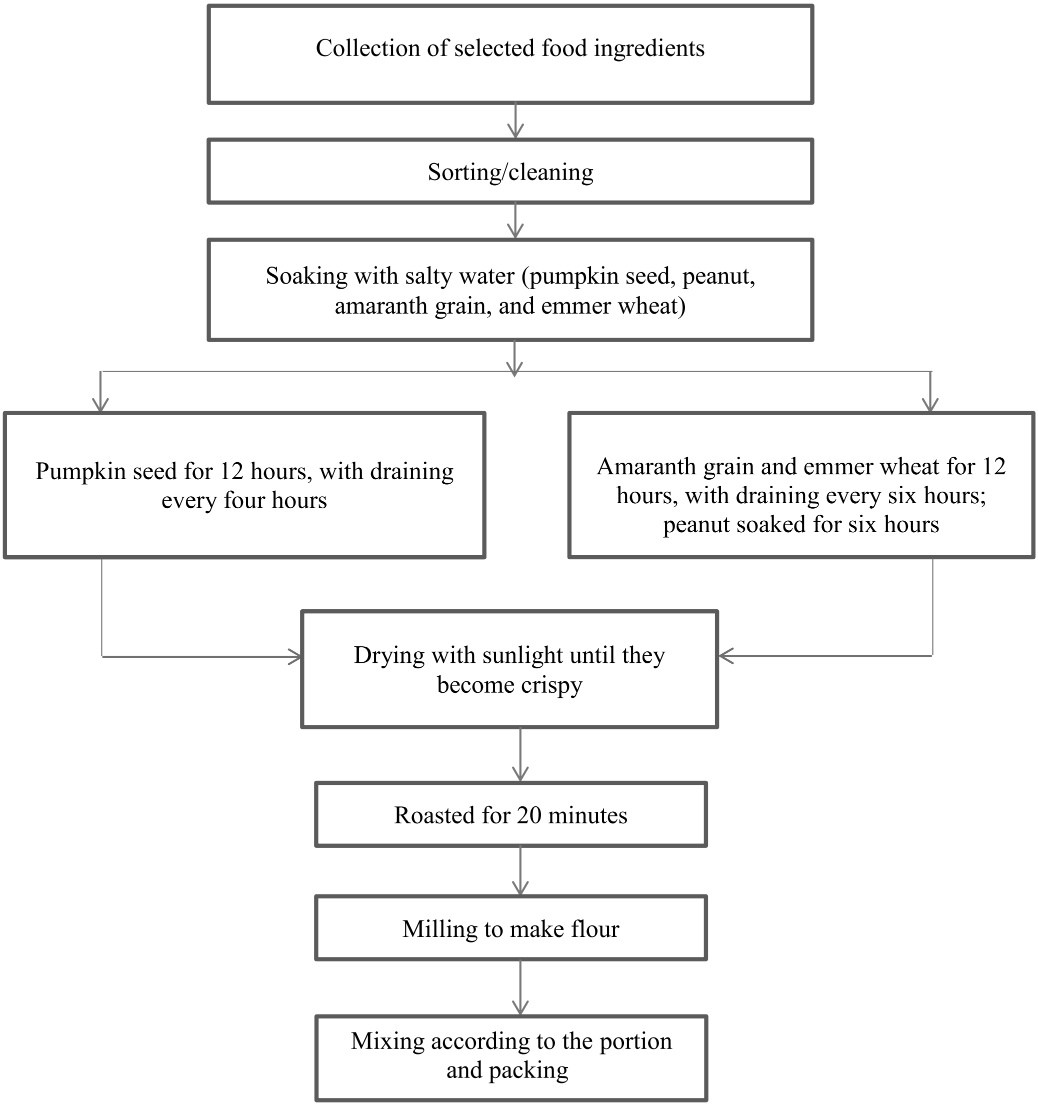

Figure 2: Processing flow of local-ingredients-based supplement

Regarding supplement development, Nutrisurvey computer software, employing linear programming, was used to determine the proportion of the supplements' ingredients. Table 4 summarizes the four supplements (LIBS 1, LIBS 2, LIBS 3, and LIBS 4) prepared from the mixture, with different proportions of each ingredient. The nutrient content of each supplement was based on composition, intended to attain the recommended daily allowances for children with MAM aged 6 to 59 months [75, 100].

Table 4: Proportion of ingredients within food samples/100gm

Food samples (g)	Pumpkin seed (g)	Peanut (g)	Amaranth (g)	Flaxseed (g)	Emmer wheat (g)
LIBS 1	20	20	20	20	20
LIBS 2	25	20	15	20	20
LIBS 3	25	15	20	25	15
LIBS 4	30	25	20	15	10

g: gram; LIBS: local-ingredients-based supplement

In Paper III, the child's length was measured to the nearest 0.1 cm, using a locally prepared wooden measuring board for children aged 6 to 23 months. For children aged 24 to 59 months, the height was measured to the nearest 0.1 cm using a Seca height. We used a non-stretchable standard UNICEF plastic tape measure for measuring the MUAC. We considered the MUAC measurement to be taken halfway between the acromion and olecranon processes, with the measuring tape fitting comfortably, but not creating a depression on the left upper arm.

In this paper, participants in both the intervention and control groups were visited every week for 12 weeks to collect anthropometric measurements using the MUAC and to gather evidence on supplement use and morbidity. Weight and height/length were measured monthly using the same equipment that was used at the baseline. We evaluated bilateral pitting edema by pressing for three seconds on the dorsum of the foot. Children who developed SAM were sent to the SAM clinic based on the follow-up measurement of anthropometry.

Distribution of supplements

The supplements were provided in the morning as breakfast for the subjects from both groups. A similar amount of food was provided for children aged 6 to 23 months and 24 to 59 months [150]. We assigned food distributors who had been trained in the preparation of porridge to visit each household daily to assist caregivers in the preparation of the porridge and feeding, as well as to advise, assess, and resolve feeding problems. Likewise, they checked for and measured the amount of supplement consumed by the children. For CSB+, 150 g was diluted with 600 ml water and cooked for 10 to 15 minutes, while 125.2 g of LIBS was diluted with 400 ml water and cooked for 10 to 15 minutes. The food distributors used a local measuring cup with numbers to check and measure the amount of supplements consumed by the children. Refeeding was performed if not all of the prepared porridge was consumed.

Data analysis

For Paper I, the data taken from the interviews and FGDs was transcribed verbatim (a word-for-word record); Express Scribe transcription software (Pro v 7.03 NCH Software Pty Ltd) was used to transcribe the interviews. An initial coding framework was generated by the primary researcher and research assistants after independent manual coding of transcripts. The descriptive phenomenological method of Colaizzi was used to analyze the data. In this approach, there are seven steps involved in the analysis of qualitative data [151] (Fig 3). The data were imported and coded in the computer software of ATLAS.ti 8 and analyzed by the same software. The result was reported based on the Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist to report results [152].

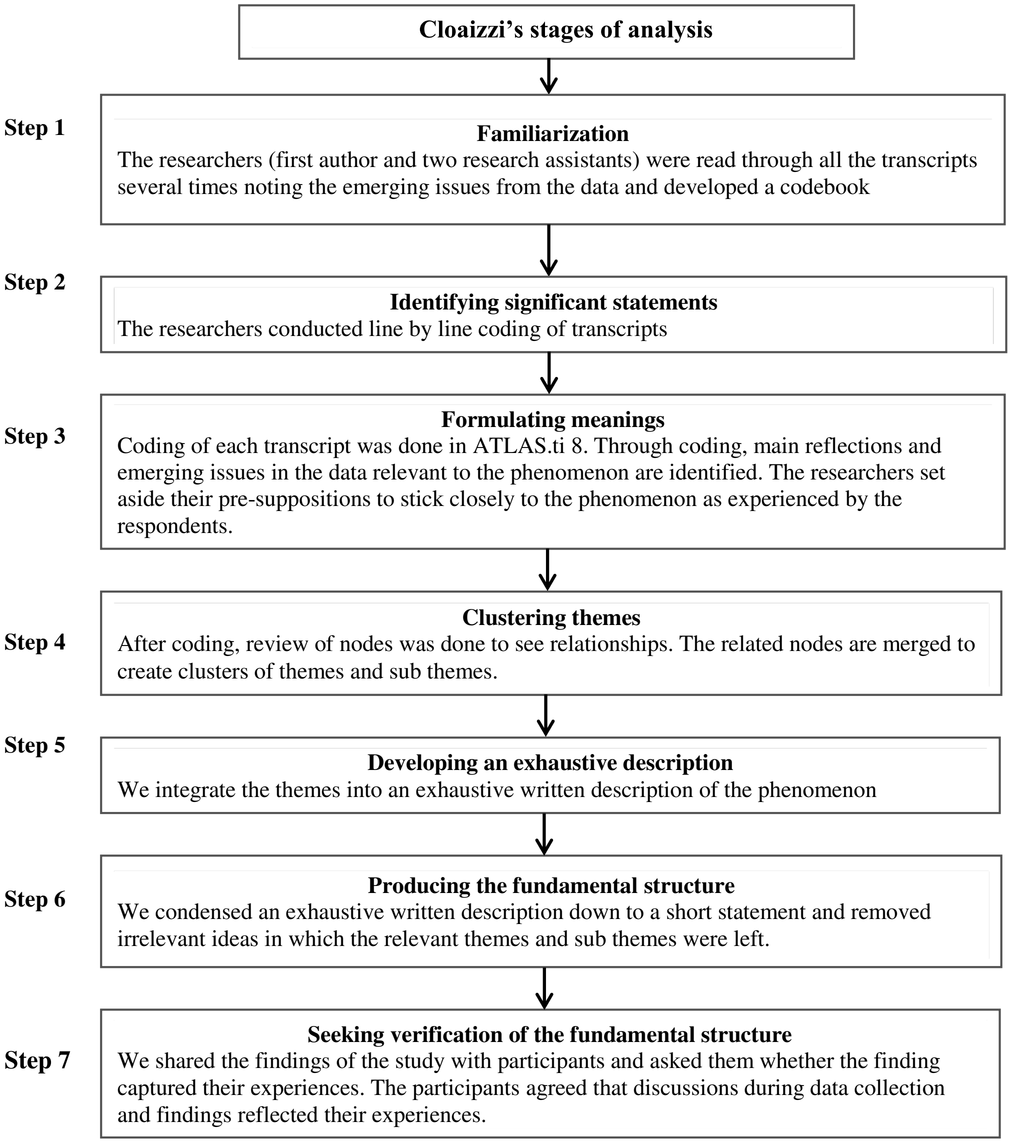

Figure 3: Colaizzi's stages in descriptive phenomenological analysis and how it was applied in this study [151].

For Paper II, the nutrient analysis was done in the Ethiopian Health and Nutrition Research Institute and Hawassa University food science laboratory. Nutrient analysis consists of proximate and mineral analysis.

In the proximate analysis**,** the nutrient composition of the supplements was estimated by the standardized procedure of the Association of Official Analytical Chemists (AOAC) [153]. We maintained a triplicate measurement of nutrients. The moisture content of supplements is significant for their shelf life, with better storage stability maintained by the lower moisture content of the supplement [154]. The AOAC Official Method 925.10 was used to determine the moisture content of the LIBS [155], while the determination of ash content was done using AOAC Official Method 923.03 – Direct method [156]. Determination of crude fiber content was done by AOAC Official Method 962.09 – Ceramic fiber filter [157]. We used AOAC Official Method 920.39 – Soxhelt to analyze the crude fat content [156]. The crude protein content was determined by ESISO 1871: 2013 test method [157]. Carbohydrate content was calculated by difference including fiber: carbohydrate percent = 100-(moisture content percent + crude protein percent + fat percent + fiber percent + ash percent). The Atwater's conversion factor: 4 kcal/g for carbohydrate, 4 kcal/g for protein, and 9 kcal/g for fat was used to determine the energy [158].

In the mineral analysis, calcium content was estimated using the AOAC Official Method 923.03 - EDTA titration method [156, 159]. The atomic absorption/emission spectrophotometer equipment was used to determine iron, zinc, potassium, and phosphorus contents. Regarding anti-nutrients, phytate was determined by using the Latta and Eskin method [160], as modified by Vaintraub and Lapteva [161].

In Paper II, the determination of molar ratio of phytate to mineral was done. The inhibitory effects of phytate on the bio-availability of minerals were determined by phytate-to-minerals molar ratios. We divided the weight of phytate and minerals with its atomic weight to determine the molar ratio of phytate and minerals. Phytate-to-mineral mole ratio was calculated as follows [162, 163]:

$$Molar\ ratio = \frac{Moles\ of\ anti-nutrient}{Moles\ of\ mineral}$$

The molar mass of the phytate used was 660 g/mol. The recommended critical values used in this work are *Phytate* : Zinc > 15, *Phytate* : Iron > 1, and *Phytate* : Calcium > 0.24[163].

The analysis of data was done using the Statistical Package for the Social Sciences (SPSS 20) (IBM Chicago, IL, U.S.A.) and STATA 15 (StataCorp LLC) (Paper II and III). Values were expressed as grams with means of triplicates ± standard deviation. One-way analysis of variance (ANOVA) and posthoc Tukey test were used to compare the difference in proximate, mineral, and anti-nutrient content among food groups. The significance of differences was set at 0.05 level of probability ($p < 0.05$) (Paper II).

In Paper III, the field supervisors controlled all data collection sheets for completeness. We used EpiData version 3.1. (Odense, Denmark) for data entry. Double data entry was done at once to ensure data quality. We used both intention-to-treat (ITT) and per protocol (PP) analyses, and the 95 percent confidence interval (CI) level was used to interpret any differences, based on the recommendations for analyzing and reporting equivalence and non-inferiority trials [94]. The ITT analyses involved all patients who were randomly assigned, while the PP analysis excluded children who refused, transferred out of the management program, or were lost to follow-up, but involved children who died, or were discharged as cured or non-cured.

Comparisons of baseline characteristics between CSB+ and LIBS were summarized as percentages and means (±SDs). Comparisons of outcomes between the LIBS and CSB+ groups were made by using a chi-square test for categorical variables and generalized estimating equations (GEE) for continuous variables. Non-inferiority was inferred by estimating the differences in the estimated proportion between the groups, along with a 95 percent CI. Our trial was testing against a one-sided hypothesis, but the decision of non-inferiority was based on a two-sided 95 percent confidence interval, even if we dealt with the lower limit of the interval (Paper III).

The Kaplan-Meier (log-rank) curve of survival analysis was used to predict the recovery time between groups. P values < 0.05 were set to be statistically significant. The mean difference in weight gain, mean difference of MUAC and mean difference of height or length gain were computed to describe the magnitude of the difference between the two groups. Rates of weight gain through the whole period of follow-up were estimated in g/kg body weight/day and compared between the study groups. These were calculated by dividing the weight gain (weight at exit minus weight at admission), expressed in grams, by the weight at admission (in kilograms) and the length of stay (in days). Risk difference was calculated by OpenEpi and MDCalc software. We used ENA for SMART 2011 software to calculate the anthropometric indexes (Paper III). The major statistical methods used in this thesis are presented in Table 5.

Table 5: Major statistical methods used for data analysis

Statistical method	Paper(s)
Descriptive statistics	Paper I, II &III
One-way analysis of variance (ANOVA)	Paper II
Anthropometric analysis (Z-scores)	Paper III
Student's t-test	Paper III
Fisher's exact test	Paper III
Chi square test	Paper III
Kaplan-Meier (log-rank)	Paper III
Generalized Estimated Equation	Paper III

Quality measurements

For Paper II, we stored the food ingredients, as well as the developed supplements, in areas that were clean and free of rodents and/or pests. Before starting the supplement development process, training in food hygiene was given to supplement-processing workers. Continuous supervision of supplement processors was done. Regular medical checkups of supplement processors were done throughout the supplement development. Before processing the supplement, the supplement processors wore clean plastic gloves after washing and drying their hands thoroughly. They used hair coverings and protective coats during supplement development. When processing the food, we carried out the procedures such as sorting, immersing into salty water to remove contaminated floating ingredients, washing, skinning, dehydrating and roasting. We used magnets to remove metallic wastes. We restricted the frequency with which the processing equipment was cleaned with soap and water and simply dry-wiped to prevent the introduction of water into LIBS during development. These procedures all helped to ensure that supplements were produced in safe and hygienic manner [164, 165].

In Paper III, we recruited two research teams that involved two supervisors, 12 data collectors and 18 food distributors. The principal investigator trained the supervisors and data collectors seven days before the beginning of the study. The training covered the study objectives, data collection systems, questions found in the questionnaire, interview techniques, and anthropometric measurements. The training was based on WHO recommendations for anthropometric measurement protocols, particularly for anthropometric measurement techniques, periodic standardization, and daily calibration of equipment [150]. In addition, before study initiation, five days of training was given to the food distributors on supplement distribution technique, feeding procedures, and cooking of supplementary foods.

To ensure that the enrolled child was fed with a full portion, we delivered an extra amount of supplement to the mother/caregiver whose child was a twin. While two children suffering from MAM were found in the same household, we delivered the same supplements for both children; however, only the randomly selected child was taken as a study subject. In a situation where the enrolled child was not at home at the time of follow-up, the data collectors revisited the households until they found the child. All activities were overseen daily by supervisors. We also monitored the food distribution process, feeding techniques, and use of the provided food supplements, among randomly selected households on a twice-monthly basis.

Ethical considerations

This thesis was approved by the Hawassa University College of Medicine and Health Sciences Institutional Review Board (IRB/024/10) and the Regional Committees for Medical and Health Research Ethics in Norway (2018/69/REK vest). The approval obtained from Hawassa University College of Medicine and Health Sciences Institutional Review Board covered all sites included in the study.

During obtaining the ethical approval from the regional committees for medical and health research ethics in Norway, we faced a challenge in continuing the superiority trial that we had planned to conduct. In the superiority trial, we had planned to assign LIBS to the intervention group and nutrition counseling (standard treatment of MAM in food-secure districts) to the control group. However, the Regional Committees for Medical and Health Research Ethics in Norway suggested providing food supplements to the control group as well, since all subjects had already developed MAM. We then selected the active control group and assigned CSB+, and shifted to a non-inferiority trial.

Written permission was obtained from the Wolaita Zone Health Office. Verbal (getting thumb marks after reading the information) and written informed consent were obtained from all caregivers of children who met enrollment criteria before the recruitment of their children into the study. The purpose of the study and methods of data collection, confidentiality, and voluntary participation were explained to the children's mothers, who were then invited to sign an informed consent form. All interviews and intervention procedures were conducted in privacy. No serious adverse reactions were detected. The trial protocol was registered at the Pan-African Clinical Trials Registry under the number: PACTR201809662822990. It was registered on 12 September, 2018.

Results

Paper I: Barriers to existing management practices for moderate acutely malnourished children

We assessed perceptions of mothers and health service providers toward barriers to existing management practices for children with MAM in Wolaita, Southern Ethiopia. Forty-seven mothers and eight caregivers attended FGDs. Ten IDIs with four HEWs and six WDA workers were conducted.

The mothers and health service providers identified six main themes that demonstrated their perceptions toward barriers to existing management practice for MAM: i) possible reasons for MAM; ii) identification of child with MAM; iii) management services for MAM; iv) mother- or caregiver-level barriers; v) service provider-level barriers; and vi) measures to improve the service.

We have shown that the shortage of child-caring time, lack of awareness, large household size, and maternal malnutrition were mentioned as possible reasons for MAM. Household work burden prevents mothers or caregivers from caring for their children properly. In addition, small business traders do not have time to see their children and practice the nutrition education received from service providers. We found that some mothers do not feed their baby regularly due to a lack of awareness toward appropriate childhood-feeding practices. Instead, they give dry family foods when the child is hungry. As a result, children would often become ill and hence end up with MAM.

Identification of children with MAM was done by occasional house-to-house screening using the MUAC, during the immunization sessions (vaccination program and vaccination campaign) and on the mothers' or caregivers' initiative. In addition, non-governmental organizations have done screening of children for MAM occasionally. The service providers had monthly screening programs by visiting from house to house and they also visit families who are worried about their child's nutritional status. Occasional house-to-house screening of children for MAM and family-initiated screening of children for MAM (service provider-level barriers) were mentioned by mothers or caregivers as the perceived barriers to management practice for MAM among children aged 6 to 59 months.

More than half of the mothers or caregivers did not know exactly what MAM was. They described the state as low weight without body swelling and lost hair, but they knew they would stay in counseling if their child's MUAC was on the yellow mark. We found that the nutrition counseling (primarily) and follow-up were the existing management practices for MAM. The counseling topics covered exclusive breastfeeding practices, healthy complementary feeding practices, types of different food ingredients that children need, preparation of porridge from cereals and vegetables, hygiene, family planning, vaccination, and communicable disease control.

Our finding showed that mothers or caregivers agreed that the management services for MAM are inadequate. Shortage of food and money, selling-out of cultivated food without reserving sufficient food at home, large household size and shame about having a child with malnutrition were mother- or caregiver-level barriers that prevent them from implementing the nutrition counseling provided. These barriers were the key obstacles that prevent mothers or caregivers from diversifying their children's diet. The lack of repeated follow-up by the service providers, ignoring management of MAM and leaving responsibility for the management of MAM to the family were mentioned as service provider-level barriers. The health service providers also mentioned that nutrition counseling only is not enough, as the children are progressing to SAM; they further pointed to the fact that there is inadequate or no delivery of supplementary food for MAM.

Our finding shows that perceived measures needed to improve the management service for MAM were focused, routine, and inclusive (including all mothers of children aged below five years and fathers) counseling about appropriate feeding practice, and supplementation with therapeutic food.

Paper II: Development and nutrient evaluation of a LIBS to treat MAM

We aimed to develop a LIBS for the treatment of MAM. In addition, we evaluated the nutritive values of the LIBS.

We developed four food supplements named LIBS 1, LIBS 2, LIBS 3, and LIBS 4. The nutrient analysis revealed that the protein content of the four food supplements ranges from 20.3 g to 22.6 g. The fat content of the four food supplements ranges from 29.3 g to 33. 5 g. The carbohydrate content of the four LIBSs ranges from 35.4 g to 40.0 g. The range of energy is from 509.5 kcal to 570 kcal for the four food supplements. The fiber content ranges from 6 g to 8 g for all LIBSs. For moisture content of the four food supplements, the range is from 2.8 g to 3.7 g. The ash content of the four LIBS ranges from 2.1 g to 4.3 g. The proximate (protein, fat, carbohydrate, fiber, moisture, and ash) contents of the four food supplements are within the recommended values for proximate compositions for treating MAM.

The protein, fat, and energy contents of LIBS 4 were significantly higher than the other supplements. LIBS 2 had significantly higher content of fiber than all other supplements. There is no significant difference in the moisture content of LIBS 1 and LIBS 2. The lowest ash content is found in LIBS 4.

The mineral composition of the four food supplements ranged from 75.6 mg to 115.6 mg for calcium, 473.1 mg to 570.2 mg for potassium, 79.3 mg to 114.4 mg for sodium, 4.1 mg to 5.6 mg for zinc, 8.2 mg to 10.2 mg for iron, and 442.6 mg to 470.4 mg for phosphorous. The range of anti-nutrient (phytate) is from 2.1 mg to 4.3 mg. The mineral and anti-nutrient content of supplements are within the recommended values of for the treatment of MAM, except for calcium.

LIBS 4 had significantly the highest amount of iron, zinc, phosphorous, and potassium. The calcium content was highest in LIBS 3, and it was significantly different among the four supplements. The highest content of phosphorus was found in LIBS 4. The highest amount of sodium was found in LIBS 1, whereas the lowest sodium content was found in LIBS 3. The magnesium content of the four supplements varied significantly. The lowest amount of magnesium was found in LIBS 1, whereas the highest amount of magnesium was found in LIBS 2. There was significant difference in phytate content among the four supplements. LIBS4 had the least amount of phytate. Phytate-mineral ratios were below the recommended critical values for four supplements.

Paper III: A local-ingredients-based supplement is an alternative to corn-soy blends plus for treating MAM

We aimed to evaluate if the LIBS 4 is comparable with CSB+ in treating moderate acute malnutrition among children aged 6 to 59 months. In Paper III, LIBS indicates LIBS 4.

Of the 1,006 children screened for MAM, 324 children with MAM aged 6 to 59 months were enrolled either for LIBS (n = 162) or CSB+ (n = 162). Of 324 children involved in the study, 311 (96%) children with MAM and their mothers/caregivers completed the study. The main reason for seven who were lost to follow-up was moving from the study site. The remaining six were discontinued due to SAM.

The comparison of baseline characteristics between the LIBS and CSB+ groups was done. There was no significant difference between the LIBS and CSB+ groups. We found that the overall proportion of recovery from MAM was 72.2 percent at the end of the 12-week intervention. ITT and PP analysis revealed that there was no difference in recovery between LIBS and CSB+ groups. In ITT analysis, we found that the recovery of 75.9 percent in the LIBS group and 71 percent in the CSB+ group, whereas the PP analysis showed recovery of 76.58 percent for LIBS and 72.90 percent for CSB+. In ITT analysis, the risk differences for LIBS compared with CSB+ were 4.9 percent (95 percent CI: –4.70, 14.50) and risk difference = 3.7 percent (95 percent CI: –5.91, 13.31) in PP analysis. Both ITT and PP analysis showed that LIBS was non-inferior compared with CSB+ in terms of the recovery rate (predefined non-inferiority margin of risk difference for recovery was = –7).

In both ITT and PP analysis, there was no difference in daily weight gain between LIBS and CSB+ groups. ITT analysis showed that the risk difference for LIBS compared with CSB+ was 0.10 (95 percent CI: –0.33, 0.53), whereas PP analysis showed that the risk difference for LIBS compared to CSB+ was 0.04 (95 percent CI: –0.38, 0. 47). Both ITT and PP analyses showed that the LIBS group was non-inferior compared with the CSB+ group (predefined non-inferiority margin of risk difference = –1.3 g/kg/day).

In the ITT and PP analyses, there was no difference in MUAC gain between the LIBS and CSB+ groups. There was no difference in daily length/height gain over 12 weeks between the LIBS and CSB+ groups.

In the ITT analysis, the mean (SD) recovery time for the LIBS group was 54.27 days (26.74) and for the CSB+ group was 56.9 days (25.99), giving a difference of −2.64 days (95 percent CI: −8.40, 3.13 days). The mean recovery time (SD) for the LIBS group was 53.52 days (26.65) and for the CSB+ group, it was 55.68 days (25.91) in PP analysis, giving a difference of −2.17 (95 percent CI: −7.97, 3.64 days). ITT and PP analysis showed that the mean recovery time in the LIBS group was non-inferior to the CSB+ group (predefined non-inferiority margin of risk difference = 14 days).

Discussion

In this thesis, we divided the discussion into two parts. Firstly, we discuss the methodological aspects. Thereafter, the main findings of this thesis are discussed.

Methodological discussions

In this thesis, we assessed perceptions of mothers and health service providers towards barriers to existing management practices for moderate acutely malnourished children (phenomenological study). We developed a LIBS from locally available food ingredients (descriptive study). We also evaluated if a LIBS was an alternative to CSB+ for treating MAM among children aged 6 to 59 months (randomized controlled non-inferiority trial). The plan for showing how to evaluate if LIBS is comparable with CSB+ for treating MAM was described in the study protocol (Paper IV) [109].

Study design

In this thesis, we used a descriptive phenomenological qualitative design (Paper I), descriptive study design (Paper II), and a randomized controlled non-inferiority design (Paper III).

The qualitative research method generates a detailed explanation of participants' emotional state, thoughts, and experiences, and interprets the meanings of their activities [166]. Qualitative study is concerned with better understanding of the meaning of certain circumstances for health professionals and patients, and how their interactions are made within a specific social situation [167]. A phenomenological design is one of the qualitative study designs. In the descriptive phenomenological approach, the researcher analyzes the descriptions given by respondents and classifies them into meaning-laden statements, collecting those meanings that are important to build the phenomenon being studied [168].

We chose the descriptive phenomenological qualitative design to investigate the lived experience of the mothers or caregivers and service providers of the barriers in the existing management practice for MAM. Though mothers of children with MAM are getting routine nutrition counseling on the management of MAM, the children are either still developing the condition or progressing to the severe form [76]. By implementing the current management practice for MAM, there might be an assumption that the children are getting adequate management of

MAM. Thus, understanding the lived experience of mothers or caregivers and service providers regarding the barriers of existing management practice for MAM is essential. Using a descriptive phenomenological qualitative design, we can understand the meaning of the barriers that hinder the implementation of current management practice for MAM, for the mothers or caregivers and service providers**.**

There were limitations in applying the descriptive phenomenological qualitative method. The first one was about bracketing. Bracketing means suspending one's innate preconceptions about a phenomenon in order to grasp the truth of the phenomenon without bias [169]. We tried to keep complete bracketing by setting aside preconceptions while listening to and reflecting on the lived experiences of the respondents; however, it was challenging to develop a pure description of the participants' experiences. Since our expertise lies in the area of public health and nutrition, pure bracketing toward the phenomena was challenging. In reality, bracketing cannot be achieved completely [170].

Another limitation was social desirability bias. Social desirability is the tendency of some participants to respond in a manner they think to be more socially acceptable than would be their 'right' or true response. The respondents do this to avoid receiving negative evaluations and to have a favorable image of themselves [171]. In our study, we included the HEWs and WDAs as respondents. As these personnel belong to the official administrative structures, they might respond to the interview questions in such a manner that might support the existing management practice for MAM. To alleviate this bias, we have kept anonymity, provided the respondents a brief overview of the study at the start, maintained the privacy of respondents, ensured confidentiality, asked the respondents indirect questions during data collection, and included mothers or caregivers of children with MAM aged 6 to 59 months.

The descriptive study design that we used in Paper II was about the development of a LIBS and a nutrient evaluation of it. The steps in how to develop the LIBS, including processing and how to evaluate its nutrients, were described in this study.

In Paper III, we used an active randomized controlled non-inferiority trial. A randomized controlled non-inferiority trial is one in which the intent of a study is to establish that the new intervention is not considerably worse than a control treatment [172]. Therefore, a non-inferiority design statistically tests the null hypothesis (H_0) that the new intervention is inferior to the previous one (active control) by more than a pre-defined margin ($-\Delta$). The alternative hypothesis (H_1) states that the difference in the effect between the new intervention and active control is less than a pre-defined margin ($-\Delta$) [173].

In a non-inferiority trial, the placebo control is believed to be unethical or unreliable for some other reason. This drives us to conduct active controlled trials, in which the new intervention is compared to a well-established active control [174]. In Paper III, we tested the LIBS for its effect in treating MAM compared with CSB+ rather than using placebo as a comparator. CSB+ is a standard food supplement that is claimed to be effective in treating MAM [93, 97], and we used it as an active control or a comparator for the LIBS, such that the potential risk of bio-creep in non-inferiority trials was prevented.

This non-inferiority trial, to the best of our knowledge, was the first study using locally developed supplements based on local food ingredients to compare with the standard treatment for MAM (CSB+) in Ethiopia. We have used locally available and culturally acceptable food ingredients to formulate the supplement, with our result meeting the Sphere standard regarding recovery rate (>75 percent) and loss to follow-up rate (<15 percent) [175].

Selection bias

Selection bias can arise through the identification of the study subjects [176]. In qualitative research, the samples are commonly assumed to have been chosen purposefully. This is because cases with a lot of information are identified and selected for the most effective use of limited resources [177]. Purposive sampling encompasses finding and selecting individuals or groups of individuals who are particularly knowledgeable or experienced about the topic of interest [178]. In contrast to the probability sampling used in quantitative research, purposeful sampling selects 'information-rich' cases [179]. In Paper I, we used purposive sampling to select mothers or caregivers of children with MAM and service providers (HEWs and WDAs). We selected these groups, assuming that they are knowledgeable and can have the ability to share their experiences and opinions regarding the topic.

Selection bias is the result of "systematic differences in the baseline characteristics" of the groups being compared. The existence of these systematic differences indicates that the distribution of predictors differs between the groups being compared [180]. In Paper III, we selected Damot Pulassa District considering the high level of food insecurity, high level of child malnutrition, good geographical location and access to transportation. From the district, we selected the six *kebeles* (Waribira Golo, Bibiso Olola, Waribira Suke, Shanto, Tomtome, and Lera) randomly. Children aged 6 to 59 months found in the selected *kebeles* were screened for MAM according to the eligibility criterion. Randomization was used to assign children into LIBS and CSB+ groups. Randomization confirms that every single subject has the same chance of getting any treatments under study, creating similar intervention groups, which are comparable in all key characteristics apart from the intervention each group obtains. The main advantage of randomization is that it balances groups in terms of known and unknown (residual) confounding effects, which enables statistical inferences of treatment effects [181, 182].

Children were allocated into each group using a 1:1 ratio. In a randomized controlled trial, a balanced allocation of subjects into each group will maximize the statistical power [155]. The allocation was started by generating a computer-generated list of random numbers. Secondly, we asked the mothers/caregivers to pick a sequentially numbered opaque sealed envelope that corresponded to either LIBS or CSB+ such that the assignment of subjects into one or other group by the investigator was prevented. In practice, randomization can be accomplished through various methods of random allocation (e.g., by using opaque envelopes, allocation tables, or computer-based random number generators) [183, 184]. We assigned a research assistant, who was not otherwise involved with the study, to do the randomization process. Separating the person who generates a random allocation from the person who recruits subjects confirms allocation concealment [185].

Information bias

Information bias is a type of error that occurs when a measurement of an exposure or outcome is skewed in some way. Interviewer bias, patient loss to follow-up or attrition bias, bias from the misclassification of subjects, and performance bias are all examples of information bias [176]. Information bias is common during the data collection stage [186]. In Paper I, we interviewed mothers or caregivers of children with MAM and service providers. These subjects had important experiences regarding the topic. However, the inclusion of service providers may introduce information bias (through social desirability bias) because they might respond to the interview questions in a way that supports current MAM management practices. We tried to alleviate this bias by triangulating the information through doing focus group discussions with the mothers or caregivers. As a strength, we aimed to keep complete bracketing; however, putting the predetermined knowledge of the researchers aside to induce a pure description of the participants' experiences was challenging. In practice, pure bracketing may be difficult to achieve.

In Paper II, we faced challenges during the development of the supplements. The main one was lack of proper facilities in the study setting for the analysis of some micronutrients. Different nutrition laboratories were used to analyze the nutrient composition of the LIBS because there were limited nutrition laboratories that could carry out all the nutrient analysis at once. This may have introduced measurement bias, since different measurers participated in the process of nutrient analysis. To alleviate this bias, we tried to triangulate the measurements of proximate analysis. We also used triplicate measurements of nutrients for the statistical analysis.

Difficulties in reporting the values of vitamins were another challenge. We had different results of Vitamin A and C from different nutrient laboratories. We left off these results from reporting as a finding. However, the development of a LIBS from locally available food items for treating MAM was the study strength. In addition, almost all nutrients found in the LIBS were within the recommended range of nutrients for treating MAM.

In Paper III, we used double-blinding to eliminate interviewer bias as well as performance bias. Performance bias is a systematic difference between groups in the care that is provided which will be less likely in blinded trials [180]. Randomization can prevent bias from misclassification of subjects. In Paper III, the overall loss to follow-ups was low (1.5 percent) and no differences were observed between groups. To control attrition bias, we did weekly follow-ups to collect data and daily visits to distribute supplements.

Standardization of anthropometric measurements was conducted to reduce measurement bias. However, we recognized that this study is still susceptible to measurement bias, since there was a turnover of trained data collectors and frequent measurements of anthropometrics (Paper III). Another limitation that might introduce information bias was not measuring the daily consumption of home diets by the children. This may introduce information bias, since the intake of home food might vary between the LIBS and CSB+ groups.

Confounding

Confounding is a systematic distortion in the measurement of the effect of an exposure on an outcome due to the association of exposure with another extraneous or third variable called a confounder [187]. Confounders can distort observed exposure-outcome relationships [188]. This is commonly termed as a 'mixing' or 'blurring' of effects. A way of controlling confounding in research is randomization [189]. In Paper III, we used a randomized controlled non-inferiority trial following the three steps of randomization: allocation sequence generation, allocation concealment, and implementation of the allocated sequence. In this paper, we also used double-blinding: caregivers, data collectors, and food distributors were blinded for the intervention. An appropriate allocation process and blinding are crucial to ensure randomization. Randomization has the goal of balancing known and unknown confounding factors [184]**.** In Paper III, we ensured the comparability of the LIBS and CSB+ groups in the baseline comparison.

Sample size: Assessing type I and type II errors

In qualitative research, sample adequacy is a criterion for assessing the quality and reliability of the work. The saturation principle is the most widely used principle for determining sample size and assessing its sufficiency [179]. In Paper I, we conducted focus group discussions and in-depth interviews till saturation of content was achieved; 55 mothers or caregivers in focus group discussion and ten service providers in in-depth interviews were included in these. Unlike quantitative study, qualitative study is hypothesis-generating study [190]. Thus we could not assess type I and type II errors in Paper I.

In a quantitative research study, having a sufficient sample size reduces the risk of presenting a type II error (false negative findings) and improves the precision of the estimates made [191]. In Paper III, the pre-specified non-inferiority margin was fixed appropriately, based on the stated recovery rates of children who received standard treatment and children with MAM without any treatment. From this, we then got the appropriate non-inferiority margin that enabled us to have an adequate sample size. The extent of a non-inferiority margin basically decides the size of a trial [174]. We fixed a 7 percent non-inferiority margin, and this required 324 children, 162 in intervention group and 162 in control group. The randomization process we used in Paper III is less likely to result in a biased sample of study subjects.

Causation

In comparison to other observational studies, randomized controlled trials are the 'gold standard' for evaluating causal relationships [192]. In randomized controlled trials, randomization minimizes bias and provides a rigorous tool for examining cause-and-effect links between intervention and outcomes [193].

In Paper III, we conducted a non-inferiority trial with the hypothesis that LIBS is similar to CSB+ in treating MAM among children aged 6 to 59 months. We assessed the similarity of outcome of interest between LIBS and CSB+ groups. In the process of conducting Paper III, we did a rigorous randomization, which minimized confounding by distributing confounders into LIBS and CSB+ groups uniformly. The prevalence of other causes (confounders) that affect the strength of causality was minimized in Paper III.

Consistency is met because the reproducibility of the study (Paper III) is maintained since the study protocol of Paper III was published; the data were shared and published accompanied by the results, the method of data analysis was clearly described, and randomization process was thoroughly done.

Plausibility was met because there is scientific evidence showing that supplements made from locally available food can treat children with MAM [75]. We developed the intervention food (LIBS) from locally available, nutritious food ingredients and tested for its effectiveness in treating MAM among children aged 6 to 59 months, compared with CSB+. Such a study had not previously been conducted in Ethiopia. The findings we observed may be new to public health in Ethiopia. However, we compared our results with similar studies done in other countries [77, 90, 92, 93].

Even if the recovery rate is similar in the LIBS and CSB+ groups, the specificity of findings could be met, since the recovery rate from MAM in both LIBS and CSB+ groups is specific to the intervention. There might be multiple determinants that may affect the specificity of findings, but randomization and comparability of LIBS and CSB+ groups regarding baseline characteristics could enhance the specificity of the findings.

The findings from Paper III could show the true biological gradient (dose-effect) relationship. Children with MAM needed additional nutrients compared to non-malnourished children. LIBS and CSB+ were intervention foods, and we compared their effectiveness in treating MAM. Of children who were assigned for LIBS, 75.9 percent recovered from MAM, while 71 percent of children who were assigned to the CSB+ recovered from MAM. A study done in Burkina Faso showed that 57.8 percent of children recovered from MAM with no supplementation [77]. Another study done in Ethiopia, revealed that 54.2 percent of children recovered from MAM without supplementation [76]. Thus, we suggest that the recovery rate among children with MAM depended on the provision of supplementary foods.

