Outcomes of Moderate Acute Malnutrition and their determinants in under-five children: a prospective cohort study from a food-secure setting in rural Ethiopia

A partnership study for the USAID ENGINE programme in Ethiopia, implemented by

Valid International, Jimma University and Save the Children

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Executive Summary

Introduction: Acute malnutrition (AM) continues to be a major global public health problem, affecting an estimated 51.5 million children aged under 5 years and being associated with 12.6% of all under-5 child mortality [1]. When compared to adequately nourished children, children suffering from AM have increased risk of mortality, impaired physical and cognitive development, and more infections. Moderate acute malnutrition (MAM) is more prevalent than severe acute malnutrition (SAM) and affects approximately 64% of all those categorized as having AM[1].

Study Objectives: To determine the outcomes of untreated MAM and their determinants through follow-up of moderately acutely malnourished children aged 6-59 months. Specifically, to determine the proportion of recovery, non-response and deterioration to SAM; determine the incidence of SAM and mortality; measure the average duration of MAM episode (time to recovery and time to deterioration); identify child, household, and caretaker characteristics associated with the different outcomes; and compare the outcomes of MAM in the study population with the Sphere minimum standards and reports from targeted supplementary feeding programmes (TSFPs) in food-insecure settings.

Methods: The study was conducted from September 2013 – March 2014 in Mana and Dedo woredas of Jimma Zone in South-western Ethiopia, selected to represent food-secure rural settings where there was no supplementary feeding program, but where other health and nutrition services were delivered according to the national policy. This was an observational, prospective cohort study of MAM children followed for seven months. A child was categorized as having MAM if his/her MUAC was ≥11.0cm and <12.5cm with no bilateral pitting oedema. After baseline, children were followed weekly for 28 weeks. This period included the peak malnutrition period right through to the post-harvest period. Children's nutritional and morbidity parameters were evaluated weekly. Any child that deteriorated to SAM (MUAC <11.0cm and/or bilateral pitting oedema) at any point was referred to the nearest health facility. Questionnaires included child, household and caretaker related variables. Weight, height or length and MUAC were assessed using standard measurement techniques. 923 children were followed up weekly for seven months and 884 children were included in analysis.

Final outcomes were assigned to children at 28 weeks:

- **Recovery** was defined as reaching MUAC ≥12.5cm with no oedema at week 28 and never experienced a SAM episode throughout the follow up period.
- A **non-responder** was defined as a child who never reached MUAC <11.0 cm and never developed bilateral pitting oedema but whose MUAC still remained below 12.5cm throughout the 28 weeks of follow up.
- **Deteriorated to SAM** was defined as reaching a MUAC <11.0 cm or presenting pitting bilateral oedema at any point during follow up. This group was divided into those who remained SAM at 28th week of follow up, those who met MAM criteria at 28th week of follow up (MUAC was ≥11.0cm and <12.5cm with no bilateral pitting oedema) and those who met recovery criteria (no oedema and MUAC ≥12.5cm) at 28th week.
- The two remaining categories were **died** (confirmed by a home visit) and **loss to follow-up**.

Key Results

- 54.2% of children recovered, 32.5% were non-responders, 9.3% experienced at least one episode of SAM, 0.9% died and 3.7% were lost to follow up.
- Most children who developed SAM were still MAM at the end of the follow up.
- Overall the incidence rate of SAM was 1.57 per 100 children-months. This equates to 3% of children developing SAM every 2 months of follow up. When compared to children enrolled with a MUAC between 12.0cm and 12.4cm, the incidence rate of SAM was almost 4 and 15 times higher in children enrolled with a MUAC between 11.5 cm and 11.9 cm and between 11.0 cm and 11.4 cm respectively.
- MUAC at admission was the only variable independently associated with risk of developing SAM.
- Children classified at enrolment as severely wasted by WHZ or having a MUAC between 11.5cm and 11.9 cm had a significantly higher risk of remaining moderately malnourished at the end of the follow up.
- Other factors thatwere associated with remaining moderately malnourished included coming from a household from the fourth lowest wealth quintile, unsafe disposal of the youngest child's faeces and mother's workload in the least heavy tertile.
- The cumulative probability (mean and 95% CI) of recovering from MAM by the 28th of follow up without experiencing an episode of SAM was 65.9 (62.0-69.8)%.
- The median time to recovery from enrolment was 9 (4 - 15) weeks.
- The indicators of wasting (MUAC and weight-for-length/height Z-score) had the strongest associations with recovery, with the most wasted children having the lowest chance of recovering by the end of follow up. Children aged <24 months at enrolment had a lower chance of recovery than older children. Children of mothers with the heaviest working index category had a better chance of recovery than those of mothers of the least heavy working index category. Being in wealthiest category was associated with increased chance of recovery. Among WASH indicators, drinking water from an improved water source was associated with increased chance of recovery.
- A total of 8 deaths were documented during the study period giving a mortality rate of 0.9% (8/884). The incidence of death was 0.13 per 100 person-months, equating to an under-5 mortality rate of 0.44 deaths per 10,000 child days.
- Of the 8 children who died, seven had a MUAC <11.5 cm at one point before the death was recorded, including 3 who had a MUAC <11.0cm.
- Overall length/height-for-age z-scores (HAZ) exhibited a statistically significant ($p<0.001$) change of -0.31(-0.41, -0.20) z-scores over the follow up period.

Conclusion: The present study has highlighted the following key points:

1. Nearly half of children who are MAM at the beginning of the post-harvest season either develop SAM or cross the four months of best food security without recovering. Many therefore risk entering the next hunger season in a highly vulnerable condition.
2. The incidence of SAM is particularly alarming when WHO (2006) MUAC cut-offs are used.

3. The incidence of death was low compared to the expected incidence but SAM was diagnosed prior to death in seven of the eight deaths.
4. The period during which anthropometry improved coincided with the period of lowest morbidity from diarrhoea, respiratory infection and febrile episodes.
5. MUAC category at enrolment was the best predictor of final outcomes in all models and could be used as a basis for targeted intervention.
6. Stunting is widespread in areas of Ethiopia classified as food secure. The process of stunting continued even when there was correction of wasting, especially in children less than 24 months. SAM occurred in the most stunted children.
7. In children less than 24 months, failure to correct wasting was also associated with a higher deficit in height gain.

Our results indicate that children who suffer from MAM during the post-harvest season in a food secure zone experience an unacceptably high incidence of SAM and low recovery rate. This highlights the need to re-assess the current strategy for addressing MAM in areas classified as food secure. It is likely that if the study was implemented during the hunger period, the rate of deterioration to SAM would have been even higher, with a concomitant increase in mortality. It is concerning that many of the children who did not recover will enter the next hunger season in such a vulnerable condition, with likely consequences of increased risk of SAM and death.

Policy recommendations

- Criterion for admission to the outpatient treatment of SAM (OTP): MUAC based admission criterion should shift from MUAC <11.0cm to MUAC <11.5cm.
- Criterion for discharge from OTP: Children admitted based on MUAC criterion should be discharged using the criterion MUAC ≥12.5cm.
- Children who have developed advanced MAM but are not eligible for OTP (i.e. those with MUAC 11.5 cm to <12.0 cm) should be referred to support under the Enhanced Outreach Strategy /Targeted Supplementary Feeding during the most vulnerable period of the year (July to November) in settings considered food secure.
- Integrate household food security assessment with the existing routine deworming and vitamin A campaigns preceding the hunger season and ensure that all households identified as at risk of food insecurity are linked to the food security schemes implemented in the area e.g. the Productive Safety Net Programme (PSNP), the Household Asset Building Programme (HABP) or the Complementary Community Investment Programme (CCI).
- Strengthen the Community-based Nutrition activities for the prevention and treatment of MAM in the community.
- Support mechanisms for better integration between programming for acute and chronic malnutrition in food secure settings in Ethiopia.
- Further research is recommended on:
    - Cost-effectiveness of Community-Based Nutrition in nutrition rehabilitation of children with MAM during pre-harvest and post-harvest season in comparison with alternative approaches including linkage to food security schemes, TSF, CMAM and cash transfers.

- Outcomes of MAM during the hunger season in food secure woredas experiencing seasonal hunger with high quality community nutrition and health services. Two cohorts would be beneficial: one of healthy children and another of MAM children, recruited at the beginning of the hunger season and followed up throughout the hunger and best food security seasons.
- Identification of the food security profile, dietary diversity profile, disease profile, environmental characteristics and household income of the period associated with the best growth velocity and the lowest incidence of SAM (December and January).

1 Introduction

Acute malnutrition (AM) continues to be a major global public health problem, affecting an estimated 51.5 million children aged under 5 years and being associated with 12.6% of all under-5 child mortality [1]. When compared to adequately nourished children, children suffering from AM have increased risk of mortality, impaired physical and cognitive development, and infections [1]. Moderate acute malnutrition (MAM) is more prevalent than severe acute malnutrition (SAM) and affects approximately 64% of all those categorized as having AM [1].