Coherence is met because several studies investigating whether the recovery from MAM among children aged 6 to 59 months is comparable between RUSF made from local food and CSB+ have provided similar conclusions [77, 89, 90, 93]. An addition, the LIBS groups met the Sphere goal of 75 percent recovery (Paper III).

Despite its limitations, the randomized controlled trial is widely recognized as a powerful method for proving causality [194]. In Paper III, the intervention we conducted preceded the outcome, and thus the effect that we evaluated at the end of the intervention is linked with the supplement we provided. We ensured this because we used strict randomization, allocation and blinding processes. Such processes reduce bias and provide a reliable tool for examining cause-and-effect relationships between an intervention and its outcomes. The evidence we reported in Paper III is based on the randomized experiments. Therefore, the findings from Paper III met the temporality and experimentation criteria.

Validity of the research

The validity of a study pertains to how well the findings among the study subjects reflect the true study results among similarly situated people outside the study. It can be divided into two categories: internal and external validity [195]. The internal validity refers to the degree to which the observed difference between groups can be accurately linked to the intervention under investigation. On the other hand, external validity is the degree to which test results can be applied to 'real-world' populations [196, 197]. The lack of internal validity has a negative impact on the quality of evidence obtained from a study and, therefore, we cannot draw any conclusions. Bias and random error could threaten the internal validity of a study [184, 195].

In Paper I, we ensured trustworthiness by maintaining four dimension criterion strategies (credibility, dependability, confirmability and transferability). In this way, we can avoid our motives, perspectives, experiences, backgrounds, and prior hypotheses from influencing data interpretation. Thus, the internal validity could be maintained. However, we recognize that it is more controversial and difficult to generalize the qualitative finding to other settings.

Evaluation of internal validity includes looking out for sources of bias or systematic error and random error or chance [184]. The appropriate randomization process that we used in Paper III could eliminate bias and random error. The study setting, participant selection and differences between trial interventions are issues that may affect the external validity. Thus, a rigorously conducted randomized controlled trial allows for unbiased participant selection and treatment comparison [197], in which the external validity could be maintained.

Internal validity is a requirement for external validity. External validity is irrelevant when internal validity is not ensured [184]. In Paper III, we can claim that the internal validity was maintained in which the external validity also ensured. To improve generalizability of the study findings, we did not exclude subjects without a valid reason, as this reduces the representativeness of the randomized controlled trial findings. In Paper III, we excluded children with SAM, based on WHO 2009 child growth standards and/or children with bilateral pitting edema [141], children with medical complications that prevented them from safely consuming supplementary food, and children already participating in other food intervention programs.

Neutrality and interests

In Paper I, we maintained the scientific rigor and trustworthiness of the data collection to ensure neutrality. We attempted to maintain complete bracketing, but putting aside the researcher's predetermined understanding to induce a pure description of the participants' experiences was challenging. Pure bracketing may be difficult to achieve in practice. In Paper III, use of random allocation of subjects, allocation concealment and blinding ensured the neutrality of the study.

Such processes have the advantage of preventing the introduction of the researcher's idea that can interfere with obtaining the true results.

Discussion of main findings

We found that six themes emerged from the investigation of perceptions from mothers/caregivers and health service providers toward barriers to existing management practice for children with MAM aged 6 to 59 months: i) possible reasons for MAM, ii) identification of the child with MAM, iii) management services for MAM, iv) mother- or caregiver-level barriers, v) service provider-level barrier, and vi) measures to improve the service. Organized inclusive counseling and provision of supplementary food were identified as measures to improve the existing management practices for MAM. The four LIBS (LIBS 1, LIBS 2, LIBS 3, and LIBS 4) were developed to treat children with MAM. The proximate (protein, fat, carbohydrate, fiber, moisture and ash) compositions of the four LIBS were within the recommended range of nutrients to treat children with MAM. The mineral and anti-nutrient (potassium, phosphorous, iron, sodium, zinc, magnesium, phytate, and phytate-to-mineral ratios) contents of the four LIBS were within the recommended range of nutrients to treat children with MAM. The calcium level in all the LIBS is lower than the recommended level of calcium to treat MAM. LIBS 4 (with the improved amount of nutrients and least amount of phytate) was non-inferior to the CSB+ in treating children with MAM aged 6 to 59 months in terms of recovery rate, average weight gain, average height or length gain, average MUAC gain and time to recovery.

Perceptions from mothers and health service providers towards barriers to existing management practice for moderate acutely malnourished children

The time constraints of mothers or caregivers in caring for their children have been perceived as a possible reason forf MAM. Similar results have been obtained from the studies done by Hyder et al. and Berhane et al. [198, 199] showing that an increased workload for mothers or caregivers affects the health status of children negatively and that, if time is made available, improved child health outcomes can be achieved. Other studies done in Uganda and Rwanda showed that the heavy workload of the primary caregiver of the child was a challenging situation for optimal child-feeding practices [200]. However, other studies argued that reducing carers' working hours did not benefit or worsen their children's health [76]. Likewise, a retrospective study conducted in rural Ethiopia suggested that labor-saving technology was linked to an increased malnutrition rate since it was related to higher fertility in women [201]. These discrepancies might indicate further examination of the relationship between maternal workload and child malnutrition.

The lack of adequate knowledge toward appropriate childhood feeding practices due to a lack of formal education of mothers was mentioned as another possible reason for MAM. This finding agrees with a study done in Uganda showing a lack of adequate knowledge regarding appropriate childhood feeding practices which emerged as a barrier to caring for children [202]. Spending inadequate time to nourish the child and lacking feeding of sufficient amounts of complementary foods to meet the nutrient requirements of the child have been related to the caregiver's lack of adequate knowledge [77]. This suggests that a lack of education may be affecting key aspects of child feeding and, as a result, negatively influencing child nutritional status. Similarly, findings from studies done in Ghana and Nigeria showed that a mother's practical nutrition knowledge may be more relevant than formal maternal education for child nutrition achievements and may substitute for formal education in reducing undernutrition among children [203, 204]. This shows that, in communities with limited access to formal education and poor educational attainment, mothers' knowledge of health and nutrition may reinforce the positive nutrition outcomes among children.

Occasional house-to-house screenings for MAM, selection of children with MAM during the immunization sessions (vaccination program and vaccination campaign) and selection of children with MAM through the initiation of mothers or caregivers were the ways of identifying children with MAM. This shows that service providers and mothers or caregivers have a role in the screening for MAM. Occasional house-to-house screening is a service provider-level barrier to managing MAM. It might not help to identify all children with MAM and reach the marginalized groups. Family-initiated screening is a service provider-level barrier that is always based on a mother's or caregiver's symptom-based report or a referral from another health facility. This demonstrates that, while healthcare providers are responsible for screening children for MAM, mothers or caregivers play a part in the process. Furthermore, if the mother fails to report her child's condition, the child may not be screened for MAM.

The screening process is done using only MUAC as a screening tool. This is because MUAC is an easy, quick and powerful tool, using simple colored plastic, for the screening of acute malnutrition at the community level [205, 206]. MUAC can be used safely and effectively as the sole anthropometric measure for admission, follow-up, and discharge from malnutrition treatment [207, 208]. This shows that MUAC is an effective measure to detect children most in need of treatment and it is less susceptible to mistakes compared to other indices.

Nutrition counseling and follow-up visit(s) were recognized as management practices for MAM for children aged below five years who are admitted to the management program for MAM. Monthly counseling on exclusive breastfeeding practices, complementary feeding practices, and preparation of porridge from cereals and vegetables, hygiene, family planning, vaccination, and communicable disease controls was given to the mothers or caregivers of children with MAM. This is in line with a study done by Lenters et al. [41]. In the study area, the provision of nutrition counseling only may be due to the district being identified as food secure. However, the food security status of the district might not ensure household food security [76]. Besides, nutrition advice is often inadequate or lacking, and it is frequently provided by healthcare workers or volunteers who lack experience and communication skills [209].

The results from the present study suggested that HEWs or WDA workers should do monthly follow-up visits through house-to-house visits, in addition to counseling, to check the children's recovery from MAM. House-to-house visiting of children with MAM is a recommended technique to achieve maximum results in management of MAM [43].

Our finding showed that household food shortage is perceived as a maternal- or caregiver-level obstacle. This may be because the household's food reserve status is low and the market price of the foods increased. Even if the mothers or caregivers have awareness about good feeding practices, they cannot well implement nutritional advice because of the lack of food at home. If HFS is maintained, counseling could have a good outcome in treating MAM.

Another maternal- or caregiver-level obstacle perceived by our respondents is their financial status. Children who missed or had reduced meals because of a household lacking money were more expected to be acutely malnourished than those who did not [210]. Further, as stated by Abitew, monthly income declines or low socioeconomic status reduce the household purchasing power and therefore, decrease access to food [211]. Similarly, another study done in Burkina Faso stated that the higher recovery rate from MAM occurred where there were fair levels of food security, which enabled the effective implementation of nutrition advice at home [77]. These findings are consistent with our findings showing that household food shortage and financial limitations are perceived as maternal-level barriers that inhibit the mothers or caregivers from implementing nutritional advice. This might be explained as: when there is restricted access to nutritious food, the mothers or caregivers cannot feed their child with sufficient and/or diversified food, and hence, the mothers or caregivers cannot implement the nutrition advice they received. In addition, there might be a disparity between available farmland and household population size.

The finding of the present study revealed that selling-out of cultivated food without saving at home was pointed out as a maternal- or caregiver-level obstacle that negatively affects the implementation of management practice for MAM. The households are carrying out inappropriate usage of their farm crops in order to get money in hand. It could also be explained that households might use their farm crops to cover different household expenses.

Our findings from Paper I revealed that one of the maternal- or caregiver-level barriers to the implementation of nutrition advice given to mothers or caregivers of children with MAM is large household size. The food available to larger families per head was often lower than that available to smaller families, and this variation was revealed in the growth rate [210]. Another study from Ethiopia revealed that having a large family increases pressure on household food security [212]. Our finding shows that a larger family per household was one of the barriers that inhibit the implementation of nutrition advice given to mothers or caregivers of children with MAM. This may be due to the fact that a large family has a high need for more food availability at home. These results may encourage reinforcing the community education that helps to lower the birth rate such that the average family size could be decreased.

In this study, the results show that women whose children had MAM were embarrassed when seeking therapeutic care and perceived the state as an indication of inadequate parental care, such as poor food provisioning. This is in line with a study done in Kenya and Malawi showing that caregivers of children with acute malnutrition experience stigmatization, as shown in the emotional state of shame, humiliation and embarrassment stated in the process of accessing treatment [213, 214]. This implies that acute malnutrition of children is inseparable from hunger and poverty in the rural community.

In this study, lack of repeated follow-up of children with MAM is reflected as a service provider-level barrier. The explanation here is that follow-up visiting is one of the present management practices for MAM in which the HEWs or WDA workers can deliver nutrition advice and assess the progress of a child with MAM. Therefore, a lack of frequent follow-up visits will affect negatively the recovery of children from MAM.

In Paper I, ignoring the management of children with MAM and leaving the responsibility of managing children with MAM to the family are service provider-level obstacles. This indicates that MAM often goes unnoticed even when it progresses to SAM, which is a life-threatening condition.

The findings from this thesis showed that limited or no provision of supplementary food is a service-level barrier that makes the management service provided to the children with MAM insufficient to treat the condition. This is in line with a study done by Philip James, showing that there is an unsatisfactorily high occurrence of SAM and a low recovery rate in an area where food supplements are not accessible for managing MAM [76]. Other studies done by Marzia Lazzerini and KO Ajao revealed that treatment of MAM with food supplements is more effective than counseling only [45, 210]. This could probably be due to the fact that counseling on feeding practices is not helpful when the actual household food availability is limited. A systematic review done by Natasha Lelijveld reported that seven out of 11 studies revealed treating children with MAM using food supplements to be superior in terms of anthropometric outcomes compared with counseling only [83]. This finding implies that food supplements do support recovery from MAM. This might be explained that children with MAM require increased intake of nutrients to recover from MAM.

The finding from this study revealed that including mothers and fathers of children with MAM in nutrition counseling sessions would have a positive effect in managing MAM. In rural communities, men are often make the decisions on several household activities, including what food should be purchased from the market. This might be due to men being decisive and economically influential compared to women in unindustrialized countries. Men’s limited involvement in day-to-day childcare, child feeding, and nutrition activities is common in sub-Saharan Africa, although their involvement can lessen the burden of work responsibilities undertaken by mothers or caregivers [215]. One study reported that, to achieve optimal child feeding, mothers or caregivers need their husband's social support because men's support is one of the key influences on child feeding [216]. Different studies revealed that husbands are the key spokespersons for their families, and their opinions and advice are highly valued by mothers and children when seeking healthcare services [77, 217, 218]. Fathers' physical, financial, and psychosocial support will finally influence child feeding practice [216].

The current study has shown that focused and routine counseling including all mothers of children below five years and fathers was identified as the main measure to improve the existing management practice for MAM. This is consistent with a study done in Burkina Faso showing that nutrition counseling has been proven a valuable substitute for supplementary feeding if the attendance to the counseling session is ensured by caregivers [77]. In addition, the provision of supplementary food in addition to counseling was mentioned as a suggestion to improve the existing management practice for MAM. A study done by Roy et al. showed that children with MAM who received both food supplementation and intensive nutritional education had greater improvement in nutritional status compared to children with MAM whose mothers/caregivers received intensive nutrition education only [215]. This implies that supplementary feeding of children with MAM in addition to counseling might enhance recovery from MAM and prevent the progression to the severe form.

Development and nutritional evaluation of LIBS to treat MAM among children aged below five years

In this study, we developed the four LIBS from pumpkin seed, peanut, amaranth grain, flaxseed, and emmer wheat.

The protein content of the four supplements ranged from 20.3 g to 22.6 g. A significantly higher content of protein is found in LIBS 4. All the four LIBS have a protein content that is within the recommended values of protein for treating children with MAM [75]. A study done in Malawi showed that the protein composition found in the intervention foods (soy-based ready-to-use food and whey-based ready-to-use food given to a child with MAM were 11.06 g and 11.42 g, respectively [85]. These values are less than our finding (20.3 g to 22.6 g). The higher content of protein in LIBS 4 might be due to using a higher proportion of pumpkin seed and peanut while developing this supplement. Different studies show that pumpkin seed and peanut are rich sources of essential protein and may make a significant contribution to the daily protein allowance [154, 219]. Pumpkin seeds are densely packed with beneficial nutrients such as amino acids [220]. These findings implied that the addition of pumpkin seed and peanut in the LIBS could help overcome protein-energy malnutrition.

The fat content of the four LIBS ranged from 29.3 g to 33.5 g. The significantly higher amount of fat was found in LIBS 4, whereas the significantly lower content of fat was found in LIBS 1. All four LIBS have a fat content that is within the recommended level for therapeutic supplements for treating children with MAM [75]. Similar to our finding, a previous study done in Burkina Faso showed that the highest fat content among lipid-based nutrient supplements prepared for treating MAM was 32.1 g [221]. The higher amount of fat detected in LIBS 4 might be due to the use of a higher amount of pumpkin seed while developing it. The study done by Sharma and Lakhawat revealed that pumpkin seed is quite rich in crude fat and oil [154]. Another study also mentioned that pumpkin seed is an excellent source of unsaturated fatty acids [222]. These sources show that using pumpkin seed while developing LIBS could benefit child health and meet energy deficiency, since pumpkin seed rich in fat, which is a good source of calories.

In this study, the carbohydrate content of the LIBS ranged from 35.4 g to 40.0 g. A significantly higher amount of carbohydrate is found on LIBS 1. However, the highest energy content (533.5 kcal) is found on LIBS 4, whereas the lowest is found in LIBS 1. There was no significant difference between LIBS 1, LIBS 2, and LIBS 3. The higher amount of energy in LIBS 4 might be due to LIBS 4 having the highest amount of fat. The fat has more than twice as many calories per gram as carbohydrates and proteins. Foods produced for children with MAM should have concentrated energy for their increased energy needs [223]. The calorie content in our study is higher than a study done in Uganda which showed that the highest calorie content of study foods for treating MAM was 487.3 kcal [89]. In contrast, our finding is slightly lower than a study done in Sierra Leone which reported that the calorie content of four supplementary foods for treating MAM ranged from 552.85 kcal to 560 kcal [224]. However, all four LIBS contained more energy than the recommended minimum of 380 kcal for fortified blended foods [87].

The fiber content of the LIBS ranged from 6.0 g to 8.3 g. The fiber content of LIBS 2 (8.3 g) was significantly higher than that of the other supplements. The higher fiber content in LIBS 2 might be due to the higher proportion of flaxseed in it. Flaxseed is abundant in dietary fiber, making it an important part of the human diet [223, 225]. Dietary fiber is an important component of the digestive process. Soluble fiber primarily has prebiotic qualities, but insoluble fiber helps prevent constipation [87]. On the other hand, constipation is not the most concerning issue among malnourished children. Thus, children's meals should have a small amount of insoluble fiber but a high amount of soluble fiber. Due to a paucity of research on the effects of insoluble fiber on children, no limitations have been set [101].

The four LIBS had moisture content ranging from 2.8 g to 3.7 g. The moisture content of LIBS 2 was the highest, whereas LIBS 3 was the lowest. The moisture content of all supplements was within the recommended level for the proper storage of dehydrated foodstuff [226]. The moisture content of LIBS 1 and LIBS 2 did not significantly differ. Additionally, there was no significant difference in moisture content between LIBS 3 and LIBS 4. However, LIBS 1 and LIBS 2 were significantly different from LIBS 3 and LIBS 4. This could be because the moisture level of the seed is determined by its hydroscopic capacity, and for LIBS 1 and LIBS 2, as well as LIBS 3 and LIBS 4, we employed equal or nearly equal percentages of individual elements.

Total ash content ranged from 2.1 g to 4.3 g. It was significantly different for all supplements. The lowest ash content was found in LIBS 4 and the highest was found in LIBS 3. Our finding conforms to a study done in Uganda showing that the ash contents found in the supplementary foods provided for treating children with MAM were 2.1/100 g and 4.1/100 g [89]. This could be explained as LIBS is safe to treat the child with MAM.

The calcium content of the four LIBS differed significantly. It was in the range of 104.6 mg to 115.6 mg. LIBS 3 has the highest calcium content. All the LIBS have lower calcium levels than those recommended for children with MAM [93]. This might be due to children with MAM requiring a higher amount of calcium than that contained in the locally available plant-based foods.

The potassium content of all LIBS differed significantly. It ranged from 553.4 mg to 666.1 mg. LIBS 4 had the highest potassium level (666.1 mg/532 kcal). These levels were relatively similar to the recommended value (1100 mg to 1400 mg/1000 kcal) [100, 227]. This showed that the ingredients we used to develop LIBS can yield the recommended amount of potassium for treating children with MAM. All malnourished children have depleted potassium levels. Potassium should be present in sufficient amounts in supplemental foods to maintain renal and fecal excretion of it [87].

In this study, the phosphorous values ranged from 442.6 mg to 470.4 mg. LIBS 1 had the least amount of phosphorus, whereas LIBS 4 had the highest content. These values agreed with the values of phosphorus reported in the study done by Amegovu and colleagues [93]. Additionally, our finding is similar to a study done in Sierra Leone which reported that the phosphorous content of four food supplements used for treating children with MAM ranged from 239.96 mg to 750 mg [224].

The iron content of all LIBS was significantly different. It ranged from 8.2 mg to 10.2 mg. LIBS 4 had the highest iron level (10.2 mg/100g and 532 kcal/100g), whereas LIBS 1 had the lowest iron level (8.2 mg/100g and 510kcal/100g). These values were higher than the recommended levels of iron in locally available food for treating MAM (9 mg/1000 kcal) [100]. A study done by Gabriel Nama Medoua and colleagues showed that the iron content found in the supplementary food given to children with MAM was ranged from 8.4 mg/1339 kcal to 8.58 mg/1339 kcal [90]. These values are lower than our findings. This difference might be because the ingredients that we used for developing the LIBS were rich in iron. Similar to our finding, a study done by Crystal Karakochuk reported that the iron content of ready-to-use supplementary food (one of the study foods) provided to treat children with MAM was 10.6 mg [92].

The sodium content of the four LIBS ranged from 79.4 mg to 104.4 mg. The highest amount of sodium was found in LIBS 1 (104.4 mg/510 kcal), whereas the lowest sodium content was found in LIBS 3 (79.4 mg/515 kcal). This finding conforms to a study done in southern Ethiopia which reported that the sodium level found in the study foods provided to children with MAM ranged from 83 mg to 267 mg [92], and higher than a study done in Malawi [85]. The total body sodium is considerably increased during malnutrition. Foods that contain high sodium levels would then be non-beneficial [87]. The sodium level in this study did not exceed the maximum recommended level (500 mg/1000 kcal) set by WHO [75].

This study showed that the zinc content for all LIBS ranged from 4.1 mg to 5.6 mg. The significantly high content of zinc was found in LIBS 4, whereas the lowest amount was found in LIBS 1. The zinc contents of LIBS 1, 2, and 3 were not significantly different. Zinc is a vital mineral that supports in preventing diarrhea in malnourished children [101]. In this study, the zinc content of the supplements was higher than the food supplements used for treating MAM (CSB++) [77], CSB and sorghum-peanut blend [87] and close to the recommended levels of zinc [100]. This finding showed that the ingredients that we used to develop LIBS can meet the zinc requirement of children with MAM.

In this study, the magnesium content of all LIBS differed significantly. It ranged from 176.2 mg to 206 mg. LIBS 1 had the lowest amount, whereas LIBS 2 had the highest amount. The magnesium content found in these newly developed supplements were consistent with the study done by Stobaugh HC [85] and comparable with the recommended values of magnesium for children with MAM [75, 100]. This finding showed that the newly developed LIBS could meet the required amount of magnesium for treating children with MAM.

The phytate content of all supplements differed significantly. LIBS 4 contained the least amount of phytate. The molar ratios of phytate to zinc, phytate to iron, and phytate to calcium were all below the recommended critical limits for any supplement. Because phytate has a strong binding affinity for minerals, it is known to lower their bio-availability, particularly for Zn, Ca, Mg, and Fe. When a mineral binds to phytic acid, it transforms into an insoluble form, precipitates and becomes indigestible. As a result, over-use can lead to mineral deficiency and other problems [162, 228]. The normal level of phytate-to-mineral molar ratio identified in this study indicated that all the newly developed supplements have good mineral bio-availability. This could be due to the ingredients being soaked in salty water for several hours as part of the supplement preparation process. According to Ochola's research, food processing activities such as soaking grains and germinating them can reduce phytic acid levels [107].

LIBS 4 is different from the other newly developed supplements in terms of protein, fat, energy, iron, zinc, phosphorous, and potassium. The other nutrients of LIBS 4, such as magnesium, calcium, and sodium, were at lower levels when compared to the LIBSs with the highest values. The number of these nutrients was comparable to the recommended daily intakes for children with MAM aged 6-59 months, as well as the standard therapeutic food (CSB+) used to treat children with MAM [75, 87, 100].

LIBS is an alternative to CSB+ for treating MAM among children aged 6 to 59 months

In this randomized controlled non-inferiority trial, we compared the efficacy of LIBS in treating children with MAM compared to CSB+. In this trial, the ITT and PP analyses revealed that children with MAM who got LIBS were non-inferior in terms of recovery rate, weight gain, recovery time, MUAC gain, and length/height gain, compared to those who received CSB+. Only the LIBS groups could achieve the Sphere goal of 75 percent recovery.

The recovery rate from MAM observed in this study was similar to the recovery rates of MAM with supplementary feeding stated in other studies (67 percent to 82.3 percent) [77, 90, 92, 93] and higher than the recovery rates of MAM with child-centered counseling intervention only (57.8 percent) [77]. The fact that the PP and ITT analyses presented similar recovery rate results, as well as the non-inferiority of LIBS compared to CSB+, provide substantial evidence that LIBS is an excellent alternative to CSB+ in treating MAM [229].

Our results are consistent with those of a study conducted in Uganda, which found that standard therapeutic food for MAM (CSB+) and a locally developed supplement resulted in a similar recovery rate among children with MAM [93]. The comparable recovery rate between the LIBS and CSB+ groups could be explained by the fact that both supplements have a similar energy density, as energy density in supplementary foods is critical for the recovery of children with MAM [101]. Energy is required during malnutrition to promote catch-up growth and maintain the replacement of both lean and fat tissue [100].

In this study, the overall rate of loss to follow-up was similar between the LIBS and CSB + groups, and met the Sphere target rates for defaulting (≤ 15 percent). The lost-to-follow-up rate was remarkably low (1.5 percent), much lower than that of previous studies, which had default rates of 4 percent - 5 percent [230-232]. This might be due to the weekly follow-up done by the researchers and the daily visits done by food distributors. For a long time, CSB+ has been used as a standard therapeutic food for treating MAM, and it is widely approved, with a well-known feeding procedure in the study area. In various settings, CSB+ is organoleptically tolerated [96]. A LIBS was developed using culturally recognized and accepted ingredients and prepared in a similar way to conventional food (CSB+). This could be another explanation for the comparability of the default rate between the two groups.

In this study, 2 percent of the children did not respond to treatment, but continued to lose weight and progress to SAM. Between the two groups, there was no significant difference in the number of children who developed SAM. The reason for developing SAM is unknown, but it could be explained by the possibility that these children had an untreated disease, rather than just household food insecurity. However, compared to studies conducted in Cameroon [90], Malawi [96], and Burkina Faso [77], this rate of progression to SAM finding is lower.

The average weight gain observed in the LIBS group was not inferior to that observed in the CSB+ group. This could be explained by the fact that the supplements given to both groups had a comparable total energy. Another explanation could be that, before feeding the children, both supplements were cooked with the similar amount of water such that the mass of supplements fed to the children was comparable. The findings were also higher than that of weight gain observed in the studies conducted in Cameroon and Malawi [90, 233] and compared favorably with a study conducted in Malawi [96].

In this study, the recovery time between the LIBS and CSB+ groups was similar. The LIBS and CSB+ groups recovered at equal rates in this study. This finding conforms with other studies, such as those conducted in Cameroon to assess the efficacy of CSB+ and RUSF in treating MAM [90], and Uganda to examine the efficacy of sorghum-peanut blend and CSB+ as therapeutic foods for MAM [93]. In contrast to a study done in Burkina Faso [77] and Sierra Leone [224], the recovery time was extended. However, it was within the acceptable Sphere Standards ($\leq$ 90 days) [93].

The length/height gain was similar between the LIBS and CSB+ groups. This could be explained by the fact that the LIBS and CSB+ contain similar amount of protein and zinc. Complementary, supplementary, and therapeutic foods with high quality protein are effective for promoting the growth of children [234]. Similarly, zinc is essential for growth and development, and is classified as a growth type II mineral [100]. It has direct effects on the main hormonal system

(IGF-I/GH) that controls growth in the postnatal period [235]. Our finding was consistent with the study done by Stobaugh [85] and higher than studies conducted by LaGrone et al., Nikièma et al., and Patel et al. [77, 96, 233].

Conclusions and recommendations

Conclusions

Objective 1 was to assess the perceptions of mothers or caregivers and service providers toward barriers to existing management practice for MAM among children aged 6 to 59 months (Paper I).

The results suggested that management of MAM among children aged 6 to 59 months is negatively affected by mother- or caregiver-level barriers and service provider-level barriers. Barriers at the maternal level were household food shortage and financial limitations, selling-out of cultivated food without reserving sufficient food at home, large household size, and shame about child malnutrition status. Barriers at the service provider level were occasional house-to-house screening for MAM, family-initiated counseling, lack of repeated follow-up, leaving the management responsibility for children with MAM to the family, and limited or no provision of therapeutic supplements to children with MAM. These findings highlighted that interventions addressing food shortage and financial constraints of households, in addition to counseling, could improve management services for MAM.

Objective 2 aimed to develop a LIBS and evaluate its nutritional value for treating children with MAM aged 6 to 59 months (Paper II).

The key finding was that supplementary food for children with MAM aged 6 to 59 months was successfully developed using locally available ingredients such as pumpkin seed, peanut, amaranth grain, flaxseed, and emmer wheat. Except for calcium, the nutrients were within the recommended range of required nutrients. The LIBS 4, in particular, contains an excellent amount of nutrients for the treatment of MAM in children. As a result, LIBS 4 could be used in the rural community to manage children with MAM. Fortification of micronutrients such as ascorbic acid and calcium to the formulation is recommended.

Objective III aimed to evaluate if the LIBS is similar to CSB+ in treating children with MAM (Paper III).

We showed that LIBS was found to be non-inferior to conventional food (CSB+) in treating MAM, and both supplements were relatively effective in treating MAM among children aged 6 to 59 months. The results of this study demonstrate that LIBS can be used as an alternative to CSB+ in treating MAM in Ethiopia. As a result, the potential for enhancing the use of LIBS should be encouraged.

Recommendations

Operational recommendations

In Paper I (Objective 1), we assessed the barriers to management of children with MAM aged 6 to 59 months among mothers or caregivers and service providers, and we recommended as follows:

- Strengthen existing management practices by maintaining routine screening for MAM and follow-up.
- Ensure interventions addressing household food shortages.
- Ensure interventions addressing financial constraints of households.
- Strengthen focused and inclusive counseling.

In Paper II (Objective II), we developed LIBS for treating MAM among children aged 6 to 59 months; we make the following recommendations:

- Enhance the production of food ingredients that have potential to be used in LIBS, to ensure availability and sustainability.
- Fortify LIBS with micronutrients such as ascorbic acid and calcium.

In Paper III (Objective III), we evaluated if LIBS is similar to CSB+ in treating MAM among children aged 6 to 59 months, and we recommended as follows:

- Promote scaling up of LIBS for treating MAM in food-secure districts where there is no food supplementation.

- Promote scaling up of LIBS as an alternative to CSB+ for treating children with MAM.

Policy recommendations

- We recommended that health systems for managing MAM among children aged 6 to 59 months be strengthened. This is needed at health facilities, especially health posts, and should prioritize routine screening of children for MAM, and enhance counseling and food supplementation, and follow-up (Paper I).
- Policy attention should be given to enhancing the development of therapeutic food for treating children with MAM from locally available food ingredients and enhancing the link between agricultural and nutrition sectors (Paper II).
- Policy makers should recognize the use of LIBS in treating children with MAM and enhance the scaling-up of LIBS for managing children with MAM

For research

- Further research should look into the perception of barriers expressed at various levels and how these match/differ across the structures within the health service system in the local context.
- Evidence on the product's shelf life and sustainability is needed.
- Community perceptions of the LIBS as a treatment for MAM should also be investigated.
- Evidence on the effectiveness of LIBS after fortification with some micronutrients is needed (a superiority trial).
- The cost-effectiveness of the LIBS should be investigated.

References

1. Saunders J, Smith T. Malnutrition: causes and consequences. Clinical Medicine. 2010; 10(6): 624-627.
2. Obasohan PE,Walters SJ, Jacques R, Khatab K. Risk factors associated with malnutrition among children under-five years in sub-Saharan African countries: a scoping review. International Journal of Environmental Research and Public Health. 2020; 17: 8782.
3. Dukhi N. Global prevalence of malnutrition: evidence from literature. IntechOpen. 2020; http://dx.doi.org/10.5772/intechopen.92006
4. Ngo J, Ortiz-Andrellucchi A, Majem LS. Malnutrition: concept, classification and magnitude. Encyclopedia of Food and Health. 2016; 610-630.
5. 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: 831-834.
6. Simonyan H, Sargsyan, Balalian AA, Davtyan K, Gupte HA. Short-term nutrition and growth indicators in 6-month- to 6-year-old children are improved following implementation of a multidisciplinary community-based programme in a chronic conflict setting. Public Health Nutrition. 2020; 23(1): 134-145.
7. 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.
8. Nimpagaritse M, Korachais C, Nsengiyumva G, Macq J, Meessen B. Addressing malnutrition among children in routine care: how is the Integrated Management of Childhood Illnesses strategy implemented at health centre level in Burundi? BMC Nutrition. 2019; 5: Article 22.
9. Roba AA, Assefa N, Dessie Y, Tolera A, Teji K, Elena H, et al. Prevalence and determinants of concurrent wasting and stunting and other indicators of malnutrition among children 6–59 months old in Kersa, Ethiopia. Maternal & Child Nutrition. 2021; 17(3): e13172.
10. Park SE, Kim S, Ouma C, Loha M, Wierzba TF, Beck NS. Community management of acute malnutrition in the developing world. Pediatric Gastroenterology Hepatology Nutrition. 2012; 15(4): 210-219.
11. 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: 19-23.
12. World Health Organization (WHO). Global nutrition targets 2025: policy brief series. Geneva: World Health Organization; 2014.
13. Amaha ND. Ethiopian progress towards achieving the global nutrition targets of 2025: analysis of sub-national trends and progress inequalities. BMC Research Notes. 2020; 13: Article 559.
14. Yirga AA, Mwambi HG, Ayele DG, Melesse SF. Factors affecting child malnutrition in Ethiopia. African Health Sciences. 2019; 19(2): 1897-1909.
15. Kassie GW, Workie D. Determinants of under-nutrition among children under five years of age in Ethiopia. BMC Public Health. 2020; 20: Article 399.
16. Endris N, Asefa H, Dube L. Prevalence of malnutrition and associated factors among children in rural Ethiopia. BioMed Research International. 2017; 2017: 6587873.

17. Abdulahi A, Shab-Bidar S, Rezaei S, Djafarian K. Nutritional status of under-five children in Ethiopia: a systematic review and meta-analysis. Ethiopian Journal of Health Sciences. 2017; 27(2): 175-188.
18. Gebru TT, Abady GG, Teklu FG, Tesfamichael YA, Bitow MT, Tekola KB, et al. The eradication of malnutrition in all its types has an absolute necessity for health, ethical, political, economic, and social purposes, with special attention paid to the needs of children and women. Pan African Medical Journal. 2019; 33(330): 1-11.
19. Workie SB, Mekonen T, Fekadu W, Mekonen TC. Level of undernutrition and its determinants among children aged 12–59 months in Wolaita District, Ethiopia. Pediatric Health, Medicine and Therapeutics. 2020; 11: 109-117.
20. Asfaw M, Wondaferash M, Taha M, Dube L. Prevalence of undernutrition and associated factors among children aged between six to fifty nine months in Bule Hora district, South Ethiopia. BMC Public Health. 2015; 15: Article 41.
21. Yisak H, Gobena T, Mesfin F. Prevalence and risk factors for under nutrition among children under five at Haramaya district, Eastern Ethiopia. BMC Pediatrics. 2015; 15: Article 212.
22. Birhanu MM. Systematic reviews of prevalence and associated factors of under five malnutrition in Ethiopia: finding the evidence. International Journal of Nutrition and Food Sciences. 2015; 4(4): 459-464.
23. Adem F, Edessa D, Bayissa B, Hassen MM, Mohammed MA. Treatment outcomes and associated factors in hospitalised children with severe acute malnutrition: a prospective cohort study. Pediatric Health, Medicine and Therapeutics. 2020; 11: 235-243.
24. Saaka M, Galaa SZ. Relationships between wasting and stunting and their concurrent occurrence in Ghanaian preschool children. Journal of Nutrition and Metabolism. 2016; 2016: 4654920.
25. Wie GT, Tsegaye D. Determinants of acute malnutrition mmong children aged 6–59 months visiting public health facilities in Gambella Town, Southwest Ethiopia: Unmatched case-control study. Nutrition and Dietary Supplements. 2020; 12: 147-156.
26. Seboka BT, Alene TD, Ngusie HS, Hailegebreal S, Yehualashet DE, Gilano G, et al. Spatial variations and determinants of acute malnutrition among under-five children in Ethiopia: evidence from 2019 Ethiopian Demographic Health Survey. Annals of Global Health. 2021; 87(1): 114. http://doi.org/10.5334/aogh.3500
27. De Pee S, Grais R, Fenn B, Brown R, Briend A, Frize J, et al. Prevention of acute malnutrition: distribution of special nutritious foods and cash, and addressing underlying causes – what to recommend when, where, for whom, and how. Food and Nutrition Bulletin. 2015; 36(1): 24-29.
28. Abate BB, Tilahun B, Kassie AM, Kassaw MW. Treatment outcome of Severe Acute Malnutrition and associated factors among under-five children in outpatient therapeutics unit in Gubalafto Wereda, North Wollo Zone, Ethiopia. PLoS ONE. 2020; 15(9): 1-13.
29. Manary MJ, Sandige HL. Management of acute moderate and severe childhood malnutrition. BMJ. 2008; 337: 1227-1230.
30. 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. Lancet. 2013; 382: 427-451. https:// doi.org/10.1016/S0140-6736(13)60937-X
31. Dipasquale V, Cucinotta U, Romano C. Acute malnutrition in children: pathophysiology, clinical effects, and treatment. Nutrients. 2020; 128: 2413.

32. Govender I, Rangiah S, Kaswa R, Nzaumvila D. Malnutrition in children under the age of 5 years in a primary health care setting. South African Family Practice. 2021; 63(1): a5337.
33. 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: Article 1027.
34. Karim MR, Al Mamun AS, Rana MM, Mahumud RA, Shoma NN, Dutt D, et al. Acute malnutrition and its determinants of preschool children in Bangladesh: gender differentiation. BMC Pediatrics. 2021; 21: Article 573.
35. Bliss J, Jensen N, Thiede B, Shoham J, Dolan C, Sibson V, Fenn B. Factors associated with the risk of acute malnutrition among children aged 6 to 36 months in households targeted by an emergency cash transfer program. Food and Nutrition Bulletin. 2016; 37(3): 387-400.
36. 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): 243-260. https:// doi.org/10.1016/S0140-6736(07)61690-0
37. Abitew DB, Worku A, Mulugeta A, Bazzano AN. Rural children remain more at risk of acute malnutrition following exit from community based management of acute malnutrition program in South Gondar Zone, Amhara Region, Ethiopia: a comparative cross-sectional study. PeerJ. 2020; 8. https://doi.org/10.7717/peerj.8419
38. Chase RP, Kerac M, Grant A, Manary M, Briend A, Opondo C, Bailey J. Acute malnutrition recovery energy requirements based on mid-upper arm circumference: secondary analysis of feeding program data from 5 countries, Combined Protocol for Acute Malnutrition Study (ComPAS) Stage 1. PLoS ONE. 2020; 15(6): e0230452.
39. Das JK, Salama 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.
40. Prost A, Nair N, Copas A, Pradhan H, Saville N, Tripathy P, et al.. Mortality and recovery following moderate and severe acute malnutrition in children aged 6–18 months in rural Jharkhand and Odisha, eastern India: a cohort study. PLoS Medicine. 2019; 16(10): e1002934.
41. Lenters LM, Wazny K, Webb P, Ahmed T, Bhutta ZA. Treatment of severe and moderate acute malnutrition in low- and middle-income settings: a systematic review, meta-analysis and Delphi process. BMC Public Health. 2013; 13(Suppl. 3): S23.
42. Central Statistical Agency. Ethiopia Demographic and Health Survey 2011. ICF International Calverton; 2012.
43. Reginald A, Patrick W, Brown R. Management of moderate acute malnutrition. In: Current knowledge and practice. CMAM Forum Technical Brief; 2014.
44. UNICEF. The state of the world's children in numbers: revealing disparities, advancing children's rights. New York, 2014.
45. Lazzerini M, Rubert L, Pani P. Specially formulated foods for treating children with moderate acute malnutrition in low- and middle-income countries. Cochrane Database Systematic Reviews. 2016; 6: CD009584. https://doi.org/10.1002/ 14651858.CD009584.pub2.

46. Briend A, Prinzo ZW. Dietary management of moderate malnutrition: time for a change. Food and Nutrition Bulletin. 2009; 30(3): 265-481.
47. Briend A, Khara T, Dolan C. Wasting and stunting – similarities and differences: policy and programmatic implications. Food and Nutrition Bulletin. 2015; 36(1): S15-S23.
48. Pelletier DL, Frongillo EA,Schroeder DG, Habicht JP.The effects of malnutrition on child mortality in developing countries. Bulletin of the World Health Organization. 1995; 73(4): 443-448.
49. Shankar AH. Nutritional modulation of malaria morbidity and mortality. Journal of Infectious Diseases. 2000; 182(Suppl 1): 37-53.
50. Incidence correction factors for moderate and severe acute child malnutrition from 2 longitudinal cohorts in Mali and Burkina Faso. American Journal of Epidemiology. 2020; 189(12): 1623-1627.
51. Olofin I, McDonald CM, Ezzati M, Flaxman S, Robert E. Black RE, et al. Associations of suboptimal growth with all-cause and cause-specific mortality in children under five years: a pooled analysis of ten prospective studies. PLoS ONE. 2013; 8(5): e64636.
52. Tickell KD, Sharmin R, Deichsel El, Lamberti LM, Walson JL, Faruque ASG, et al.The effect of acute malnutrition on enteric pathogens, moderate-to-severe diarrhoea, and associated mortality in the Global Enteric Multicenter Study cohort: a post-hoc analysis. Lancet Global Health. 2020; 8: 215-224.
53. Wegner CW, Loech C, Mokhtar N. Moderate acute malnutrition: uncovering the known and unknown for more effective prevention and treatment. Food and Nutrition Bulletin. 2015; 36(1): 3-8.
54. Adamu WA, Jara D, Alemayehu M, Burrowes S. Risk factors associated with poor health outcomes for children under the age of 5 with moderate acute malnutrition in rural Fagita Lekoma District, Awi Zone, Amhara, Ethiopia. BMC Nutrition. 2017; 3: Article 88.
55. World Health Organization. The management of nutrition in major emergencies. Geneva; 2000.
56. Manyama IB, Abate G, Tamiru M. The Emergency Nutrition Coordination Unit of Ethiopia: roles, responsibilities and achievements. Field Exchange. 2011; 40: 32.
57. Delbiso TD, Rodriguez-Llanes JM,Donneau AF, Speybroeckc N, Guha-Sapir D. Drought, conflict and children's undernutrition in Ethiopia 2000–2013: a meta-analysis. Bulletin of the World Health Organization. 2017; 95: 94-102.
58. Gebrehiwot T, Veen AVD, Maathuis B. Spatial and temporal assessment of drought in the Northern highlands of Ethiopia. International Journal of Applied Earth Observation and Geoinformation. 2011; 13(3): 309-321.
59. Ethiopia. Joint statement on infant and young child feeding in emergencies. 2021.
60. Leza T, Kuma B. Determinants of rural farm household food security in Boloso Sore District of Wolaita Zone in Ethiopia. Asian Journal of Agricultural Extension, Economics & Sociology. 2015; 5(2): 57-68.
61. Pinstrup-Andersen P. Food security: definition and measurement. Food Security. 2009; 1: 5-7.
62. Saaka M, Osman SM. Does household food insecurity affect the nutritional status of preschool children aged 6–36 months? International Journal of Population Research. 2013; Article ID 304169. https://doi.org/10.1155/2013/304169
63. United States Agency for International Development (USAID). Tackling food insecurity and malnutrition in Ethiopia through diversifcation. 2012.

64. Tebeje NB, Biks GA, Abebe SM, Yesuf ME. Magnitude of child food insecurity, its association with child immunization and household wealth status, and coping strategies in Dabat Demographic and Surveillance System North West Ethiopia. International Journal of Pediatrics. 2020. https://doi.org/10.1155/2020/3746354
65. Mota AA, Lachore ST, Handiso YH. Assessment of food insecurity and its determinants in the rural households in Damot Gale Woreda, Wolaita Zone, Southern Ethiopia. Agriculture & Food Security. 2019; 8: Article 11.
66. Eneyew A, Bekele W. Causes of household food insecurity in Wolayta: Southern Ethiopia. Journal of Stored Products Research. 2012; 3(3): 35-48.
67. Gazuma EG, Asttatike AA. Socioeconomic determinants of food insecurity among rural households in Wolaita Zone, Southern Ethiopia. Economics. 2019; 8(2): 55-61.
68. CSA. Agricultural Sample Survey. Addis Ababa, Ethiopia. 2017.
69. WHO, WFP, UNSSCN, UNICEF. Community-based management of severe acute malnutrition: A joint statement by WHO, WFP, UNSCN, UNICEF. 2007.
70. United Nations Children's Fund. Evaluation of community management of acute malnutrition (CMAM): Global Synthesis Report. New York. 2013.
71. Akparibo R, Booth , Lee AC. Recovery, relapse and episodes of default in the management of acute malnutrition in children in humanitarian emergencies: a systematic review. Humanitarian Evidence Programme. Oxford: Oxfam GB. 2017.
72. ENN. Government experiences of scale-up of Community-based Management of Acute Malnutrition (CMAM). A synthesis of lessons. Emergency Nutrition Network, CMAM Conference, Addis Ababa, 2011. 2012.
73. Jimenez M, Stone-Jimenez M. Preventing moderate acute malnutrition (MAM) through nutrition-specific interventions. CMAM Forum Technical Brief. 2014.
74. Langendorf C, Roederer T, de Pee S, Brown D, Doyon S, Mamaty AA, et al. Preventing acute malnutrition among young children in crises: a prospective intervention study in Niger. PLoS Medicine. 2014; 11(9): e1001714.
75. World Health Organization (WHO). (2012). Technical note: supplementary foods for the management of moderate acute malnutrition in infants and children 6–59 months of age. Geneva: WHO.
76. James P, Sadlaw K, Wondafrash M, Argaw A, Luo H, Geleta B, et al. Children with moderate acute malnutrition with no access to supplementary feeding programs experience high rates of deterioration and no improvement: results from a prospective cohort study in rural Ethiopia. PLoS ONE. 2016; 11(4): e0153530.
77. Nikièma L, Huybregts L, Kolsteren P, Lanou H, Tiendrebeogo S, Bouckaert K, et al. Treating moderate acute malnutrition in first-line health services: an effectiveness cluster-randomized trial in Burkina Faso. American Journal of Clinical Nutrition. 2014; 100: 241-249. https://doi.org/10.3945/ajcn.113.072538
78. Lelijveld N, Jalloh AA, Kampondeni SD, Seal A, Wells JC, Goyheneix M, et al. Brain MRI and cognitive function seven years after surviving an episode of severe acute malnutrition in a cohort of Malawian children. Public Health Nutrition. 2018; 22(8): 1406-1414.
79. 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? Lancet. 2013; 382(9890): 452-477.

80. Kennedy E, Branca F, Webb P, Bhutta Z, Brown R. Setting the scene: an overview of issues related to policies and programs for moderate and severe acute malnutrition. Food & Nutrition Bulletin. 2015; 36: 9-14.
81. Fabiansen C, Yameogo CW, Iuel-Brockdorf AS, Cichon B, Rytter MJH, Kurpad A, et al. Effectiveness of food supplements in increasing fat-free tissue accretion in children with moderate acute malnutrition: A randomised 2×2×3 factorial trial in Burkina Faso. PLoS Medicine. 2017; 14(9): e1002387.
82. World Health Organization (WHO). Assessing and managing children at primary health-care facilities to prevent overweight and obesity in the context of the double burden of malnutrition. Updates for the integrated management of childhood illness (IMCI) – Guideline. 2017.
83. Lelijveld N, Beedle A, Farhikhtah A, Elrayah EE, Bourdaire J, Aburto N. Systematic review of the treatment of moderate acute malnutrition using food products. Maternal & Child Nutrition. 2020; 16(1): e12898.
84. Ashworth A, Ferguson E. Dietary counseling in the management of moderate malnourishment in children. Food and Nutrition Bulletin. 2009; 30: 406-433.
85. Stobaugh HC, Ryan KN, Kennedy JA, Grise JB, Crocker AH, Thakwalakwa C, et al. Including whey protein and whey permeate in ready-to-use supplementary food improves recovery rates in children with moderate acute malnutrition: a randomized, double-blind clinical trial. American Journal of Clinical Nutrition. 2016; 103: 926-933. https://doi.org/10.3945/ajcn.115.124636
86. Javan R, Kooshik A, Afzalaghaee M, Aldaghi M, Yousefi M. Effectiveness of supplementary blended flour based on chickpea and cereals for the treatment of infants with moderate acute malnutrition in Iran: a randomized clinical trial. Electronic Physician. 2107; 9(12): 6078-6086.
87. Amegovu AK, Ogwok P, Ochola S, Yiga P, Musalima JH, Mutenyo E. Formulation of sorghum-peanut blend using linear programming for treatment of moderate acute malnutrition in Uganda. Journal of Food Chemistry and Nutrition. 2013; 01(02): 67-77.
88. Lin CA, Manare MJ, Maleta K, Briend A, Ashorn P. An energy-dense complementary food is associated with a modest increase in weight gain when compared with a fortified porridge in Malawian children aged 6–18 Months. The Journal of Nutrition. 2008; 138: 593-598.
89. Kajjura RB, Veldman FJ, Kassier SM. Effect of a novel supplementary porridge on the nutritional status of infants and young children diagnosed with moderate acute malnutrition in Uganda: a cluster randomised control trial. Nutrition & Dietetics. 2019; 32: 295-302.
90. Medoua GN, Natsma PM, Ndzana ACA, Essa'a VJ, Tsafack JJT, Dimodi HT. Recovery rate of children with moderate acute malnutrition treated with ready-to-use supplementary food (RUSF) or improved corn-soya blend (CSB+): a randomized controlled trial. Public Health Nutrition. 2015; 19(2): 363-370. https://doi.org/10.1017/S1368980015001238
91. De Pee S, Bloem MW. Current and potential role of specially formulated foods and food supplements for preventing malnutrition among 6- to 23-month-old children and for treating moderate malnutrition among 6- to 59-month-old children. Food and Nutrition Bulletin. 2009; 30: 434-463.

92. Karakochuk C, van den Briel T, Stephens D, Zlotkin S. Treatment of moderate acute malnutrition with ready-to-use supplementary food results in higher overall recovery rates compared with a corn-soya blend in children in southern Ethiopia: an operations research trial. American Journal of Clinical Nutrition. 2012; 96: 911-916. https://doi.org/10.3945/ajcn.111.029744
93. Amegovu AK, Ochola S, Ogwok P, Yiga P, Musalima J, Juliana M. Efficacy of sorghum-peanut blend and corn-soy blend plus in the treatment of moderate acute malnutrition in children aged 6–59 months in Karamoja, Uganda: a cluster-randomized trial. Nutrition and Dietary Supplements. 2014; 6: 75-84.
94. Ackatia-Armah RS, McDonald CM, Doumbia S, Erhardt JG, Hamer DH, Brown KH. Malian children with moderate acute malnutrition who are treated with lipid-based dietary supplements have greater weight gains and recovery rates than those treated with locally produced cereal-legume products: a community-based, cluster-randomized trial. American Journal of Clinical Nutrition. 2015; 101: 632-645.
95. Marchione TJ. Foods provided through U.S. Government Emergency Food Aid Programs: policies and customs governing their formulation, selection and distribution. Journal of Nutrition. 2002; 132(7): 2104-2111.
96. Lagrone L, Trehan I, Meuli GJ, Wang RJ, Thakwalakwa C, Maleta K, et al. A novel fortified blended flour, corn-soy blend "plus-plus," is not inferior to lipid-based ready-to-use supplementary foods for the treatment of moderate acute malnutrition in Malawian children. American Journal of Clinical Nutrition. 2012; 95(1): 212-219. https:// doi: 10.3945/ajcn.111.022525
97. United Nations Children's Fund (UNICEF). Technical Bulletin No. 16 Supercereal products. Available at www.unicef.org/supply
98. Dijkhuizen P. Processed complementary foods in the World Food Programme. Food and Nutrition Bulletin. 2000; 21: 62-64.
99. Isanaka S, Barnhart DA, McDonald CM, Ackatia-Armah RS, Kupka R, Doumbia S. Cost-effectiveness of community-based screening and treatment of moderate acute malnutrition in Mali. BMJ Global Health. 2019; 4: e001227.
100. Golden MH. Proposed recommended nutrient densities for moderately malnourished children. Food and Nutrition Bulletin. 2009; 30(3 Suppl): S267-342. https://doi.org/10.1177/15648265090303S302
101. Michaelsen KF, Hoppe C, Roos N, Kaestel P, Stougaard M, Lauritzen L, et al. Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age. Food and Nutrition Bulletin. 2009; 30 (3): 343-405. https://doi.org/10.1177/15648265090303S303
102. Baer DJ, Novotny JA. Metabolizable energy from cashew nuts is less than that predicted by Atwater factors. Nutrients. 2019; 11(1): 33.
103. Briend A, Akomo P, Bahwere P, de Pee S, Dibari F, Golden MH. Developing food supplements for moderately malnourished children: lessons learned from ready-to-use therapeutic foods. Food and Nutrition Bulletin. 2015; 36(1): 53-58.
104 Gilani GS, Xiao CW, Cockell KA. Impact of antinutritional factors in food proteins on the digestibility of protein and the bioavailability of amino acids and on protein quality. British Journal of Nutrition. 2012; 108: 315-332.
105. Hurrell RF. Phytic acid degradation as a means of improving iron absorption. International Journal for Vitamin and Nutrition Research. 2004; 74: 445-452.

106. Roos N, Sørensen JC, Sørensen H, Rasmussen SK, Briend A, Yang Z, Huffman SL. Screening for anti-nutritional compounds in complementary foods and food aid products for infants and young children. Maternal & Child Nutrition. 2013; 9(suppl 1): 47-71.
107. Ochola S. Effect of steeping and germination on the diastatic activity and sugar content in amaranth grains and viscosity of porridge. Journal of Agriculture and Food Technology. 2013; 3(1): 1-7.
108. Singh S, Gamlath S, Wakeling L. Nutritional aspects of food extrusion: a review. International Journal of Food Science Technology. 2007; 42: 916-929.
109. Nane D, Hatloy A, Tadesse E, Lindtjørn B. Research protocol local-ingredients-based supplementary food as an alternative to corn-soya blends plus for treating moderate acute malnutrition among children aged 6 to 59 months: a randomized controlled non-inferiority trial in Wolaita. BMC Public Health. 2019; 19: Article 1689. https://doi.org/10.1186/s12889-019-8031-3
110. UNHCR/WFP. Guidelines for selective feeding: the management of malnutrition in emergencies. 2009.
111. Maternal, Infant and Young Child Nutrition Working Group (Formulation Subgroup). Formulations for fortified complementary foods and supplements: review of successful products for improving the nutritional status of infants and young children – ten year strategy to reduce vitamin and mineral deficiencies. Food and Nutrition Bulletin. 2009; 30(2): 239-255.
112. Aychiluhm SB, Gelaye KA, Angaw DA, Dagne GA, Tadesse AW, Abera A. Determinants of malaria among under-five children in Ethiopia: Bayesian multilevel analysis. BMC Public Health. 2020; 20: Article 1468.
113. United Nations Department of Economic and Social Affairs, Population Division. World Population Prospects 2019 (revised). Available from http://population.un.org/wpp/Download/Standard/Population/. Accessed 28 December 2021.
114. Alebachew, A, Waddington C. Improving health system efficiency: Ethiopia: human resources for health reforms. World Health Organization. 2015. https://apps.who.int/iris/handle/10665/187240
115. FMOH. Health sector transformation plan. Addis Ababa: Federal Ministry of Health of Ethiopia. 2015.
116. Tesfaye G, Loxton D, Chojenta C, Assefa N, Roger Smith R. Magnitude, trends and causes of maternal mortality among reproductive aged women in Kersa health and demographic surveillance system, eastern Ethiopia. BMC Women's Health. 2018; 18: Article 198.
117. Deribew A, Tessema GA, Deribe K, Melaku YA, Lakew Y, Amare AT. Trends, causes, and risk factors of mortality among children under 5 in Ethiopia, 1990–2013: findings from the Global Burden of Disease Study 2013. Population Health Metrics. 2016; 14: 42.
118. Argaw MD, Desta BF, Bele TA, Ayne AD. Improved performance of district health systems through implementing health center clinical and administrative standards in the Amhara region of Ethiopia. BMC Health Services Research. 2019; 19(1): 127.
119. Ministry of Health Ethiopia. Realizing universal health coverage through primary health care: a roadmap for optimizing the Ethiopian Health Extension Program 2020 – 2035. Addis Ababa, Ethiopia. 2020.

120. Yitbarek K, Abraham G, Morankar S. Contribution of Women's Development Army to maternal and child health in Ethiopia: a systematic review of evidence. BMJ Open. 2019; 9: e025937.
121. Swanson V, Hart J, Byrne-Davis L, Merritt R, Maltinsky W. Enhancing behavior change skills in health extension workers in Ethiopia: evaluation of an intervention to improve maternal and infant nutrition. Nutrients. 2021; 13(6): 1995.
122. Karim AM, Admassu K, Schellenberg J, Alemu H, Getachew N, Ameha A. Effect of Ethiopia's health extension program on maternal and newborn health care practices in 101 rural districts: a dose-response study. PLoS ONE. 2013; 8(6): e65160.
123. Maes K, Closser S, Tesfaye Y, Gilbert Y, Abesha R. Volunteers in Ethiopia's Women's Development army are more deprived and distressed than their neighbors: cross-sectional survey data from rural Ethiopia. BMC Public Health. 2018; 18: Article 258.
124. Ayana G, Bekele TH, Kuche D, Hailu AA, Eshetu S, Petros A. et al. Linkages between health and agriculture sectors in Ethiopia: a formative research study exploring barriers, facilitators and opportunities for local level coordination to deliver nutritional programmes and services. BMC Nutrition. 2017; 3(1): 69. https://doi.org/10.1186/s40795-017-0189-4
125. Jilito MF, Wedajo DY. Agricultural extension agents' education and turnover intentions in public extension services in Ethiopia. International Journal of Agricultural Extension. 2021; 09(02): 183-191.
126. Gecho Y, Ayele G, Lemma T, Alemu D. Rural household livelihood strategies: options and determinants in the case of Wolaita Zone, Southern Ethiopia. Social Sciences. 2014; 3(3): 92-104.
127. Moss C, Bekele TH, Salasibew MM, Sturgess J, Ayana G, Kuche D. Sustainable Undernutrition Reduction in Ethiopia (SURE) evaluation study: a protocol to evaluate impact, process and context of a large-scale integrated health and agriculture programme to improve complementary feeding in Ethiopia. BMJ Open. 2018; 8(7): e022028.
128. Melese M, Tamirat M, Alemu M. Household food insecurity and coping strategies in Southern Ethiopia. Agriculture & Food Security. 2021; 10: Article 23.
129. Berra WG. Household food insecurity predicts childhood undernutrition: a cross-sectional study in West Oromia (Ethiopia). Journal of Environmental and Public Health. 2020; Article ID 5871980.
130. Labena F, Kassa Y, Gambura E. Tuberculosis and public health care workers: infection prevention and control practices and associated factors among governmental health centers and hospitals in Wolaita Zone, Southern Ethiopia. Journal of Multidisciplinary Healthcare. 2021; 14: 2111-2122.
131. Cochrane L, Gechoc Y. Data on the demographics, education, health and infrastructure: Wolaita Zone, Ethiopia. Data in Brief. 2018; 21: 2095-2102.
132. Desalegn K, Loha E, Meskele M. The current status and factors associated with Implanon service provision by the health extension workers at the health post level, Wolaita Zone, Southern Ethiopia: a cross-sectional study. Journal of Family & Reproductive Health. 2017; 11(1): 7-17.
133. Barba FM, Huybregts L, Leroy JL. Incidence correction factors for moderate and severe acute child malnutrition from 2 longitudinal cohorts in Mali and Burkina Faso. American Journal of Epidemiology. 2020; 189(12): 1623-1627.

134. Satiawati KDKD, Januraga PP. Attitudes toward supplemental nutrition assistance programs in caregivers of children with moderate-acute malnutrition younger than 5 years in Denpasar, Bali: a qualitative study. Food and Nutrition Policy. 2018; 39(3): 466-474.
135. Wagh VD, Deore BR. Ready to use therapeutic food (RUTF): an overview. Advances in Life Science and Health. 2015; 2(1): 11-15.
136. James PT, Briel NVD, Rozet A, Israe AD, Fenn B, Navarro-Colorado C. Low-dose RUTF protocol and improved service delivery lead to good programme outcomes in the treatment of uncomplicated SAM: a programme report from Myanmar. Maternal & Child Nutrition. 2015. 11: 859-869.
137. Board NE. Samia Zekaria Member and Secretary, Population Census Commission. 2007.
138. Workie SB, Mekonen T, Fekadu W, Mekonen TC. Level of undernutrition and its determinants among children aged 12-59 months in Wolaita District, Ethiopia. Pediatric Health, Medicine and Therapeutics. 2020; 11: 109-117.
139. Chichiabellu TY, Mekonnen B, Astawesegn FH, Demissie BW, Anjulo AA. Essential newborn care practices and associated factors among home delivered mothers in Damot Pulassa Woreda, Southern Ethiopia. Reproductive Health. 2018; 15: Article 162.
140. Ethiopia: Food insecurity revised emergency appeal no. MDRET005. 2008 [cited 2020 Aug 15]. Available from: https://reliefweb.int/report/ethiopia/ethiopia-food-insecurity-revised-emergency-appeal-nomdret005
141. World Health Organization and United Nations Children's Fund. WHO child growth standards and the identification of severe acute malnutrition in infants and children. Geneva: WHO; 2009.
142. USDA: US Department of Agriculture, Agricultural Research Service (USDA). National Nutrient Database for Standard Reference. FoodData Central, Release 21. 2008. http://www.ars.usda.gov/ba/bhnrc/ndl. Accessed 25 November 2018.
143. NutriSurvey [Nutrient analysis software]. EBISpro, Germany. (2007). Retrieved from http://www.nutrisurvey.de.
144. Gilda P, Elbourne DR, Altman DG, Pocock SJ, Evans SJW. Reporting of noninferiority and equivalence randomized trials: an extension of the CONSORT statement. JAMA. 2006; 295(10): 1152-1160.
145. Kummervold PE, Johnsen JAK, Skrøvseth SO, Wynn R. Using noninferiority tests to evaluate tele-medicine and E-health service: systematic review. Journal of Medical Internet Research. 2012; 14(5): e132.
146. Sicotte M, Ledoux M, Zunzunegui MV, Aboubacrine SA, Nguyen VK, ATARAO group. Reliability of anthropometric measures in a longitudinal cohort of patients initiating ART in West Africa. BMC Medical Research Methodology. 2010; 10: 102. https://doi.org/10.1186/1471-2288-10-102.
147. WHO Multicentre Growth Reference Study Group. Reliability of anthropometric measurements in the WHO Multicentre Growth Reference Study. Acta Pædiatrica. 2006; 450: 38-46.
148. Mason M. Sample size and saturation in PhD studies using qualitative interviews. Forum: Qualitative Social Research. 2010; 11(3). https://doi.org/10.17169/fqs-11.3.1428
149. Forero R, Nahidi S, Costa JD, Mohsin M, Fitzgerald G, Gibson N. Application of four-dimension criteria to assess rigour of qualitative research in emergency medicine. BMC Health Services Research. 2018; 18(120): 1-11.

150. The United Nation Refugee Agency. Guidelines for selective feeding: the management of malnutrition in emergencies. Geneva: UNHCR, United Nations High Commissioner for Refugees; 2011.
151. Morrow R, Rodriguez A, King N. Colaizzi's descriptive phenomenological method. Psychologist. 2015; 28(8): 643-644.
152. Tong A, Sainsbure P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. International Journal for Quality in Health Care. 2007; 19(6): 349-357.
153. Association of Official Analytical Chemists (AOAC) (2000). Official methods of analysis of AOAC international, 17th ed. Gaithersburg, MD: Association of Official Analytical Chemists.
154. Sharma G, Lakhawat S. Development, quality evaluation and acceptability of pumpkin seed flour incorporated in gravy. Journal of Nutrition and Food Sciences. 2017; 7(4): 1000613.
155. McCleary BV, Sloane N, Draga A, Lazewska I. Measurement of total dietary fiber using AOAC Method 2009.01 (AACC International Approved Method 32-45.01): evaluation and updates. Cereal Chemistry. 2013; 90(4): 396-414.
156. Association of Official Analytical Chemists (AOAC) (2005). Official methods of analysis of AOAC International, 18th ed. Gaithersburg, MD: Association of Official Analytical Chemists.
157. Derib A, Wegayehu F, Amhaeyesus B, Mitiku A, Weldetsadik K. Characterization of teff (Eragrostis tef Zucc. Trotter [cv. Magna]) in Minjar Shenkora district of central Ethiopia African Journal of Food, Agriculture, Nutrition and Development. 2018; 18(3): 13664-13676
158. Food and Agriculture Organization (FAO). Food energy – methods of analysis and conversion factors. FAO Food and Nutrition Paper. 2003; 77.
159. Wu S, Wu Y. Proximate composition and nutritional evaluation of the adductor muscle of pen shell. 3 Biotech. 2017; 7(3): 160.
160. Latta, M, Eskin M. Simple and rapid colorimetric method for phytate determination. Journal of Agricultural and Food Chemistry. 1980; 28: 1315-1317.
161. Vaintraub IA, Lapteva NA. Colorimetric determination of phytate in unpurified extracts of seeds and the products of their processing. Journal of Analytical Biochemistry. 1988; 175: 227-230.
162. Gargari B, Mahboob S, Razavieh SV. Content of phytic acid and its mole ratio to zinc in flour and breads consumed in Tabriz, Iran. Food Chemistry. 2007; 100: 1115-1119.
163. Borquaye LS, Darko G, Laryea MK, Gasu EN, Amponsah NAA, Appiah EN. Nutritional and anti-nutrient profiles of some Ghanaian spices. Cogent Food & Agriculture. 2017; 3(1): 1348185.
164. Henry CK, Xin JLW. Application of Hazard Analysis Critical Control Point in the local manufacture of ready-to-use therapeutic foods (RUTFs). Food and Nutrition Bulletin. 2014; 35(2): 57-63.
165. Osendarp S, Rogres B, Ryan K, Manary M, Akomo P, Bahwere P, Belete H. Ready-to-use foods for management of moderate acute malnutrition: considerations for scaling up production and use in programs. Food and Nutrition Bulletin. 2015; 36(1): 59-64.

166. Rahman MS. The advantages and disadvantages of using qualitative and quantitative approaches and methods in language “Testing and Assessment” research: a literature review. Journal of Education and Learning. 2017; 6(1): 102-112.
167. Khankeh H, Ranjibar M, Khorasani-Zavareh D, Boroujeni AZ, Johansson E. Challenges in conducting qualitative research in health: a conceptual paper. Iranian Journal of Nursing and Midwifery Research. 2015; 20(6): 635-641.
168. Penner JL, McClement SE. Using phenomenology to examine the experiences of family caregivers of patients with advanced head and neck cancer: reflections of a novice researcher. International Journal of Qualitative Methods. 2008; 7(2): 92-101.
169. Sorsa MA, Kiikkala I, Åstedt-Kurki P. Bracketing as a skill in conducting unstructured qualitative interviews. Nurse Researcher. 2015; 22(4): 8-12.
170. Humble F, Cross W. Being different: a phenomenological exploration of a group of veteran psychiatric nurses. International Journal of Mental Health Nursing. 2010; 19: 128-136.
171. Meisters J, Hoffmann A, Musch J. Controlling social desirability bias: an experimental investigation of the extended crosswise model. PLoS ONE. 2020; 15(12): e0243384.
172. Schumi J, Wittes JT. Through the looking glass: understanding non-inferiority. Trials. 2011; 12: 106.
173. Gupta R, Gupta H,, Banker M. The impact of an inappropriate non-inferiority margin in a non-inferiority trial. Human Reproduction. 2016; 31(12): 2892-2897.
174. D’Agostino RB, Massaro JM, Sullivan LM. Non-inferiority trials: design concepts and issues - the encounters of academic consultants in statistics. Statistics in Medicine. 2003; 22: 169-186.
175. The Sphere Project. Humanitarian charter and minimum standards in humanitarian response, 3rd edition. Practical Action Publishing: Rugby, UK. 2011.
176. Pannucci CJ, Wilkins EG. Identifying and avoiding bias in research. Plastic and Reconstructive Surgery. 2010; 126(2): 619-625.
177. Palinkas LA, Horwitz SM, Green CA, Wisdom JP, Duan N, Hoagwood K. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. Administration and Policy in Mental Health. 2015; 42(5): 533-544.
178. Cresswell JW, Clark VP. Designing and conducting mixed method research, 2nd edition. Sage; Thousand Oaks, CA. 2011.
179. Vasileiou K, Barnett J, Thorpe S, Young T. Characterising and justifying sample size sufficiency in interview-based studies: systematic analysis of qualitative health research over a 15-year period. BMC Medical Research Methodology. 2018; 18: Article 148.
180. Mansournia MA, Higgins JPT, Sterne JAC Hernán MA. Biases in randomized trials: a conversation between trialists and epidemiologists. Epidemiology. 2017; 28(1): 54-59.
181. Suresh KP. An overview of randomization techniques: an unbiased assessment of outcome in clinical research. Journal of Human Reproductive Sciences. 2011; 4(1): 8-11.
182. Lim CY, In J. Randomization in clinical studies. Korean Journal of Anesthesiology. 2019; 72(3): 221-232.
183. Spieth PM, Kusbasch AS, Penzlin AI, Illigens BM, Barlinn K, Siepmann T. Randomized controlled trials – a matter of design. Neuropsychiatric Disease and Treatment. 2016; 12: 1341-1349.
184. Akobeng AK. Assessing the validity of clinical trials. Journal of Pediatric Gastroenterology and Nutrition. 2008; 47: 277-282.

185. Zhang Z, Peluso MJ, Gross CP, Viscoli CM, Kernan WN. Adherence reporting in randomized controlled trials. Clinical Trials. 2014; 11(2): 195-204.
186. Rothman K, Greenland S, Lash TL. Modern epidemiology, 3rd edition. Lippincott Williams & Wilkins. 2008.
187. Bours MJL. A nontechnical explanation of the counterfactual definition of confounding. Journal of Clinical Epidemiology. 2020; 121: 91-100.
188. Wallach JD, Serghiou S, Chu L, Egilman AC, Vasiliou V, Ross JS Ioannidis JP. Evaluation of confounding in epidemiologic studies assessing alcohol consumption on the risk of ischemic heart disease. BMC Medical Research Methodology. 2020; 20: Article 64.
189. Jager KJ, Zoccali C, Macleod A, Dekker FW. Confounding: what it is and how to deal with it. Kidney International. 2008; 73: 256-260.
190. Caldwell J. Introducing qualitative hypothesis-generating research. The Yeshiva University Fatherhood Project. 2017: 1-9.
191. Biau DJ, Kernéis S, Porcher R. The importance of sample size in the planning and interpretation of medical research. Clinical Orthopaedics and Related Research. 2008; 466: 2282-2288.
192. Gvozdenović E, Malvisi L, Cinconze E, Vansteelandt S, Nakanwagi P, Aris E, Rosillon D. Causal inference concepts applied to three observational studies in the context of vaccine development: from theory to practice. BMC Medical Research Methodology. 2021; 21: Article 35.
193. Hariton E, Locascio JJ. Randomised controlled trials – the gold standard for effectiveness research. BJOG. 2018; 125(13): 1716.
194. Kim J, Shin W. How to do random allocation (randomization). Clinics in Orthopedic Surgery. 2014; 6(1): 103-109.
195. Patino CM, Ferreira JC. Internal and external validity: can you apply research study results to your patients? The Brazilian Journal of Pulmonology. 2018; 44(3): 183.
196. Cipriani A, Purgato M, Barbui C. Why internal and external validity of experimental studies are relevant for clinical practice? Epidemiologia e Psichiatria Sociale. 2009; 18(2): 101-103.
197. Paul M, Bronstein E, Yahav D, Goldberg E, Bishara J, Leibovici L. External validity of a randomised controlled trial on the treatment of severe infections caused by MRSA. BMJ Open. 2015; 5: e008838.
198. Hyder AA, Maman S, Nyoni JE, Khasiani SA, Teoh N, Premji Z. The pervasive triad of food security, gender inequity and women's health: exploratory research from sub-Saharan Africa. African Health Sciences. 2005; 5(4): 328-334.
199. Berhane Y, Gossaye Y, Emmelin M, Hogberg U. Women's health in a rural setting in societal transition in Ethiopia. Social Science and Medicine. 2001; 53: 1525-1539.
200. Ahishakiye J, Bouwman L, Brouwer ID, Matsiko E, Armar-Klemesu M, Koelen M. Challenges and responses to infant and young child feeding in rural Rwanda: a qualitative study. Journal of Health, Population and Nutrition. 2019; 38: Article 43.
201. Kajjura RB, Veldman FJ, Kassier SM. Maternal perceptions and barriers experienced during the management of moderately malnourished children in northern Uganda. Maternal & Child Nutrition. 2020; 16. https://doi.org/10.1111/mcn.13022
202. Rasheed S, Haider R, Hassan N, Pachón H, Islam S, Jalal CSB. Why does nutrition deteriorate rapidly among children under 2 years of age? Using qualitative methods to

understand community perspectives on complementary feeding practices in Bangladesh. Food and Nutrition Bulletin. 2011; 32: 192-200.
203. Appoh LY, Krekling S. Maternal nutritional knowledge and child nutritional status in the Volta Region of Ghana. Maternal & Child Nutrition. 2005; 1: 100-110.
204. Fadare O, Amare M, Mavrotas G, Akerele D, Ogunniyi A. Mother’s nutrition-related knowledge and child nutrition outcomes: empirical evidence from Nigeria. PLoS ONE. 2019; 14(2): e0212775.
205. Laillou A, Prak S, de Groot R, Whitney S, Conkle J, Horton L. Optimal screening of children with acute malnutrition requires a change in current WHO guidelines as MUAC and WHZ identify different patient groups. PLoS ONE. 2014; 9(7): e101159.
206. Abitew DB, Yalewu AW, Bezabih AM, Bazzano AN. Comparison of mid-upper-arm circumference and weight-for-height Z-score in identifying severe acute malnutrition among children aged 6–59 months in South Gondar Zone, Ethiopia. Journal of Nutrition and Metabolism. 2021; 8830494.
207. Alé FG, Phelan KP, Issa H, Defourny I, Le Duc G, Harczi G. Mothers’ screening for malnutrition by mid-upper arm circumference is non-inferior to community health workers: results from a large-scale pragmatic trial in rural Niger. Archives of Public Health. 2016; 74(1): 38.
208. Goossens S, Bekele Y, Yun O, Harczi G, Ouannes M, Shepherd S. Mid-upper arm circumference based nutrition programming: evidence for a new approach in regions with high burden of acute malnutrition. PLoS ONE. 2012; 7(11): e49320.
209. Pietravalle A, Scilipoti M, Cavallin F, Lonardi M, Tshikamb IM, Robbiati C. Nutritional education during rehabilitation of children 6–24 months with acute malnutrition, under unavailability of therapeutic/supplementary foods: a retrospective study in rural Angola. BMC Pediatrics. 2021; 21(94). https://doi.org/10.1186/s12887-021-02560-z
210. KO Ajao, EO Ojofeitimi, AA Adebayo, AO Fatusi, OT Afolabi. Influence of family size, household food security status, and child care practices on the nutritional status of under-five children in Ile-Ife, Nigeria. African Journal of Reproductive Health. 2010; 14(4): 123-132.
211. Abitew DB, Yalewu AW, Bezabih AM, Bazzano AN. Predictors of relapse of acute malnutrition following exit from community-based management program in Amhara region, Northwest Ethiopia: an unmatched case-control study. PLoS ONE. 2020; 15(4): e0231524.
212. Ayele AW, Kassa M, Fentahun Y, Edmealem H. Prevalence and associated factors for rural households food insecurity in selected districts of east Gojjam zone, northern Ethiopia: cross-sectional study. BMC Public Health. 2020; 20: Article 202.
213. Bliss JR, Njenga M, Stoltzfus RJ, Pelletier DL. Stigma as a barrier to treatment for child acute malnutrition in Marsabit County, Kenya. Maternal & Child Nutrition. 2016; 12: 125-138.
214. Flax VL. ‘It was caused by the carelessness of the parents’: cultural models of child malnutrition in southern Malawi. Maternal & Child Nutrition. 2013; 11(1): 104-108.
215. Roy SK, Fuchs GJ, Mahmud Z, Ara G, Islam S, Shafique S. Intensive nutrition education with or without supplementary feeding improves the nutritional status of moderately-malnourished children in Bangladesh. Journal of Health, Population and Nutrition. 2005; 23(4): 320-330.