1.1 Whilst the contribution of SAM to global mortality and morbidity has been widely recognized [2,3], with resulting consensus on international treatment protocols [4], the management of MAM remains debated. However, over recent years much effort has been made to harmonise the understanding of MAM and its management [5,6], yet consensus, especially in non-emergency and relatively food secure settings of low and middle income countries, is still not reached. For some experts, provision of a food supplement should not be considered as the only way to treat MAM. They advocate for the exploration and scale up of approaches that may be more sustainable [7,8]. Indeed, recent studies have suggested that nutrition counselling for better utilisation of food available in the community through health and nutrition child-centred counselling, focusing on improving infant and young child feeding practices, may be as effective as specialized food based interventions [9,10]. Some agencies have also used Positive Deviance as an approach to facilitate behaviour change and reduce the occurrence of under-nutrition [11]. Another strategy proposed is the 'food-based' approach, which does not aim to supplement or replace usual family meals, but instead aims to increase the nutrient uptake from existing sources of natural food [12]. However, to date, the effectiveness of these alternative approaches has not yet been confirmed [7,10,13]. In Ethiopia AM remains an extensive and seemingly embedded problem. During the Demographic and Health Survey of 2011, 10% of under-five children in the country had acute malnutrition, with 70.0% of those having MAM [14]. Ethiopia's 2013 National Nutrition Plan acknowledges this with an overall goal for reducing the prevalence of wasting from 9.7% to 3% by 2015. Under results 2.1 and 2.2 there is a commitment to 'ensure access to quality management of severe and moderate malnutrition'. However,

most of the action steps are designed with SAM treatment in mind. Indeed, the current strategy in Ethiopia is to restrict Targeted Supplementary Feeding Programs (TSFP) for treatment of MAM (implemented through provision of supplementary food products) to selected woredas of the country defined as chronically food insecure. In areas not considered chronically food insecure, food accessibility is not considered to be a determinant factor for AM and routine health interventions including Enhanced Outreach Service (EOS) of vitamin A supplementation and deworming, safe water, improved sanitation and nutrition counselling are considered sufficient to prevent and treat MAM. Unfortunately, relative food security at the woreda level does not necessarily equate to nutritional security in all households [14–17]. Indeed, a recent unpublished survey revealed an average prevalence of MAM in nineteen food secure woredas of 4.9%, which when viewed at the national scale represents the status of hundreds of thousands of children. Data describing the short term outcomes of these children and their determinants is lacking and the present study aims to help close this gap. Study Hypotheses and Objectives

1.1.1 Hypotheses

- In a food-secure setting where health and nutrition services exist according to the national policy, 4% of children (6-59 months) with Moderate Acute Malnutrition (MAM) will deteriorate to Severe Acute Malnutrition (SAM) in the absence of a supplementary feeding program.
- In a food-secure setting where health and nutrition services exist according to the national policy, 49% of children (6-59 months) will recover from MAM in the absence of supplementary feeding program.

1.1.2 Study Objectives

This study aims to determine the outcomes of untreated MAM and their determinants through follow-up of moderately acutely malnourished children aged 6-59 months. The specific objectives are to:

- Determine the proportion of recovery, non-response and deterioration to SAM;
- Determine the incidence of SAM;
- Determine incidence of death;
- Measure the average duration of MAM episode (time to recovery and time to deterioration);
- Identify child, household, and caretaker characteristics associated with the different outcomes;

- Compare the outcomes of MAM in the study population with the Sphere minimum standards and reports from TSFPs in food-insecure settings.

2 Methods

2.1 Study area

The study was conducted in Mana and Dedo woredas of Jimma Zone in South-western Ethiopia (figure 1). These study areas were selected to represent food-secure rural settings where there was no supplementary feeding program, but where other health and nutrition services were delivered according to the national policy. These services included the Integrated Management of Maternal, Neonatal and Childhood Illnesses (IMNCI), the Integrated Community Case Management of illness (ICCM), and the Community-based Management of Acute Malnutrition (CMAM) to treat SAM. Through the Enhanced Outreach Strategy (EOS) Vitamin A supplementation and deworming treatment is scheduled for distribution at 6-monthly campaigns. Immunisation, basic nutrition and sanitation counselling are provided through the health extension system. Subsistence farming is the dominant form of livelihood in the area. Major crops produced in the area are cereals (maize, teff, sorghum and barley), pulses (beans and peas), cash crops (coffee and khat), and root crops (false banana and potato) [18–20]. Mana and Dedo woredas have a similar agro-ecological pattern.

Figure 1: Map of Jimma zone in Ethiopia, with study woredas circled. Adapted from[21].

2.2 Study design

This was an observational, prospective cohort study of MAM children followed for seven months. For this study, a child was categorized as having MAM if the MUAC was ≥11.0 and <12.5cm with no bilateral pitting oedema. The period of follow-up was set at 28 weeks in order to follow children from the peak malnutrition period through to the post-harvest period (figure 2). Eligible children were identified during a 10-day (5 days per woreda) exhaustive house-to-house MUAC and bilateral pitting oedema screening implemented by 82 trained community health volunteers (CHVs). The baseline household questionnaire was then administered from August, 19th to September, 14th. After baseline the children were followed weekly for 28 weeks by a total of 40 data collectors. The first weekly follow up took place from September 1st to September 8th in Dedo woreda and from September 16th to September 26th in Mana woreda. Over this follow up period children's nutritional and morbidity parameters were evaluated weekly. Any child that deteriorated to SAM (MUAC <11.0cm and/or bilateral pitting oedema) at any point during the follow up was referred to the nearest health facility and managed as per existing protocol and continued to be followed up. CHVs

received a one-day refresher training on MUAC and oedema screening techniques, and data collectors received 8 days of training on anthropometry, assessment of oedema and questionnaire delivery.

2.3 Data collection methods and procedures

Data were collected on pre-tested structured questionnaires prepared in Amharic and Afan Oromo. The questionnaire included child, household and caretaker related variables. Child-related variables included sex, age at enrolment, child-feeding index, immunization status, access to EOS, incidence of common childhood illnesses, hand washing and baseline nutritional status. Household variables included questions to assess wealth index, household size, main income generating activity, food security status, water and sanitation questions, geographical access to primary health care, death of a family member and household head information. Caretaker-related variables included relationship to the child, age, educational status, occupation, work index, access to and source of information about recommended child feeding and care practices, hand washing, disposal of young child faeces and health seeking behaviour. Weight, height or length and MUAC were taken of the children in minimal clothing and no shoes using standard measurement techniques.

2.4 Sample Size

Sample size was calculated using the web-based OpenEpi software [22]. Anticipating a 10 % deterioration to SAM with 95% of confidence interval of ±2.5% (CI limit 7.5% to 12.5%), assuming a design effect of 1.5 and a loss of follow up of 20%, the required sample size was 996. This sample size was not reached but the loss to follow up was much lower than anticipated, making the sample of 884 children successfully followed up sufficient for the principal outcomes.

2.5 Data management and statistical analysis

923 children were followed up weekly for seven months. Figure 3 summarises the exclusions made to the dataset which resulted in 884 children included for analysis. Data were doubled entered at the field level using Epi Data version 3.2 [23]. Data cleaning and all data analysis was performed using Stata 12.0 or 13.0 [24,25]. Anthropometric indices were calculated in Stata according to WHO (2006) growth standards [26]using the zscore06 command [27].

	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Coffee			Harvesting									
Maize	Weeding	Weeding	Harvesting		Selling	Land preparation			Sowing			Weeding
Teff	Sowing	Weeding	Harvesting			Selling				Land preparation		Sowing
Wheat	Sowing	Weeding	Harvesting			Selling				Land preparation		Sowing
Sorghum	Weeding	Weeding		Harvesting		Land preparation			Sowing		Weeding	
Barley	Sowing	Weeding	Harvesting			Selling				Land preparation		Sowing
Enset		3 year preparation period before consumption										
Avocado	Harvesting								Harvesting			
Mango	Harvesting								Harvesting			
Banana									Harvesting			
Potato				Harvesting								
Food Security	**Worst**		**Best food security**									**Worst**
Diseases		**Malaria**										
Follow-up		**Cohort follow- up**										

Figure 2: Seasonal calendar of Jimma zone, indicating study duration. Adapted from [21].

2.6 Variables transformation and statistical analysis

The household wealth index was assessed using the standard criteria from the Ethiopia 2011 Demographic and Health Survey [14]. Wealth index scores and resulting quintiles were generated from the data by principal components analysis using the methodology described in detail in Vyas and Kumaranayake [28] and further summarized by Rutstein et al. [29].Water, sanitation and Hygiene (WASH) were summarised into standard binary variables as recommended by the WHO & UNICEF (2006) methodology [30]. Hand washing scores for the child and caretaker were created by assigning no=0 and yes=1 for seven hand washing questions, totalling the scores and dividing into three categories with the lowest category containing scores 0-2, the middle one containing scores 3-5 and the highest category containing scores 6 and 7. Household food security status was summarised using the nine questions and scoring methodology from the Household Food Insecurity Access Scale (HFIAS), described in detail by Coates J et al. [31]. The feeding practice of children was summarised using the Infant and Child Feeding Index (ICFI) score [32,33]. The final three ICFI categories were then grouped so that those with scores of 0-2 were assigned to the lowest group, 3-4 to the middle group and 5-6 to the highest group. Two health-seeking behaviour variables were created regarding what the caregiver did when the child was ill. 'Good' health-seeking behaviours were defined as taking the child to the health facility, giving the child modern medicine, giving more food, giving more clean water, having a separate plate for the child and increasing the amount of attention given. 'Poor' behaviours included giving traditional medicine, giving less food and water, and prioritising traditional healer or other faith healing practices.