216. Kansiime N, Atwine D, Nuwamanaya S, Bagenda F. Effect of male involvement on the nutritional status of children less than 5 years: a cross sectional study in a rural southwestern district of Uganda. Journal of Nutrition and Metabolism. 2017; 2017: 3427087.
217. Bredesen JA.Women's use of healthcare services and their perspective on healthcare utilization during pregnancy and childbirth in a small village in northern India. American International Journal of Contemporary Research. 2013; 3: 1-9.
218. Fotso JC, Fogarty L. Progress towards millennium development goals 4 & 5: strengthening human resources for maternal, newborn and child health. BMC Health Services Research. 2015; 15 (Suppl. 1): S1.
219. Settaluri V, Kandala C, Puppala N, J. Sundaram J. Peanuts and their nutritional aspects – a review. Food and Nutrition Sciences. 2012; 3: 1644-1650
220. Dotto JM, Chacha JS. The potential of pumpkin seeds as a functional food ingredient: a review. Scientific Africa. 2020. 2020: e00575.
221. Iuel-Brockdorf AS, Draebel TA, Ritz C, Fabiansen C, Cichon B, Christensen VB. Evaluation of the acceptability of improved supplementary foods for the treatment of moderate acute malnutrition in Burkina Faso using a mixed method approach. Appetite. 2016; 99(2016): 34-45.
222. Lemus-Mondaca R, Marin J, Rivas J, Sanhueza L, Soto Y, Vera N. Pumpkin seeds (Cucurbita maxima). A review of functional attributes and by-products. Revista Chilena de Nutrición. 2019; 46(6): 783-791.
223. Singh KK, Mridula D, Rehal J, Barnwal P. Flaxseed: a potential source of food, feed and fiber. Critical Reviews in Food Science and Nutrition. 2011; 51(3): 210-222.
224. Griswold SP, Langlois BK, Shen Y, Cliffer IR, Suri DJ, Walton S. Effectiveness and cost-effectiveness of 4 supplementary foods for treating moderate acute malnutrition: results from a cluster-randomized intervention trial in Sierra Leone. American Journal of Clinical Nutrition. 2021; 114: 973-985.
225. Mudau N, Ramavhoya K, Onipe OO, Jideani AI. Plant- and animal-based protein sources for nutritional boost of deep-fried dough. Frontiers in Sustainable Food Systems. 2021; 5(763437): 1-9. https://doi.org/10.3389/fsufs.2021.763437
226. Codex Alimentarius Commission. Codex standard for processed cereal based foods for infants and young children (CODEX STAN 074-1981, REV.1-2006). 2006. Retrieved from http://www.sciepub.com/reference/232485
227. Bahwere P, Banda T, Sadler K, Nyirenda G, Owino V, Shaba B. Effectiveness of milk whey protein-based ready-to-use therapeutic food in treatment of severe acute malnutrition in Malawian under-5 children: a randomised, double-blind, controlled non-inferiority clinical trial. Maternal & Child Nutrition. 2014; 10(3): 436-451.
228. Hurrell RF. Influence of vegetable protein sources on trace element and mineral bioavailability. Journal of Nutrition. 2003; 133(9): 2973-2977.
229. Kaul S, Diamond GA. Good enough: a primer on the analysis and interpretation of noninferiority trials. Annals of Internal Medicine. 2006; 145: 62-69.
230. Matilsky DK, Maleta K, Castleman T, Manary MJ. Supplementary feeding with fortified spreads results in higher recovery rates than with a corn/soy blend in moderately wasted children. Journal of Nutrition & Food Sciences. 2009; 139: 773-778.
231. Nackers F, Broillet F, Oumarou D, Djibo A, Gaboulaud V, Guerin PJ. Effectiveness of ready-to-use therapeutic food compared to a corn/soy-blend-based pre-mix for the

treatment of childhood moderate acute malnutrition in Niger. Journal of Tropical Paediatrics. 2010; 56: 407-413.
232. Lagrone L, Cole S, Schondelmeyer A, Maleta K, Manary MJ. Locally produced ready-to-use supplementary food is an effective treatment of moderate acute malnutrition in an operational setting. Annals of Tropical Paediatrics. 2010; 30: 103-108.
233. Patel MP, Sandige HL, Ndekha MJ, Briend A, Ashorn P, Manary MJ. Supplemental feeding with ready-to-use therapeutic food in Malawian children at risk of malnutrition. Journal of Health, Population and Nutrition. 2005; 23: 351-357.
234. Uauy R, Kurpad A, Tano-Debrah, Otoo GE, Aaron GA, Toride Y, et al. Role of protein and amino acids in infant and young child nutrition: protein and amino acid needs and relationship with child growth. Journal of Nutrition Science and Vitaminology. 2015; 61: 192-194. https://doi.org/10.3177/jnsv.61.S192
235. Rivera JA, Hotz C, Gonzalez-Cossio T, Neufeld L, Garcia-Guerra A. The effect of micronutrient deficiencies on child growth: a review of results from community-based supplementation trials. Journal of Nutrition & Food Sciences. 2003; 133: 4010-4020. https://doi.org/10.1093/jn/133.11.4010S

Original papers

Paper I

Barriers to management of moderate acute malnutrition among children aged 6-59 months in Damot Pulassa, Wolaita, South Ethiopia: a phenomenological study of mothers and health service providers

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Abstract

Background

Management of children with moderate acute malnutrition (MAM) needs to improve to reduce the transition from MAM to severe acute malnutrition (SAM).

Objective

This study aimed to assess barriers to management of MAM among children aged 6-59 months in Damot Pulassa, Wolaita, South Ethiopia.

Method

This descriptive phenomenological design used six focus group discussions with mothers or caregivers of children aged 6 to 59 months and ten in-depth interviews with health service providers. Data were analyzed using Colaizzi's descriptive phenomenological method.

Result

Six themes were identified: Possible reasons for MAM; identification of a child with MAM; management services of MAM; maternal-level barriers; service provider-level barrier, and suggestions to improve the service. Shortage of food and money, selling out of self-produced food without having sufficient reserves at home, large household size, shame on having children with malnutrition, occasional house-to-house screening for MAM, family-initiated screening, leaving the management responsibility of children with MAM to the family, no provision of supplementary food, and lack of repeated follow-up visits were the main obstacles for managing MAM.

Conclusion

Maternal-level barriers and service provider-level barriers affect the management of MAM negatively in Damot Pulassa, Wolaita. Children with MAM living in the area ineligible for food supplementation could deteriorate to SAM. The provision of nutrition counseling to the mothers of children with MAM without food supplementation placed children with MAM at increased risk of negative outcome. Thus, the government should give more attention and facilitation in promoting supplementary food into the existing management of MAM.

Keywords

Moderate acute malnutrition, perception, existing management practice, barriers, phenomenological study, Wolaita, Ethiopia

Introduction

Worldwide, moderate acute malnutrition (MAM) affects approximately 33 million children below 5 years of age and these children have a 3 times increased risk of death compared to well-nourished children [1,2]. MAM is defined by a weight-for-height z-score between −2 and −3 and/or mid-upper arm circumference (MUAC) of between 11.5 cm and 12.5 cm, without bilateral pitting edema [3, 4, 5]. A large number of guidelines for managing MAM exist [5, 6, 7]. However, there is currently no standardized method for managing MAM [6, 8]. If children with MAM do not receive adequate management, they may progress towards severe acute malnutrition (SAM), which could be a life-threatening condition. However, MAM has not received the consideration it deserves and is not frequently seen as of public health importance [8, 9].

The supplementary feeding program is one of the recommendations for the management of children with MAM. Supplementary feeding programs are classified as targeted supplementary feeding programs or blanket supplementary feeding programs, depending on the beneficiaries. A blanket method delivers supplemental food to all vulnerable children within a definite population, irrespective of whether or not children are acutely malnourished. This method has been used to treat MAM when prevalence rates are higher than 20 percent. A targeted approach offers supplemental provisions only for children with MAM. It is frequently chosen when MAM and SAM prevalence rates are from 10-14 percent [7, 8].

In conditions where caregivers may have access to affordable food, but the knowledge and practices in how to use it are limited, nutrition counseling has been used as a method for MAM management. Nutrition counseling emphasizes disseminating information on appropriate feeding practices, which can improve dietary diversity and achieve desired nutritional outcomes, as well as progress in hygiene and sanitation practices [10].

Challenges faced in MAM management include the high unit cost of products, having low coverage of programs, focusing on generalized prevalence rates rather than season-specific incidence rates, and frequent high defaulting. Using a variety of definitions and classifications across different MAM management programs is also considered a challenge. This leads to confusion over the inclusion and exclusion criteria for MAM [6, 11].

In Ethiopia, the current strategy for managing MAM is to restrict targeted supplementary feeding programs to particular districts of the country defined as chronically food insecure. In areas not selected as chronically food insecure, there are no food supplementation programs. In such areas, the alternative management approach consists of vitamin A supplementation and deworming, water treatment to make appropriate for drinking, enhanced sanitation, and nutrition counseling [4, 12].

A key step toward better future programs and policies is to improve our understanding of the community's and health care workers' views, experiences, and preferences of maternal and child health care services. Discussion with mothers who are the primary caregiver of a child and service providers provides insight about barriers to management of MAM among children aged 6 to 59 months. Such contextual knowledge contributes to the development of recommendations on the management practice of MAM that could be implemented at the local level and improve existing management guidelines of MAM among children. Little research has been done to assess community perceptions towards barriers of the existing management practices for MAM in Ethiopia, both among the service providers and beneficiaries. There is a high prevalence of malnutrition in the country. This study aimed to explore barriers to management of moderate acute malnutrition among children aged 6-59 months in Damot Pulassa, Wolaita, South Ethiopia: a phenomenological study of mothers and health service providers.

Methods and materials

Study setting and study period

This study was conducted in Damot Pulassa district of Wolaita Zone, which is located 328 kilometers south of Addis Ababa. Damot Pulassa is a rural district with an estimated population of 130,515 people, and a population density of 700 people per square kilometer [4, 13]. There is a persistent disparity in the land and population balance resulting in endemic food insecurity because the district is characterized by fragmented farm and land ownership [14]. The population is mainly growing maize, beans, and sweet potatoes. Rain failure and pests are persistent problems and frequently drive much of the population into hunger and malnutrition. Damot Pulassa has five health centers and 23 health posts. These health posts are led by health extension workers (HEWs) and deliver nutrition-linked services like nutrition education, screening of the nutritional status of young children, and nutritional management of malnourished children. The study was carried out between June and July 2018. In that period there was no targeted supplementary feeding program in the area.

Study design

This study used a descriptive phenomenological qualitative design. This design is used to attain an understanding of the right meaning of a phenomenon of interest through engaging detailed descriptions of the mothers or caregivers and service provider's perception toward barriers during managing acute moderately malnourished children [15, 16]. In this approach the perception of researchers is bracketed or set aside, to acquire the lived experience of the participants [17].

Study population and sampling procedure

In the six focus group discussions, eight to ten mother or caregiver-child pairs per group were recruited. The total number of mother or caregiver-child pairs who participated in the study was 55. To identify subjects that are especially knowledgeable about or experienced informants toward the existing management practice of MAM and its barriers, the mothers or caregivers were purposively enrolled from the community with the assistance of HEWs who know the local population. The rationale and power of purposeful sampling are found in selected cases with a lot of information to explore in-depth. Information-rich cases are those from which a lot can be learned about topics that are important to the objective of inquiry, hence the term "purposeful sampling. Studying information-rich cases gives insights and in-depth understanding toward the study topic [18]. The recruitment criteria for mothers or caregivers was that they had a child or children aged 6 to 59 months currently suffering from MAM who had been admitted to the management program for MAM. Ten in-depth interviews were carried out with four HEWs and six Women's Development Army workers (WDAs); these are first-level community-based health care volunteers who provide support in the management practices for acute malnutrition. Informants were purposely selected from the HEWs and WDAs based on their relevant experience (i.e. they function in a role detecting and managing children with MAM). None of the potential participants declined to participate.

Research instrument

Open-ended semi-structured focus group discussion guides and in-depth interview guides were developed following an extensive review of the relevant literature. The focus group discussion and in-depth interview guides were prepared in English and translated into the local language, *Wolaitato*. This was followed by a back-translation into English to ensure internal validity. A pilot study comprising one focus group discussion and one in-depth interview was carried out among respondents who were not included in the study samples. The pilot test aimed to determine whether the particular focus group discussion and in-depth interview guides were clear, thus confirming reliability.

Data collection

The focus group discussions were applied by the first author and research assistants (two facilitators and one note-taker). The research assistants are trained on study objectives and methodology and who were fluent in *Wolaitato*, the local language spoken by mothers. Before starting the data collection, the participants were informed about the objective and procedure of the study. Participants were then asked about their willingness to continue and to provide oral as well as written informed consent. The focus group discussions were conducted in privacy at sites that were accessible to participants (i.e. health posts and health centers). During focus group discussions, each mother or caregiver had the chance to share her opinions on a question raised before moving to another question in which active participation was ensured. Each focus group discussion lasted between 50 and 70 minutes.

Face-to-face in-depth interviews were the second method of data collection done by the first author using the local languages of HEWs and WDAs, *Wolaitato*. Probing to get detailed information was done. All the in-depth interviews were performed privately at the workplace of each health worker. Two trained research assistants helped the first author with note-taking and audio recording. Each in-depth interview had an approximate duration of 60 to 80 minutes.

Focus group discussions and in-depth interviews were done till saturation of content was achieved; this occurs when additional interviews do not provide new information to data already collected and they become simply redundant [19]. At the end of focus group discussions and in-depth interviews, the facilitator of focus group discussions and the interviewer of in-depth interviews moderated the scribed content of the notes to define assertion and meaning with mothers to improve face validity. Data collected from focus group discussions and in-depth interviews were audio-recorded with permission from the participants.

Trustworthiness and quality assurance

Based on four dimension criteria, we kept the data collection scientifically rigorous and trustworthy [20]. Credibility: To accomplish this, we have spent time in the field, done peer debriefing and member check. To obtain an in-depth understanding, it has been kept throughout group discussion and interview. Dependability: With the help of the supervisor, the research team created a data audit to ensure that the data and findings were rich-thick, consistent, and stable over time. Confirmability: We were able to assess the accuracy of the results and the truthfulness of the participants' perspectives by using data audit and triangulation. Transferability: We have done purposive sampling to get specific data relative to the context. In addition, we provided detailed descriptions to help readers determine whether the findings could be applied to their situation.

Data analysis and management

Data collected in the focus group discussions and in-depth interviews were transcribed verbatim (a word-for-word record). Transcription of interviews was assisted by Express Scribe transcription software (Pro v 7.03 NCH Software Pty Ltd). An initial coding framework was generated by the primary researcher and research assistants after manual coding of transcripts independently. Data were analyzed using Colaizzi's descriptive phenomenological method. Using this approach, there are seven steps involved in analysis of qualitative data [21] (Figure 1). The data were imported and coded in the computer software of ATLAS.ti 8 and analyzed by the same software (Scientific Software Development GmbH). The Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist was used to report findings [22].

Ethics approval and consent to participate

The ethical approval for the study was obtained from Hawassa University College of Medicine and Health Sciences Institutional Review Board (IRB/024/10) and regional committees for medical and health research ethics in Norway, 2018/69/REK vest. Verbal, as well as written informed consent was obtained from the participants. The confidentiality of the information provided was maintained at all stages of data analysis.

Results

We conducted six focus group discussions with forty seven mothers and eight caregivers and ten in-depth interviews with four HEWs and six WDA workers. The mothers' or caregivers' characteristics are described in Table 1. The mean age of mothers or caregivers was 30 years; most of them were mothers and the rest were grandmothers. Nearly 80 % of them were housewives. The majority of mothers or caregivers were married. Nearly half of mothers or caregivers had not attended formal school.

The educational status of the HEWs ranged from a diploma and above, whereas the educational status of WDA workers ranged from secondary school completed and above (Table2).

Six main themes demonstrate perceptions from mothers and health service providers towards existing management practice of MAM and its barriers experienced: 1) Possible reasons for

MAM; 2) Identification of child with MAM; 3) Management services of MAM; 4) Mothers or caregivers-level barriers; 5) Service provider-level barrier, and 6) Suggestions to improve the service (Table 3).

Theme 1 Possible reasons of MAM

We present the possible reasons for MAM in to give the basis for the management of MAM among children. The possible reasons for MAM may act as a background to understand the context for the barriers towards existing management practice of MAM

Shortage of child-caring time, lack of awareness, a large household size, and maternal malnutrition were mentioned as the possible reasons for MAM.

Shortage of child-caring time

Work overload prevents mothers or caregivers from caring for their children appropriately. In addition to this, small business traders do not have time to see their children. A mother of 31 years old said: "As to me, I have a workload at home. For example, caring for children, cooking for the family, drawing water, preparing firewood, going to the market, and sometimes farming, has made me not feed my child properly. Not only that, it has prevented me from attending the counseling offered by HEWs and WDA workers." Likewise, a HEW of 28 years old said: "Some of the mothers who have small businesses are unable to practice the nutrition education received from service providers because they have no time to care for their affected child; they are not at home throughout the day."

Lack of adequate knowledge

Respondents revealed that due to a lack of adequate knowledge towards appropriate childhood feeding practices, some mothers do not feed their baby regularly enough to ensure adequate intake. Instead, they give dry family foods when the child is hungry. As a result, children would often become ill and hence end up with MAM. A mother of 30 years old said: “Lack of knowledge may be the main cause for inappropriate feeding of the child. Some mothers do not feed their children regularly because they have no idea to prepare food for the child. Not only that, some mothers feed their child with easily un-chewable food.”

Theme 2 Identification of children with MAM

Mothers or caregivers who participated in the focus group discussions revealed that their children had been screened for MAM. They mentioned that the process of screening was done by measuring the upper arm of the child with plastic tape. The majority of mothers or caregivers reported that both HEWs and WDA workers were involved in the screening process. In this theme, the perceived barriers mentioned by mothers or caregivers were occasional house to house screening of children for MAM and family initiated screening of children for MAM.

Occasional house to house screening using MUAC

One of the obstacle mentioned by the mothers or caregivers was that the screening sometimes done with occasional household visiting by service providers. A mother of 25 years old said: “The most used way for screening of children is measuring upper arm by plastic tape. Based on the measurement result, they classified children as having low weight or not. The HEWs are doing this service occasionally.” Both mothers or caregivers and service providers mentioned that, sometimes, non-governmental organizations had done the screening of children below five years for MAM but it was not continuous. WDAs of 40 years old said: “Sometimes, non-governmental organizations has done the screening of children for MAM and support the affected children but the program was not continuous.”

The service providers informed that they have monthly screening programs for identification of children with MAM using the measurement of MUAC, by visiting house to house. They have also mentioned that they visit families who worry about their child's nutritional status. A 32-years-old HEW said: "I go out and do house-to-house visits every month to screen children for acute malnutrition. Sometimes I visit households with children suspected of MAM based on the report of mothers."

Screening while immunization session

According to the report of both mothers or caregivers and service providers, children with MAM were identified during the routine vaccination program and vaccination campaign as well. A grandmother of 39 years old said: "We have a commonplace in our area where we meet with the HEWs when there are a vaccination campaign and some other meeting. When the WDA workers inform us to bring our children to the site, we take them and they measure MUAC for all children through the vaccination program and classified children as affected or not."

Family initiated screening

The perceived barriers mentioned by the mothers or caregivers were that screening is done either by HEWs or by other medical persons working in health centers (when the family brought their children to visit health institutions for other medical reasons) or at the initiation of mothers or caregivers. Some mothers also mentioned that the screening process started when mothers or caregivers report the condition of their children to the service providers. A mother of 30 years old said: "When we presented with a sick child to the health center, medical persons working in the health center referred our child to HEWs after identifying the child as affected." A grandmother of 40 years old also said: "As I know, I have brought my child to the health post more than once since she gets thin and has a loss of appetite … The HEW measured my child's arm with plastic tape and told me as she has a moderate low weight." Likewise, service providers mentioned that they screen children for MAM when the children are referred from other health facilities and when the mothers report the condition of the children. A 32-year -old HEW said: "I also screen the children, when mothers or caregivers bring their children for other medical reasons, and when they come and report to me, as their children are being thin…"

Theme 3 Management practices of MAM

More than half of the focus group discussants did not know exactly what MAM was; they described the condition as low weight without body swelling and lost hair, but they knew they would stay in counseling if their child's upper arm measurement was on the yellow mark on the plastic tape. In addition to this, they often mentioned the provision of Plumpy'nut (a nutritional supplement) for the severe form. Generally, mothers/caregivers and HEWs described similar existing management practices for MAM. These included nutrition counseling and follow-up visit(s). They also mentioned about the inadequacy of existing management service of MAM. In this theme, the perceived barrier mentioned by mothers or caregivers toward existing management practice of MAM were difficulties to implement the counseling advice because of household food shortage, and ignoring management of MAM and leaving the management responsibility to the family. The perceived barrier mentioned by service providers toward existing management practice of MAM was limited or no provision of therapeutic supplement.

Nutrition counseling

The mothers or caregivers said that the existing management service for MAM is primarily counseling. The counseling topics cover healthy complementary feeding practices, types of different food ingredients that the children need, as well as hygiene. These services are mostly given by the HEWs and sometimes by WDA workers. Some of the mothers or caregivers mentioned that they get these services when they bring their child for vaccination. Others informed that they are getting the service every month. A mother of 35 years old said: “As I know, I am getting an education from HEWs on hygiene and demonstration to feed our child with porridge made from different food ingredients like cabbage, potato, carrot, maize, and egg. Sometimes the HEWs visit my home to provide counseling and check my child.” Similarly, service providers (HEWs and WDA workers) mentioned they do home visits, providing monthly counseling on exclusive breastfeeding practices, complementary feeding practice, preparation of porridge from cereals and vegetables, hygiene, family planning, vaccination, and communicable disease control. The perceived barrier toward existing management practice of MAM mentioned by all health service providers was that there is limited or no provision of supplements for MAM. HEWs of 30-years-old said: “I have advised caregivers by visiting households monthly with different topics like exclusive breastfeeding practices, complementary feeding practice, hygiene, family planning, vaccination, and communicable disease control. Other than the above services, we are not providing any supplements.”

Follow-up visit(s)

Mothers or caregivers mentioned that the HEWs, as well as WDA workers, were visiting their home and checking their child’s status. Almost all service providers agreed on having follow-up visits to check the progress of children with MAM, once the children are identified and registered as such. A 40-years-old HEW said: “I also do follow-up checks for registered MAM cases for their progress and to counsel mothers or caregivers. Similarly, I send WDA workers to do follow-up visits of registered children with MAM by measuring MUAC.”

Adequacy of the service given

According to the mothers or caregivers, they agreed that the management services for MAM are inadequate. The barrier toward management services of MAM perceived by some of mothers or caregivers was that it is difficult to implement the counseling advice because of the shortage of food in their house. They also raised that getting counseling only on feeding practices is not bringing improvement to their children with MAM. A 31-years-old mother said: “I can say that my child with moderate thinness is not improving with the current service. It is my delight if I can implement what I learned about how to feed, but I can’t.” Another barrier mentioned by the mothers or caregivers was that MAM is an ignored condition because the management of it is left to the family; however, the children always develop edema within a short period. A 30-years-old mother said: “The problem is that children with moderate thinness were ignored. The surprise here is caregivers have no option to care for their children other than giving family food and breast milk. The service providers are only providing counseling on feeding practice and advising us to follow up with our kids at home.”

The perceived barrier mentioned by the health service providers was that nutrition counseling only is not helpful as the children are progressing to the severe form of acute malnutrition; they further pointed to the fact that there is limited or no provision of supplementary food for MAM. A 34-years-old HEW said: “I think the management services for MAM are less appropriate to people who cannot access food according to our advice. Some can be improved through counseling but not satisfied. Mostly, they progress into severe form. So I think it's better to think about something else.” Likewise, a 31-years old WDA indicated that the children with MAM are not benefited from the management compared with SAM children. She mentioned: “….We are providing a therapeutic supplement to SAM children but we are not giving a therapeutic supplement to children with MAM, it is because of the management guideline of MAM, so that, they are not getting improved as needed."

Theme 4 Mothers or caregivers level barriers

According to mothers or caregivers, the barriers that prevent them from implementing the nutrition counseling were a shortage of food and money, selling-out of self-produced food without reserving sufficient food at home, large household size, and shame on having a child with malnutrition. These were the main obstacles that prevent mothers or caregivers from diversifying the children's diet.

Shortage of food and money

Most respondents felt that the shortage of food and money at home prevented them to implement what they learned about feeding their children with MAM. A 30-years-old-mother said: "To be honest, I have a shortage of food and money in my house. As a result, I was unable to provide my child with better food. My child is a 3-year-old boy; he only eats family food, not baby food. Even if I feed my baby well today, I can't do it tomorrow. I am sure that there are many mothers like me because we know each other. Health professionals are teaching us, without consideration of our circumstances; that is why the counseling has little importance to our children." Another mother of 32 years old said: "The problem with us is that we do not feed our children adequately. It is directly linked to our limited economy. We have a noticeable shortage to implement what we know about child feeding." A 43-years-old grandmother indicated that the counseling service given to the mothers or caregivers of children with MAM is not useful for the poor. She mentioned, "People are offended with the management of MAM like getting only education. I am not interested in education and even not attend the session because it has no help for poor like me.”

Selling out of the self-produced crops without reserving sufficient food at home

Respondents also felt that selling out of all self-produced crops was another obstacle for cash restricted families from having adequate food at home. Even if the farms look green, the families could not be benefited from it. A 35-years-old-mother said: “We cannot say that there is no problem with us, because the sale of all crops cultivated at our farm has made our children hungry.” The respondents also mentioned that there is a disagreement between men and women towards the use of cultivated crops. A 40-years-old WDA worker said: “Our area is looking green right? But most families have nothing to feed their children. In our area, there is a disagreement between husband and wife regarding farm crop use. Men sell self-produced crops without reserving sufficient food at home to get money in which the household remained within sufficient food to eat. That is why families are not getting enough food.”

Large household size

IDIs revealed that the large household size is an obstacle negatively affecting children with MAM. A high number of family members may constrain the mother's capability to monitor her children's feeding practices because they assume the child has been fed somewhere else. A 31-years-old WDA said: “Despite food shortages and financial difficulties for mothers or caregivers, they have still other gaps. For example, they are giving birth to more children with limited spacing because they are not using contraceptives properly.” Likewise, a mother of 33 years old mentioned that the restricted resources might be stretched to supply unexpected visitors in addition to extended family. She mentioned, ”….sometimes you may cook food that is just enough for your family and then the neighbors turn up and you are indebted to feed them too. At that time, your children do not get enough food."

Shame on child malnutrition status

Our respondents mentioned that shame on the malnutrition status of children is one of the barriers that prevent mothers or caregivers from seeking service. Some of the respondents reported that mothers or caregivers whose children become wasted felt that the community may undermine them. A 28-years-old mother said: "when my child wasted I don't want to report to HEWs about my child's case as it is because of food shortage rather I believe and disclose it is because of illness. Otherwise, my neighbors undermine or gossip me as I can't feed my child."

Theme 5 Service provider-level barriers

In addition to the barriers mentioned under the themes of identification of children with MAM and management services of MAM (the occasional house-to-house screening of children for MAM, family-initiated screening, ignoring the management of MAM and leaving the management of MAM responsibility to the family), lack of repeated follow-up by the service providers mentioned as the service provider-level barrier.

Lack of repeated follow-up

Health service providers stated that they lack repeated follow-up of their children with MAM. Most of the time, they just give nutrition counseling to caregivers of children with MAM at the time of admission. A 40-years-old HEW said: "We provide information to the mothers of children with MAM regarding how to feed their affected child consistently and clearly during admission time but I feel that we are not doing it repeatedly. We need to do a repeated follow-up."

Theme 6 Perceived suggestions to improve the service

Both mothers or caregivers and service providers considered management of MAM with counseling of appropriate feeding practice, in addition to a therapeutic supplement, to be a positive option through which the children with MAM will improve. However, they also mentioned some concerns and made related suggestions.

Organized and inclusive counseling

Some said that the counseling service given by the service providers is not focused, routine, and inclusive. They have suggested that it needed to be focused, routine and include all mothers and fathers of children aged below 5 years. A 35-years-old mother said: “Counseling on feeding practice is good but there was no exact time which was known by us and service providers. [It was] not focused and it was not involving all mothers with children under 5 years old. So, it is better to improve in this regard.”

One of the mothers mentioned that where the mothers were not in control of family incomes; thus, they often did not have the authority to implement knowledge of nutritional needs into practices. Even though the mothers provided with nutrition counseling, the husbands were often made the judgment about what food should be bought. Mothers also mentioned since their husbands are not directly involved in nutrition counseling sessions and child feeding, they may not be ready to participate in nutritious food prepared for the children. A 30-years-old mother said: “I am always responsive to my children regarding the preparation of food but I have no economic power to buy nutritious food. I tried to provide nutrition information to my husband that I get from the service providers but he was not being convinced. As to me, it is better to include the husbands in the nutrition counseling session.”

Supplementary feeding

Our respondents mentioned that supplementary feeding is highly needed to manage children with MAM in addition to nutrition counseling. They reported that household food shortages and economical limitations prevented them from implementing nutrition counseling. A 34- years-old-mother said: “feeding children with MAM with supplementary food is the better management option compared to the provision of nutrition counseling only. With nutrition counseling only, most of the children with MAM deteriorate to the severe form.

Discussion

This study attempted to assess barriers to management of moderate acute malnutrition among children aged 6-59 months in Damot Pulassa, Wolaita, South Ethiopia: a phenomenological study of mothers and health service providers. The findings that emerged from this study were possible reasons for MAM, identification of a child with MAM, types of management services of MAM, mothers or caregivers-level barriers, service provider-level barrier, and suggestions to improve the service.

In this study, shortage of child-caring time and lacks of adequate knowledge were mentioned as the possible reasons for MAM. The time constraints of mothers or caregivers in caring for their children have been perceived as a cause of MAM. This is in line with the studies done by Hyder et al. and Berhane et al. showing how an increased workload for women negatively affects their child’s health status and that, if time is made available, improved child health outcomes can be attained [23,24]. Another study done in Uganda, revealed that the heavy workload of the primary caregiver of the child was a major barrier to improving child-feeding practices [25]. However, another study argued that a reduction in the working time of caregivers did not improve their child's health status or affected it negatively [12]. Similarly, a retrospective study done in rural Ethiopia proposed that labor-saving technology was associated with an increased malnutrition rate since it related to increased fertility in women [26].

Our findings have shown that a lack of adequate knowledge towards appropriate childhood feeding practices due to a lack of formal education of mothers mentioned as another possible reason for MAM. This finding is in line with a study done in Uganda showing a lack of adequate knowledge regarding appropriate childhood feeding practices emerged as a barrier to caring for children [27]. Caregiver's lack of adequate knowledge has also been found to be related to spending inadequate time to nourish the child and lacking feeding of sufficient amounts of complementary foods to meet the child's energy and micronutrient requirements [28]. This shows that lack of knowledge may be impacting critical parts of child-feeding and thus, affect child nutritional status negatively.

The findings from this study have shown that occasional house-to-house screening for MAM, screening for MAM through immunization program, and family-initiated screening for MAM were the ways how the health service providers are identifying children with MAM. Occasional house to house screening for MAM might not help to identify all children with MAM and reach the marginalized groups. Screening for MAM during the immunization program might be helpful to identify children below two years because these children are mostly included under the routine immunization program. Family initiated screening is always based on either the symptom-based report of mothers or caregivers or referral from other health units. This shows that mothers or caregivers have a role in the screening of children for MAM though it is the role of health service providers. Further, if the mother didn't report about the status of her child, the child might not be screened for MAM. Thus, occasional house-to-house screening for MAM and family-initiated screening are the service provider-level barriers.

In this study, the screening process was done using only MUAC as a screening tool. There is an increasing understanding that MUAC can be used safely and successfully as the single anthropometric measure for admission, follow-up, and discharge from malnutrition treatment [29, 30]. MUAC is an easy, quick, and powerful screening tool for acute malnutrition at the community level [31]. This is due to the current national guidelines on screening for acute malnutrition. The advantages of MUAC are that it is a better measure to identify children most in need of treatment and it is less prone to mistakes compared to other indices.

The current study has shown that children aged below five years who are admitted to the management program of MAM getting nutrition counseling and follow-up visit(s) as management of MAM. Nutrition counseling is perceived as the primary management service for MAM. As stated by Prinzo and Briend, nutrition advice is provided to families on the assumption that they have access to all foodstuffs required for feeding their children but lack the knowledge of how to implement this knowledge [11].

Mothers or caregivers of children with MAM got monthly counseling on exclusive breastfeeding practices, complementary feeding practices, and preparation of porridge from cereals and vegetables, hygiene, family planning, vaccination, and communicable disease controls. This is in agreement with the results of the meta-analysis done by Lenters et al [8]. Only providing counseling as management to MAM may be because the study area is classified as food secure, even though the respondents reported that they had a shortage of food at home. In Ethiopia, the current strategy for the management of MAM is to restrict supplementary feeding programs to selected districts defined as chronically food insecure. However, in areas not considered as chronically food insecure, there are no food supplementation programs, and instead, there is nutrition counseling [4, 12]. However, there might be food-insecure households in areas seen as food-secure [12].

Our study showed that, once children below 5 years of age are identified as having MAM, the HEWs or WDA workers do monthly visits, in addition to counseling, to check the children's progress. To achieve maximum results in the management of MAM, home visiting is one of the recommended techniques [7]. This might help service providers to easily identify if children with MAM are progressing positively or negatively, and to decide on possible referrals.

In the current study, the respondents claimed that the management service that had been given to their moderately malnourished children is not adequate to treat the condition, since their children have mostly progressed to the severe form of acute malnutrition. Further, as reported by Philip James, in an area where supplementary feeding programs are not accessible for the management of MAM, there is an unsatisfactorily high occurrence of SAM and a low recovery rate [12]. Similarly, another study showed that treatment of MAM with food supplements is more effective than counseling only [10, 32]. This could probably be due to counseling on feeding practices and the actual household food availability is not balanced.

In this study, ignoring the management of children with MAM and leaving the responsibility of managing children with MAM to the family are the service provider-level barriers mentioned by the mothers or caregivers. This shows that MAM is not getting recognition though it progresses to the severe form of acute malnutrition which is life threatening condition.

Our finding showed that household food shortage is perceived as a maternal-level obstacle. This may be because the household's food reserve status is low and the market price of the foods increased. Even if the mothers or caregivers know good feeding practices, they cannot effectively implement nutritional advice because of the shortage of food at home. This finding leads to the idea that, if there was the availability of food at home, nutritional counseling would have improved outcomes. Further, the provision of improved, well-organized, and inclusive counseling may help positively.

Another obstacle perceived by our respondents is their financial limitation. Children who avoided or reduced meals because of lacking money were more likely to be wasted than those who did not [33]. Further, as reported by Abitew DB, low socioeconomic status or monthly income decreases the household purchasing power and hence, reduces access to food [34]. Likewise, another study done in Burkina Faso reported that the higher recovery rate from MAM was where the fair levels of food security, which enabled the effective implementation of nutrition advice at home [32]. The explanation here is that when there is limited access to have nutrient-dense food, the mothers or caregivers cannot feed their child with adequate and diversified food, and thus, the mothers or caregivers can't implement the nutrition counseling they received. Besides, there might be an imbalance between available farmland and household population size.

In the present study selling out of self-produced food without reserving at home was mentioned as the maternal or caregiver-level barrier that influences the implementation of management practice of MAM. To get money in hand, households are doing inappropriate usage of their farm crops.

Our findings have shown that the large household size was one of the barriers that prevent the implementation of nutrition advice given to mothers or caregivers of children with MAM. The food available to larger families per head was frequently lower than that available to smaller families and this difference was reflected in the growth rate [33]. The explanation here might be the imbalance between available food at home and household population size affect the children negatively.

In this study, the findings revealed that women whose children had MAM were ashamed when seeking care and perceived the condition as a sign of insufficient parental care, such as poor food provisioning. This is in line with a study done in Kenya and Malawi showing that caregivers of children with wasting practice stigmatization, as shown in the emotional state of shame, humiliation and embarrassment stated in the process of accessing treatment [35,36]. The explanation here might be child wasting is inseparable from hunger and poverty in the rural community.

Our study revealed that lack of repeated follow-up of children with MAM is considered as a service-provider-level barrier. The explanation here is that follow-up visit(s) is one of the existing management practices of MAM in which the HEWs or WDA workers can provide nutrition counseling and evaluate the progression of a child with MAM. Thus, a lack of repeated follow-up visits will influence the recovery of children from MAM negatively.

The current study has shown that organized and inclusive counseling and provision of supplementary food were identified as the suggestions to improve the existing management practice of MAM. The respondents revealed that the presence of well-organized and focused counseling for beneficiaries is necessary for the management of MAM. This is in agreement with a study done in Burkina Faso showing that nutrition counseling might demonstrate to be a valuable substitute delivered that presence to a counseling session by caregivers is confirmed [32]. Another study done by Natasha Lelijveld reported that the standardization of quality and content of nutrition advice interventions needs concern [37].

In the present study, the findings have shown that including mothers and fathers of children aged below five years in nutrition counseling sessions would have a positive influence on the management of MAM. Men were often decided on different household activities including what food should be bought from the market. This might be due to men are economically powerful and decisive compared to women in developing countries. According to different studies, husbands are considered as the primary spokespersons for their family, and their say and counsel are also very respected by mothers and children in utilizing health-care services [32, 38, 39]. In sub-Saharan Africa, the restricted participation of men in the day-to-day care of the child, child-feeding, and nutrition activities is common even though, the involvements of men have a potential benefit to reduce the burden of work responsibilities faced by caregivers [40].

Our study identified that management of MAM with counseling of appropriate feeding practice in addition to supplementary feeding may have a positive outcome in treating children with MAM. As a study done by Roy et al. shows, children with MAM who were receiving intensive nutrition education only had reduced improvement in nutritional status compared to the children with MAM who received both food supplementation and intensive nutrition education [41]. This shows that children with MAM may need to have supplementary feeding in addition to counseling for them to recover from the condition or to prevent progression to SAM.

The study had some limitations. The main one is that there might be social desirability bias because service providers are included as respondents in in-depth interviews. They might answer the interview questions in such a way that might support the existing management practices for MAM. This bias was alleviated by including mothers or caregivers as respondents in the focus group discussions. We tried to keep complete bracketing but challenged with the opinion of putting aside predetermined knowledge to induce a pure description of the participants experiences. In practice, pure bracketing may be difficult. However, we maintained the bracketing approach by separating our personal experiences and knowledge from reflecting on the lived experiences of the respondents as much as possible. This indicates that the interpretation of the research results was not affected by our beliefs or experiences. This bracketing confirms the validity of results.

In our study, we choose to include mothers or caregivers for the focus group discussions and the most grassroots level health service providers, namely the HEW and WDAs for an in-depth interview. HEWs and WDAs are the main health service providers in the rural areas assigned to manage acute malnutrition. We could have chosen to include staff in the district health office. This could have added perspectives from Wolaita zone health office staff, and enabled a fuller insight into the matter, as well as comparing whether the perception of barriers expressed at the various levels match/differ across the structure within that local context. This is something that can be recommended for a further study of the responsibility levels within the health service system. However, this was seen to go beyond the scope of the present study.

Despite the limitations, the study gives qualitative evidence on the perceptions of mothers/caregivers and service providers on the barriers to existing management practice of MAM among children aged 6-59 months. An intense and in-depth understanding of barriers to existing management practice of MAM were identified and showed in the results. It, therefore, provides support for programs that aim to promote or improve management services for MAM in the area.

Conclusion

MAM among children aged 6 to 59 months has been managed by counseling or nutrition advice only. The identification of children with MAM was based on the measurement of MUAC. Maternal-level barriers and service provider-level barriers affect the management of MAM negatively. Household food shortages and financial limitations, selling out of self-produced food without reserving sufficient food at home, large household size, and shame on child malnutrition status are maternal-level barriers. Occasional house to house screening for MAM, family initiated screening for MAM, leaving the management responsibility of children with MAM to the family, and limited or no provision of therapeutic supplement to children with MAM, and lack of repeated follow-up) are service-provider-level barriers. These obstacles make the management services for MAM inadequate and lead to progression to SAM. In such situations, the government should consider interventions addressing the food shortage and financial constraints of households, in addition to counseling to improve the management services for MAM.

Authors' note

DN, designed the study, analyzed the interview and discussion data, interpreted the result and drafted the manuscript. AH, and BL were responsible for the design of study, assisted to analyze the data and interpret the results as well as critically reviewed the manuscript. All authors were responsible for drafting and revising the document and approved the final version.

Data availability

The datasets used during the current study are available from the corresponding author on reasonable request.

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Declaration of Conflicting Interests

All authors declare that they have no competing interests.

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References

1. Wagner CW, Loechl C, Mokhtar. Moderate acute malnutrition: Uncovering the known and unknown for more effective prevention and treatment. Food and Nutrition Billetin. 2015; 36(1): 1-8
2. Matilsky DK, Maleta K, Castleman T, Manary MJ. Supplementary Feeding with Fortified Spreads Results in Higher Recovery Rates Than with a Corn/Soy Blend in Moderately Wasted Children. Journal of Nutrition. 2009; 139:773-778.
3. World Health Organization and United Nations Children's Fund. *WHO child growth standards and the identification of severe acute malnutrition in infants and children*. Geneva: WHO; 2009.
4. Central Statistical Agency. *Ethiopia Demographic and Health Survey 2011*. Calverton, MD: ICF International; 2012.
5. World Health Organization. *Supplementary foods for the management of moderate acute malnutrition in infants and children 6–59 months of age*. Technical note. Geneva: WHO; 2012.
6. Bhutta ZA, Das JK, Rizvi A, et al. Evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost? Lancet. 2013;382(9890):452–77.
7. Annan RA, Webb P, Brown R. *Management of moderate acute malnutrition: current knowledge and practice*. CMAM Forum Technical Brief; 2014. https://www.ennonline.net › attachments › MAM-management-CMAM-For .

8. Lenters LM, Wazny K, Webb P, Ahmed T, Bhutta ZA. Treatment of severe and moderate acute malnutrition in low- and middle-income settings: a systematic review, meta-analysis and Delphi process. *BMC Public Health*. 2013;13 Suppl 3:S23.

9. Ashworth A, Ferguson E. Dietary counseling in the management of moderate malnourishment in children. *Food Nutr Bull*. 2009;30:S406–33

10. Lazzerini M, Rubert L, Pani P. Specially formulated foods for treating children with moderate acute malnutrition in low- and middle-income countries. *Cochrane Database Syst Rev*. 2013;6:CD009584. https://doi.org/10.1002/ 14651858.CD009584.pub2.

11. Prinzo ZW, Briend A. Dietary management of moderate malnutrition: time for a change. Food Nutr Bull. 2009; 30(3):Suppl:S265–481.

12. James P, Sadlaw K, Wondafrash M, et al. Children with moderate acute malnutrition with no access to supplementary feeding programmes experience high rates of deterioration and no improvement: results from a prospective cohort study in rural Ethiopia. *PLoS One*. 2016;10:1371.

13. Chichiabellu TY, Mekonnen B, Hailemichael F, Astawesegn, Demissie BW, Anjulo AA. Essential newborn care practices and associated factors among home delivered mothers in Damot Pulasa Woreda, southern Ethiopia. *Reproductive Health*. 2018;15:Article 162.

14. Internation Federation of Red Cross and Red Crescent Societies. Ethiopia: *food insecurity revised emergency appeal no*. MDRET005. 2008.

15. Laverty SM. Hermeneutic phenomenology and phenomenology: A comparison of historical and methodo logical considerations. *Int J Qual Methods*. 2003; 2(3): 1-29.

16. Lopez KA, Willis DG. Descriptive versus interpretive phenomenology: Their contribution to nursing knowl edge. *Qual Heal Res*. 2004; 14(5):726-735.

17. Rodriguez A, Smith J. Phenomenology as a healthcare research method. *Evid Based Nurs*. 2018. 21(4): 96-98.

18. Benoot C, Hannes K, Bilsen J. The use of purposeful sampling in a qualitative evidence synthesis: A worked example on sexual adjustment to a cancer trajectory. *BMC Medical Research Methodology*. 2016; 16(21):1-12.

19. Mason M. Sample size and saturation in PhD studies using qualitative interviews. Forum: *Qualitative Social Research*. 2010;11(3). http://dx.doi.org/10.17169/fqs-11.3.1428

20. Roberto Forero, S.N., Josephine De Costa, Mohammed Mohsin, Gerry Fitzgerald, Nick Gibson, Sally McCarthy, Patrick Aboagye-Sarfo, Application of four-dimension criteria to assess rigour of qualitative research in emergency medicine. BMC Health Serv Res, 2018. 18(120): p. 1-11.

21. Morrow R, Rodriguez A, King, N. Colaizzi's descriptive phenomenological method. *The Psychologist.* 2015; 28(8): 643-644.

22. Tong A, SainsburyP, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care*. 2007. 19(6): p. 349-357.

23. Hyder AA, Maman S, Nyoni JE, et al. The pervasive triad of food security, gender inequity and women's health: exploratory research from sub-Saharan Africa. *Afr Health Sci*. 2005;5(4):328–334.

24. Berhane Y, Gossaye Y, Emmelin M, Hogberg U. Women's health in a rural setting in societal transition in Ethiopia. *Soc Sci Med*. 2001;53:1525–39.

25. Nankumbi J, Muliira JK. Barriers to Infant and Child-feeding Practices: A Qualitative Study of Primary Caregivers in Rural Uganda. *J HEALTH POPUL NUTR*. 2015;**33:**106-116.

26. Gibson MA, Mace R. An energy-saving development initiative increases birth rate and childhood malnutrition in Rural Ethiopia. *PLoS Med*. 2006;3(4):e87.

27. Kajjura RB, Veldman FJ, Kassier SM. Maternal perceptions and barriers experienced during the management of moderately malnourished children in northern Uganda. *Matern Child Nutr*. 2020; **16**: p. 1-11.

28. Rasheed S, Haider R, Hassan N, et al. Why does nutrition deteriorate rapidly among children under 2 years of age? Using qualitative methods to understand community perspectives on complementary feeding practices in Bangladesh. *Food Nutr Bull*. 2011; **32**: p. 192-200.

29. Alé FG, Phelan KP, Issa H, et al. Mothers screening for malnutrition by mid-upper arm circumference is non-inferior to community health workers: results from a large-scale pragmatic trial in rural Niger. *Arch Public Health*. 2016;74(1):38.

30. Goossens S, Bekele Y, Yun O, Harczi G, Ouannes M, Shepherd S. Mid-upper arm circumference- based nutrition programming: evidence for a new approach in regions with high burden of acute malnutrition. *PLoS One*. 2012;7(11):e49320.

31. Laillou A, Prak S, de Groot R, et al. Optimal screening of children with acute malnutrition requires a change in current WHO guidelines, as MUAC and WHZ identify different patient groups. *PLoS One*. 2014;9(7):e101159.

32. Nikie’ma L, Huybreqts L, Kolsteren P,et al. Treating moderate acute malnutrition in first-line health services: an effectiveness cluster-randomized trial in Burkina Faso. *Am J Clin Nutr*. 2014;100: 241–9.

33. Ajao KO, Ojofeitim EO, Adebayo AA, Fatusi AO, Afolabi OT. Influence of Family Size, Household Food Security Status, and Child Care Practices on the Nutritional Status of Under-five Children in Ile-Ife, Nigeria. *African Journal of Reproductive Health*. 2010; **14**(4): p. 123-132.

34. Abitew DB, Worku A, Mulugeta A, Bazzano AN. Predictors of relapse of acute malnutrition following exit from community-based management program in Amahara region, Northwest Ethiopia: An unmatched case-control study. *PLoS One*. 2020; **15**(4): p. 1-17.

35. Bliss JR, Njenga M, Stoltzfus RJ, Pelletier DL. Stigma as a barrier to treatment for child acute malnutrition in Marsabit County, Kenya. *Maternal and Child Nutrition*. 2016; **12**: 125-138.

36. Flax VL. ‘It was caused by the carelessness of the parents’: cultural models of child malnutrition in southern Malawi. *Maternal & Child Nutrition*. 2013. **11**(1): 104-108.

37. Lelijveld N, Beedle A, Farhikhtah A, Elrayah EE, Bourdaire J, Aburto N. Systematic review of the treatment of moderate acute malnutrition using food products. *Matern Child Nutr*. 2020; **16**: 1-14.

38. Bredesen JA. “Women’s use of healthcare services and their perspective on healthcare utilization during pregnancy and childbirth in a small village in northern India,.. *American International Journal of Contemporary Research*. 2013; **3**: p. 1-9.

39. Fotso JC, Fogarty L. Progress towards millennium development goals 4 & 5: strengthening human resources for maternal, newborn and child health. *BMC Health Services Research*. 2015; **15**.

40. Aubel J. The role and influence of grandmothers on child nutrition: culturally designated advisors and caregivers. *Matern Child Nutr*. 2012. **8**: 19-35.

41. Roy SK, Fuchs GJ, Mahmud Z, et al. Intensive nutrition education with or without supplementary feeding improves the nutritional status of moderately-malnourished children in Bangladesh. *J Health Popul Nutr*. 2005; 23(4):320–30.

Table 1 Demographic characteristics of FGD participants (N=55)

Characteristics (55)	n (%)
Age of caregivers in years	
19-25	12 (21.8)
26-30	19 (34.5)
31-35	15 (27.3)
>35	9 (16.4)
Marital status	
Married	49 (89.1)
Widowed	6 (10.9)
Relation with the child	
Mother	47 (85.5)
Grandmother	8 (14.5)
Education	
No formal schooling	23 (41.8)
Primary	26 (47.3)
Secondary	6 (10.9)
Occupation	
Housewife	43 (78.2)
Business owner	10 (18.2)
Farmer	2 (3.6)

n: number

Table 2 Demographic characteristics of health service providers (N=10)

Characteristics (10)	n (%)
Age of service providers	
25-30	4 (40)
>30	6 (60)
Marital status	
Single	3 (30)
Married	6 (60)
Widowed	1(10)
Education	
Secondary	2 (20)
Diploma and above	8 (80)

n: number

Table 3 Summary of themes and sub-themes from the interview data

No.	Themes	Sub-themes
1	Possible reasons for MAM	1.1 Shortage of child-caring time
		1.2 Lack of adequate knowledge
2	Identification of child with MAM	1.1 Occasional house-to-house screening using MUAC
		1.2 Screening while immunization session
		1.3 Family-initiated screening
3	Management services of MAM	2.1 Counseling
		2.2 Follow-up visit(s) 2.3 Service adequacy
4	Mothers/caregivers level barriers	5.1 Shortage of food and money
		5.2 Selling out of all self-produced food without reserving sufficient food at home
		5.3 Large household size
		5.4 Shame on child malnutrition status
5	Service provider level barrier	6.1 Lack of repeated follow-up
6	Suggestions	7.1 Organized and inclusive counseling
		7.2 Provision of supplementary feeding

No: number; MUAC: Mid Upper Arm Circumference; MAM: Moderate Acute Malnutrition

Paper II

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ORIGINAL RESEARCH

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Development and nutritional evaluation of local ingredients-based supplements to treat moderate acute malnutrition among children aged below five years: A descriptive study from rural Wolaita, Southern Ethiopia

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Abstract
In Ethiopia, moderate acute malnutrition (MAM) is a persistent public health problem. The current management approaches for MAM among children are counseling in food-secure settings and food supplementation in chronically food-insecure areas. The objective of this study was to develop a local ingredients-based supplement (LIBS) for treating MAM among children. Collection of food ingredients (pumpkin seed, amaranth grain, flaxseed, peanut, and emmer wheat) was made. Sorting, soaking, drying, roasting, and milling of ingredients were done. Nutrient analysis was done using triplicate measurements of each nutrient. One-way ANOVA was used to analyze differences in means with ± standard deviation of nutrient measurements among the supplements. The nutrient content of four developed LIBS ranged from 20.3 g to 22.5 g for protein, 29.3 g to 33.5 g for fat, 509.5 kcal to 570.0 for kcal, 6.0 g to 8.5 g for fiber, 2.8 g to 3.7 g for moisture, and 2.1 g to 4.3 g for ash. The mineral and antinutrient components ranged from 75.6 mg to 115.6 mg for calcium, 473.1 mg to 570.2 mg for potassium, 79.3 mg to 114.4 mg for sodium, 4.1 mg to 5.6 mg for zinc, 8.2 mg to 10.2 mg for iron, 442.6 mg to 470.4 mg for phosphorous, and 2.1 mg to 4.3 mg for phytate. The LIBS with the highest portion of pumpkin seed had significantly highest amounts of protein, fat, calories, iron, zinc, and potassium. The results found were within the recommended range of required nutrients for the treatment of children with MAM. Therefore, LIBS may be used for the management of children with MAM.

KEYWORDS
development, Ethiopia, local ingredients-based supplement, moderate acute malnutrition

1 | INTRODUCTION

Globally, moderate acute malnutrition (MAM) (weight for height < −2 to ≥ −3 Z scores) affects approximately 5% of children below 5 years of age (Black et al., 2013). MAM is widespread in developing countries and a persistent public health problem in Ethiopia (Adamu et al., 2017; Central Statistical Agency (CSA), 2017; ; ;). The 2016 Ethiopian Demographic and Health Survey (EDHS) stated that 38 percent of children below five years of age were stunted, and 10 percent had acute malnutrition (CSA, 2017).

Children with MAM are more likely to suffer delays in their physical growth and cognitive development and are at greater risk of death than well-nourished children (LaGrone et al., 2012). If children with MAM are not adequately managed, MAM can progress to severe acute malnutrition (SAM), which is a life-threatening condition (James et al., 2016; World Health Organization (WHO), 2012; ; ; ; ; ; ; ;).

Children with MAM have nutritional requirements that differ from nonmalnourished and SAM children (WHO, 2012). They need a high energy intake and essential nutrients to recover the existing deficiencies and to support normal growth (Amegovu et al., 2013; Karakochuk et al., 2012). Diets deficient in important nutrients, combined with a high burden of infectious disease, are among the underlying causes of malnutrition in young children (Nga et al., 2013). In 2012, the World Health Organization (WHO) stated that the provision of locally available, nutrient-dense foods can help to improve the nutritional status of MAM children and prevent SAM (WHO, 2012).

A variety of food supplements are presently used to treat MAM (Medoua et al., 2015). These consist of corn-soy blend (CSB) (de Pee & Bloem, 2009); BP5 biscuits (Medoua et al., 2015); and lipid-based nutrient products (Ackatia et al., 2015). Of these therapeutic supplements, the most commonly used is fortified blended flour, mainly CSB prepared as porridge (Medoua et al., 2015; de Pee & Bloem, 2009). However, in addition to the high commodity cost, there are concerns about their long-term sustainability (Isanaka et al., 2019; Nikie'ma et al., 2014).

In nutritional management of MAM, optimal feeding of locally accessible nutrient-dense foods has been shown to be effective at the household level (Ashworth & Ferguson, 2009). These food supplements can be developed from locally available foods that are accessible to all the people and include the necessary amounts of nutrients. Local food ingredients are cheap and can provide key nutrients needed for the effective recovery of children with MAM (Andrew et al., 2013). Therefore, ready-to-use supplementary food (RUSF) made from locally available, nutritionally dense foods might have a positive effect on treating MAM children (Wagh & Deore, 2015).

In resource-limited countries, counseling and either general or targeted distribution of CSB are often given as management of children with MAM (Nikie'ma et al., 2014; de Pee & Bloem, 2009). Unfortunately, the existing management strategy of MAM in Ethiopia is to limit supplementary feeding programs (SFPs) to selected districts of the country defined as chronically food-insecure. There are no food supplementation programs for MAM children in food-secure areas. In these districts, dietary counseling, vitamin A supplementation, and deworming are the strategies used to manage MAM children (James et al., 2016).

Local food materials can be cheap and provide essential nutrients required for the successful recovery of children with MAM. As far as our knowledge is concerned, there is no local development of supplementary food from local ingredients for the treatment of MAM in Ethiopia. On the other hand, WHO recommends the use of locally available, nutritionally dense foods for the treatment of children with MAM (WHO, 2012). In the current work, pumpkin seeds, peanuts, amaranth grain, flaxseeds, and emmer wheat were used in the formulation of four local ingredients-based supplements (LIBS). This paper mainly focuses on the development and quality evaluation of these LIBS. The objective of this study was to develop a local ingredients-based supplement for treating MAM among children.

2 | METHODS

2.1 | Selection of food ingredients

A checklist was prepared to list all food ingredients which are commonly consumed in the study area. Different international nutrient databases, such as the United States Department of Agriculture (USDA), the Food and Agriculture Organization (FAO), as well as national food databases (Ethiopian food composition table), were reviewed to determine the nutritive value of ingredients. The final selection of candidate food ingredients that have the potential to be developed into a supplement was done based on their availability, accessibility, cost, and nutritive value. All selected ingredients (pumpkin seeds, peanuts, amaranth grain, flaxseeds, and emmer wheat) were purchased from the local markets found in the Wolaita zone.

2.2 | Supplement processing

All ingredients were hand-sorted to remove damaged seeds, foreign matter, and shriveled and/or discolored seeds. The small-sized debris was further removed by sieving with perforated shakers. The cleaned pumpkin seed, amaranth grain, and emmer wheat were washed thoroughly with tap water and soaked in salty water. Pumpkin seed was soaked for 12 hr, with draining every four hours. Peanut was soaked for 6 hr. Amaranth grain and emmer wheat were soaked for 12 hr, with draining every six hours. After draining the soaked ingredients, we spread them in the sunlight to dry until they become crispy. The peanut and flaxseed were wiped. Each ingredient was roasted separately at approximately 150°C for approximately 20 min, with continuous stirring, until it developed an aroma. The roasted ingredients

FIGURE 1 Processing flow of local ingredients-based supplement. Collection of selected food ingredients = candidate food ingredients (pumpkin seed, amaranth grain, flaxseed, peanut, and emmer wheat) that have the potential to develop into supplement were collected. Sorting/cleaning = damaged seeds, foreign matter, and the shriveled and/or discolored seeds were removed from all food ingredients by hand-sorting. Soaking in salty water (pumpkin seed, peanut, amaranth grain, and emmer wheat) = the cleaned pumpkin seed, peanut, amaranth grain, and emmer wheat were soaked in salty water. Pumpkin seed for 12 hr with draining every 4 hr; peanut for 6 hr = pumpkin seed was soaked in salty water for 12 hr with draining every 4 hr, and peanut was soaked for 6 hr. Amaranth grain and emmer wheat for 12 hr with the draining of every 6 hr = amaranth grain and emmer wheat were soaked in salty water for 12 hr with draining every 6 hr. Drying in sunlight until they become crispy = all ingredients (pumpkin seed, amaranth grain, flaxseed, peanut, emmer wheat) dried in sunlight until they become crispy. Roasted for 20 min = each dried ingredient was roasted at approximately 150°C for approximately 20 min. Milling to make flour = milling of individual ingredients was done using flour miller. Mixing according to the portion and packing = the flour of ingredients was mixed according to the determined portion of each ingredient to form the supplement and packed

were cooled. After cooling, the peanuts were skinned and separated from seeds by winnowing. Finally, the milling of individual ingredients was done using a flour miller (Figure 1).

2.3 | Supplement development

Determinations of proportion of the supplements' ingredients were done by Nutrisurvey computer software, employing linear programming. Four supplements (LIBS 1, LIBS 2, LIBS 3, and LIBS 4) were formed from the mixture, with different proportions of each ingredient (Table 1). The nutrient content of each formulation was dependent on composition, intended to match the recommended daily allowances for children aged 6 to 59 months (Golden, 2009; WHO, 2012).

2.4 | Nutrient analysis

The nutrient analysis was done at the Ethiopian Health and Nutrition Research Institute (EHNRI) and Hawassa University Food Science Laboratory.

TABLE 1 Proportion of ingredients within food samples/100 gm

Food samples (g)	Pumpkin seed (g)	Peanut (g)	Amaranth (g)	Flaxseed (g)	Emmer wheat (g)
LIBS 1	20	20	20	20	20
LIBS 2	25	20	15	20	20
LIBS 3	25	15	20	25	15
LIBS 4	30	25	20	15	10

Abbreviations: g, gram; LIBS, local ingredients-based supplement.

2.4.1 | Proximate analysis

The standardized procedure of the Association of Official Analytical Chemists (AOAC) was followed to estimate the nutrient composition of the supplements (AOAC, 2005). Triplicate measurement of nutrients was maintained. The moisture content of supplements is significant for their shelf life, with better storage stability maintained by the lower moisture content of the supplement (Sharma & Lakhawat, 2017). The moisture content of the LIBS was determined using AOAC Official Method 925.10 (McCleary et al., 2013), while the determination of ash content was made using AOAC Official Method 923.03—Direct method (AOAC, 2000). The crude fiber content was determined by AOAC Official Method 962.09—Ceramic Fiber Filter method (Derib et al., 2018). The crude fat content was analyzed by using AOAC Official Method 920.39—Soxhelt (AOAC, 2000). Determination of crude protein content was made by ESISO 1871:2013 test method (Derib et al., 2018). Carbohydrate content was calculated by difference including fiber: CHO% = 100-(moisture content% + crude protein% + fat% + fiber% + ash %). Determination of energy was done by using the Atwater's conversion factor: 4 kcal/g for carbohydrate, 4 kcal/g for protein, and 9 kcal/g for fat (Food and Agriculture Organization (FAO), 2003).

2.4.2 | Mineral and antinutrient analysis

Calcium content was determined by using the AOAC Official Method 923.03—EDTA titration (AOAC, 2000; Wu & Wu, 2017). Iron, zinc, potassium, and phosphorus contents were determined by using atomic absorption/emission spectrophotometer equipment. Phytate was determined by using the Latta and Eskin method (Latta & Eskin, 1980), as modified by Vaintraub and Lapteva (1988).

2.4.3 | Determination of the molar ratio of phytate to mineral

In this study, phytate-to-mineral molar ratios were used to determine the inhibitory effects of phytate on the bioavailability of minerals. The molar ratio of phytate and minerals was determined by dividing the weight of phytate and minerals with its atomic weight. Phytate-to-mineral mole ratios were calculated as follows (Borquaye et al., 2017; Gargari et al., 2007):

$$\text{Molar ration} = \frac{\text{Moles of anti} - \text{nutrient}}{\text{Moles of mineral}}$$

The molar mass of the phytate used was 660 g/mol. The recommended critical values used in this work are (phytate: Zn)> 15, (phytate: Fe)> 1, and (phytate: Ca) >0.24 (Borquaye et al., 2017).

2.5 | Quality control

The food ingredients, as well as developed supplements, were stored in areas that were clean and free of rodents. Supplement processing workers received food hygiene training before starting the supplement development process. Constant supervision of supplement processors was done. They received regular medical checkups throughout the supplement development. They also washed and thoroughly dried their hands before processing the supplement and wore clean plastic gloves, hair coverings, and protective coats during supplement development. To prevent the introduction of water into LIBS during development, we restricted the frequency with which the processing equipment was cleaned with soap and water and simply dry-wiped it clean as an alternative.

2.6 | Statistical analysis

Data analysis was carried out using the Statistical Package for the Social Sciences (SPSS 20). Values were expressed as grams with means of triplicates ± standard deviation. The comparison of the difference in proximate, mineral, and antinutrient content among food groups was analyzed using a one-way analysis of variance (ANOVA) and post hoc Tukey's test. The significance of differences was considered at 0.05 level of probability ($p < .05$).

3 | RESULTS AND DISCUSSION

3.1 | Proximate composition

3.1.1 | Protein content

The protein content of the four food supplements ranged from 20.3 g to 22.6 g. LIBS 4 (22.6 g) had significantly higher protein content than the others (Table 2). The protein content of all the four LIBS is within the recommended values of protein for the management of MAM (WHO, 2012). The protein content of LIBS 4 was possibly a result of using the highest proportions of pumpkin seed and peanut while developing this supplement. Pumpkin seed and peanut are good sources of high-quality protein and might contribute considerably to the recommended human daily protein allowance (Settaluri et al., 2012; Sharma & Lakhawat, 2017). Since these two ingredients have a higher protein content, it might be assumed that the addition of pumpkin seed and peanut in this therapeutic supplement has the potential to overcome protein-energy malnutrition.

3.1.2 | Fat content

The fat content of the four food supplements ranged from 29.3 g to 33.5 g. The least amount was found in LIBS 1 (29.3 g), whereas the

TABLE 2 Proximate composition of food supplements/100 gm

Components	LIBS 1	LIBS 2	LIBS 3	LIBS 4
Protein (g)	20.7 ± 0.2^{b}	21.3 ± 0.3^{b}	20.3 ± 0.6^{b}	22.6 ± 0.3^{a}
Fat (g)	29.3 ± 0.4^{c}	31.3 ± 4^{b}	31.6 ± 0.7^{b}	33.5 ± 0.04^{a}
CHO (g)	40.0 ± 0.4^{a}	37.3 ± 0.2^{b}	37.5 ± 0.5^{b}	35.4 ± 1.4^{c}
Fiber (g)	6.5 ± 0.2^{b}	8.3 ± 0.3^{a}	6.0 ± 0.6^{b}	6.0 ± 0.2^{b}
Moisture (g)	3.6 ± 0.1^{a}	3.73 ± 0.2^{a}	2.8 ± 0.3^{b}	3.0 ± 0.1^{b}
Ash (g)	2.47 ± 0.1^{c}	3.6 ± 0.3^{b}	4.3 ± 0.1^{a}	2.1 ± 0.03^{d}

Abbreviations: CHO, carbohydrate; LIBS, local ingredients-based supplement; g, gram.

Values are means of triplicates ± standard deviation. Values with a different superscript in a row are significantly different ($p < .05$).

highest amount of fat was found in LIBS 4 (33.5 g). There was no significant difference in fat content between LIBS 2 and LIBS 3. LIBS 1 was significantly lower in fat content than the other LIBS, whereas LIBS 4 was significantly higher than the others (Table 2). The fat content of all the LIBS is within the range of recommended fat content of therapeutic supplements for MAM (WHO, 2012). LIBS 4 having the highest amount of fat might be due to using the highest proportion of pumpkin seed while formulating it. Pumpkin seed is quite rich in crude fat and oil (Sharma & Lakhawat, 2017). Children with MAM have high energy requirements needing a diet with adequate fat content, which is also required for the absorption of vitamins A and E (Michaelsen et al., 2009). Therapeutic supplements must contain an adequate amount of fat to deliver the required energy to the malnourished child.

3.1.3 | CHO and energy content

In this study, the CHO content of the supplements ranged from 35.4.0 g to 40.0 g. The mean values for LIBS 2 and LIBS 3 were similar. The CHO content of LIBS 1 was significantly higher than the other LIBS (Table 2). The energy values ranged from 509.5 kcal to 532.0 kcal. The energy level of LIBS 4 was significantly higher than the other supplements, whereas LIBS 1 was the lowest. There were no significant differences between LIBS 1, LIBS 2, and LIBS 3. The high energy value in LIBS 4 was possibly as a result of this supplement having the highest amount of fat and protein in it. Concentrated energy is an essential quality of foods developed for children with MAM, given their increased energy requirements (Singh et al., 2011). The energy contents of all four LIBS were beyond the indicated minimum amount of 380 kcal for fortified blended foods (Amegovu et al., 2013).

3.1.4 | Fiber content

The fiber content of the LIBS ranged from 6.0 g to 8.3 g (Table 2). LIBS 2 (8.3 g) had significantly higher fiber content than all other supplements. The high fiber content for LIBS 2 might be due to it having the highest proportion of flaxseed. Flaxseed contains a very high amount of dietary fiber, making it important in the human diet (Singh et al., 2011). Dietary fiber plays a vital role in the digestion process. Mainly, soluble fiber conveys prebiotic properties, whereas insoluble fiber averts constipation (Amegovu et al., 2013). However, constipation is not the most important concern in malnourished children. This leads to recommending a low intake of insoluble fiber in the diets but a high intake of soluble fiber in children. Unfortunately, no limits have been set due to limited evidence on problems caused by insoluble fiber in children (Michaelsen et al., 2009).

3.1.5 | Moisture content

The moisture content of the four LIBS ranged from 2.8 g to 3.7 g. There was no significant difference in the moisture content of LIBS 1 and LIBS 2. Also, there was no significant difference in the moisture content of LIBS 3 and LIBS 4. However, LIBS 1 and LIBS 2 were significantly different from LIBS 3 and LIBS 4 (Table 2). This might be because the moisture content depends on the hydroscopic capacity of the seed, and we used the equal/nearly equal portions of individual ingredients for making LIBS 1 and LIBS 2, and for LIBS 3 and LIBS 4.

The highest moisture content was found in LIBS 2, and the lowest was found in LIBS 3 (Table 2). The moisture content is within the recommended level for the proper storage of dehydrated foodstuff (Codex Alimentarius Commission, 2006).

3.1.6 | Ash content

Total ash content ranged from 2.1 g to 4.3 g. It was significantly different for all supplements. The lowest ash content was found in LIBS 4 (Table 2).

3.2 | Mineral and antinutrient composition

3.2.1 | Calcium content

The calcium content was significantly different among the four supplements. It ranged from 104.6 mg to 115.6 mg/100 g. The calcium content was highest in LIBS 3 (Table 3). The values for all the LIBS are lower than the recommended calcium levels for children with MAM (Amegovu et al., 2014).

TABLE 3 Mineral and antinutrient composition of food samples/100gm

Parameters	LIBS 1	LIBS 2	LIBS 3	LIBS 4
Calcium (mg)	104.6 ± 0.05^{c}	111.1 ± 0.2^{b}	115.6 ± 0.15^{a}	107.0 ± 2.0^{c}
Potassium (mg)	553.4 ± 0.4^{d}	568.0 ± 0.5^{c}	601 ± 0.3^{b}	666.1 ± 0.2^{a}
Phosphorous (mg)	442.6 ± 0.8^{c}	444.6 ± 2.3^{c}	454.5 ± 2.2^{b}	470.4 ± 0.7^{a}
Iron (mg)	8.2 ± 0.1^{c}	9.0 ± 0.2^{b}	8.9 ± 0.5^{b}	10.2 ± 0.1^{a}
Sodium (mg)	104.4 ± 0.03^{a}	98.01 ± 0.08^{c}	79.4 ± 0.1^{d}	88.3 ± 0.3^{b}
Zinc (mg)	4.1 ± 0.1^{b}	4.5 ± 0.2^{b}	4.9 ± 0.01^{b}	5.6 ± 0.2^{a}
Magnesium (mg)	176.2 ± 0.2^{d}	206 ± 0.2^{a}	189.4 ± 0.1^{c}	200.5 ± 0.5^{b}
Phytate (mg)	2.47 ± 0.1^{c}	3.6 ± 0.3^{b}	4.3 ± 0.1^{a}	2.1 ± 0.03^{d}

Abbreviations: LIBS, local ingredients-based supplement; mg, milligrams.
Values are means of triplicates ± standard deviation. Values with a different superscript in a row are significantly different ($p < .05$).

3.2.2 | Potassium content

The potassium content was significantly different among the supplements. It ranged from 553.4 mg to 666.1 mg/100 g. The highest potassium content was found in LIBS 4 (666.1 mg/532 kcal) (Table 3). These levels were relatively similar to the recommended value (1,400 mg/1,000 kcal) (Golden, 2009). All malnourished children have depleted potassium levels. Supplementary foods should contain an adequate amount of potassium to maintain renal and fecal excretion of it (Amegovu et al., 2013).

3.2.3 | Phosphorus content

The phosphorous values ranged from 442.6 mg to 470.4 mg/100 g (Table 3). The least amount of phosphorus was found in LIBS 1, whereas the highest content was found in LIBS 4. These values were similar to the values of phosphorus indicated in the study done by Amegovu and colleagues (Amegovu et al., 2014).

3.2.4 | Iron content

The iron content was significantly different among supplements. It ranged from 8.2 mg to 10.2 mg/100 g. The highest iron content was found in LIBS 4 (10.2 mg/532 kcal), whereas the lowest was found in LIBS 1 (8.2 mg/510 kcal) (Table 3). These values were higher than the recommended levels of iron for the management of MAM (9 mg/1,000 kcal) by Golden (2009). This might be because the ingredients that we used for the development of LIBS 4 were rich in iron.

3.2.5 | Sodium content

The sodium content of the four LIBS ranged from 79.4 mg to 104.4 mg/100 g. The highest amount of sodium was found in LIBS 1 (104.4/510 kcal), whereas the lowest sodium content was found in LIBS 3 (79.4 mg/515 kcal) (Table 3). During malnutrition, the total body sodium is considerably increased. Foods that contain high sodium levels would then be nonbeneficial (Amegovu et al., 2013). In this study, the values for sodium did not exceed the maximum recommended level (500 mg/1,000 kcal) set by WHO (2012).

3.2.6 | Zinc content

The zinc content for the four supplements ranged from 4.1 mg to 5.6 mg/100 g. The zinc content in LIBS 4 was significantly highest, whereas the lowest amount was found in LIBS 1. There were no statistical differences in the zinc contents of LIBS 1, 2, and 3 (Table 3). Zinc is an important mineral that helps in preventing diarrhea in malnourished children (Michaelsen et al., 2009). In this study, the zinc values of the supplements were higher than the food blends used for the management of MAM and close to the recommended values for zinc (Amegovu et al., 2013; Golden, 2009).

3.2.7 | Magnesium content

In this study, the magnesium content of the four supplements varied significantly. It ranged from 176.2 mg to 206 mg/100 g. The lowest amount was found in LIBS 1, whereas highest amount in LIBS 2 (Table 3). The magnesium content found in these newly developed

TABLE 4 Comparison of antinutrient-to-mineral molar ratio with recommended critical values

Molar ratio	LIBS 1	LIBS 2	LIBS 3	LIBS 4	Critical values
Phytate:Zn	0.06^{c}	0.08^{b}	0.09^{a}	0.04^{d}	15
Phytate:Fe	0.03^{b}	0.03^{b}	0.04^{a}	0.02^{c}	1
Phytate:Ca	0.002^{a}	0.002^{a}	0.002^{a}	0.001^{b}	0.24

Abbreviations: LIBS, local ingredients-based supplement.
Values with a different superscript in a row are significantly different ($p < .05$).

TABLE 5 Nutrient composition of the supplementary foods with the established recommendations

Nutrients	LIBS 4 per 1,000 kcal	CSB + per 1,000 kcal	Recommended values per 1,000 kcal
Protein (gm)	42.5	40	20–43
Fat (gm)	63	25.4	25–65
Iron (mg)	19	39	13–20
Zn (mg)	10.5	9.9	20
Calcium (mg)	201	2,117	1,000–1,400
Phosphorous (mg)	884	1,152	850–1,400
Potassium (mg)	1,252	1,487	1,600
Magnesium (mg)	377	170.5	300
Sodium	166	65	<500

Abbreviations: CSB+, corn-soy blend plus; mg, milligram; LIBS, local ingredients-based supplement.

supplements was in line with the study done by Stobaugh HC (Stobaugh et al., 2016), and comparable with the recommended values of magnesium for children with MAM (Golden, 2009; WHO, 2012).

3.2.8 | Phytate content

The phytate levels of all supplements were significantly different (Table 3). The least amount of phytate was found in LIBS 4.

3.2.9 | Phytate-to-mineral ratios

Phytate-to-zinc, phytate-to-iron, and phytate-to-calcium molar ratios were below the recommended critical values for any supplement (Table 4). Phytate is known to reduce the bioavailability of minerals, mainly Zn, Ca, Mg, and Fe because it has a strong binding affinity to minerals. When a mineral binds to phytic acid, it converts into insoluble form, precipitates, and will not be absorbable in the intestines. Thus, its high intake can cause mineral deficiency and undesirable (Gargari et al., 2007; Hurrell, 2003). The normal level of phytate-to-mineral molar ratio identified in this study showed that there is a good bioavailability of minerals for all newly formulated supplements. This might be because of soaking the ingredients with salty water for several hours as a supplement processing step. As a study done by Ochola, food processing steps like soaking of grains and germinating can reduce the phytic acid (Ochola, 2013).

3.2.10 | Comparison of the nutrient composition of LIBS 4 with the recommended levels for children with MAM

Among the newly formulated supplements, LIBS 4 is differently high in protein, fat, energy, iron, zinc, phosphorous, and potassium. The other nutrients of LIBS 4 such as magnesium, calcium, and sodium had lower values compared with the highest values among LIBSs. The amount of these nutrients were comparable with the recommended daily allowances for children aged 6–59 months with MAM, and it is also comparable with the conventional therapeutic food (CSB+) for the treatment of children with MAM (Amegovu et al., 2013; Golden, 2009; WHO, 2012) (Table 5).

4 | CONCLUSIONS AND RECOMMENDATIONS

Supplementary food for children with MAM aged 6–59 months, as evaluated in the present study, has been successfully developed using pumpkin seed, peanut, amaranth grain, flaxseed, and emmer wheat, which are locally available ingredients. The results found were within the recommended range of required nutrients except for calcium. Specifically, LIBS 4 contains an optimal amount of nutrients desirable for the treatment of children with MAM. LIBS 4 may, therefore, be used for the management of children with MAM in the rural community.

There is a need to determine the shelf life of the developed supplements and do a cost analysis of the superior supplement. Clinical trials need to be carried out to test the effectiveness of the developed supplements compared with other supplementary food in treating MAM among children. Fortification of the formulation with micronutrients such as ascorbic acid and calcium is also recommended. Production of ingredients should be enhanced to make ingredients readily available and ensure sustainability.

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CONFLICT OF INTEREST

All authors declare that they have no competing interests.

ETHICAL REVIEW

This study was approved by the Hawassa University College of Medicine and Health Sciences Institutional Review Board (IRB/024/10) and regional committees for medical and health research ethics in Norway (2018/69/REK vest).

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REFERENCES

Ackatia-Armah, R. S., McDonald, C. M., Doumbia, S., Erhardt, J. G., Hamer, D. H., & Brown, D. H. (2015). Malian children with moderate acute malnutrition who are treated with lipid-based dietary supplements have greater weight gains and recovery rates than those treated with locally produced cereal-legume products: A community-based, cluster-randomized trial. *American Journal of Clinical Nutrition*, *101*, 634–645. https://doi.org/10.3945/ajcn.113.069807

Adamu, W., Jara, D., Alemayehu, M., & Burrowes, S. (2017). Risk factors associated with poor health outcomes for children under the age of 5 with moderate acute malnutrition in rural Fagita Lekoma District, Awi Zone, Amhara, Ethiopia. *BMC Nutrition*, *3*, 88. https://doi.org/10.1186/s40795-017-0208-5

Amegovu, A. K., Ochola, S., Ogwok, P., Yiga, P., Musalima, J., & Juliana, M. (2014). Efficacy of sorghum-peanut blend and corn-soy blend plus in the treatment of moderate acute malnutrition in children aged 6–59 months in Karamoja, Uganda: A cluster randomized trial. *Nutrition and Dietary Supplements*, *6*, 75–84. https://doi.org/10.2147/NDS.S64720

Amegovu, A. K., Ogwok, P., Ochola, S., Yiga, P., Musalima, J. H., & Mutenyo, E. (2013). Formulation of a sorghum-peanut blend using linear programming for treatment of moderate acute malnutrition in Uganda. *Journal of Food Chemistry and Nutrition*, *01*, 67–77. https://doi.org/10.2147/NDS.S64720

Ashworth, A., & Ferguson, E. (2009). Dietary counseling in the management of moderate malnourishment in children. *Food and Nutrition Bulletin*, *30*, S405–S433. https://doi.org/10.1177/15648265090303S304

Association of Official Analytical Chemists (AOAC) (2000). *Official methods of analysis of AOAC International*, 17th ed. Gaithersburg, MD: Association of Official Analytical Chemists.

Association of Official Analytical Chemists (AOAC) (2005). *Official methods of analysis of AOAC International*, 18th ed. Gaithersburg, MD: Association of Analytical Communities.

Black, R. E., Victora, C. G., Walker, S., Bhutta, Z. A., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., Uauy, R. & Maternal and Child Nutrition Study Group (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet*, *382*, 427–451. https://doi.org/10.1016/S0140-6736(13)60937-X

Borquaye, L. S., Darko, G., Laryea, M. K., Gasu, E. N., Amponsah, N. A. A., & Appiah, E. N. (2017). Nutritional and anti-nutrient profiles of some Ghanaian spices. *Cogent Food & Agriculture*, *3*(1348185). https://doi.org/10.1080/23311932.2017.1348185

Central Statistical Agency (CSA) – Government of Ethiopia (2017). *Ethiopia demographic and health survey 2016*. Ethiopia: Addis Ababa. https://microdata.worldbank.org/index.php/catalog/2886

Codex Alimentarius Commission (2006). *Codex standard for processed cereal-based foods for infants and young children (CODEX STAN 074-1981, REV. 1-2006)*. Retrieved from http://www.sciepub.com/reference/232485

de Pee, S., & Bloem, M. W. (2009). Current and potential role of specially formulated foods and food supplements for preventing malnutrition among 6- to 23-month-old children and for treating moderate malnutrition among 6- to 59-month-old children. *Food and Nutrition Bulletin*, *30*(3 Suppl), S434–S463. https://doi.org/10.1177/15648265090303S305

Derib, A., Wegayehu, F., Amhaeyesus, B., Mitiku, A., & Weldetsadik, K. (2018). Characterization of teff (Eragrostis tef Zucc. Trotter [cv. Magna]) in Minjar Shenkora district of central Ethiopia. *African Journal of Food, Agriculture, Nutrition and Development*, *18*, 13664–13676.