2.7 Outcomes

Final outcomes were assigned to children at 28 weeks. The definitions of final outcomes are as follow:

- **Recovery** was defined as reaching MUAC ≥12.5cm with no oedema at week 28 and never experienced a SAM episode throughout the follow up period.
- A **non-responder** was defined as a child who never reached MUAC <11.0 cm and never developed bilateral pitting oedema but whose MUAC still remained below 12.5cm throughout the 28 weeks follow up.
- **Deteriorated to SAM** was defined as reaching a MUAC <11.0 cm or presenting pitting bilateral oedema any time during follow up

  A new episode of SAM within the same child was diagnosed when a weekly SAM diagnosis was separated from the previous episode by a minimum of two clear weeks of MUAC >11.0cm with no oedema.
- The two remaining categories were **died** (confirmed by a home visit) and **loss to follow-up**.

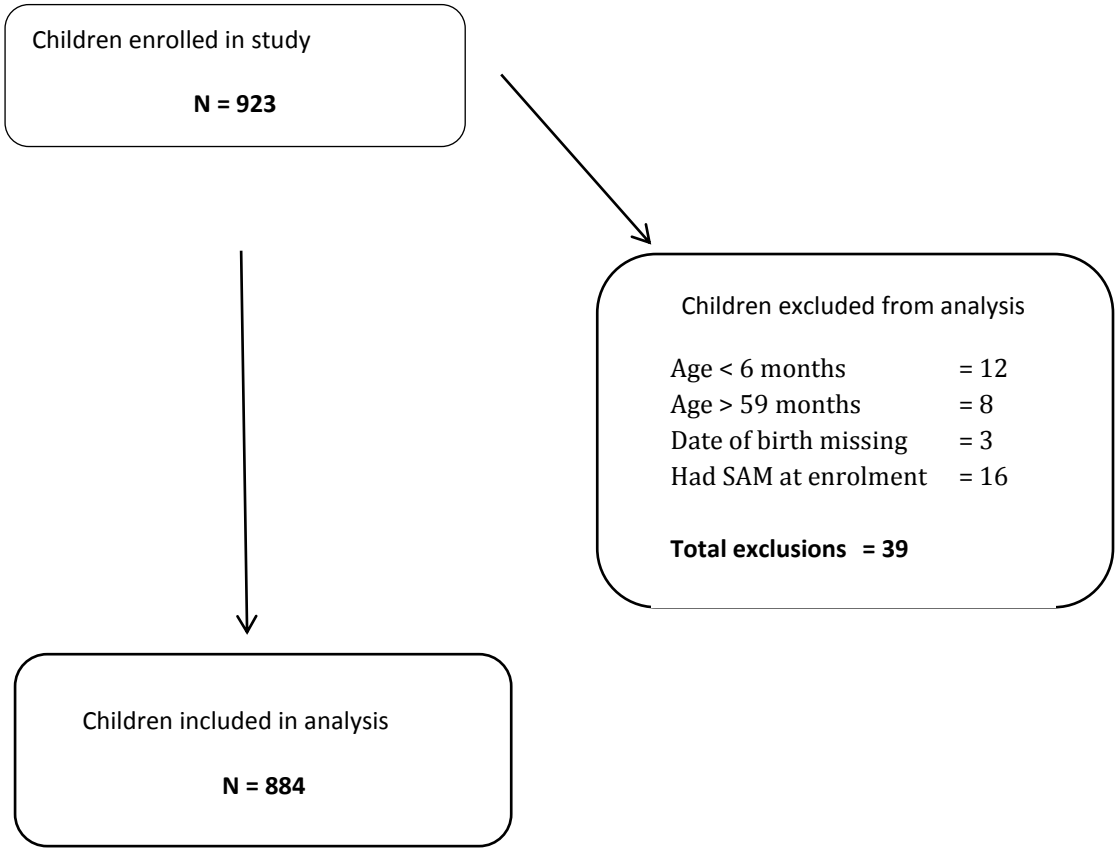

Figure 3: Summary of children excluded from data analysis

Given the growing interest regarding the relationship between severe acute malnutrition and stunting [34,35] and the need to integrate acute malnutrition and chronic malnutrition programming that emerged while the study was already ongoing, the following unplanned endpoints were also considered and included in this report:

- Decrease in the height-for-age z-score in children below 24 months
- Decrease in the height-for-age z-score in children 24 months and older
- Percentage of expected length/height increment achieved for children <24 months at enrolment
- Percentage of expected length/height increment achieved for children aged 24 months or older at enrolment.

The percentage of length/height increment was calculated using WHO 2006 growth standards. For each age and sex at enrolment, the expected length/height increment was calculated as follows:

$$\%\ increment\ achieved = \frac{(\text{Height gain}) * 100}{\text{Median height reference End} - \text{Median height reference Start}}$$

With 'median height reference start' being the median height at enrolment of a child of the same age (in months) and sex according to WHO 2006 growth standards and 'median height reference end' being the median height a child of the same age (in months) and sex seven months later.

Other outcomes were also measured in order to provide insights relevant to future study design.

Characteristics of the cohort are described using proportions for categorical and categorised continuous variables and means or medians for continuous variables as appropriate. Outcomes are presented for the whole cohort using the Ethiopian operational definition of SAM (MAM defined for this study as 11.0-12.4cm, and SAM <11.0cm). Key results are also analysed using the WHO (2006) MUAC cut-off of SAM <11.5cm (therefore excluding children enrolled with MUAC 11.0-11.4cm). These results are presented in the Annex. Deterioration to SAM incidence is calculated using the first episode. Survival plots for mortality and deterioration to SAM are stratified by MUAC admission category and final outcome, and compared using the log-rank test. Appropriate univariable and multivariable statistical tests including tests adapted for cohort data analysis and survival were used to describe the results, determine strength of the association between predictors and the different outcomes and identify independent predictors for each of the outcomes. For multivariable models, age (categorized as <24 months versus ≥ 24 months), gender, ICFI in 3 categories, HFIA in 3 categories, and the number of topics recently covered during counselling sessions by HEW were imposed in the models given the study assumptions and hypothesis of good food security and health services in the study area.

2.8 Ethical considerations

The study was approved by the ethical review board of Jimma University on 23rd March, 2013. Enrolment onto the study was voluntary and data collection and follow up were initiated after obtaining written consent from the caregiver.

3 Results

3.1 Baseline characteristics

Table 1 summarises the socio-demographics characteristics, WASH practices, food security situation, and health and nutrition conditions at baseline of the 884 children analysed. Of note, the sample contains proportionally more girls and younger children. Mothers were young with the majority of them being illiterate. The majority of households had appropriate WASH practices yet the proportion of those with inappropriate WASH practices remained significant. EOS and HEW activities were sub-optimal as indicated by the proportion of those who did not receive a HEW visit in the past month, alongside the coverage of those who received preventive Vitamin A supplementation and deworming medication in the past 6 months[1]. Less than a quarter of children were sleeping under insecticide impregnated mosquito nets. The majority of households were categorised as having food insecurity with a third of them experiencing severe food insecurity. Over two thirds of children were stunted at enrolment with almost half of children being already severely stunted. The weight-for-height z-score (WHZ) classified over 60% of these MAM children as not being wasted. The morbidity was high as indicated by the proportion of children who experienced diarrhoea and cough in the past two weeks. Figure 4 below depicts the moving average of morbidity. It shows that the percentage of children who were reported by the caregiver as having diarrhoea, fever or cough during the previous week was 33.4% at the first week of follow up and then stabilised to approximately 15% from the 15th week of follow up onwards.

3.2 Final outcomes of the MAM cohort

Table 2 shows that overall over half of children enrolled never deteriorated to SAM and recovered (MUAC ≥12.5cm) by the end of the study, but this also means that over 40% of the enrolled children did not recover. Most children who developed SAM were still MAM as measured by MUAC at the end of the follow up. Of the 82 children who developed SAM, 17 had 2 episodes and 2 had 3 episodes, giving a total of 103 SAM episodes experienced overall. The median duration of SAM was 2 weeks [IQR 1-6]. Of the 32 children lost to follow up, at the last known measurement 21 (65.6%) of these children were MAM status and 9 (34.4%) had MUAC ≥12.5cm.

When this analysis was restricted to the 325 children who met supplementary feeding programme (SFP) admission and recovery criteria as defined in Ethiopian SFP protocols (SAM <11.0cm, MAM 11.0-11.9cm), the distribution of the different final outcomes were 64.0% (208/325) for recovered, 12.3% (40/325) for remained MAM, 0.9% (3/325) for died, 3.7% (12/325) for lost to follow up and 19.1%(62/325) for developed SAM. Results and commentary on the equivalent analysis when the WHO (2006) MUAC cut-off for SAM (<11.5cm) is used is presented in Supplementary tables 1 and 2 (Annex).