Food and Agriculture Organization (FAO). (2003). *Food energy – methods of analysis and conversion factors*. FAO Food and Nutrition Paper 77. http://www.fao.org/3/Y5022E/Y5022E00.htm

Gargari, B., Mahboob, S., & Razavieh, S. (2007). Content of phytic acid and its mole ratio to zinc in flour and breads consumed in Tabriz, Iran. *Food Chemistry*, *100*, 1115–1119. https://doi.org/10.1016/j.foodchem.2005.11.018

Golden, M. H. (2009). Proposed nutrient requirements of moderately malnourished populations of children. *Food and Nutrition Bulletin*, *30*(3 Suppl), S237–S342. https://doi.org/10.1177/15648265090303S302

Hurrell, R. F. (2003). Influence of vegetable protein sources on trace element and mineral bioavailability. *Journal of Nutrition*, *133*(9), 2973S–2977S.

Isanaka, S., Barnhart, D. A., McDonald, C. M., Ackatia-Armah, R. S., Kupka, R., Doumbia, S., Brown, K. H., & Menzies, N. A. (2019). Cost-effectiveness of community-based screening and treatment of moderate acute malnutrition in Mali. *BMJ Gloalb Health*, *4*(2), e001227. https://doi.org/10.1136/bmjgh-2018-001227

James, P., Sadler, K., Wondafrash, M., Argaw, A., Luo, H., Geleta, B., Kedir, K., Getnet, Y., Belachew, T., & Bahwere, P. (2016). Children with moderate acute malnutrition with no access to supplementary feeding programmes experience high rates of deterioration and no improvement: Results from a prospective cohort study in rural Ethiopia. *PLoS One*, *11*(4), e0153530. https://doi.org/10.1371/journal.pone.0153530

Karakochuk, C., van den Briel, T., Stephens, D., & Zlotkin, S. (2012). Treatment of moderate acute malnutrition with ready-to-use supplementary food results in higher overall recovery rates compared with a corn-soya blend in children in southern Ethiopia: An operations research trial. *American Journal of Clinical Nutrition*, *96*, 911–916. https://doi.org/10.3945/ajcn.111.029744

LaGrone, L. N., Trehan, I., Meuli, G. J., Wang, R. J., Thakwalakwa, C., Maleta, K., & Manary, M. J. (2012). A novel fortified blended flour, corn-soy blend “plus-plus”, is not inferior to lipid-based ready-to-use supplementary foods for the treatment of moderate acute malnutrition in Malawian children. *American Journal of Clinical Nutrition*, *95*, 212–219. https://doi.org/10.3945/ajcn.111.022525

Latta, M., & Eskin, M. (1980). Simple and rapid colorimetric method for phytate determination. *Journal of Agricultural and Food Chemistry*, *28*, 1315–1317.

McCleary, B. V., Sloane, N., Draga, A., & Lazewska, I. (2013). Measurement of total dietary fiber using AOAC method 2009.01: Evaluation and updates. *Cereal Chemistry*, *90*, 396–414. https://doi.org/10.1094/CCHEM-10-12-0135-FI

Medoua, G. N., Ntsama, P. M., Ndzana, A. C. A., Essa’a, V. J., Tsafack, J. J. T., & Dimodi, H. T. (2015). Recovery rate of children with moderate acute malnutrition treated with ready-to-use supplementary food (RUSF) or improved corn-soya blend (CSB+): A randomized controlled trial. *Public Health Nutrition*, *19*, 363–370. https://doi.org/10.1017/S1368980015001238

Michaelsen, K. F., Hoppe, C., Roos, N., Kaestel, P., Stougaard, M., Lauritzen, L., Mølgaard, C., Girma, T., & Friis, H. (2009). Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age. *Food and Nutrition Bulletin*, *30*(3 Suppl), S343–S404. https://doi.org/10.1177/15648265090303S303

Nga, T. T., Nguyen, M., Mathisn, R., Hoa, D. T. B., Minh, N. H., Berger, J., & Wieringa, F. T. (2013). Acceptability and impact on anthropometry of a locally developed ready to use therapeutic food in pre-school children in Vietnam. *Nutrition Journal*, *12*, 120(2013). https://doi.org/10.1186/1475-2891-12-120

Nikièma, L., Huybregts, L., Kolsteren, P., Lanou, H., Tiendrebeogo, S., Bouckaert, K., Kouanda, S., Sondo, B., & Roberfroid, D. (2014). Treating moderate acute malnutrition in first-line health services: An effectiveness cluster-randomized trial in Burkina Faso. *American Journal of Clinical Nutrition*, *100*, 241–249. https://doi.org/10.3945/ajcn.113.072538

Ochola, S. (2013). Effect of steeping and germination on the diastatic activity and sugar content in amaranth grains and viscosity of porridge. *Journal of Agriculture and Food Technology*, *3*(1), 1–7.

Settaluri, V., Kandala, C., Puppala, N., & Sundaram, J. (2012). Peanuts and their nutritional aspects: A review. *Food and Nutrition Sciences*, *3*(12), 1644–1650. https://doi.org/10.4236/fns.2012.312215

Sharma, G., & Lakhawat, S. (2017). Development, quality evaluation and acceptability of pumpkin seed flour incorporated in gravy. *Journal of Nutrition & Food Sciences*, *7*(4), 1000613, https://doi.org/10.4172/2155-9600.1000613

Singh, K. K., Mridula, D., Rehal, J., & Barnwal, P. (2011). Flaxseed: A potential source of food, feed and fiber. *Critical Reviews in Food Science and Nutrition*, *51*(3), 210–222. https://doi.org/10.1080/10408390903537241

Stobaugh, H. C., Ryan, K. N., Kennedy, J. A., Grise, J. B., Crocker, A. H., Thakwalakwa, C., Litkowski, P. E., Maleta, K. M., Manary, M. J., & Trehan, I. (2016). Including whey protein and whey permeate in ready-to-use supplementary food improves recovery rates in children with moderate acute malnutrition: A randomized, double-blind clinical trial. *American Journal of Clinical Nutrition*, *103*(3), 926–33. https://doi.org/10.3945/ajan.115.124636

Vaintraub, I. A., & Lapteva, N. A. (1988). Colorimetric determination of phytate in unpurified extracts of seeds and the products of their processing. *Analytical Biochemistry*, *175*(1), 227–230. https://doi.org/10.1016/0003-2697(88)90382-X

Wagh, V. D., & Deore, B. R. (2015). Ready to use therapeutic food (RUTF): An overview. *Advances in Life Science and Health*, *2*(1), 11–15.

World Health Organization (WHO) (2012). *Technical note: Supplementary foods for the management of moderate acute malnutrition in infants and children 6–59 months of age*. Geneva: WHO. https://apps.who.int/iris/handle/10665/75836

Wu, S., & Wu, Y. (2017). Proximate composition and nutritional evaluation of the adductor muscle of pen shell. 3. *Biotech*, *7*(3), 160. https://doi.org/10.1007/s13205-017-0840-4

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Paper III

PLOS ONE

RESEARCH ARTICLE

A local-ingredients-based supplement is an alternative to corn-soy blends plus for treating moderate acute malnutrition among children aged 6 to 59 months: A randomized controlled non-inferiority trial in Wolaita, Southern Ethiopia

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Abstract

Background

Globally, moderate acute malnutrition (MAM) affects approximately 5% of children below five years of age. MAM is a persistent public health problem in Ethiopia. The current approach in Ethiopia for managing MAM is a supplementary feeding program; however, this is only provided to chronically food-insecure areas. The objective of the study was to compare a local-ingredients-based supplement (LIBS) with the standard corn-soy blend plus (CSB+) in treating MAM among children aged 6 to 59 months to test the hypothesis that the recovery rate achieved with LIBS will not be more than 7% worse than that achieved with CSB+.

Methods and findings

We used an individual randomized controlled non-inferiority trial design with two arms, involving 324 children with MAM aged 6 to 59 months in Wolaita, Southern Ethiopia. One hundred and sixty-two children were randomly assigned to each of the two arms. In the first arm, 125.2 g of LIBS with 8 ml of refined deodorized and cholesterol-free sunflower oil/day was provided. In the second arm, 150 g of CSB+ with 16 ml of refined deodorized and cholesterol-free sunflower oil/day was provided. Each child was provided with a daily ration of either LIBS or CSB+ for 12 weeks. Both intention-to-treat (ITT) and per-protocol (PP) analyses were done. ITT and PP analyses showed non-inferiority of LIBS compared with CSB+ for recovery rate [ITT risk difference = 4.9% (95% CI: -4.70, 14.50); PP risk difference = 3.7% (95% CI: –5.91, 13.31)]; average weight gain [ITT risk difference = 0.10 g (95% CI: -0.33 g, 0.53 g); PP risk difference = 0.04 g (95% CI: -0.38 g, 0.47 g)]; and recovery time [ITT risk difference = -2.64 days (95% CI: -8.40 days, 3.13 days); PP difference -2.17 days

(95% CI: -7.97 days, 3.64 days]. Non-inferiority in MUAC gain and length/height gain was also observed in the LIBS group compared with the CSB+ group.

Conclusions

LIBS can be used as an alternative to the standard CSB+ for the treatment of MAM. Thus, the potential of scaling up the use of LIBS should be promoted.

Trial registration

Pan-African Clinical Trial Registration number: PACTR201809662822990.

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

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Introduction

Globally, acute malnutrition remains a major public health problem, affecting an estimated 55 million children below five years of age [1, 2]. Acute malnutrition occurs when there is severe weight loss [3] possibly caused by inadequate energy and protein intake [4], and infections. Such events frequently occur during periods of prolonged food insecurity, poverty, poor feeding practices, and inadequate household food accessibility [5, 6]. When a repeated episode of acute malnutrition occurs, often along with infections, it can lead to stunting (chronic malnutrition) [3, 7, 8]. Sometimes, especially if the child is less than two years of age, it can also affect other developmental features such as brain impairment [9].

Acute malnutrition is categorized as moderate or severe [7]. Moderate acute malnutrition (MAM) is defined as weight-for-height z-score (WHZ) between -3 and -2 z-scores of the WHO Child Growth Standards median and/or mid-upper arm circumference (MUAC) between $\geq$11.5 cm and <12.5 cm without bipedal edema [10–12]. Severe acute malnutrition (SAM) is defined as WHZ <-3 SD or a MUAC of <110 mm, or the presence of nutritional edema [7, 13]. According to the Ethiopian Demographic Health Survey (EDHS) 2011, about 10% of children aged below five years of age suffered from acute malnutrition, and among these, 70% had MAM [14]. Children with MAM have a three-fold higher risk of morbidity and mortality than their normal counterparts [1, 15].

There is presently no standardized approach for managing MAM, especially in relatively food secure settings of low- and middle-income countries [12, 16, 17]. In Ethiopia, the current approach for the management of MAM is a supplementary feeding program (SFP), although this is limited to areas where chronic food insecurity exists. In districts not determined to be persistently food insecure, there are no food supplementation strategies for children with MAM. In these districts, the approach to managing children with MAM includes vitamin A supplementation, deworming, and dietary counseling delivered to the caregivers of children [14, 18].

Children with MAM are commonly treated with fortified blended flours, especially corn-soy blend (CSB), super cereal/corn-soy blend plus (CSB+), and super cereal plus/corn-soy blend plus with milk and oil (CSB++) [12, 15, 19]. The current food blends used for managing MAM are CSB+ and CSB++. CSB+ contains corn (64%), whole soya beans (24%), sugar (10%), vegetable oil, and vitamin and mineral premix. CSB++ is made from corn (58%), dehulled soya beans (20%), dried skim milk powder (8%), sugar (10%), vegetable oil, and vitamin and mineral premix; it is used as a complement to breast milk. The combinations of the cereal (corn or maize) and the legume (soya bean) were refined, blended, and precooked (by roasting) for children with MAM below five years of age [12]. These standard food supplements are effective in treating MAM; however, such management is temporary and unsustainable for managing recurrent malnutrition in poverty-hit countries [15].

The dietary management of MAM could be done by using locally accessible nutrient-dense foods [11]. Local ingredients that are available and accessible can be developed at the household level; they are easy to develop, cheap, and yet contain adequate amounts of the required nutrients [15]. In this paper, the new supplement is referred to as a local-ingredients-based supplement (LIBS); it is made of locally available ingredients such as pumpkin seed, peanut, amaranth grain, flaxseed, and emmer wheat. The proportions of these ingredients were designed to have the required amount of nutrients for managing MAM among children aged 6 to 59 months [11].

Different studies showed that CSB+ had similar effects of treating MAM compared to other food supplements prepared for the treatment of MAM [10, 15, 20]. The differences are too narrow to feasibly conduct a superiority trial. We, therefore, conducted a non-inferiority trial to determine whether LIBS is at least as effective as CSB+ in treating MAM.

To resolve the limited delivery of supplements among children with MAM, the usefulness of LIBS needs to be explored. Besides this, adequate research has not been conducted in Ethiopia on supplementary food that was developed using locally available ingredients, even though it has the potential to contribute to treating MAM. This study aims to evaluate if children aged 6 to 59 months suffering from MAM, treated with 125.2g of LIBS and 8 ml of sunflower oil/day, for 12 weeks, would not have an inferior recovery rate compared to similar children treated with 150 g CSB+ and 16 ml of sunflower oil/day (with a 7% margin of non-inferiority).

Materials and methods

Ethics approval and consent to participate

This study was approved by the Hawassa University College of Medicine and Health Sciences Institutional Review Board (IRB/024/10) and Regional Committees for Medical and Health Research Ethics in Norway (2018/69/REK vest). The approval obtained from the institutional review boards covered all sites included in the study. The purpose of the study and methods of data collection, confidentiality, and voluntary participation were explained to the mothers of children who were invited to sign an informed consent form. Verbal (getting thumb marks after reading the information) and written informed consent were obtained from all caregivers of children who met enrollment criteria before the recruitment of their children into the study. All interviews and intervention procedures were conducted in privacy.

This trial was registered at Pan-African Clinical Trial Registration as PACTR201809662822990. The authors confirmed that all ongoing and related trials for these food supplements were registered.

Subject and setting

We conducted the study in Damot Pulassa district in the Wolaita zone in the South-Western part of Ethiopia, where there is a high level of food insecurity and child malnutrition. Damot Pulassa is characterized by having fragmented farm and land ownership. Damot Pulassa has the highest population density in Ethiopia reaching up to 600 persons per square kilometer in some *Kebeles* (smallest administrative units) of it. The discrepancy between population and land balance has by far continued to be the primary cause of endemic food insecurity in the area [21]. According to a study protocol of this trial, Damot Pulassa district is characterized as maize and root crop livelihood area as these are the main crops cultivated in the district [5]. This district has five health centers and 23 health posts (one per *kebele*) that are led by health extension workers. These health facilities deliver nutrition-linked services like counseling on feeding practices, screening for nutritional status of young children, and nutritional management of acutely malnourished children.

Damot Pulassa district (Woreda) was purposely selected based on a consideration of the high level of food insecurity, high level of child malnutrition, and access to transportation. All the kebeles in the district had similar admission loads to the management program of MAM, for practical reasons, six out of the 23 kebeles were randomly selected for the study. Children aged 6 to 59 months with MAM, living in selected *kebeles* of Damot Pulassa district were included in the study. Children were excluded if they had SAM (based on WHO 2009 child growth standards), and/or if they had bilateral pitting edema [22], or had any illness or other medical complications that prevented the children from safely consuming supplementary food. The trained research teams and HEWs assessed the children for SAM. Medical complications of children were assessed by the senior pediatric nurse working in the below five years clinic. Children were also excluded if they were simultaneously involved in another supplementary feeding program. Recruited children were identified as MAM according to their MUAC values, and not only according to the values of weight-for-height/length z-scores. The respondents were mothers or caregivers of selected children.

Study design and intervention

This study was a randomized, controlled, non-inferiority trial that assessed the efficacy of 125.2 g of LIBS with 8 ml of refined deodorized and cholesterol-free sunflower oil/day (the intervention), compared with conventional treatment, which is CSB+ in the amount of 150 g of CSB+/day with 16 ml of refined deodorized and cholesterol free-sunflower oil (the control), in treating MAM for 12 weeks.

Outcome variables and quality measurements

The primary outcome was recovery rate: percentage of children who attained a MUAC $\geq$12.5 cm and/or WHZ $\geq$ -2 without bipedal edema at the end of 12 weeks. The secondary outcomes were the mean recovery time (the duration within 12 weeks in which the child recovered from MAM) and average weight gain. Children who progressed to SAM during the study or persisted as moderately malnourished at the end of the 12-week follow-up were considered to have failed management for MAM. The selection of outcome measures was based on similar studies [15, 20, 23].

There were two research teams, each team consisted of one supervisor, six data collectors, and eighteen food distributors (selected females living in the study area). The supervisors and data collectors were trained by the principal investigator for seven days before the start of study. The training covered the objectives of the study, data collection systems, questions found in the questionnaire, interview techniques, and anthropometric measurements. Training in anthropometric measurement techniques, periodic standardization, and daily calibration of equipment was done based on WHO recommendations for anthropometric measurement protocols [24]. Before study start, the female food distributors were trained for five days on a daily supplement distribution, cooking of supplementary foods such as porridge and feeding of a child.

When the child was a twin, we provided an additional amount of supplementary food to the caregiver to ensure that the enrolled child was fed with a full portion. When two children with MAM were found in the same household, we provided similar supplements for both children but only the randomly selected child was taken as a study subject. When the recruited child was not at home during the time of follow-up, data collectors and food distributers revisited such households until they found the child. Supervisors oversaw activities daily. The food distribution process, feeding techniques, and use of the provided food supplements were monitored among randomly selected households on a twice-monthly basis.

Sample size calculation

We calculated the sample size to investigate if LIBS was not inferior to CSB+ in terms of the recovery rate among children with MAM aged 6 to 59 months. The sample size was calculated based on 80% power of the test, 7% margin of non-inferiority, and assuming a recovery rate with CSB+ of 67%. Considering the above assumptions, a total of 324 children (162 subjects per study group), allowing for a 10% withdrawal rate were required to be sure that the lower limit of a two-sided 95% confidence interval (CI) was above the -7% margin of non-inferiority. The anticipated 10% dropout rate was used based on the observed dropout rate reported in two studies [11, 24]. The non-inferiority margin (-7%) was set depending on the previous studies that showed the comparator group (children who received CSB) had a recovery rate from MAM of 67% [19] and the recovery rate from MAM without any treatment was 54% [18], hence the difference is 13%. The non-inferiority margin was specified considering that the LIBS group has at least a 7% (the average of the difference of two proportions) higher recovery rate than in a group with no supplementary food (placebo). This was based on the recommendations of selecting a non-inferiority margin [25] For this sample size calculation, the Pharma-School sample size calculator for non-inferiority trials was used.

Recruitment of study participants

The trained data collectors, accompanied by health extension workers, visited all households found in selected *kebeles* (Waribira Golo, Bibiso Olola, Waribira Suke, Shanto, Tomtome, and Lera) in Damot Pulassa district with children aged 6 to 59 months, to assess children for eligibility by measuring MUAC. The recruitment was done from August 27 to September 20, 2018. Children with MUAC $<$12.5 cm were recorded and brought to the actual screening site with their mother/caregiver, where MUAC was re-measured, and weight and height or length were taken. In addition to the values of MUAC (i.e. between $\geq$11.5 cm and $<$12.5 cm), we used the WHZ or weight for length z-score for recruitment (i.e. WHZ: between −3 and −2 Z-scores). When the child was identified as moderately malnourished according to the MUAC and not according to the values of weight-for-height/length z-scores, we recruited them according to their MUAC values. Children aged 6 to 23 months were measured for weight and length, and children aged 24 to 59 months were measured for weight and height. Edematous malnutrition was also assessed using the bilateral pitting edema criterion. The screening for MAM was continued until the sample size was met.

Randomization

A computer-generated randomization list that contained codes was prepared using random allocation software. The allocation ratio was 1:1. Mothers selected an envelope containing coded numbers that matched with one of the two supplementary foods. A research assistant who was not otherwise involved with the study implemented the randomization process. After randomization, the investigator further classified children into sub-groups, with equal numbers of subjects based on their neighborhood. This was done to facilitate assigning one food distributor per sub-group, where food distributors simply had to access the households with a selected child. The food distribution process was organized by the research assistant who was aware of which number corresponded to which food. This person did not take part in the food distribution.

Blinding

This study was double-blinded, that are, caregivers, data collectors, and food distributors were blinded for the intervention. Both supplements were packed with the same plastic packs, similar in color and texture, and they were prepared and distributed in the same way. The sugar which was provided for the intervention group was blended with the flour before packing. Sunflower oil was distributed with the supplement for both intervention and control groups. Food distributors were assigned to support caregivers in cooking the porridge with 8 ml of oil for the intervention group and with 16 ml of oil for the CSB+ group. We distributed the oil with colored plastic cups.

Data collection and follow-up

Before introducing the interviews, the study questionnaires were subjected to pilot-testing and were refined for clarity and correctness. The interviews were conducted with selected caregivers of children with MAM aged 6 to 59 months, for collecting baseline information such as socio-demographic and economic status, child's age, dietary habits, breastfeeding practices, and history of child and maternal illness. The child's weight was measured with a Seca weight scale to the nearest 0.1 kg. The data collectors ensured that the scale was positioned on a flat, firm surface, and weighing was done with light clothing.

The length was measured to the nearest 0.1 cm, using a locally prepared wooden measuring board for children aged 6 to 23 months. For children aged 24 to 59 months, height was measured to the nearest 0.1 cm using a Seca height scale. Before height measurement, the data collectors ensured that the height board was on level ground and the child was barefoot; the collector kneeled to get to the level of the child and encouraged the caregiver to help. For length, data collectors measured the child lying down, being sure that the length board was placed on a flat and stable surface.

MUAC was assessed by non-stretchable standard United Nations Children's Fund (UNICEF) plastic tape measures. The measurement was taken halfway between the acromion and olecranon processes, with the measuring tape fitting comfortably, but without making a depression on the left upper arm. This was done twice for every child, using two different data collectors, and the average of the two measures was recorded to the nearest 0.1 cm. Participants in both groups were visited every week for consecutive 12weeks to collect anthropometric measurements using MUAC, and information on supplement use and morbidity. Every month, anthropometric data were collected with identical equipment as used at baseline. Bilateral pitting edema was assessed by pressing for three seconds on the dorsum of the foot. Based on the follow-up measurement of anthropometry, children who developed SAM were sent to the SAM clinic.

Description of interventions and distribution of supplements

Subjects in the intervention group received a daily ration of 125.2 g of LIBS with 8 ml of refined deodorized and cholesterol-free sunflower oil for 12 weeks. The composition of LIBS was: 30 g of pumpkin seed, 25 g of peanut grain, 20 g of amaranth grain, 15 g of flaxseed, 10 g of emmer wheat, and 25.2 g of cane sugar with 8 ml of refined deodorized and cholesterol-free sunflower oil. This supplement (one serving) yielded 699 kcal, 22.6 g protein, 56.9 g carbohydrate, and 40.89 g fat. The cane sugar was added to LIBS in which the taste of LIBS made better and the amount of calories that should come from carbohydrates was improved but still lower than the level of carbohydrate found in the CSB+ (conventional food provided for children with MAM in the control group). Likewise, children in the control group received 150 g of CSB+/day with 16 ml of refined deodorized and cholesterol-free sunflower oil; this yielded 751 kcal, 21.25 g protein, 95 g carbohydrate, and 31.76 g fat daily for 12 weeks. The participants from both groups were served the supplements in the morning as breakfast (Table 1). Children aged 6–23 months and 24 to 59 months received a similar amount of food [24]. The food distributors who were trained for the preparation of porridge visited each household daily to provide the supplement and help the caregivers in the preparation of the porridge and feeding, to advise, assess, and resolve problems with feeding. The 150g of CSB+ was diluted with 600 ml water and cooked for 10 to 15 minutes whereas the 125.2g of LIBS was diluted with 400 ml water and cooked for 10 to 15 minutes. The food distributors checked and measured the amount of supplements consumed by the children using the local measuring cup with numbers. In case of not consuming all the prepared porridge, re-feeding was done.

Data analysis

The field supervisors controlled all data collection sheets for completeness. Data entry was done using Epi Data v. 3.1. (Odense, Denmark). Double data entry was done simultaneously to ensure data quality. According to the recommendations for analyzing and reporting equivalence and non-inferiority trials, both intention-to-treat (ITT) and per-protocol (PP) analyses were done, and the 95% CI level was used to interpret any differences [24]. The ITT analyses involved all patients who were randomly allocated, whereas the PP analysis excluded children who refused, transferred out of the management program, or were lost to follow-ups, but included children who died, or were discharged as cured or non-cured. Statistical analysis was done using SPSS v. 20 (IBM Chicago, IL, U.S.A.) and STATA 15 (StataCorp LLC) software.

Comparisons of baseline and outcomes characteristics between CSB+ and LIBS were summarized as percentages and means (±SDs). Comparison of outcomes between the LIBS and CSB+ groups were made by using a chi-square test for categorical variables and generalized estimating equations (GEE) for continuous variables. Differences in the estimated proportion

Table 1. Nutrient composition of the supplementary foods.

Nutrient	125 gm of LIBS with 8 ml sunflower oil	150 gm of CSB+ with 16ml of sunflower oil
Energy (kcl)	698.5	750.84
Protein (g)	22.6	21.25
Carbohydrate (g)	56.9	95.0
Fat (g)	40.89	3176
Ash (g)	2.1	4.3
Iron (mg)	8.1	6.00
Zn (mg)	5.6	7.5
Calcium (mg)	100.00	195.00
Phosphorous (mg)	470.55	300.00
Potassium (mg)	666.14	600.00
Magnesium (mg)	394.7	107.75
Sodium (mg)	84.6	41.25
Folic acid (µg)	49.4	90.00

Abbreviations: LIBS: local-ingredients-based supplement; CSB+: corn-soy blend plus; kcal: kilocalorie; g: gram; and mg: milligram.

Note: Nutrient values for the LIBS ration were calculated by using the United States Department of Agriculture (USDA) food composition database and NutriSurvey software. Nutrient values for the CSB+ were adapted from Amegovu KA, Ogwok P, Ochola S, Yiga P, Musalima HJ, Mutenyo E. Formulation of sorghum-peanut blend using linear programming for treatment of moderate acute malnutrition in Uganda. J Food Chem and Nutr. 2013; 1(2):67–77.

https://doi.org/10.1371/journal.pone.0258715.t001 between the groups along with 95% CI were estimated to infer non-inferiority. Our trial is testing against a one-sided hypothesis, but the decision of non-inferiority is based on a two-sided 95% confidence interval, even if we deal with the lower limit of the interval. The recovery time between groups was predicted in Kaplan-Meier (log-rank) curves of survival analysis. Mean difference in weight gain, mean difference of MUAC gain, and mean difference in height/length gain were computed to describe the magnitude of the difference between the two groups. Rates of weight gain through the whole period of follow-up were estimated in g/kg body weight/day and compared between the study groups. These were calculated by dividing the weight gain (weight at exit minus weight at admission), expressed in grams, by the weight at admission (in kilograms), and the length of stay (in days). Anthropometric indexes were calculated using ENA for SMART 2011 software.

Results

The enrollment process and trial profile for the study participants

A total of 1006 children were screened for MAM, of whom 682 children were excluded because 650 children were without MAM and 32 children did not meet inclusion criteria. In the study, 324 children with MAM aged 6 to 59 months were enrolled to either LIBS (n = 162) or CSB+ (n = 162). Of these, 311 (96%) children with MAM and their mothers/caregivers completed the study, with seven lost to follow-up and six discontinued due to SAM. The reason for all those lost to follow-ups was moving from the study site. The enrollment and allocation of participants, lost to follow-ups, discontinued, and completed the study are illustrated in **(Fig 1).** No serious adverse reactions were detected.

Baseline characteristics of the study participants

Baseline characteristics were compared between the LIBS and CSB+ groups (Table 2). The mean (SD) age of the mothers in the LIBS group was 31.5 (5.91) years and 32.27 (6.27) years in the CSB+ group. The mean (SD) age of the children in the LIBS group was 21.96 (11.32) months and 21.18 (11.81) months in the CSB+ group. Most children were from agricultural households, with six to eight persons per household and with a low rate of literacy. More than half of children, 54.6% of children in the LIBS group, and 64.2% of children in the CSB+ group had morbidity history based on two weeks recall.

Outcomes in the two intervention arms over 12 weeks

Fisher's exact test showed that the overall proportion of children who recovered was 72.2%, whereas 1.9% deteriorated to SAM, 24.4% remained in MAM, and 1.5% was lost to follow-ups at the end of the 12-week intervention.

The proportion of children who recovered was similar for LIBS and CSB+ groups in both ITT and PP analysis. ITT analysis showed recovery of 75.90% for LIBS (95% CI: 68.76, 81.89) and 71.0% for CSB+ (95% CI: 63.56, 77.44) (p = 0.314), whereas the PP analysis showed recovery of 76.58% for LIBS (95% CI: 69.37., 82.54) and 72.90% for CSB+ (95% CI: 65.39, 79.30) (p = 0.454) The risk differences for LIBS compared with CSB+ were 4.9% (95% CI: -4.70, 14.50) in ITT analysis and risk difference = 3.7% (95% CI: -5.91, 13.31) in PP analysis (Table 3). Both PP and ITT analyses showed that LIBS was non-inferior compared with CSB + in terms of the recovery rate, as the entire CI of the difference between the two groups was above the predefined non-inferiority margin of risk difference (-7%). Besides, both PP and ITT showed that LIBS is not significantly different from CSB+ because the two-sided 95% CI crosses the 0 outcome difference (**Fig 2**).

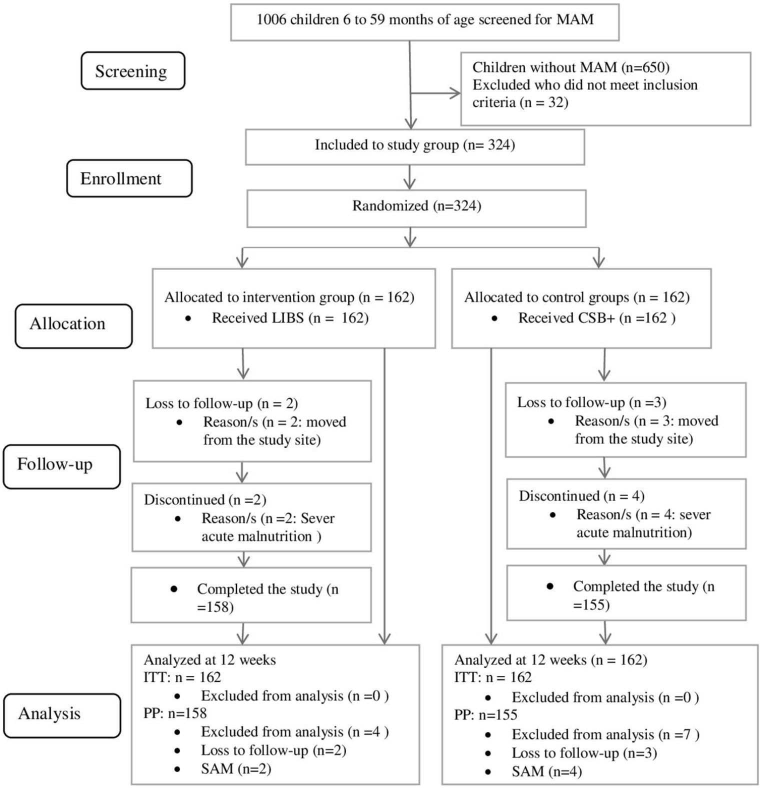

Fig 1. Flowchart of study enrollment to completion. Screened for MAM, children aged 6 to 59 months who screened for moderate acute malnutrition; Children without MAM, children aged 6 to 59 months who did not have moderate acute malnutrition; Randomized children aged 6 to 59 months who were assessed positive for moderate acute malnutrition, fulfilled the inclusion criteria, were recruited and randomly allocated; The loss to follow-up, children who were randomly allocated to intervention and control groups and stopped participating in the study at any stage of the study; Discontinued due to SAM, children who were randomly allocated to intervention and control groups and discontinued from the study at any stage of the study; Analyzed at 12 weeks, children aged 6 to 59 months whose information was analyzed at 12 weeks; ITT and PP analysis are done. Abbreviations: MAM: moderate acute malnutrition; LIBS: local-ingredients-based supplement; CSB+: corn-soy blend plus; SAM: severe acute malnutrition; ITT: intention to treat; PP: per-protocol.

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The daily weight gain was similar in both groups. In ITT analysis, the mean weight gain (SD) among children in the LIBS group was 3.18 (1.89) g/kg/day, whereas the mean weight gain (SD) among children in the CSB+ group was 3.09 (2.05) g/kg/day (p = 0.642) The PP analysis showed that the mean weight gain (SD) among children in the LIBS group was 3.25 (1.86) g/kg/day, whereas the mean weight gain (SD) among children in the CSB+ group was 3.21 (1.98) g/kg/day (p = 0.838). Both ITT and PP analyses showed that LIBS group was non-inferior compared with the CSB+ group (predefined non-inferiority margin of risk difference = -1.3 g/kg/d) [ITT risk difference = 0.10 (95% CI: -0.33, 0.53); PP risk difference = 0.04 (95% CI: -0.38, 0. 47)] (**Fig 3 and Table 3**). The ITT analysis showed that the mean MUAC gain (SD) for the LIBS group was 0.12 (0.07) mm/day and 0.11 (0.08) mm/day for the CSB+ group.

Table 2. Baseline characteristics of study subjects per treatment and control group.

Characteristics (N = 324)	LIBS (n = 162)	CSB+ (n = 162)
Sex of child [n (%)]		
Male	67 (41.4)	70 (43.2)
Female	95 (58.6)	92 (56.8)
Age of the child in months [mean (SD)]	21.96 (11.32)	21.18 (11.81)
Age of the mother in years [mean (SD)]	31.5 (5.91)	32.27 (6.27)
Maternal MUAC (cm), [mean (SD)]	22.01(1.48)	22.17 (1.55)
The education level of respondents [n (%)]		
Non-formal education	111 (68.5)	112 (69.1)
Primary	46 (28.4)	37 (22.8)
Secondary and above	5 (3.1)	13 (8.1)
Occupation of the household head [n (%)]		
Farmer	95 (58.6)	73 (45.1)
Daily worker	25 (15.4)	41 (24.3)
Business owner	30 (18.6)	33 (20.4)
Monthly paid worker	6 (3.7)	8 (4.9)
Handcrafts	6 (3.7)	7 (4.3)
Morbidity based on two weeks recall [n (%)]		
Yes	90 (55.6)	104 (64.2)
No	72 (44.4)	58 (35.8)
Household size [n (%)]		
3 to 5	42 (25.9)	47 (29.0)
6 to 8	96 (59.3)	102 (63.0)
>8	24 (14.8)	13 (8.0)
Use of bed net by the child [n (%)]		
Yes	128 (79.02)	116 (71.6)
No	34 (20.98)	46 (28.4)
MUAC of the child (cm), mean (SD)	12.0 (0.36)	12.05 (0.32)
Weight of the child (kg), mean (SD)	8.03 (1.23)	7.94 (1.26)
Height of the child (cm), mean (SD)	76.33 (6.68)	76.29 (6.79)
WHZ, mean (SD)	-2.29 (0.47)	-2.33 (0.29)

LIBS: local-ingredients-based supplement; CSB+: improved corn-soy blend; WHZ: weight-for-age Z score; MUAC: mid-upper arm circumference.

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In PP analysis, the mean MUAC gain (SD) for the LIBS group was 0.12 (0.07) mm/day and 0.11 (0.07) mm/day for the CSB+ group. Both ITT and PP analyses showed that there is no difference in MUAC gain between the two groups (p>0.05). There was no difference in daily length/height gain over 12 weeks between the LIBS and CSB+ groups (p>0.05) (Table 3).

Overall, the mean (SD) recovery time (predefined non-inferiority margin of risk difference = 14 days) in the ITT analysis for the LIBS group was 54.27 days (26.74) and for the CSB + group, it was 56.9 days (25.99), giving a difference of -2.64 days (95% CI: -8.40, 3.13 days). In PP analysis, the mean recovery time (SD) for the LIBS group was 53.52 days (26.65) and for the CSB+ group, 55.68 days (25.91), giving a difference of -2.17 (95% CI: -7.97, 3.64 days) (Table 3). Both ITT and PP analysis showed that the mean recovery time in the LIBS group is non-inferior to the CSB+ group (**Fig 4**).

There is no difference in recovery time between the LIBS and CSB+ groups in ITT analysis p = 0.368 (**Fig 5**) and in PP analysis, p = 0.466 (**Fig 6**).

Table 3. Outcomes in the two intervention arms over 12 weeks.

Outcomes	All (N = 324)	LIBS (n = 162)	CSB+ (n = 162)	Proportion/mean difference with its 95% CI	P-value
Recovery rate [n (%)]					
ITT	238 (73.5)	123 (75.9)	115 (71.0)	4.9 (-4.70, 14.50)	0.314
PP	234 (74.8)	121 (76.6)	113 (72.9)	3.7 (-5.91. 13.31),	0.454
Weight gain (g/kg/day ±SD)					
ITT	3.14 (2.0)	3.18 (1.89)	3.09 (2.05)	0.10 (-0.33, 0.53)	0.642
PP	3.23 (1.92)	3.25 (1.86)	3.21 (1.98)	0.04 (-0.38, 0.47)	0.838
MUAC gain (mm/day ±SD)					
ITT	0.12 (0.08)	0.12 (0.07)	0.11 (0.08)	0.01(-0.01, 0.03)	0.209
PP	0.12 (0.07)	0.12 (0.07)	0.11(0.07)	0.01 (-0.01, 0.02)	0.392
Height gain (mm/day ±SD)					
ITT	0.4 (0.3)	0.39 (0.26)	0.36 (0.25)	0.04 (-0.02, 0.10)	0.208
PP	0.38 (0.25)	0.40 (0.25)	0.37 (0.25)	0.03 (-0.02, 0.09)	0.244
Recovery time (mean in days ±SD)					
ITT	55.6 (26.4)	54.27 (26.74)	56.90 (25.99)	-2.64 (-8.40, 3.13)	0.368
PP	54.6 (26.3)	53.52 (26.65)	55.68 (25.91)	-2.17 (-7.97, 3.64)	0.466

LIBS: local-ingredients-based supplement; CSB+: improved corn-soya blend; g: gram; kg: kilogram; MUAC: mid-upper arm circumference; mm: millimeter; ITT: intention-to-treat; PP: per-protocol.

Data are n (%) when using the chi-square test and mean ± SD and mean difference (95% CI) when using the generalized estimating equation.

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Discussion

This randomized controlled non-inferiority trial compared the efficacy of LIBS and CSB+ in treating MAM. In this study, the ITT, as well as PP analyses, showed that children with MAM

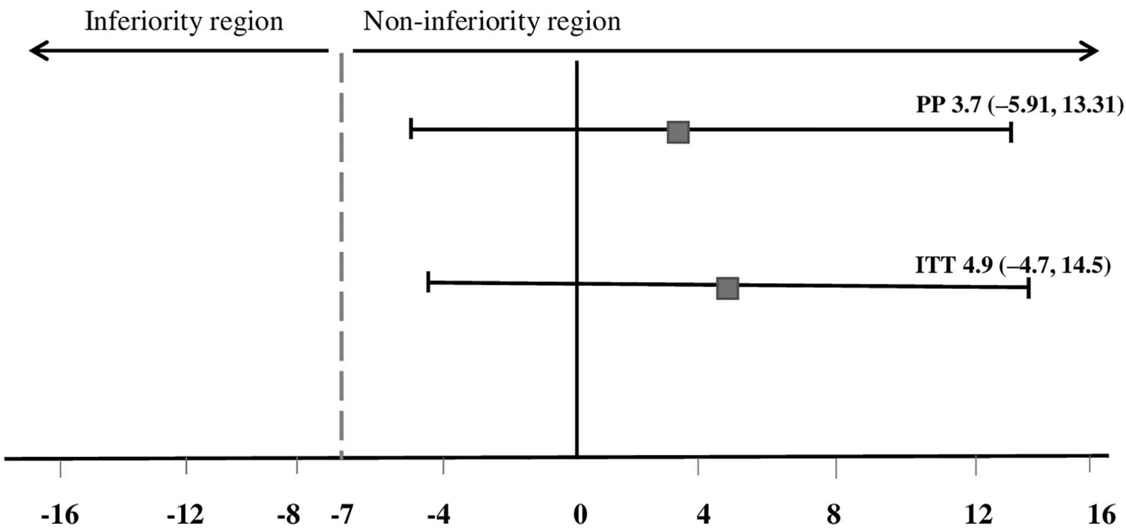

Fig 2. Difference in recovery rate between LIBS and CSB+ groups. The recovery rate in the LIBS group was non-inferior compared with the CSB+ group. Numbers are risk differences in recovery rates between groups (%). The dotted line indicates the predefined non-inferiority margin. Abbreviations: LIBS: local-ingredients-based supplement; CSB+: corn-soy blend plus; PP: per-protocol; ITT: intention to treat.

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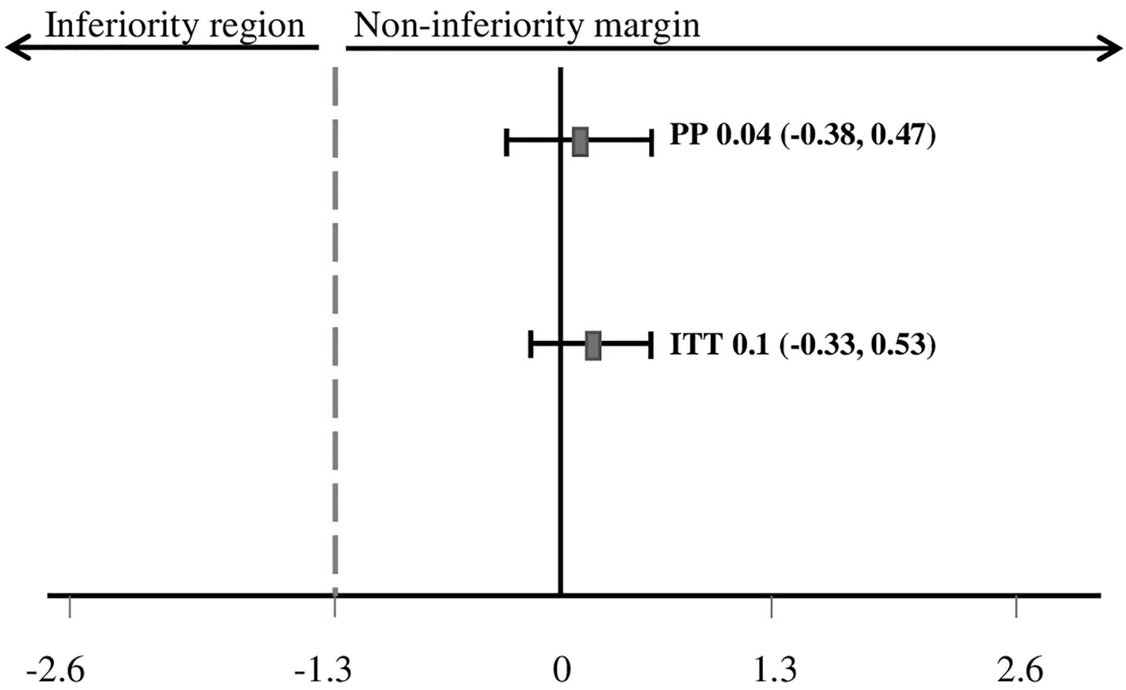

Fig 3. Difference in average weight gain (g/kg/day) between LIBS and CSB+ groups. The average daily weight gain in the LIBS group was non-inferior compared with the CSB+ group. Numbers are risk differences in average weight gains between groups (g/kg/day). The dotted line indicates the predefined non-inferiority margin. Abbreviations: LIBS: local-ingredients-based supplement; CSB+: corn-soy blend plus; PP: per-protocol; ITT: intention-to-treat. The generalized estimating equation was used.

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who received LIBS were not inferior compared with those who received CSB+ in terms of recovery rate, weight gain recovery time, MUAC gain, and length/height gain. Only the LIBS groups met the Sphere goal of 75% recovery.

The recovery rate of MAM observed in this study was comparable with the recovery rates of MAM with supplementary feeding reported in other studies (67% to 82.3%) [10, 15, 19, 26] and higher than the recovery rates of MAM with child-centered counseling intervention only (57.8%) [26]. The comparability of recovery rate with other studies, the non-inferiority of LIBS compared with CSB+, and the fact that the PP and ITT analyses presented similar results of recovery rate are strong evidence indicating that LIBS is an excellent alternative to CSB+ in treating MAM [27].

Additionally, these results are in line with findings of a study done in Uganda where standard therapeutic food for MAM (CSB+) and a locally produced supplement resulted in a comparable recovery rate among wasted children [15]. By contrast, this finding was inconsistent with a study done in Malawi [20], where the efficacy of CSB++ was compared with that of two RUSFs in treating MAM.

A possible explanation for the comparable recovery rate between LIBS and CSB+ groups could be related to both supplements having a similar energy density, as the energy density found in supplementary food is important for the recovery of MAM children [28]. During

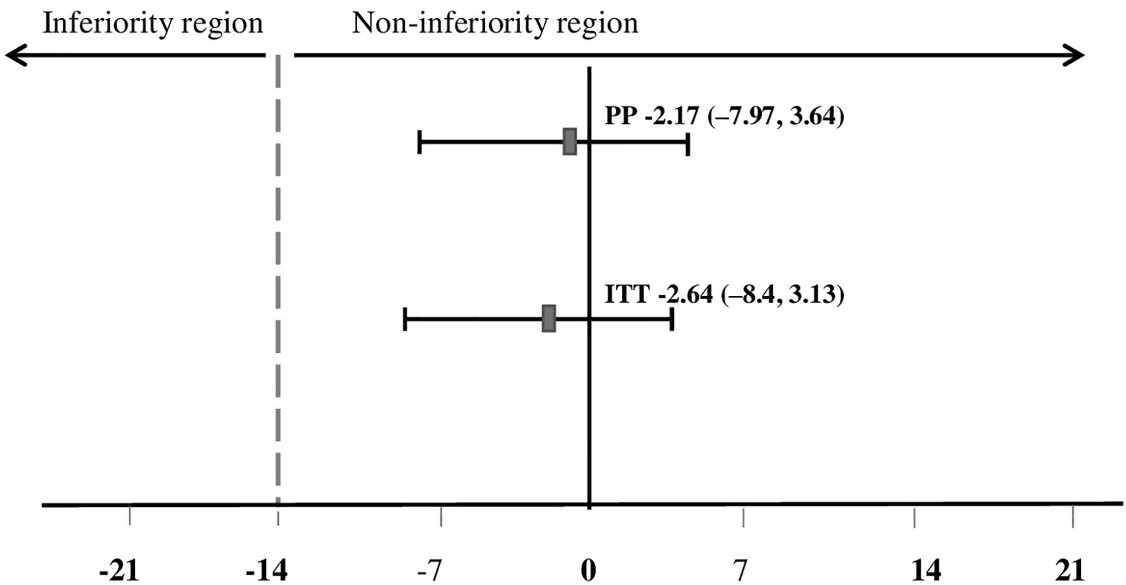

Fig 4. Difference in recovery time in days between LIBS and CSB+ groups. The recovery time in the LIBS group was non-inferior compared with the CSB+ group. Numbers are risk differences of recovery time in days between groups. The dotted line indicates the predefined non-inferiority margin. Abbreviations: LIBS: local-ingredients-based supplement; CSB+: corn-soy blend plus; PP: per-protocol; ITT: intention to treat. The generalized estimating equation was used.

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malnutrition, energy is needed to enhance catch-up growth and maintain the replacement of the loss of both lean and fat tissue [29].

In this study, the overall rate of loss to follow-up was similar between the LIBS and CSB + groups and met the Sphere target rates for defaulting (≤15%). In the present study, the lost-to-follow-up rate was remarkably low (1.5%), much lower than that of previous studies, which had default rates of 4% to ≥5% [30–32]. This might be due to the weekly follow-up done by the researchers and the daily visits done by food distributors.

CSB+ has been used as a standard therapeutic food for MAM for a long time and is very well accepted, with a renowned feeding protocol in the study area. CSB+ is organoleptically tolerable in various settings [20]. Similarly, LIBS was developed from culturally known and acceptable foods and prepared with a similar appearance to conventional food (CSB+). This could be another explanation for the comparability of the default rate between the two groups.

About 2% of children recruited in this study did not respond to treatment, but continued to lose weight and developed SAM. There was no significant difference in the number of children who developed SAM between the two groups. The reason for the progression to SAM is unknown and might not be related only to household food insecurity, in that it could be explained by the hypothesis that these children had an untreated illness. However, this rate of progression to SAM finding is lower than studies done in Cameroon [10], Malawi [20], and Burkina Faso [26].

This study showed that the average weight gain observed in the LIBS group was not inferior to the CSB+ group. This could be explained by the fact that the total energy provided by the supplements in both groups was comparable. Another explanation might be that both supplements need to be cooked before feeding to the child. The amount of water needed for the

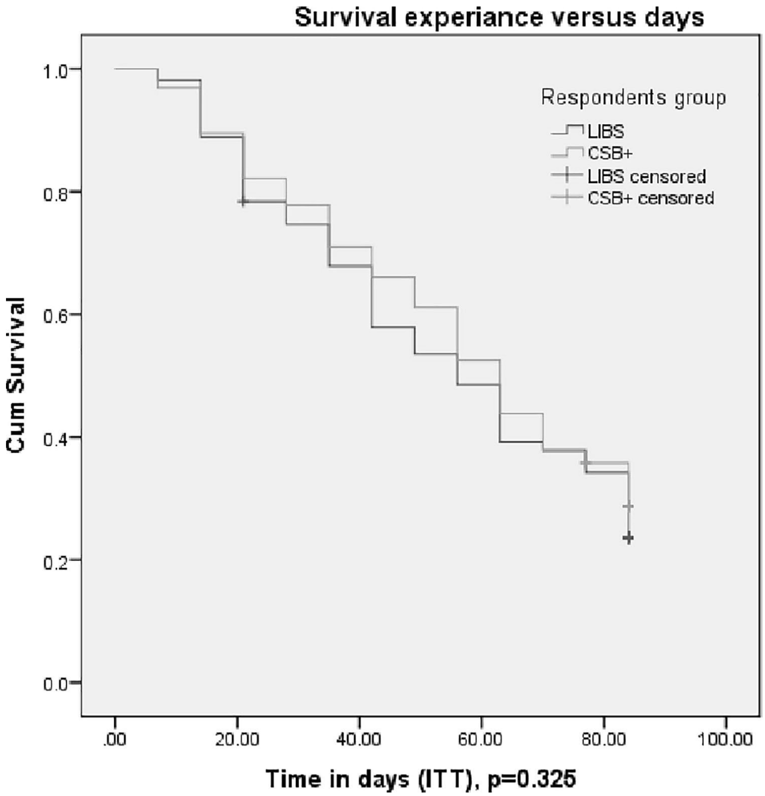

Fig 5. Recovery of children with moderate acute malnutrition over time in the LIBS and CSB+ arms in ITT analysis. The recovery of children with MAM over time in the LIBS group was similar to the CSB+ group. Survival analysis, Kaplan-Meier curves and Log-rank tests were used to analyze and describe the data. Abbreviations: MAM: moderate acute malnutrition; LIBS: local-ingredients-based supplement; CSB+: corn-soy blend plus; ITT: intention to treat.

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cooking of both supplements was similar in that the mass of supplements fed to children was comparable. The finding also compared favorably with weight gain observed in a study carried out in Malawi [20] and was higher than studies done in Cameroon and Malawi [10, 33].

In this study, the recovery time between the LIBS and CSB+ groups was similar. This finding is supported by other studies, for example, in Cameroon, where the efficacy of CSB+ and RUSF were compared in treating MAM [10], and in Uganda, where the efficacy of sorghum-peanut blend and CSB+ had been compared as therapeutic food for MAM [15]. By contrast, the recovery time was extended compared with a study done in Burkina Faso [26] However, it was within the acceptable Sphere Standards ($\leq$ 90 days) [15].

The length/height gain was comparable between the two groups. This could be explained by the similar amount of protein and zinc found in the LIBS and CSB+. Complementary, supplementary, and therapeutic foods with good quality protein are effective for promoting the growth of children [34]. Similarly, zinc is vital for growth and development and is a growth

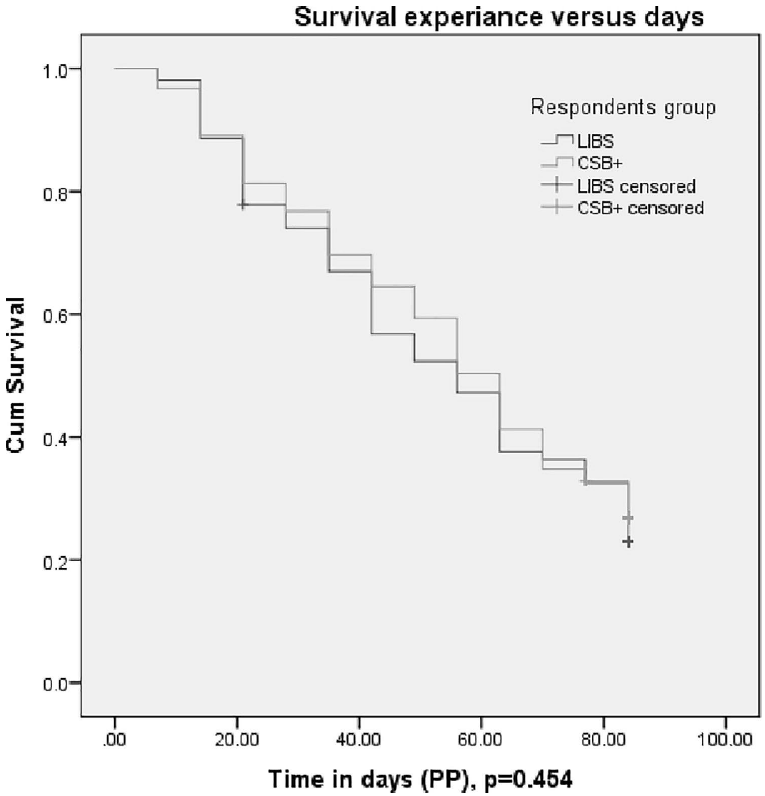

Fig 6. Recovery of children with moderate acute malnutrition over time in the LIBS and CSB+ arms in PP analysis. The recovery of children with MAM over time in the LIBS group was similar to the CSB+ group. Survival analysis, Kaplan-Meier curves, and Log-rank tests were used to analyze and describe the data. Abbreviations: MAM: moderate acute malnutrition; LIBS: local-ingredients-based supplement; CSB+: corn-soy blend plus; PP: per-protocol.

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type II [29]. It has direct effects on the key hormonal system (IGF-I/GH) that controls growth in the postnatal phase [35]. Our finding was comparable with the study done by Stobaugh [36] and better than studies done by LaGrone et al., Nikièma et al., and Patel et al. [20, 26, 33].

This non-inferiority trial, to the best of our knowledge, was the first study so far using locally developed supplements based on local food ingredients to compare with the standard treatment of MAM (CSB+) in Ethiopia. One of the strengths of this study is that we have used locally available and culturally acceptable food ingredients to formulate the supplement. Another strength is meeting the Sphere standard regarding recovery rate, recovery time, and loss to follow-up rate. The daily home visits by food distributors and weekly home follow-ups by the data collectors allowed us to minimize the lost-to-follow-up rate. However, the study had some limitations. The main limitation of this study was not monitoring the children's overall dietary intake during the treatment and not having a non-supplemented control group. Thus, we could not measure the contribution of the home diet. Another limitation of this study was that we did not test the shelf life of the newly developed LIBS product. The shelf life of the product is critical if this product is to be used in the future as therapeutic food for treating children with MAM.

Conclusion

The present study showed that LIBS was non-inferior to conventional food (CSB+) in treating MAM, and both supplements were relatively successful for treating MAM in children aged 6 to 59 months. The finding from this study provides an experimental indication that LIBS can be used as an alternative to CSB+ in the management of MAM in Ethiopia. Thus, the potential for scaling up the use of LIBS should be promoted. Further studies should also examine concerns such as the product's shelf life, and its sustainability, and cost-effectiveness. Community perceptions of the LIBS as a treatment for MAM should also be tested. The evidence drawn from this study will be shared with the public and with policymakers as LIBS has the potential to increase recovery from MAM and decrease the burden of malnutrition.

Supporting information

S1 File. CONSORT checklist.
(DOC)

S2 File. Fully anonymized database in SPSS format.
(SAV)

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Investigation: Debritu Nane, Anne Hatløy, Bernt Lindtjørn.

Methodology: Debritu Nane, Anne Hatløy.

Project administration: Debritu Nane, Bernt Lindtjørn.

Resources: Debritu Nane, Bernt Lindtjørn.

Software: Debritu Nane.

Supervision: Debritu Nane, Anne Hatløy, Bernt Lindtjørn.

Validation: Debritu Nane, Anne Hatløy, Bernt Lindtjørn.

Visualization: Debritu Nane, Anne Hatløy.

Writing – original draft: Debritu Nane.

Writing – review & editing: Debritu Nane.

References

1. 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. https://doi.org/10.1016/S0140-6736(07)61690-0 PMID: 18207566
2. 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. Lancet. 2013; 382:427–51. https://doi.org/10.1016/S0140-6736(13)60937-X PMID: 23746772
3. Wie GT, Tsegaye D. Determinants of acute malnutrition among children aged 6–59 months visiting public health facilities in Gambella Town, Southwest Ethiopia: Unmatched case-control study. Nutrition and Dietary Supplements. 2020; 12:147–156.
4. Dipasquale V, Cucinotta U, Romano C. Acute Malnutrition in Children: Pathophysiology, Clinical Effects, and Treatment. Nutrients. 2020; 12(2413):1–9.
5. Nane D, Hatloy A, Tadesse E, Lindtjørn B. Research protocol local ingredients-based supplementary food as an alternative to corn-soya blends plus for treating moderate acute malnutrition among children aged 6 to 59 months: a randomized controlled non-inferiority trial in Wolaita. BMC Public Health. 2019; 19(1689):1–9. https://doi.org/10.1186/s12889-019-8031-3 PMID: 31842852
6. Tessema M, Belachewu T, Ersino G. Feeding patterns and stunting during early childhood in rural communities of Sidama, South Ethiopia. PAMJ. 2013; 14(75):1–12. https://doi.org/10.11604/pamj.2013.14.75.1630 PMID: 23646211
7. Manary MJ, Sandige HL. Management of acute moderate and severe childhood malnutrition. BMJ. 2008; 337:1227–1230 https://doi.org/10.1136/bmj.a2180 PMID: 19008271
8. 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) prioritization exercise. PLoS ONE. 2020; 15 (2); 1–13.
9. Lelijveld N, Jalloh AA, Kampondeni SD, Seal A, Wells JC, Goyheneix M, et al. Brain MRI and cognitive function seven years after surviving an episode of severe acute malnutrition in a cohort of Malawian children. Public Health Nutr. 2018; 22(8): 1406–1414. https://doi.org/10.1017/S1368980018003282 PMID: 30501662
10. Medoua GN, Natsma PM, Ndzana ACA, Essa'a VJ, Tsafack JJT, Dimodi HT. Recovery rate of children with moderate acute malnutrition treated with ready-to-use supplementary food (RUSF) or improved corn–soya blend (CSB+): a randomized controlled trial. Public Health Nutrition. 2015; 19(2): 363–370. https://doi.org/10.1017/S1368980015001238 PMID: 25939394
11. World Health Organization (WHO). (2012). Technical note: supplementary foods for the management of moderate acute malnutrition in infants and children 6–59 months of age. Geneva: WHO.
12. Annan R, Webb P, Brown R. Management of moderate acute malnutrition (MAM): current knowledge and practice. CMAM Forum Technical Brief. 2014 Sep [cited 2020 Aug 15]. Available from https://www.ennonline.net/managementofmamcurrentknowledgeandpractice
13. Bhandari N, Mohan SB, Bose A, Iyengar SD, Taneja S, Mazumder S, et al. Efficacy of three feeding regimens for home-based management of children with uncomplicated severe acute malnutrition: a randomized trial in India. 2016; 1:e000144.
14. Central Statistical Agency. Ethiopian Demographic and Health Survey 2011. Addis Ababa, Ethiopia, and Calverton, Maryland, USA. 2012.
15. Amegovu AK, Ochola S, Ogwok P, Yiga P, Musalima J, Juliana M. Efficacy of sorghum-peanut blend and corn-soy blend plus in the treatment of moderate acute malnutrition in children aged 6–59 months in Karamoja, Uganda: a cluster-randomized trial. Nutr Diet Suppl. 2014; 6:75–84.
16. Stobaugh H. Maximizing recovery and growth when treating moderate acute malnutrition with whey-containing supplements. Food Nutr Bull. 2018; 39(2): S30–34. https://doi.org/10.1177/0379572118774492 PMID: 30238798
17. Kennedy E, Branca F, Webb P, Bhutta Z, Brown R. Setting the scene: an overview of issues related to policies and programs for moderate and severe acute malnutrition. Food Nutr Bull. 2015; 36(1): S9–14 https://doi.org/10.1177/15648265150361S102 PMID: 25902609
18. James P, Sadlaw K, Wondafrash M, Argaw A, Luo H, Geleta B, et al. Children with moderate acute malnutrition with no access to supplementary feeding programs experience high rates of deterioration and no improvement: results from a prospective cohort study in rural Ethiopia. PLoS One. 2016; 10:1371: 1–26
19. Karakochuk C, van den Briel T, Stephens D, Zlotkin S. Treatment of moderate acute malnutrition with ready-to-use supplementary food results in higher overall recovery rates compared with a corn-soya blend in children in southern Ethiopia: an operations research trial. Am J Clin Nutr. 2012; 96:911–6. https://doi.org/10.3945/ajcn.111.029744 PMID: 22952175

20. LaGrone LN, Trehan I, Meuli GJ, Wang RJ, Thakwalakwa C, Maleta K, et al. A novel fortified blended flour, corn-soy blend "plus-plus," is not inferior to lipid-based ready-to-use supplementary foods for the treatment of moderate acute malnutrition in Malawian children. Am J Clin Nutr. 2012; 95:212–9. https://doi.org/10.3945/ajcn.111.022525 PMID: 22170366

21. Ethiopia: Food insecurity revised emergency appeal no. MDRET005. 2008 [cited 2020 Aug 15]. Available from: https://reliefweb.int/report/ethiopia/ethiopia-food-insecurity-revised-emergency-appeal-no-mdret005.

22. World Health Organization and United Nations Children's Fund. WHO child growth standards and the identification of severe acute malnutrition in infants and children. Geneva: WHO; 2009.

23. Ackatia-Armah RS, McDonald CM, Doumbia S, Erhardt JG, Hamer DH, Brown KH. Malian children with moderate acute malnutrition who are treated with lipid-based dietary supplements have greater weight gains and recovery rates than those treated with locally produced cereal-legume products: a community-based, cluster-randomized trial. Am J Clin Nutr. 2015; 101:632–45. https://doi.org/10.3945/ajcn.113.069807 PMID: 25733649

24. The UN Refugee Agency and World Food Programme. Guidelines for selective feeding: the management of malnutrition in emergencies. Geneva, UNHCR; 2011.

25. Piaggio G., Elbourne DR, Pocock SJ, Evans SJW, Altman DG, & The CONSORT Group. Reporting of noninferiority and equivalence: Randomized trials extension of the CONSORT 2010 statement. JAMA: Journal of the American Medical Association. 2010; 308(24): 2594–2604.

26. Nikièma L, Huybregts L, Kolsteren P, Lanou H, Tiendrebeogo S, Bouckaert K, et al. Treating moderate acute malnutrition in first-line health services: an effectiveness cluster-randomized trial in Burkina Faso. Am J Clin Nutr. 2014; 100,241–9. https://doi.org/10.3945/ajcn.113.072538 PMID: 24808482

27. Kaul S, Diamond GA. Good enough: a primer on the analysis and interpretation of noninferiority trials. Ann Intern Med. 2006; 145:62–69.

28. Michaelsen KF, Hoppe C, Roos N, Kaestel P, Stougaard M, Lauritzen L, et al. Choice of foods and ingredients for moderately malnourished children 6 months to 5 years of age. Food Nutr Bull. 2009; 30 (3): S343–405. https://doi.org/10.1177/15648265090303S303 PMID: 19998864

29. Golden MH. Proposed recommended nutrient densities for moderately malnourished children. Food Nutr Bull. 2009; 30(3): S267–342. https://doi.org/10.1177/15648265090303S302 PMID: 19998863

30. Matilsky DK, Maleta K, Castleman T, Manary MJ. Supplementary feeding with fortified spreads results in higher recovery rates than with a corn/soy blend in moderately wasted children. J Nutr. 2009; 139:773–8. https://doi.org/10.3945/jn.108.104018 PMID: 19225128

31. Nackers F, Broillet F, Oumarou D, Djibo A, Gaboulaud V, Guerin PJ, et al. Effectiveness of ready-to-use therapeutic food compared to a corn/soy-blend-based pre-mix for the treatment of childhood moderate acute malnutrition in Niger. J Trop Pediatr. 2010; 56(6):407–13. https://doi.org/10.1093/tropej/fmq019 PMID: 20332221

32. Lagrone L, Cole S, Schondelmeyer A, Maleta K, Manary MJ. Locally produced ready-to-use supplementary food is an effective treatment of moderate acute malnutrition in an operational setting. Ann Trop Paediatr. 2010; 30:103–8. https://doi.org/10.1179/146532810X12703901870651 PMID: 20522296

33. Patel MP, Sandige HL, Ndekha MJ, Briend A, Ashorn P, Manary MJ. Supplemental feeding with ready-to-use therapeutic food in Malawian children at risk of malnutrition. J Health Popul Nutr. 2005; 23:351–357. PMID: 16599106

34. Uauy R, Kurpad A, Tano-Debrah, Otoo GE, Aaron GA, Toride Y, et al. Role of protein and amino acids in infant and young child nutrition: protein and amino acid needs and relationship with child growth: J Nutr Sci Vitaminol. 2015; 61:192–4. https://doi.org/10.3177/jnsv.61.S192 PMID: 26598853

35. Rivera JA, Hotz C, Gonzalez-Cossio T, Neufeld L, Garcia-Guerra A. The effect of micronutrient deficiencies on child growth: a review of results from community-based supplementation trials. J Nutr Food Sci. 2003; 133:S4010–20. https://doi.org/10.1093/jn/133.11.4010S PMID: 14672304

36. Stobaugh HC, Ryan KN, Kennedy JA, Grise JB, Crocker AH, Thakwalakwa C, et al. Including whey protein and whey permeate in ready-to-use supplementary food improves recovery rates in children with moderate acute malnutrition: a randomized, double-blind clinical trial. Am J Clin Nutr. 2016; 103:926–33. https://doi.org/10.3945/ajcn.115.124636 PMID: 26864368

Appendix I: Study instruments

Part one: Discussion guide for mothers or caregivers of children with MAM aged 6 to 59 months

Demographic data

1. Date __/___/2018
2. District_________________
3. Kebele_________________
4. Numbers of subjects_____________Mothers_________Caregivers___________
5. Facilitator____
6. Note-takers__________________________, _____________________________

Awareness on existing management practice for MAM

1. Have you heard of MAM? What is MAM? Please explain.
2. How well do you know the services that children with MAM are getting? Please describe the services.
3. How do you understand that your awareness towards MAM can affect the management practice for MAM?
4. What is your opinion towards the importance of the existing management of MAM?

Accessibility of the existing management service for MAM

1. Are there health service providers in your area who talk about MAM? If participants answer yes, probe to understand more about what the service providers do during these visits, and when they do visiting.
2. What are the components of the existing management practice for MAM?
3. How do you usually access the management service of MAM for your child?
4. How did your child get admission to the management program for MAM?

Barriers while benefiting the services

1. What, if anything, makes it difficult for you to get management service for MAM for your child? Probe: What are your ideas about how to ensure you get management service for MAM for your child? Probe until the full group provides ideas.
2. How do the challenges of the management practice for MAM influence your child with MAM?

3. What could help you to get adequate management service for MAM for your child?

Satisfaction with the existing management practice of MAM

1. How do you feel about the management practice for MAM your child is currently getting?
2. Can you explain about the role of the existing management of your child with MAM?
3. Is your child recruited in the management program of MAM recovering?
7. Do you believe that the service is adequate? If the participants answer No, probe to understand more about how the service is inadequate.

Strategies to improve the management service for MAM

1. What are your comments on the strategies to improve the management practice for MAM?

Conclusion

1. Is there anything you'd like to share about your experiences with receiving/obtaining management of MAM that you think would help us to provide a better service to other children with MAM?

Thank you for your time.

Use probes as needed. These include:

• Would you give me an example?

• Can you elaborate on that idea?

• Would you explain that further?

• I'm not sure I understand what you're saying.

• Is there anything else?

Part two: In-depth interview guide for HEWs and women's development army members

1. Background information
    1.1. Date __/___/2018
    1.2. Kebele -----------------------------
    1.3. Age of the respondent------------
    1.4. Marital status ----------------------
2. What are your roles or responsibilities in this health post?
3. What are the services that children with MAM are currently getting? Please explain.
4. How and when do you identify and recruit children with MAM to the management program for MAM? When do you recognize children with MAM? Please explain.
5. How do you follow children with MAM once they are recruited to the program? When? What did you do during the follow-up? What did the mothers or caregivers do?
6. What is the role of existing management of children with MAM? Please explain.
7. To what extent are children with MAM getting admission to the program? Please elaborate.
8. What are the barriers/challenges to implementing the service? Probe: What are your ideas about how to ensure the provision of optimal management service to children with MAM? Please explain.
9. Do you think that the service you are currently providing to the children with MAM is adequate? If the respondent says yes, how do you know?
10. What is your comment the extent of recovery from MAM among recruited children?
11. Are there any other organizations or persons in this community working on the management of MAM? If the subject says yes, who are they? How you integrate with them?
12. What can you suggest for improvement?

Part three: Questionnaire for efficacy study

Baseline information from both intervention and control groups

Date __/___/2018

Interviewer Name: ________________________ Signature: _______________

ID |_____| Kebele______________

1. Socio demographic, economic characteristics & background information			
#	Question Item	Response	Instructions
Q101	Age of caregiver in years	[_____]	
Q102	What is your marital status?	0. Single 1. married 2. Separated 3. Divorced 4. Widowed	
Q103	Religion	0. Muslim 1. Orthodox 2. Protestant 3. Catholic 4. Other (specify) -----------------------	
Q104	Level of education	0. No formal schooling 1. Attended primary school (grade1-6) 2. Secondary school and above	
Q105	Occupation	0. Housewife 1. Government worker 2. Non-governmental worker 3. Business owner 4. Daily worker 5. Other (specify) --------------------	
Q106	Are the parents of the child alive?	0. Yes 1. No	If No, skip to Q108
Q107	If, yes, who is alive?	0. Mother 1. Father 2. Both 3. Not known	
Q108	The respondent's relation with the child	0. Mother 1. Grandmother 2. Sister 3. Other relatives 4. Neighbors	
Q109	How many people are currently living in this household?	[______________]	
Q110	Is there anyone who is getting another support (cash/food) in the household?	0. Yes 1. No	

Q111	How many children aged below five years currently live in the household?	[________________]	
Q112	Parity?	[________________]	
Q113	Who is the household head?	[________________________________]	
Q114	Who is the caregiver of this child?	[________________________________]	
Q115	Mother's MUAC	[____________________]	
Q116	Father's occupation	0. Monthly paid worker 1. Business owner 2. Daily worker 3. Farmer 4. Handicrafts 5. Others	
Q117	Monthly income in birr	[____________________]	
Q118	Availability of assets	0. Radio and tapes 1. Television 2. Bicycle 3. Motorcycle 4. Others	
Q119	What is the main income source of the household?	0. Food crop production (e.g. cereals, tubers) 1. Growing non-food cash crop (e.g. coffee) 2. Livestock production 3. Handicrafts 4. Sale of natural resources (firewood, charcoal) 5. Gifts from neighbors, relatives 6. Daily labour 7. Business 8. Other (specify) ------------------------------------	
Q120	Acess to mass media	0. Yes 1. No	
Q121	Number of rooms in the house	[____________________]	
Q122	Family own livestock	0. Yes 1. No	
Q117	What is the main diet in your family?	0. Maize 1. Teff 2. Sorghum 3. Wheat 4. Tubers 5. Other (specify) ------------------------------------	
Q114	How many times do you feed in a day?	0. Once 1. Two times 2. Three times	

		3. More than three times	

2. Child health and nutritional status

Q201	Sex of your child	0. Male 1. Female	
Q202	Birth date	------/------/--------	Verify from clinic card
Q203	Age in months	[__________]	
Q204	Weight (to nearest 0.1 kg)	First ___________________ Second ________________ Average. _____________	
Q205	Height (to nearest 0.1 cm)	First ______________________ Second ________________ Average _____________________	
Q206	MUAC (in millimeters)	First ______________________ Second ______________________ Average _____________________	
Q207	Does the child have edema?	0. 0 1. + 2. ++ 3. +++	Check for edema
Q208	Has the child been taken for immunization?	0. Yes 1. No	If no, go to Q211
Q209	Has your child got a vaccination card?	0. Yes 1. No	
Q210	If Yes, check for the immunizations given.	0. DPT3 1. Measles 2. Other_______________________	
Q211	Has your child taken deworming tablets in the last six months?	0. Yes 1. No	
Q212	Has your child taken Vitamin A supplementation in the last six months?	0. Yes 1. No	
Q213	How many meals did the child eat yesterday?	_______________________________	
Q214	How was the child served food?	0. Own plate 1. Plate shared with other children 2. Plate shared with adult 3. Own plate assisted by adult	
Q215	What kind of foods do you feed your child commonly?	____	
Q216	Did your child suffer from a disease in the last two weeks?	0. Yes 1. No	

Q217	If Yes, mention the diseases your child has suffered	0. Fever 1. Diarrhea 2. Skin problem 3. Cough/URTI 4. Others___________________________	
Q218	Does child sleep under a mosquito net?	0. Yes 1. No	
Q219	Are you breastfeeding your child currently?	0. Yes 1. No	(For children aged 6 to 24 months)
3. Water and Sanitation			
Q301	What is your main source of drinking water?	0. Tap 1. Well (protected) 2. Well (not protected) 3. Spring 4. Rain water 5. Other (specify) _________	
Q302	Do you practice treating your drinking water?	0. Yes 1. No	
Q303	If Yes, how do you treat your water?	0. Boiling 1. Traditional herbs 2. Use chemicals 3. Other (specify) _________	
Q304	Have you a latrine?	0. Yes 1. No	If No, skip to Q306
Q305	If Yes, what kind of toilet facility does your household have?	0. Flush toilet 1. Traditional pit latrine 2. Ventilated improved latrine 3. Open pit 4. No facility/bush/field	
Q306	Where do you dispose of rubbish?	0. Compost pit 1. In the garden 2. Bush 3. Other (specify) ____________________	
Q307	Where do you and members of your household mostly go for treatment when sick?	0. Hospital 1. Health center 2. Health post 3. Private clinic 4. Traditional healer	
Q308	Who in the house sleeps under a mosquito net?	0. Children 1. Adult men 2. Adult women 3. No one	

4. **Accessibility and utilization management programme for MAM children**			
Q401	Is your child admitted to the conventional management of MAM programme?	0. Yes 1. No	If No, skip to Q406
Q402	If yes, what are you getting?	0. Counseling 1. Food supplement 2. None	
Q403	How often do you get counseling?	0. Daily 1. Weekly 2. Every two weeks 3. Monthly 4. Other (specify) ______________	
Q404	Are you satisfied with the counseling?	0. Yes 1. No	
Q405	If No, why?	0. Unclear 1. Not consistent 2. Time taking 3. Useless 4. Other (specify) ___________	
Q406	Service from health extension worker received in past month	0. Counseling 1. Food support 2. None	
Q407	Do you experience any problem with the service providers?	0. Yes 1. No	
Q408	From where do you get program service?	0. Home visit 1. At health facility	
Q409	How far is the nearest health facility where you get your services?	_____________ in minutes	

Follow-up questionnaire for both intervention and control groups (to be asked for the monthly follow-up)

#	Question item	Response	Instruction
Q601	Child's MAM number	[_______________________]	
Q602	Date of visit	[___/____/_______]	
Q603	What portion of supplementary food was eaten by the malnourished child in the past one week?	0. None 1. <1/4th 2. 1/4th to ½ 3. About half 4. More than half 5. All	
Q604	Has the malnourished child had diarrhea (lasting for three days or longer), since the last visit?	0. Yes 1. No	

Q605	How is the appetite of the child for the regular household food?	0. Good 1. Poor 2. Don't know	
Q606	Is there anyone who is getting another support (cash/food) in the household?	0. Yes 1. No	
Q607	If Yes, what program is it?	[________________________________]	
Q608	Weight (to the nearest 0.1 kg)	First ______________________ Second ___________________ Average___________________	
Q609	Height (to the nearest 0.1cm)	First________________________ Second_____________________ Average____________________	
Q610	MUAC (in millimeter)	First_______________________ Second____________________ Average___________________	
Q611	Bipedal edema	0. 0 1. + 2. ++ 0. +++	Check for bipedal edema

7. Weekly follow-up questionnaire for both intervention and control groups

#	Question item	Response	Instruction
Q701	Child's MAM number	[_____________________]	
Q702	Date of visit	[___/______/________] dd/mm/yr	
Q703	What portion of supplementary food was eaten by the malnourished child in the past one week?	0. None 1. <1/4th 2. 1/4th to ½ 3. About half 4. More than half 5. All	
Q704	How many meals did the child eat yesterday?	[_____________________]	
Q705	Has the malnourished child had diarrhea (lasting for three days or longer) since the last visit?	0. Yes 1. No	

Q705	How is the appetite of the child for the regular household food?	0. Good 1. Poor	
Q708	Child's MUAC	First ______________________ Second ___________________ Average___________________	
Q709	Presence of edema	0. 0 1. + 2. ++ 3. +++	Check for bipedal edema

Appendix II: Ethical approval

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HAWASSA UNIVERSITY
COLLEGE OF MEDICINE AND HEALTH SCIENCES
Institutional Review Board

Ref. No: IRB/024/10

Date: 21/12/2017

Name of Researcher(s): ***Debritu Nane, Anne Hatloy and Elazar Tadesse***

Topic of Proposal: ***Effect of local ingredient based supplementary food in treating moderate acute malnutrition among children aged 6 to 59 months: A randomized controlled-trial in Wolaita.***

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.