[1] The target is >90% coverage for vitamin A supplementation and deworming medication.

Table 1: Baseline households and children characteristics

Variable *(statistics description)*	Statistics	Total N
Child sex: male, *n (%)*	360 (40.9)	881
Child age (months), *median (IQR)*	12 (12-34)	884
Household size, *median (IQR)*	6 (5-7)	884
Primary caretaker is mother, *n (%)*	826 (93.4)	884
Caretaker education: no formal, *n (%)*	648 (73.3)	884
Caretaker age, *median (IQR)*	30 (25-35)	884
Mother's MUAC category: <23cm, *n (%)*	615 (69.6)	884
Sex of the household head: male, *n (%)*	818 (92.8)	881
HH head education: no formal, *n (%)*	518 (58.6)	884
Number of people per sleeping room, *median (IQR)*	4 (3-6)	880
Land owned (hectares), *median (IQR)*	0.25 (0-0.75)	882
Person died in the household in past year: yes, *n (%)*	71 (8.0)	884
Number of food groups eaten in past 24 hours (child), *median (IQR)*	2 (1-3)	884
Household Food Insecurity Access		
Food secure, *n (%)*	288 (32.6)	884
Mildly food insecure access, *n (%)*	58 (6.6)	884
Moderately food insecure access, *n (%)*	24 (27.3)	884
Severely food insecure access, *n (%)*	297 (33.6)	884
Drinking water source: unimproved, *n (%)*	294 (33.3)	884
Drinking water treatment: unsafe, *n (%)*	869 (98.3)	884
Sanitation facility: unimproved, *n (%)*	136 (15.4)	884
Safe disposal of faeces: unsafe, *n (%)*	246 (27.8)	884
Service from health extension worker received in past month: none, *n (%)*	264 (29.9)	884
Vitamin A received in past 6 months: yes, *n (%)*	610 (69.0)	884
Deworming received in past 6 months (children aged >24mo): yes, *n (%)*	191 (52.2)	366
Child sleeps under a bed net: yes, *n (%)*	189 (21.4)	882
Transportation to nearest health facility: on foot, *n (%)*	836 (94.6)	884
Diarrhoea in past 2 weeks: yes, *n (%)*	28.3 (28.4)	884
Fever in past 2 weeks: yes, *n (%)*	265 (30.1)	882
Cough in past 2 weeks: yes, *n (%)*	249 (28.2)	882
Breastfed (age 6-24 months): yes, *n (%)*	468 (90.3)	518
WHZ, *median (IQR)*	-1.70 (-2.41,-1.0)	872
<-3, *n (%)*	111 (12.7)	872
≥-3 and <-2, *n (%)*	219 (25.1)	872
≥-2, *n (%)*	542 (62.2)	872
HAZ, *median (IQR)*	-2.89 (-4.37, -1.59)	880
<-3, *n (%)*	416 (47.3)	880
≥-3 and <-2, *n (%)*	176 (20.0)	880
≥-2, *n (%)*	288 (33.7)	880
WAZ, *median (IQR)*	-2.84 (-3.66, -1.93)	873
<-3, *n (%)*	400 (45.8)	873
≥-3 and <-2, *n (%)*	230 (26.3)	873
≥-2, *n (%)*	243 (27.8)	873

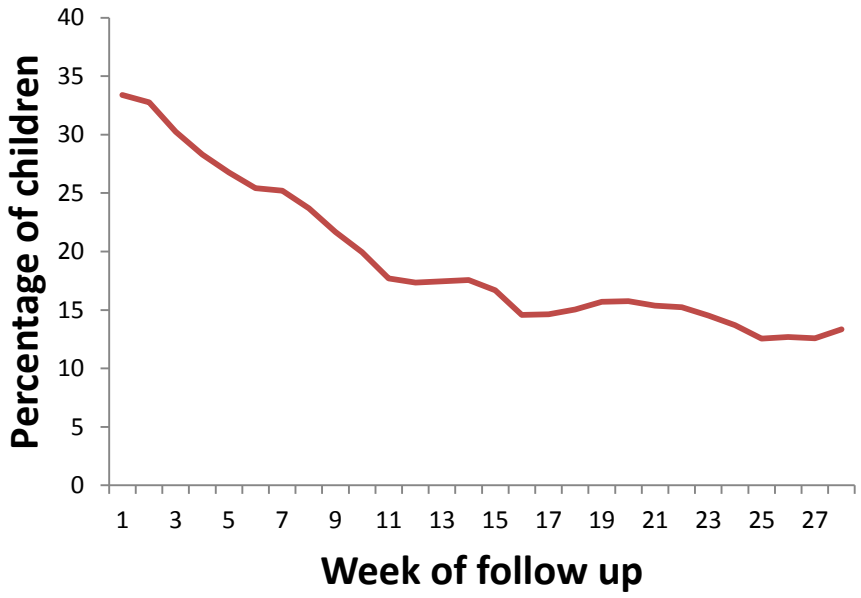

Figure 4: Trend in the percentage of children with history of diarrhoea, fever or cough

Table 2: Final Outcomes of the MAM cohort

Outcome	All children		SAM Children	
	n	%	n	%
Recovered and never SAM	479	54.2		
Non-responder (never SAM but no recovery)	287	32.5		
Total SAM (at least 1 episode)	82	9.3		100.0
SAM at week 28			9	11.0
SAM at least once but recovered			27	32.9
SAM at least once but MAM at last follow up			41	50.0
SAM at least once but died			4	4.9
SAM at least once but lost to follow up			1	1.2
Lost to follow up	32	3.7		
Died (Never SAM)	4	0.9		
Total	884	100.0		

3.3 Deterioration to Severe acute malnutrition: Incidence, cumulative probability of occurrence and predictors

Overall the incidence rate of SAM was 1.57 per 100 children-months. This equates to 3% of children developing SAM every 2 months of follow up (Table 3). This figure varies according to the MUAC category at enrolment. When compared to children enrolled with a MUAC between 12.0cm and 12.4cm, the incidence rate of SAM was almost 4 and 15 times higher in children enrolled with a MUAC between 11.5 cm and 11.9 cm and between 11.0 cm and 11.4 cm respectively, corresponding to almost 2% and 8% of children of these MUAC categories deteriorating to SAM each month of follow up (table 3).

Table 3: Incidence of Severe Acute Malnutrition (first-event)

Outcome	N	No. of episodes	Follow-up time †	Incidence rate† (95% CI)	Incidence rate ratio (95% CI)
All	884	82	52.3	1.57 (1.26-1.94)	
>=12.0 cm	558	18	34.7	0.52 (0.32-0.80)	1.0
11.5 - <12.0	215	25	12.6	1.99 (1.32-2.89)	3.8 (2.0-7.4)
11.0 -<11.5	111	39	5.03	7.75 (5.59-10.5)	14.9 (8.3-27.7)

†Expressed in 100 person-months

Figure 5 below indicates that the cumulative probability of children not deteriorating to SAM over the follow-up period. Considering the whole cohort, just over 90% of children did not develop SAM during the first 12 weeks. However, this varied considerably by category of MUAC at enrolment. 91% of children enrolled with MUAC 11.5-11.9 cm did not develop SAM over the follow-up, yet this was only 65% for enrolled with MUAC 11.0- 11.4cm. Results and commentary on the equivalent analysis when the WHO (2006) MUAC cut-off for SAM (<11.5cm) is used is presented in Supplementary figure 1 (Annex).

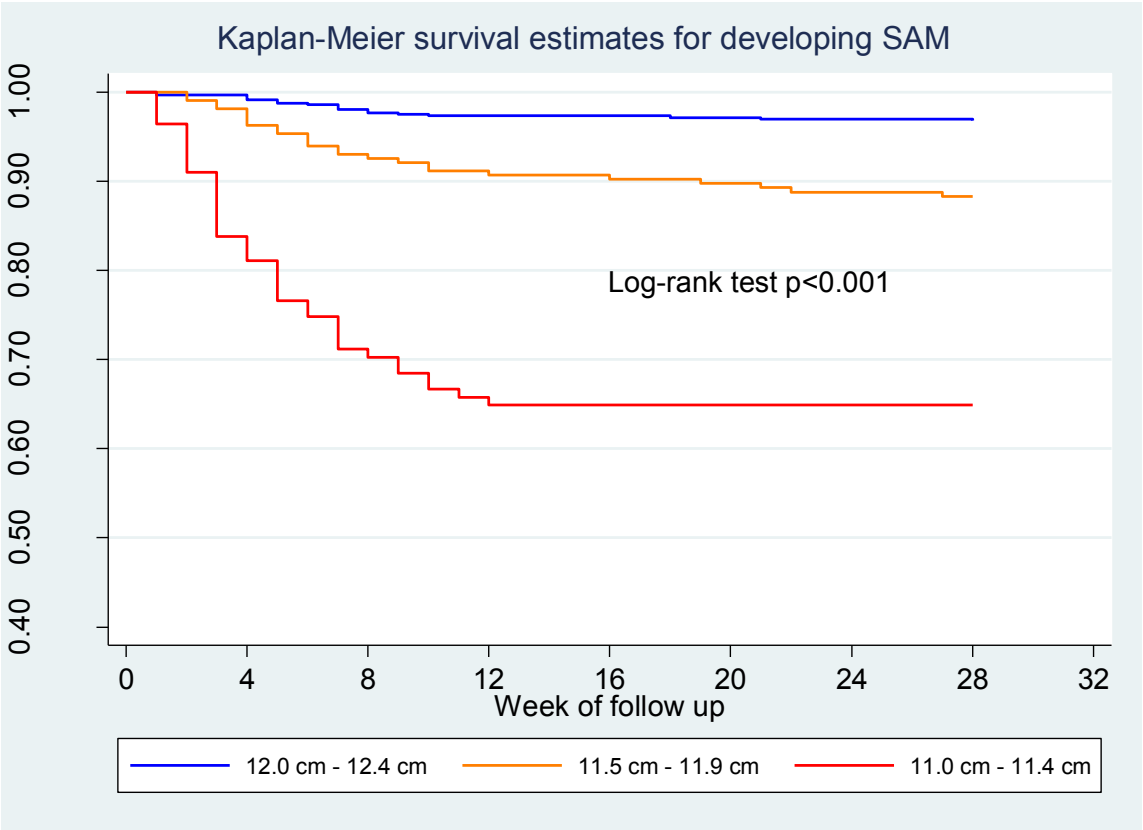

Figure 5: Survival curve for developing Severe Acute Malnutrition per MUAC category at enrolment

Table 4 below reports the list of predictors of deterioration to SAM identified. Of note, MUAC at admission was the only variable independently associated with risk of developing SAM during follow up and the association was very strong. Despite the fact that children who deteriorated to SAM were more stunted at enrolment than those who did not [median (IQR) HAZ -3.51 (-4.55, -1.93) vs. -2.84 (-4.34, -1.57); p=0.0497], HAZ was not an independent predictor of deterioration to SAM. Results and commentary on the equivalent analysis when the WHO (2006) MUAC cut-off for SAM (<11.5cm) is used is presented in Supplementary table 2 (Annex).

Table 4: Predictors of occurrence of severe acute malnutrition based on parameters at enrolment: bivariate and Cox proportional hazards analyses†

Variable	Category	N‡	% SAM	Unadjusted HR (95% C.I.)	P-value	Adjusted HR (95% C.I.)	P-value
Gender	Male	360	9.4	1.00 (base)		1.00 (base)	
	Female	521	9.2	0.96 (0.62-1.49)	0.859	0.98 (0.61-1.57)	0.937
Age group	≥ 24 months	366	7.9	1.00 (base)		1.00 (base)	
	< 24 months	518	10.2	1.30 (0.83-2.04)	0.255	1.32 (0.79-2.20)	0.292
Food insecurity	None	288	7.6	1.00 (base)		1.00 (base)	
	Moderate	299	9.0	1.18 (0.67-2.08)	0.557	1.33 (0.75-2.36)	0.335
	Severe	297	11.1	1.49 (0.87-2.56)	0.146	1.37 (0.78-2.39)	0.273
Child feeding practices score tertiles	Lowest	175	8.6	1.00 (base)		1.00 (base)	
	Middle	384	9.1	1.10 (0.58-1.96)	0.828	1.33 (0.71-2.52)	0.374
	Highest	325	9.8	1.14 (0.62-2.11)	0.667	1.58 (0.83-3.01)	0.161
MUAC category	≥ 12.0 cm	558	3.2	1.00 (base)		1.00 (base)	
	11.5 – 11.9 cm	215	11.6	3.73 (2.03-6.84)	<0.001	3.60 (1.91-6.80)	<0.001
	11.0 - 11.4 cm	111	35.1	13.5 (7.69-23.53)	<0.001	12.31(6.63-22.85)	<0.001
WHZ category (Z-score)	≥-2	540	6.7	1.00 (base)		1.00 (base)	
	≥-3 and <-2	219	12.3	1.92 (1.16-3.16)	0.002	1.35 (0.80-2.38)	0.308
	<-3	111	15.3	2.48 (1.39-4.42)	0.011	1.37 (0.74-2.53)	0.255
HAZ category (Z-score)	≥-2	288	7.3	1.00 (base)		1.00 (base)	
	≥-3 and <-2	176	6.8	0.93 (0.46-1.89)	0.089	0.88 (0.42-1.84)	0.738
	<-3	416	11.5	1.60 (0.96-2.67)	0.072	1.38 (0.78-2.44)	0.270
Topics covered by the HEW counselling	≥ 3	145	6.2	1.00 (base)		1.00 (base)	
	1-2	207	6.3	1.03 (0.44-2.41)	0.941	0.89 (0.38-2.10)	0.789
	0	531	11.3	1.88 (0.93-3.78)	0.078	1.63 (0.80-3.32)	0.181
Vitamin A in past 6 months	No	274	12.0	1.00 (base)		1.00 (base)	
	Yes	610	8.0	0.65 (0.42-1.01)	0.058	1.10 (0.69-1.76)	0.690

†N in multivariable analysis: 869 with 80 events. ‡N in bivariate analysis

Abbreviations: SAM, Severe Acute Malnutrition; CI. Confidence interval, HR, Hazard Ratio; MUAC, mid-upper arm circumference; WHZ, weight-for-height z score; HAZ, height-for-age z-score; HEW, health extension worker

3.4 Non-recovery: predictors of non-recovery

Data presented in Table 5 show that the proportion of children who remained MAM was high in all the categories of the predictors considered. Children classified at enrolment as severely wasted by WHZ and those of MUAC between 11.5cm and 11.9 cm had a significantly higher risk of remaining MAM at the end of the follow up. The other factors that were associated with remaining MAM included coming from a

household from the fourth lowest wealth quintile, unsafe disposal of the youngest child's faeces and mother's workload classified as not heavy.

Table 5: Baseline predictors of non-recovery: bivariate and logistic regression analyses†

Variable	Category	N‡	% non-recovery	Unadjusted OR (95% CI)	P-value	Adjusted OR (95% CI)	P-value
Gender	Male	343	31.2	1.00 (base)		1.00 (base)	
	Female	502	35.7	1.22 (0.91-1.64)	0.179	1.24 (0.91-1.71)	0.177
Age group	≥ 24 months	470	31.5	1.00 (base)		1.00 (base)	
	< 24 months	374	37.2	1.24 (0.92-1.66)	0.149	1.34 (0.97-1.85)	0.078
MUAC category	≥ 12.0 cm	535	27.5	1.00 (base)		1.00 (base)	
	11.5 – 11.9 cm	205	47.3	2.37 (1.70-3.31)	<0.001	2.00 (1.40-2.87)	<0.001
	11.0 - 11.4 cm	108	39.8	1.75 (1.14-2.68)	0.011	1.36 (0.84-2.17)	0.208
WHZ category	≥-2	522	30.6	1.00 (base)		1.00 (base)	
(Z-score)	≥-3 and <-2	209	36.4	1.29 (0.92-1.81)	0.136	1.33 (0.92-1.92)	0.129
	<-3	106	44.3	1.80 (1.18-2.76)	0.007	1.72 (1.07-2.75)	0.024
Child feeding	Highest	316	37.0	1.00 (base)		1.00 (base)	
practices score	Middle	363	32.2	0.81 (0.59-1.11)	0.190	0.75 (0.53-1.06)	0.100
tertiles	Lowest	169	31.4	0.78 (0.53-1.11)	0.213	0.66 (0.43-1.02)	0.065
Food insecurity	None	280	29.3	1.00 (base)		1.00 (base)	
	Moderate	284	33.1	1.19 (0.84-1.71)	0.329	1.18 (0.80-1.73)	0.412
	Severe	284	39.1	1.55 (1.09-2.20)	0.014	1.35 (0.91-1.99)	0.135
Wealth quintile	1-4	671	36.4	1.00 (base)		1.00 (base)	
	5 (Richest)	164	23.2	0.53 (0.36-0.78)	0.002	0.59 (0.39-0.91)	0.017
Mother's	least heavy	312	35.3	1.00 (base)		1.00 (base)	
working index	Middle	248	38.3	1.14 (0.81-1.61)	0.457	1.13 (0.78-1.66)	0.512
	most heavy	288	28.5	0.73 (0.52-1.03)	0.076	0.66 (0.45-0.97)	0.036
Stools disposal	unsafe	237	41.8	1.00 (base)		1.00 (base)	
	safe	611	30.8	0.62 (0.45-0.84)	0.002	0.65 (0.46-0.90)	0.011
Drinking water	unimproved	281	38.4	1.00 (base)		1.00 (base)	
source	improved	567	31.6	0.29 (0.07-1.32)	0.110	0.33 (0.72-1.55)	0.161
Hand washing	Lowest	96	36.5	1.00 (base)		1.00 (base)	
score tertiles	Middle	438	38.8	1.10 (0.70-1.75)	0.668	1.05 (0.64-1.73)	0.838
	Highest	314	26.1	0.62 (0.38-1.00)	0.051	0.65 (0.39-1.11)	0.100

†N in multivariable analysis: 820 with 278 events. ‡N in bivariate analysis

Abbreviations: CI, Confidence interval, OR, Odds Ratio; MUAC, mid-upper arm circumference; WHZ, weight-for-height z score.