☎ +046 820 92 90

Fax + 046 2208755
✉ 1560 Hawassa

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK vest	Jessica Svärd	55978497	09.03.2018	2018/70/REK vest
			Deres dato:	Deres referanse:
			21.02.2018	

Vår referanse må oppgis ved alle henvendelser

Anne Hatløy
Center for International Health

2018/70 Effekten av lokalbasert tilleggskost ved behandling av moderat akutt underernæring hos barn mellom 6 og 59 måneder i Wolaita, Etiopia

Institution responsible for the research: Universitetet i Bergen
Project manager: Anne Hatløy

Vi viser til søknad om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikk (REK vest) i møtet 12.04.2018. Vurderingen er gjort med hjemmel i helseforskningsloven (hfl.) § 10.

Project description
Acute malnutrition is a public health problem in Ethiopia. Moderate acute malnutrition (MAM) is one form of acute malnutrition. Numerous studies have mentioned that the current management practice of MAM as it related with high rates of defaulting, high related costs and low coverage. In Ethiopia, targeted supplementary feeding program is limited to food insecure districts. This study is commenced to formulate nutritious local food based supplement and look at its effect in treating MAM among children aged 6 to 59 months. A randomized controlled trial will be conducted. The study will involve assessing the current management practice of MAM, formulating a supplement from locally available nutritious food and testing the efficacy of supplement in treating MAM. The information drawn from this study will be shared to the public, policy makers and academicians as locally available nutritious foods have a potential to enhance recovery from MAM and reduce the burden of malnutrition.

Ethical review

Research protocol/Study design
In the research protocol it is written that "A randomized, controlled, community-based trial will be carried out to evaluate the efficacy of local ingredient based supplementary food (the intervention) compare with conventional treatment which is nutrition counseling (a control) in treating MAM and enhancing the time to recovery." Is it correct that the control group will receive just counseling? The committee finds this unacceptable. All children identified by the project to have MAM must receive a supplement. It would be acceptable to compare the local ingredient based supplement with a conventional type of supplement but not with just counseling. The committee wants to know what type of support the control group will receive.

Questionnaire/Interview
This is an extensive questionnaire, and some questions do not seem directly related to the purpose of the project. The committee want to know whether all questions are relevant and necessary to reach the goal of the project.

Informed consent
Informed consent will be obtained from mothers/caregivers, health extension workers and women development army members. Participants in the intervention study must be informed that they will be randomized to either intervention or control group.

Project period
The project period must cover the time needed for collection and analysis of data. The committee thinks that the project period is short for the scope of the project, and asks if the project will be able to finish all data collection and analysis before 31.12.2019.

Data processing and confidentiality
All storage of data must be in accordance to routines by the institution responsible for the study (University of Bergen). The project ends 31.12.2019, and all data must then by deleted or anonymized.

Postponed decision
REC Western Norway needs a response to the following questions in order to make a decision.
-What type of support will the control group receive?
-Is the project period long enough?
-Are all questions relevant and necessary to reach the goal of the project?

Response by the project manager

- Regarding control group: All children in the control group will be measured, and their anthropometric status calculated. Any children with MAM or SAM (moderate or severe acute malnutrition), will be referred to the nearest health facility for treatment. If necessary, they will get assistance to cover transportation costs.

- Regarding project period: The time schedule for the project is relatively tight. However, it is seen as realistic that all the data collection and analysis will be finished before 31.12.2019.

- Regarding length of questionnaire: The questions for the questionnaire is selected to be able to answer the research questions. Some of the questions is meant for the qualitative study - all of them are seen as relevant for understanding the current practice of MAM-treatment, and as a background for the development of the local produced weaning food. In the quantitative part, there is a baseline questionnaire, and a monthly and a weekly follow - all of them are reduced to a minimum number of questions to reach the goal of the project.

An additional response letter was submitted by email.
We have made a small modification in the study design by adding a second control group.

The national policy in Ethiopia for children with mild or moderate acute malnutrition (MAM) are to provide health and nutrition services through the health facilities by counceling. The main aim of this policy, is to hinder that the children develop severe acute malnutrition (SAM), and a second aim is to improve the nutritional status of the children from MAM to normal.

We want to compare if giving locally based supplementary food have an effect both on prevention of SAM and to improve the nutritional status from MAM to normal. We will therefore suggest two control groups: First group will follow the standard treatment for MAM according to the national policy. The children will be measured at twice – at the baseline and at the endpoint. The second control group will be followed with exactly the same frequency as the treatment group. They will every second day receive a visit by a fieldworker, that will ask how often the child has been eating over the last two days. MUAC will be measured every week, and height and weight every month – the same frequency as the treatment group.

By adding this second control group, it will be possible to test the effect of a close follow up of the child. If it is lack of resources, our hypothesis is that the treatment group will be better off than the two control groups. If it is lack of care, our hypothesis is that control group 2 will be able to recover close or similar to the treatment group.

The committee chair has reviewed the response.

Ethical review
REC western Norway cannot accept that the control group will receive just counseling. All children identified by the project to have MAM must receive a food supplement. It would be acceptable to compare the local ingredient based supplement with a conventional type of supplement.

REC western Norway is satisfied by the response to the other questions.

Condition to the approval
REC western Norway approves the study on the condition that the control group receives a conventional type of food supplement. Information about what supplement the control group will receive has to be sent to REC western Norway at post@helseforskning.etikkom.no.

Decision
REC Western Norway approves the project as long as the aforementioned conditions are met.

Final report and amendments
A final report must be sent no later than 30.06.2020. 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 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,

Marit Grønning
Prof. Dr.med.
Committee chair

Jessica Svärd
committee secretary

Copy to: post@uib.no

Emne: REK vest tar informasjon om hvilken type tilskudd kontrollgruppen skal få til orientering
Fra: post@helseforskning.etikkom.no
Dato: 16.03.2018 14:48
Til: Anne.Hatloy@uib.no
Kopi: post@uib.no

Vår ref. nr.: 2018/70
Prosjekttittel: "Effekten av lokalbasert tilleggskost ved behandling av moderat akutt underernæring hos barn mellom 6 og 59 måneder i Wolaita, Etiopia"
Prosjektleder: Anne Hatløy

Til Anne Hatløy.

Vi viser til Supplerende opplysninger innsendt 12.03.2018. Komiteen tar dette til orientering og har ingen ytterligere merknader.

Med vennlig hilsen
Jessica Svärd
rådgiver
post@helseforskning.etikkom.no
T: 55978497

Regional komité for medisinsk og helsefaglig forskningsetikk REK vest-Norge (REK vest)
http://helseforskning.etikkom.no

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Appendix III: Study Protocol

Study Protocol

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https://doi.org/10.1186/s12889-019-8031-3

BMC Public Health

STUDY PROTOCOL

Open Access

Research protocol local ingredients-based supplementary food as an alternative to corn-soya blends plus for treating moderate acute malnutrition among children aged 6 to 59 months: a randomized controlled non-inferiority trial in Wolaita

Debritu Nane[1,2*], Anne Hatløy[2,3], Elazar Tadesse[4] and Bernt Lindtjørn[2]

Abstract

Background: In Ethiopia, 12.5% of children below 5 years are wasted, and 9.7% are moderately wasted. The present strategy for the management of moderate acute malnutrition (MAM) is a supplementary feeding program; however, this is only provided to chronically food-insecure areas. This randomized controlled non-inferiority trial examines if Local ingredients-based supplement (LIBS) is as effective as corn-soya blends plus (CSB+) in treating moderate acute malnutrition among children aged 6–59 months.

Methods: A randomized controlled non-inferiority trial will be conducted with moderately wasted children aged 6 to 59 months in Wolaita, Ethiopia. The calculated sample size is 324 (i.e. with 162 children in each of two arms, to be assigned by randomization). The daily ration will be: 100 g of LIBS plus 25.2 g of sugar with 8 ml oil in the intervention group, and 150 g of CSB+ with 16 ml of oil in the control group. These interventions will be provided for a maximum period of 12 weeks, with follow-up performed on a weekly basis. Data analysis will be done using SPSS and STATA software. Both intention-to-treat and per protocol analyses will be done. Hazard ratio and Kaplan-Meier (log rank) curves of survival analysis will be done to predict the probability of recovery rate. Logistic regression will be used to test for interactions between independent and dependent variables. Analysis of variances, t-tests, fisher's exact test and chi-square tests will be used to assess baseline characteristics.

Conclusions: This paper will introduce to the existing research locally available nutritious foods which have the potential to enhance recovery from moderate acute malnutrition and to reduce the burden of malnutrition. The perceptions of mothers on feeding children with local ingredient-based supplementary food to assist recovery from moderate acute malnutrition will be the focus of in a qualitative study to follow; this will provide a further contribution in an evolving area of research.

(Continued on next page)

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[1]Hawassa University, School of Public and Environmental Health, PO Box 5, Hawassa, Ethiopia
[2]Centre for International Health, University of Bergen, PO Box 7800, 5020 Bergen, Norway
Full list of author information is available at the end of the article

(Continued from previous page)

Trial registration: Pan-African Clinical Trial Registration number: PACTR201809662822990, retrospectively registered on 11/09/2018.

Keywords: Moderate acute malnutrition, Local ingredients-based supplement, Corn-soya blend plus, Randomized controlled non-inferiority trial, Effectiveness

Background

Worldwide, acute malnutrition is a major contributor to deaths and disabilities in children, affecting about 51.5 million children below 5 years of age [1, 2]. Chronic food insecurity, poverty, poor feeding practice, limited household food availability and infections are considered possible reasons for developing acute malnutrition [3]. Acute malnutrition is associated with at least 12.6% child mortality, occurring among children aged below 5 years [2].

The Ethiopian Demographic and Health Survey of 2011 showed that about 10% of children aged below 5 years had acute malnutrition, and among these, 70% had MAM, defined by weight-for-height z-score (WHZ) between − 3 to − 2 Standard Deviations and/or mid-upper arm circumference (MUAC) of between ≥11.5 cm and < 12.5 cm, without bilateral pitting edema [4, 5]. Most malnutrition-related deaths occur in mildly or moderately malnourished children. In low- and middle-income countries, acute malnutrition is associated with about one in six deaths. Of these, 10.2% are due to MAM [6]. The death risk among moderately malnourished children is three-fold compared with that of non-malnourished children [1].

Children with MAM are susceptible to develop severe acute malnutrition (SAM) if they are not managed adequately. It is known that SAM has a high contribution to the global morbidity and mortality of young children. Therefore, children with MAM need to be treated with adequate nutrient-dense foods to prevent progressing to the life-threatening condition [2, 4].

In Ethiopia, the existing strategy for the management of MAM is a supplementary feeding program; however, this is restricted to districts where chronic food insecurity is present. In the areas not determined to be chronically food insecure, there are no food supplementation programs for MAM children. In these districts, the strategy to manage MAM children includes vitamin A supplementation, deworming and dietary counseling provided to the families [2]. The dietary counseling is provided to the families in these districts on the understanding that they have access to all foods required for child feeding, but lack knowledge on how best to use them [7].

In a study done in South-Western Ethiopia, without having a targeted nutrition-specific supplement to address MAM, only half of children aged 6 to 59 months recovered from MAM within 28 weeks of follow-up, with health and dietary counseling services alone. They were provided such services according to the national policy, but the recovery rate remained unsatisfactory. Even though these districts are named as food-secure areas, there are food-insecure households with acute moderately malnourished children suffering from high rates of deterioration and no improvement with the existing management. This is because household food insecurity is not determined by the food security level of districts [2].

Clinical strategies on the management of SAM have been present for many years. The implementation of these strategies has yielded positive outcomes. However, consistent study on the management of MAM is lagging behind, and much of the data is published on SAM, even if MAM is more prevalent and a gateway to developing SAM [8–10].

Children with MAM living in food-insecure areas are getting corn soya blend plus (CSB+) as a conventional supplement. Generally, CSB+ is given as a treatment to MAM children in developing countries since it has a good nutritional value for limited cost. However, there has been considerable argument in the international nutrition community concerning the nutritional suitability and competence for the treatment of MAM. CSB+ is believed by some to be a poor choice as a treatment since it does not contain important nutrients in acceptable amounts; it contains comparatively high amounts of anti-nutrient and fiber. In addition, it has a generally low fat level, and thus needs vegetable oil in order to provide the essential fatty acids and energy [11]. According to the report of different literature, the recovery rate after 8 to 16 weeks follow-up with CSB+ treatment is within the range of 67 to 76.8% [12–14].

The nutritional management of MAM have to normally be initiated on optimum usage of Local ingredient-based nutritious food [4]. Local ingredients based supplementary food are available, accessible, can be formulated at the household level and contain adequate amounts of the required nutrients [13].

In this paper, the new supplementary food referred to as Local ingredients based supplement (LIBS) made of locally available ingredients such as pumpkin seed, peanut, amaranth grain, flaxseed, and emmer wheat. Their portion designed to have the required amount of nutrients for the management of MAM among children aged 6 to 59 months.

In Ethiopia, Pumpkin cultivates widely and it is a seasonal crop that has been used for human food. Traditionally, consumers in Ethiopia using sun dried pumpkin fruit targeting at extended period storage for use during off season as part of food security plan [15]. Pumpkin is usually grows both in maize fields and vegetable gardens as well as in other more intensive agricultural systems [16]. Amaranth grain is a widely growing seed in Ethiopia [17]. It is mainly cultivated by people living in Southern Ethiopia as intercropped with sorghum and maize [18]. Emmer wheat is grown-up in marginal land in almost all districts of Ethiopia in both 'Meher' (June to September) and 'Belg'(March to May) time of year [19]. Oilseed crops like peanut and flaxseed are widely cultivated in Ethiopia and consistently found in the local markets.

To confirm timely treatment of MAM and resolve the restricted distribution of supplement among beneficiaries, LIBS need to be developed. Besides this, adequate research has not been conducted in Ethiopia on Local ingredient-based supplementary food, although it has the potential to contribute to treating MAM. The information drawn from this study will be shared with the public, policymakers and academics, as locally available nutritious foods have the potential to enhance recovery from MAM and reduce the burden of malnutrition.

Aim of the study

The objective of this study is to evaluate if LIBS is as effective as standard corn-soya blend plus in treating MAM among children aged 6 to 59 months.

Hypothesis

In MAM children aged 6 to 59 months, intervention with LIBS will, within 12 weeks (with a 7% margin of non-inferiority), will not have an inferior recovery rate as children with MAM receiving CSB+.

Methods

Study design

A randomized, controlled, non-inferiority trial will be carried out to evaluate the efficacy of LIBS (the intervention), compared with conventional treatment which is CSB+ (a control), in treating MAM.

Setting

This study will be conducted in Damot Pulassa district located in Wolaita zone. Like other districts of Wolaita, this district has the highest population densities of more than 700 persons per square kilometer [20]. The district characterized by having a fragmented farm and land ownership. The disparity between land and population balance has by far persisted the main contributing factor for the occurrence of endemic food insecurity [21]. Damot Pulassa district is classified as a maize and root crop livelihood zone because such crops are the main ones produced in the area. The district is serving by five health centers and 23 health posts. These health posts are led by health extension workers and deliver nutrition-linked services like nutrition education, screening for nutritional status of young children and nutritional management of the malnourished ones. The district was selected based on a consideration of the high level of food insecurity, high level of child malnutrition, good geographical location and access to transportation.

Study population

The study population will be children with MAM, MUAC of ≥11.5 cm and < 12.5 cm without bilateral edema and/or with weight-for-height z-scores between − 3 to − 2 Standard Deviations [4, 5]. Mothers or caregivers of selected children will be the respondents.

Inclusion criteria

- All children 6 to 59 months of age identified as MAM (MUAC of ≥11.5 cm and < 12.5 cm) [5].

Exclusion criteria

- Children with SAM based on WHO 2009 child growth standards and/or children with bilateral pitting edema [22].
- Children with any illness or other medical complications that prevent them from safely consuming supplementary food.
- Children already participating in other interventions.

Sample size calculation

The proportion of children who recover from MAM in an area where there is a supplementary feeding program (CSB+) is about 67% [12]. The sample size assumes that the expected percentage response in an experimental group is 60% and in a control group is 67%, with the non-inferiority criterion set to be an absolute value of 7%. To achieve 80% power to demonstrate non-inferiority, it is estimated that 162 subjects per group would be required, including a 10% withdrawal rate. This leads to a total required sample size of 324 subjects. The anticipated 10% dropout rate was used based on the observed dropout rate reported in two studies [12, 13]. For this sample size calculation, the PharmaSchool sample size calculator for non-inferiority trials was used.

Recruitment of study participants and randomization

Data collectors with health extension workers will visit all households with children aged 6 to 59 months. They will assess for eligibility by measuring the children's MUAC. If the child has a MUAC of < 12.5, data collectors will register and send the caregiver with the child to the actual screening site, where MUAC will be re-measured and weight and height or length will be taken. Children aged

24 to 59 months will be measured for weight and height, and children aged 6 to 23 months will be measured for weight and length. In addition to the values of MUAC (i.e. 11.5 cm to 12.5 cm), we will use the z-scores of weight for height or weight for length for recruitment (i.e. weight-for-height z-scores: between − 3 to − 2 Standard Deviations). If the child is identified as moderately malnourished according to the MUAC and not according to the values of weight-for- height/length z-scores, we will recruit them with their MUAC values. The screening procedure will be conducted by trained data collectors and facilitated by health extension workers using both MUAC and WHZ. Edematous malnutrition will also be evaluated using bilateral pitting edema criterion. The screening process will be continued until the sample size is met.

Computer generated sequentially numbered randomization list that contained codes for children who meet enrolment criteria will be prepared by the research supervisor. These children will be randomized into intervention or control groups, using random allocation software. The allocation ratio will be 1:1 (Fig. 1).

Allocation of participants to the intervention or control group will be done by one of the research team who has no information about the participant identity. After allocation into two groups, the subjects further categorized by the investigator into sub-groups, with equal numbers of children based on their location/neighborhood to assign one food distributor to each group in which food distributor can easily reach the households with the selected child.

Blinding

Caregivers, data collectors and food distributers will be blinded for the intervention. Both supplements will be packed with similar packs, and will be distributed and prepared in the same way. The sugar which will be distributed for the intervention group will be mixed with the flour before packing. Vegetable oil will be distributed for both intervention and control groups with the supplement and food distributer will be assigned to help caregivers in cooking the porridge with 16 ml of oil for CSB+ group and with 8 ml of oil for intervention groups.

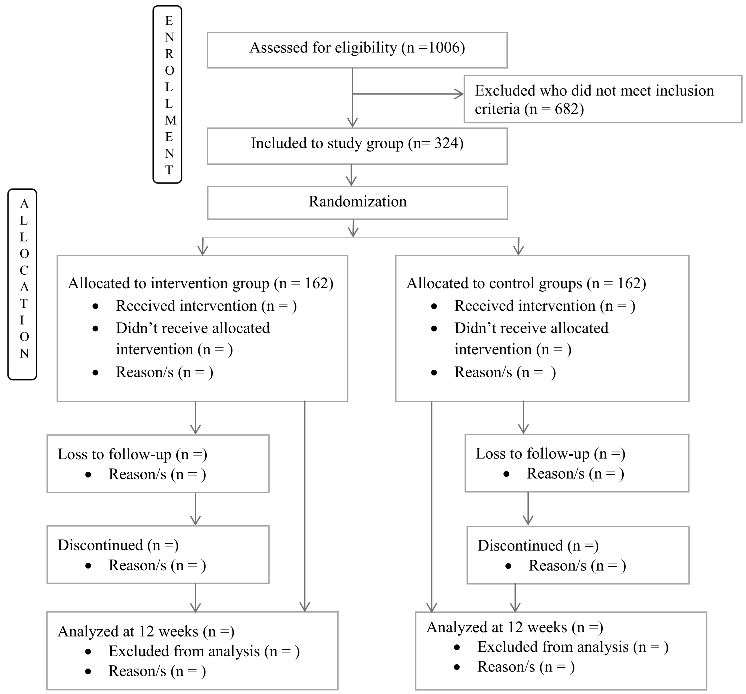

Fig. 1 Trial profile. Assessed for eligibility = Children aged 6 to 59 months who assessed for moderate acute malnutrition.. Randomized = Children aged 6 to 59 months who assessed for moderate acute malnutrition, fulfilled the inclusion criteria, recruited and randomly allocated. Loss to follow-up = Children who are randomly allocated to intervention and control groups and stop to participate in the study at any stage of the study. Discontinued = Children who are randomly allocated to intervention and control groups and discontinued from the study at any stage of the study. Analyzed at 12 weeks = Children aged 6 to 59 months whose information analyzed at 12 weeks

The data will be analyzed by an individual other than the assessor.

Data collection

Selected caregivers of children with MAM aged 6 to 59 months will be interviewed for collection of baseline data such as socio-demographic and economic status, dietary habits, child's age, breastfeeding practices and history of child and maternal illness. The child's weight will be noted using a seca weight scale to the nearest 0.1 kg. The data collectors will be sure that the scale is placed on a flat, hard, even surface and will weigh with minimal clothing.

Height will be recorded to the nearest 0.1 cm using a seca height scale for children aged 24 to 59 months. For children aged 6 to 23 months, length will be measured to the nearest 0.1 cm using a locally made wooden measuring board. Before starting height measurement, the data collectors will ensure that the height board is on level ground and the child is without shoes; the collector will kneel in order to get to the level of the child and will encourage the caregiver to help. For length, data collectors will measure the child lying down, being sure that the length board is placed on a flat and stable surface.

MUAC will be documented by non-stretchable standard United Nations Children's Fund (UNICEF) plastic tape measures. The measurement will be taken half-way between the acromion and the olecranon processes, with the measuring tape fitting comfortably, but without making a depression in the upper arm. Weekly assessment of anthropometric measurement using MUAC will be done by the data collectors for intervention as well as control groups. On a monthly basis, data collectors will again collect anthropometrics using the MUAC, height or length board and weight scale which are identical equipment to that used at baseline. At the same time, they will observe for bilateral pitting edema. Based on the follow-up measurement of anthropometry children who developed sever acute malnutrition will be referred to SAM clinic.

Description of interventions and distribution of supplementary foods

After collecting baseline information, each child in the intervention group will be given local ingredient-based supplement of 100 g with 20 g of sugar. The ration will be distributed on a daily basis for 12 weeks. The LIBS is made from 30 g of pumpkin seed, 25 g of peanut grain, 20 g of amaranth grain, 15 g of flaxseed, 10 g of emmer wheat, 25.2 g of sugar and 8 ml of oil. This supplement yielded 698.5 kcal (22.6 g protein, 40.89 g fat and 60.05 g carbohydrate). Similarly, each child in the control group will be given the conventional supplement (CSB+) with the amount of 150 g flour/day with 16 ml of oil (763.98.4 kcal, 23.5 g protein and 25 g fat) on a daily basis for a period of 12 weeks. The subjects will be served with both supplements in the morning as a breakfast (Table 1).

According to the guidelines for selective feeding, all children 6–59 months of age will receive the same amount of food [23]. During the intervention period, the food distributers will visit households daily to assist the caregivers in the preparation of porridge and feeding, to advise, assess and resolve difficulties with feeding. Besides, they will check for and quantify the amount of supplement consumed by the children.

Data quality management

Scheduled as well as unscheduled home visits and close follow-up to check feeding procedure will be made by the supervisors and investigator. If the child is a twin, an

Table 1 Nutrient composition of the supplementary foods

Nutrient	100 g of LIBS with 25.2 g of sugar plus 8 ml oil	150 g of CSB+ with 16 ml of oil
Energy (kcl)	698.5	763.98
Protein (gm)	22.6	20.25
Fat (gm)	40.89	30.76
Iron (mg)	8.1	6
Zn (mg)	5.6	7.5
Calcium (mg)	100	195
Phosphorous (mg)	470.55	300
Potassium (mg)	666.14	600
Magnesium (mg)	394.7	107.75
Sodium (mg)	84.6	41.25
Folic acid (µg)	49.4	90

Note: Nutrient values for the LIBS ration were calculated by using the USDA food composition database and NutriSurvey software. Nutrient values for the CSB+ was adapted from Amegovu KA, Ogwok P, Ochola S, Yiga P, Musalima HJ, Mutenyo E. Formulation of sorghum-peanut blend using linear programming for treatment of moderate acute malnutrition in Uganda. J Food Chem and Nutr. 2013; 1(2):67–77

Abbreviations: *LIBS* Local ingredients based supplement, *USDA* United States Department of Agriculture and *CSB+* Corn soy blend plus additional amount of supplementary food will be given to the caregiver to confirm that the enrolled child is provided with a full portion.

If two children with MAM are found in the same household, both children will receive food but only the randomly selected child will be enrolled in the study. If the recruited child is not at home during the time of follow-up, data collectors will revisit those households until they find the child. Sessions for standardization of anthropometric measurements will be carried out on a monthly basis. Monitoring of the food distribution process, feeding techniques and use of the provided food supplements will be carried out among randomly selected households on a twice-monthly basis. After data collection, the filled questionnaires will be stored in a secured place, and data entry will start. Double data entry and checking for consistencies will be carried out.

Data analysis

All data collection sheets will be controlled by the field supervisors for completeness. EpiData version 3.1 will be used for all data entry. Two data clerks will enter data simultaneously to ensure data quality. Continuous data quality evaluation will be made through automatic consistency checks. Statistical significance is set at 5% for all analyses. Statistical analysis will be done using SPSS and STATA software for survival and hazard ratio. The probability of recovery rate will be predicted in Kaplan-Meier (log rank) curves of survival analysis. T-tests, analysis of variance (ANOVAs) and chi-square tests will be used to assess baseline characteristics. In accordance with recommendations for analyzing and reporting equivalence and non-inferiority trials, both intention-to-treat (ITT) and per protocol (PP) analyses will be done, and the 95% CI will be used to infer whichever variances are significant [24]. The ITT analyses will include all children enrolled in the study whereas the PP analyses will exclude children who lost to follow-up, refused and transferred out of the management programme but include children discharged as cured, died or non-cured.

Logistic regression will be used to test for interactions between the recovery rate and other variables. Mean recovery time and median recovery time, mean differences of MUAC and mean difference between WHZ scores will be computed to describe the magnitude of the difference between the two groups.

Outcome variables

The primary outcome measure of this study will be recovery rate. 'Recovered' will be defined as when a child attains a MUAC ≥12.5 cm and WHZ scores ≥ − 2, without bipedal edema. The secondary outcomes are the mean recovery time and average weight gain. Children who developed SAM during the study and/or persisted as moderately malnourished at the end of the 3-month follow-up will be considered to have failed the management for MAM.

Participant timeline

Children aged 6 to 59 months will be assessed for MAM based on inclusion and exclusion criteria using MUAC and weight-for-height/length z-scores. The screening procedure will end within 3 weeks. Consenting of the eligible respondents (mothers of children aged 6 to 59 months) and randomization of the eligible subjects will take place 1 week after screening completed during which the subjects will be allocated into intervention and control groups, along with baseline data collection. Follow-up interviews with the anthropometric assessment will be done weekly and monthly basis after the allocation date and completed within 11 weeks. End-line data collection will take place 1 week after ending a follow-up interview (Fig. 2).

Training

Data collectors will receive training about the objectives of the study, data collection systems, interview techniques, anthropometric measurements, feeding procedures and field procedures prior to the data collection. Each question found in the questionnaire will be discussed during training, in which trainers will develop common understandings.

Standardization of anthropometric measures will be maintained. If it is possible, the same assessors will be used for all assessments.

Pretesting

Pretesting of the questionnaire will be conducted in places away from where the actual study will be conducted. For the pretesting, 16 pairs of children and caregivers, which is 5% of the total sample size, will be interviewed to check the accuracy of questions and to decide on the length of interviews. During pretesting, consistency in the interpretation of questions will be checked to identify any unclear items. After the evaluation of instruments, all proposed revisions will be done before administering in the actual study.

Harms

The food ingredients used for formulating the supplement will be foods which are already being used in these communities and are safe for consumption. The participants will get supplementary food at no cost as the treatment for their malnutrition status. There might be minimal risk of allergic reaction. There might be risk while making interactions and spending time through the process.

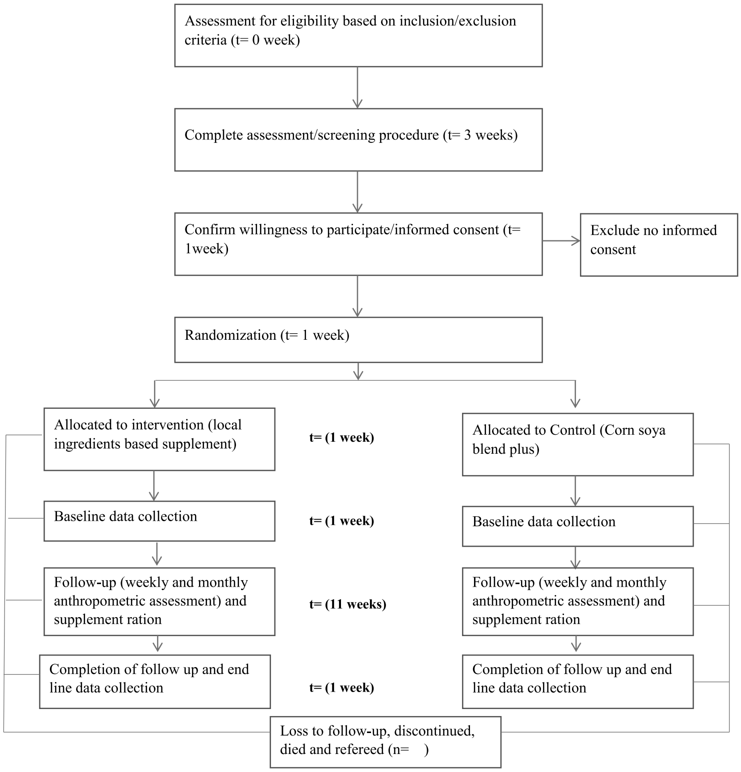

Fig. 2 Participants time line. Assessed for eligibility = Children aged 6 to 59 months who assessed for moderate acute malnutrition based on inclusion/exclusion criteria. Complete assessment = Completion of screening for moderate acute malnutrition. Confirm willingness to participate = be sure for the willingness of care givers of the subject to be included in the study / informed consent. Randomization = Process of randomizing the subjects/ children aged 6 to 59 months who assessed and claimed as moderately malnourished. Base line data collection = collection of data before starting food ration. Follow-up = Weekly as well as monthly anthropometric assessment and daily food ration. End line data collection = Collection of data after completion of the follow up. t = indicates time that the processes have done/completed

Auditing

The study is open for auditing by any concerned organization, either government or non-government.

Protocol amendment

Communication will be done regarding the protocol modification with those important stakeholders (IRB/IEC and Sponsor).

Dissemination of the result

The result of this study will be disseminated through Internal Seminars, Conference presentations using outreach and public engagement events. Regular reporting and communication to stakeholders will be done. It will also disseminate through Publications.

Potential benefits

This project will be carried out in the kebeles (neighborhoods) found in Wolaita zone where there is no provision of a supplementary feeding program. The children participating in this study will get supplementary food for their malnutrition. The intervention will enhance recovery from MAM, and those recovered from MAM will be discharged and rejoin the community.

Children who may develop serious allergic reactions like difficulty in breathing, dizziness, weakness or any unusual signs will be referred for treatment. Such participants will be excluded from the trial. Children who are temporarily sick or do not feel well will be sent to the health facility for the treatment, and their measurements will be rescheduled for other days.

SPIRIT guidelines

The study protocol followed the SPIRIT guidelines for randomized controlled trials.

Discussion

MAM is a state that needs to be managed before it progresses to the life-threatening condition which is SAM. It is known that SAM has a high contribution to the global morbidity and mortality of young children [2]. Children with MAM need to achieve catch-up growth in weight and height, and they must be able to fight against infection and disease. That is why, currently, specific nutrient recommendations have recently been established for children with MAM living in developing countries [10].

The 2012 WHO technical note on supplementary foods for treating MAM in children aged 6 to 59 months recommends the delivery of locally available, nutritious foods to enhance nutritional status and prevent SAM [4]. It is important to evaluate the effect of feeding acute moderate malnourished children with local ingredient-based supplementary food. The food supplement referred in this paper is LIBS made from locally available ingredients either cultivated locally or found in the local market. If this study demonstrates positive results, it will provide a direction to the public, policymakers and academics, as locally available nutritious foods have the potential to enhance recovery from MAM and reduce the burden of malnutrition. The current study intends to determine the recovery rate from MAM by examining baseline and end-line measurements of MUAC and WHZ scores of the subjects. It will also evaluate the average weight gain and time of recovery.

Trial status

The trial was registered with the Pan-African Clinical Trial Registry on 11/09/2018 and the trial number is PACTR201809662822990.

Abbreviations

ANOVA: Analysis of Variance; CSB +: Corn-Soy Blended Flour Plus.; ITT: Intention-to-Treat; LIBS: Local Ingredients Based Supplement; MAM: Moderate Acute Malnutrition; MUAC: Mid-Upper Arm Circumference; PACTR: Pan-African Clinical Trial Registry; PP: Per Protocol; SAM: Severe Acute Malnutrition; SFP: Supplementary Feeding Program; UNICEF: United Nations Children's Fund; WHO: World Health Organization; WHZ: Weight-for-Height Z-score

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Author's contribution

DN, AH, BL and ET were accountable for the design of study, the intervention and preparing this paper. All authors were responsible for drafting the document and have read and approved the final version.

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Availability of data and materials

The datasets used and/or analyzed during the current study will be available from the corresponding author, on reasonable request.

Ethics approval and consent to participate

Approval for the study was obtained from Hawassa University College of Medicine and Health Sciences institutional review board and regional committees for medical and health research ethics in Norway. The approval obtained from Hawassa University College of Medicine and Health Sciences institutional review board covers all sites included in the study. The purpose of the study and ways of data collection, confidentiality and voluntary participation will be explained to mothers of children invited to sign an informed consent form. Written informed consent will be obtained from all caregivers of children who meet enrolment criteria before recruitment of their children into the study. All interviews and intervention procedure will be conducted in privacy.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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References

1. Ackatia-Armah RS, McDonald CM, Doumbia S, Erhardt JG, Hamer DH, Brown KH. Malian children with moderate acute malnutrition who are treated with lipid-based dietary supplements have greater weight gains and recovery rates than those treated with locally produced cereal-legume products: a community-based, cluster-randomized trial. Am J Clin Nutr. 2015;101:632–45.
2. James P, Sadlaw K, Wondafrash M, Argaw A, Luo H, Geleta B, Kedir K, Getnet Y, Belachew T, Bahwere P. Children with moderate acute malnutrition with no access to supplementary feeding programmes experience high rates of deterioration and no improvement: results from a prospective cohort study in rural Ethiopia. PLoS One. 2016;10:1371.
3. Tessema M, Belachew T, Ersino G. Feeding patterns and stunting during early childhood in rural communities of Sidama, South Ethiopia. Pan Afr Med J. 2013;14:75.
4. World Health Organization. Supplementary foods for the management of moderate acute malnutrition in infants and children 6–59 months of age. Technical note. Geneva: WHO; 2012.
5. Reginald A, Patrick W, Brown R. Management of Moderate Acute Malnutrition. In: Current Knowledge and Practice. CMAM Forum Technical Brief; 2014.
6. Lazzerini M, Rubert L, Pani P. Specially formulated foods for treating children with moderate acute malnutrition in low- and middle-income countries. Cochrane Database Syst Rev. 2016;6:CD009584. https://doi.org/10.1002/14651858.CD009584.pub2.
7. Ashworth A, Ferguson E. Dietary counseling in the management of moderate malnourishment in children. Food Nutr Bull. 2009;30:S406–33.
8. Prinzo ZW, Briend A. Dietary management of moderate malnutrition: time for a change. Food Nutr Bull. 2009;30(3):Suppl:S265–6.
9. Nikie'ma L, Huybreqts L, Kolsteren P, Lanou H, Tiendrebeogo S, Bouckaert K, Kouanda S, Sondo B, Roberfroid D. Treating moderate acute malnutrition in

first-line health services: an effectiveness cluster-randomized trial in Burkina Faso. Am J Clin Nutr. 2014;100:241–9.
10. Golden MH. Proposed recommended nutrient densities for moderately malnourished children. Food Nutr Bull. 2009;30(3):Suppl:S267–342.
11. De Pee S, Bloem MW. Current and potential role of specially formulated foods and food supplements for preventing malnutrition among 6- to 23-month-old children and for treating moderate malnutrition among 6- to 59-month-old children. Food Nutr Bull. 2009;30:434–63.
12. Karakochuk C, van der Briel T, Stephens D, Zlotkin S. Treatment of moderate acute malnutrition with ready-to-use supplementary food results in higher overall recovery rates compared with a corn-soya blend in children in southern Ethiopia: an operations research trial. Am J Clin Nutr. 2012;96:911–6.
13. Amegovu AK, Ochola OP, Yiga P, Musalima J, Juliana M. Efficacy of sorghum peanut blend and corn soy blend plus in the treatment of moderate acute malnutrition in children aged 6–59 months in Karamoja, Uganda: a cluster randomized trial. Nutr Diet Suppl. 2014;6:75–84.
14. Medoua GN, Ntsama P, Ndzana A, Essa'a V, Tsafack J, Dimodi H. Recovery rate of children with moderate acute malnutrition treated with ready-to-use supplementary food or improved corn–soya blend : a randomized controlled trial. Public Health Nutr. 2015;19(2):363–70.
15. Workneh TS, Zinash A, Woldetsadik K. Blanching, salting and sun drying of different pumpkin fruit slices. J Food Sci Technol. 2012;51(11):3114–23.
16. Aliu S, Rusinovci I, Fetahu S, Salihu S, Zogaj R. Nutritive and mineral composition in a collection of *Cucurbita pepo* L. grown in Kosova. Food Nutr Sci. 2012;3:634–8.
17. Zebdewos A, Singh P, Birhanu G, Whiting SJ, Henry CJ, Kebeb A. Formulation of complemntary food using amaranth, chickenpea and mize improves iron, calcium and zinc content. ajfand. 2015;15(4):10290–10304.
18. Endale CM-R, Adrien S, Gilles M, Abdulaziz A, Gulelat DH. Protein Quality of Amaranth Grains Cultivated in Ethiopia as Affected by Popping and Fermentation. Food Nutr Sci. 2015;6:38–48.
19. Bethlehem M, Neela S, Solomon WF. Emmer wheat- an Ethiopian prospective: a short review. Ann Food Sci Technol. 2019;20(1):89–96.
20. Central Statistical Agency. Ethiopia Demographic and Health Survey 2011. ICF International Calverton; 2012.
21. Ethiopia. Food insecurity; Revised emrgency appeal. Ethiopia; 2008.
22. World Health Organization and United Nations Children's Fund. WHO child growth standards and the identification of severe acute malnutrition in infants and children. Geneva: WHO; 2009.
23. The United Nation Refugee Agency. Guidelines for selective feeding; the management of malnutrition in emergencies. Geneva: UNHCR, United Nations High Commissioner for Refugees; 2011.
24. Piaggio G, Elbourne DR, Altman DG, Pocock SJ, Evans SJ. Reporting of non-inferiority and equivalence randomized trials: an extension of the CONSORT statement. JAMA. 2006;295:1152–60.

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