3.5 Recovery: cumulative probability of recovering and predictors

The cumulative probability (mean and 95%CI) of recovering by the 28th of follow up without experiencing an episode of SAM was 65.9 (62.0-69.8) %. The median time to recovery was 9 (4 - 15) weeks. All these parameters varied significantly according to the category of MUAC at enrolment. The cumulative probability of recovering was 79.6 (75.3 – 83.7)% for those with MUAC at enrolment between 12.0 cm and 12.4 cm, 49.2 (41.0-58.1)% for those with MUAC at enrolment between 11.5 cm to 11.9 cm and 31.3 (21.7-43.9)% for those with MUAC at enrolment between 11.0 and 11.4 (Log-rank test p <0.001). For those who recovered,

the median times to recovery from enrolment for the same categories of MUAC were 7 (4 – 14) weeks, 13 (8 -17) weeks and 16 (14 -20) weeks, respectively. Figure 6 illustrates the probability of recovery from MAM over time. Of note, the cumulative probability increases steeply from enrolment in children enrolled with MUAC between 12.0cm and 12.4 cm, indicating a faster recovery rate for this category. The figure also shows that for children enrolled with MUAC between 11.0cm and 11.4cm, most of the recovery occurred between the 12th and 20th week. For all three categories there was almost no more recovery after the 20th week of follow up.

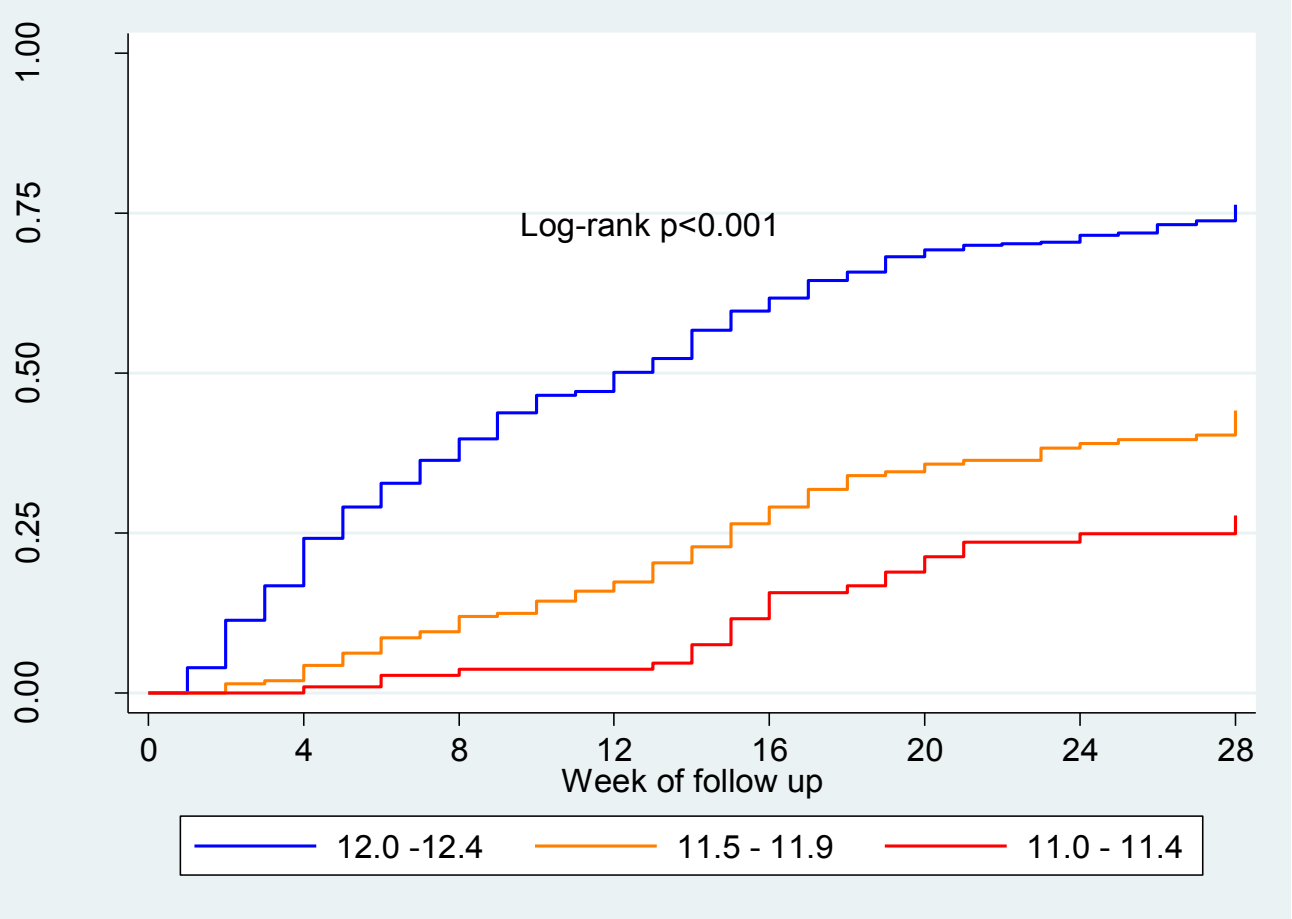

Figure 6: Survival curve for recovering for MAM for those who never deteriorate to severe acute malnutrition

Table 6 below shows the independent predictors of recovery. The indicators of wasting (MUAC and weight-for-length/height Z-score) had the strongest associations with recovery, with the most wasted children having the lowest chance of recovering by the end of follow up. Children age <24 months at enrolment had a lower chance of recovery than older children. Children of mothers with the heaviest working index category had a better chance of recovery than those of mothers of the least heavy working index category. Being in wealthiest category was associated with increased chance of recovery. Among WASH indicators, drinking water from an improved water source was associated with increased chance of recovery. Household severe food insecurity reduced chances of recovery but the association did not reach the level of significance after adjustment. No indicator of morbidity or infant feeding practices was retained in the multivariable model.

Table 6: Baseline predictors of recovery: bivariate and Cox proportional hazards analyses†

Variable	Category	N‡	% recovery	Unadjusted HR (95% CI)	P-value	Adjusted HR (95% CI)	P-value
Gender	Male	340	59.4	1.00 (base)		1.00 (base)	
	Female	500	55.0	0.89 (0.75-1.07)	0.231	0.84 (0.70-1.02)	0.083
Age group	≥ 24 months	469	60.3	1.00 (base)		1.00 (base)	
	< 24 months	374	52.4	0.88 (0.74-1.06)	0.196	0.78 (0.64-0.96)	0.020
MUAC category	≥ 12.0 cm	532	69.6	1.00 (base)		1.00 (base)	
	11.5 – 11.9 cm	203	40.9	0.37 (0.29-0.47)	<0.001	0.40 (0.31-0.52)	<0.001
	11.0 - 11.4 cm	108	24.1	0.20 (0.13-0.29)	<0.001	0.24 (0.16-0.36)	<0.001
WHZ category	≥-2	519	62.6	1.00 (base)		1.00 (base)	
	≥-3 and <-2	208	51.0	0.65 (0.52-0.81)	<0.001	0.70 (0.56-0.88)	0.003
	<-3	105	40.0	0.52 (0.37-0.71)	<0.001	0.69 (0.49-0.98)	0.036
HAZ category	≥-2	274	56.6	1.00 (base)		1.00 (base)	
	≥-3 and <-2	172	65.7	1.15 (0.91-1.47)	0.238	1.14 (0.89-1.48)	0.298
	<-3	394	53.0	0.80 (0.65-0.99)	0.038	0.89 (0.71-1.13)	0.351
Food insecurity	None	282	62.9	1.00 (base)		1.00 (base)	
	Moderate	281	58.4	0.88 (0.71-1.09)	0.251	0.87 (0.70-1.09)	0.228
	Severe	282	49.3	0.71 (0.57-0.89)	0.003	0.81 (0.63-1.03)	0.085
Wealth quintile	1-4	666	54.0	1.00 (base)		1.00 (base)	
	5 (Richest)	164	68.9	1.53 (1.24-1.90)	<0.001	1.34 (1.07-1.68)	0.010
Mother's working index	least heavy	312	54.2	1.00 (base)		1.00 (base)	
	Middle	244	51.6	0.95 (0.76-1.20)	0.673	0.97 (0.76-1.24)	0.825
	most heavy	287	64.1	1.45 (1.18-1.79)	<0.001	1.75 (1.40-2.18)	<0.001
Drinking water source	unimproved	277	50.2	1.00 (base)		1.00 (base)	
	improved	566	60.1	1.49 (0.80-2.79)	0.212	1.40 (1.14-1.73)	0.001
Child hand washing score tertiles	Lowest	300	51.0	1.00 (base)		1.00 (base)	
	Middle	394	55.6	1.09 (0.89-1.35)	0.387	0.99 (0.80-1.22)	0.917
	Highest	149	71.8	1.61 (1.26-1.07)	<0.001	1.26 (0.97-1.65)	0.083
Stools disposal	unsafe	234	50.0	1.00 (base)		1.00 (base)	
	safe	609	59.4	1.35 (1.10-1.66)	0.005	1.20 (0.96-1.49)	0.105
Topics covered by the HEW counselling	≥ 3	142	67.6	1.00 (base)		1.00 (base)	
	1-2	194	60.3	0.76 (0.78-1.00)	0.052	0.93 (0.70-1.25)	0.646
	0	506	52.6	0.67 (0.53-0.85)	0.001	0.88 (0.68-1.14)	0.348
Vitamin A in past 6 months	No	256	48.0	1.00 (base)		1.00 (base)	
	Yes	587	60.6	1.48 (1.20-1.81)	<0.001	1.05 (0.84-1.30)	0.678

†N in multivariable analysis: 856 with 467 events. ‡N in bivariate analysis

Abbreviations: CI. Confidence interval, HR, Hazard Ratio; MUAC, mid-upper arm circumference; WHZ, weight-for-height z score; HAZ, height-for-age z-score; HEW, health extension worker

3.6 Mortality: incidence of death and cumulative probability

A total of 8 deaths were documented during the study period giving a mortality rate of 0.9% (8/884). The incidence of death was 0.13 per 100 person-months, equating to an under-5 mortality rate of 0.44 deaths per 10,000 child days. Of the 8 children who died, seven had a MUAC <11.5 cm at one point before the death was recorded, including 3 who had a MUAC <11.0cm. Four children were in an episode of SAM the week

before they died. Figure 7 shows that timing of death was spread out over the duration of the follow up. All caregivers attributed the deaths to disease rather than accident. Unexpectedly, there was no death in the category of children enrolled with a MUAC between 11.0cm and 11.4cm.

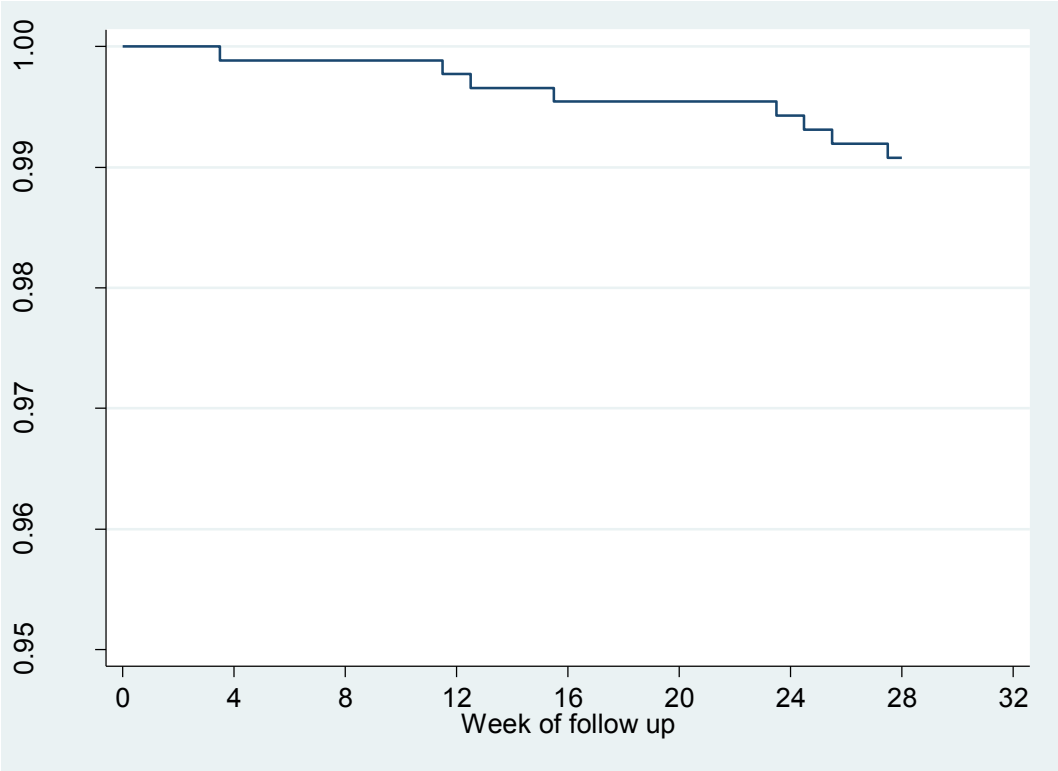

Figure 7: Cumulative probability of death

3.7 Effect on linear growth: change in height-for-age and relative percentage of linear increment

Overall length/height-for-age z-scores (HAZ) exhibited a statistically significant (p<0.001) change of -0.31(-0.41, -0.20) z-scores over the follow up period. It was -0.57 (-0.71, -0.42) Z-score for children below 24 months at enrolment (p<0.001) and +0.10 (-0.01, 0.22) for those 24 months or older at enrolment (p=0.087).

In terms of absolute height gain, children aged ≥24 months at enrolment gained a median height of 3.6 (2.3, 5.2)cm over the 7 months, equating to 79.2% of their expected age-specific height gain. The corresponding figures for those younger than 24 months at enrolment are 4.5 (2.8, 6.5)cm and 61.2%. Within each age group, the percentage of expected height gain achieved significantly varied according to the type of final outcome (data presented in section 8.3, Annex).

4 Discussion

This study has highlighted the following key points:

1. Nearly half of children who are MAM at the beginning of the post-harvest season either develop SAM or cross the four months of best food security without recovering. Many therefore risk entering the next hunger season in a highly vulnerable condition.
2. The incidence of SAM is particularly alarming when WHO (2006) MUAC cut-offs are used.
3. The incidence of death among children suffering from MAM was low compared to the expected incidence, but SAM was diagnosed prior to death in seven of the eight deaths.
4. The period during which anthropometry improved coincided with the period of lowest morbidity from diarrhoea, respiratory infection and febrile episodes.
5. MUAC category at enrolment was the best predictor of final outcomes in all models and can be used as a basis for targeted intervention.
6. Stunting is widespread in areas of Ethiopia classified as food secure. The process of stunting continued even when there was correction of wasting, especially in children less than 24 months. SAM occurred in the most stunted children.
7. In children less than 24 months, failure to correct wasting was also associated with a higher deficit in height gain.

4.1 Deterioration to SAM

Preventing deterioration from MAM to SAM is one of the main reasons for setting up a supplementary feeding programme (SFP) during food crises. There is no SAM threshold criterion for initiating a humanitarian emergency response but many humanitarian agencies used the prevalence of SAM of 2% as threshold for initiating the response although the rationale of the figure is unknown. Assuming a duration of untreated SAM of 45 days (1.5 months) as estimated by Isanaka et al, the incidence of 1.57 per 100-child months observed in our study equates to a point prevalence of around 2.36 per 100-child-months, a point prevalence high than the 2% mentioned above suggesting that the observed incidence was unacceptably high [36]. Also, during the Engine baseline survey, the prevalence of SAM (MUAC<11.0cm) in the entire below 5 years population from Oromiya was only 0.3% (0.18% in Mana Kebele) suggesting that the incidence observed in MAM children during this study is likely to be over seven-fold higher than that of the general underfive population included in the baseline survey [21]. Finally, this incidence should be considered unacceptably high because the SAM caseload resulting from this incidence is, in Oromiya zone, likely to be equivalent to that produced by a GAM above 30% [21].

In the non-humanitarian context, seasonal SFPs only target areas classified as the most food insecure, with varying criteria as to what qualifies as 'food insecure'. This decision implicitly suggests that children who develop MAM in food secure areas are at lower risk than those who develop MAM in food insecure settings. However, data to support this assumption is lacking, and our study points to a different conclusion. The cumulative incidence of SAM of 9.3% (19.1% if the cohort is restricted to those using Ethiopian MUAC cut-offs for SAM and MAM), together with the fact that every month 8% of the children enrolled with MUAC between 11.0-11.4 cm became SAM, demonstrates that MAM is a serious public health problem in settings of Ethiopia classified as food secure.

To our best knowledge, there is only one published study assessing cumulative proportion of progression to SAM in MAM children in a setting classified as food secure. This study was conducted in Burkina Faso using

WHO (2006) definitions of MAM and SAM. It observed a proportion of 11.6% progressing to SAM in the study arm with no food-based intervention, where child centred counselling (CCC) was the only intervention. In the children treated by a corn-soy blend this proportion decreased to 9.9%, and further reduced to 8.2% amongst those treated with RUSF [9]. Our observed cumulative proportion of 28.7% (when using the WHO (2006) MUAC cut-offs) is much higher than that observed in the Burkina Faso study [9]. The fact that the Burkina Faso study used WHZ based definitions of MAM and SAM and our study used MUAC-based definitions is unlikely to explain this big difference [9]. Two papers have reported deterioration rates from MAM to SAM in SFPs implemented in Ethiopia during hunger seasons in settings classified as food insecure [37,38]. The first study evaluates SFP performance in four food insecure regions of Ethiopia, from which data indicates approximately 10% deteriorated from MAM to SAM [38]. The second study tested the effectiveness of different specialised foods, reporting a cumulative proportion of 1-2% of MAM children progressing to SAM despite treatment either with CSB or RUSF [37]. This highlights the potential to reduce deterioration from MAM to SAM with a well –implemented SFP.

There is a scarcity of data allowing a direct comparison of our incidence rate of deterioration from MAM to SAM. In areas similar to our study setting the determination of the burden of acute malnutrition has usually quoted prevalence obtained from cross-sectional surveys, not incidence [1,39,40]. We can obtain a general comparison from a control group receiving no intervention (who were well nourished at enrolment) from a study in Niger. Here Isanaka *et al.* report an incidence of deterioration to SAM of 0.26 events of per child year (corresponding to 2.2 episodes per 100 child-months) [41]. However, this study used WHZ criteria and did not target MAM children. Nevertheless, the incidence observed in our study of 1.57 events per 100 child-months (and of 5.74 per 100 child-months when the WHO (2006) MUAC cut-offs are used) should be considered as high. Of particular note is the high incidence obtained among children of the lowest categories of MUAC at enrolment, emphasising the elevated health and mortality risks for this group.

4.2 Recovery

Preventing deterioration to SAM and obtaining rapid recovery from acute malnutrition should be the main objectives of all approaches to MAM management [39]. SPHERE standards for management of MAM have been set for targeted SFPs, setting 75% as minimum standard for recovery rate, and provide a useful framework for evaluation in our setting [42]. With our observed recovery rate of 54.2% this minimum standard was not met for our cohort, yet it has also proven elusive for many SFPs addressing MAM. Navarro-Colorado reviewed 82 SFPs using take-home dry ration (CSB or UNIMIX predominantly) and found a disappointing overall recovery rate of 69.6% [43]. Recovery rates from some SFPs in Ethiopia have not even achieved this figure. For example, the results of an outcome evaluation recently conducted for the World Food Programme (WFP) in Ethiopia found a recovery rate of 49% over 6 months of follow up, even when some children received a specialized food supplement at a dose of 1378 kcal per person [38]. However, the low recovery rates achieved in SFPs in Ethiopia does not mean the approach should be ignored. The proportion of children who recovered in our food secure setting was less than that achieved in SFPs targeting food insecure settings elsewhere [39,43,44], and recent studies have indicated that new generation of specialised food may lead to higher recovery rates, including in Ethiopia [37,45–47]. However, clearly the issue of sustainability and cost effectiveness of SFP scale-up has to be addressed. Our observed recovery rate is similar to that observed in the Burkina Faso study mentioned above, whereby the arm receiving no food supplement had a similar recovery rate to our cohort (57.8%) [9]. Here the authors recommended the scale-up of nutrition-specific child centred counselling for its ability to be implemented at

scale more realistically than using specialised products (despite the groups receiving the products having a higher recovery rate).

Our low recovery rate needs to be interpreted within the context that those children who did recover took a long time to do so (9 weeks). Furthermore, our study was conducted during the most food secure months and we can assume that the results would be even more alarming if the period had covered the hunger season.

We expected children who deteriorated to SAM to recover, due to the wealth of evidence documenting the effectiveness of CMAM, including in Ethiopia [48–53], and the fact that our study setting deliberately ensured CMAM services were available. On the contrary, although most of the SAM cases occurred during the first 12 weeks, 50% of them were still MAM at the 28th week and only 39.2% reached a MUAC ≥12.5cm. We are unable to confirm that all those diagnosed with SAM were admitted to the CMAM programme, although they were referred and the low mortality suggests that the majority probably received treatment. Current Ethiopian guidelines recommends discharging children from outpatient therapeutic feeding programmes (OTPs) when they have gained 20% of their admission weight and reached MUAC >11.0cm [54]. This guideline was developed prior to the emergence of evidence that MUAC can be used for monitoring the response to therapeutic feeding, that the use of percentage weight gain leads to premature discharge of those most malnourished at admission and that a discharge criteria of MUAC ≥12.5cm may be more appropriate [55–57]. Our data suggests that the current discharge criteria being used by OTPs in Ethiopia is insufficient for sustainable recovery and should be re-assessed in light of evidence published after the current guidelines were written.

4.3 Mortality

SPHERE standards have set <3% as a minimum standard for mortality for children managed with MAM [42]. Although one might expect a MAM cohort not enrolled in SFP to exceed that minimum standard, our cohort met that criterion (mortality was 0.9%). With our very low level of loss to follow up we have confidence in this estimation. Our observed mortality rate was lower than that documented in the evaluation of SFPs in four food insecure regions of Ethiopia, which was threefold what we observed (2.9%) [38]. In addition, our observed incidence of death equals the widely quoted average under-5 mortality rate for Sub-Saharan countries of 0.44 deaths per 10,000 days [42]. When compared to figures extracted by Mason *et al* from surveys conducted elsewhere in Ethiopia, our cohort may have had a better survival than that observed in the general population. Here the compiled under-5 mortality rate in Ethiopia from 76 mortality cross-sectional surveys conducted between 2007-2009 was 0.56 deaths per 10,000 child days (and 0.93 deaths per 10,000 child days when just considering rural agriculturalists) [58]. A possible explanation for the low observed mortality rate could be that our weekly follow up led to rapid referral of children with SAM and other morbidities for treatment. It is also an indirect proof of a functioning available health service.

Despite the observed low mortality, of concern is the fact that 7 of the 8 deaths occurred in children who had developed SAM at one point during follow up. Four children died during an episode of SAM. Although it is difficult to make conclusions based on such a limited number of deaths, the figure highlights again the possible high contribution of acute malnutrition to under-5 mortality in Ethiopia. During the last decade Ethiopia has made significant progress towards meeting the millennium development goal for under-5 mortality. This progress can be accelerated further if acute malnutrition, including MAM, is comprehensively addressed at scale, including in areas believed to be food secure [17,59].

4.4 Predictors

Unsurprisingly, MUAC at enrolment had the strongest association with both recovery from MAM and deterioration to SAM. The data suggests that even during the early weeks of the post-harvest season, the absence of a MAM-specific intervention (such as SFP) put these children at unacceptable risks for a prolonged period of time, with the lower the enrolment MUAC the higher the risks. It may well not be feasible to have a national intervention targeting all children with MAM using the WHO (2006) cut-off of <12.5cm. However, at the minimum, we suggest that an intervention should be considered for those with MUAC between 11.5 cm and 11.9 cm and another for children with MUAC <11.5 cm. For this last category, the change of cut-off for admission into therapeutic feeding to MUAC<11.5 cm may be the most appropriate approach given the high likelihood of deteriorating to SAM. At the global level this higher admission cut-off has already been endorsed by WHO, UNICEF and key government partners in CMAM protocols. Because in Ethiopia SAM treatment has been scaled up nationally using a decentralised approach with good geographical coverage, including in woredas classified as food secure, this recommendation may prove to be the most feasible. Indeed, in countries with a higher caseload of SAM, such as Bangladesh, shifting to the use of MUAC <11.5cm admission criteria for SAM treatment has not resulted in an unmanageable increase of workload for community health works, with quality of the other services provided remaining unaffected [51,60,61].

Given the high likelihood of deteriorating or not recovering observed for children of an enrolment MUAC between 11.5 -11.9cm, there is also a need to re-assess the current strategy and identify a better approach that may reduce MAM duration and minimise the long term consequences. Feasibility, effectiveness and cost-effectiveness of alternative approaches should be evaluated, especially those listed in the National Nutrition Programme (NNP), including MAM child-centred specific nutrition counselling, cash transfers, linkage to social protection services (safety net programme, income generation schemes), food multimix approach using locally available food and specialised food supplements [9,10,12,62,63]. Indeed, contrary to the conclusion of a review carried out in 2007, a study previously discussed has indicated that MAM child centred nutrition counselling was a credible and cost-effective alternative to SFP in Burkina Faso [7,9]. Several studies have evaluated the effectiveness of cash transfer in the prevention of MAM with mixed results suggesting that more research is need before considering this at scale [63–65]. To our best knowledge, the other alternatives to SFP listed above (apart from nutrition counselling and cash transfer) have not been sufficiently assessed for effectiveness at the national scale, further warranting the creation of an expanded evidence-base for policy making.

Wealth was associated with the evolution of MAM in our study with favourable outcomes observed in children of the wealthier households. This has been observed by others in Ethiopia and elsewhere [66–68]. Similarly most of the other predictors of outcomes identified in this study including water drinking source, sanitary disposal of stools, mother's work index, nutrition counselling and routine vitamin A intake, have been observed before [17,66–69]. The Ethiopia NNP acknowledges the importance of most of these factors and interventions, addressing them among the initiatives to be implemented within the 2013 to 2015 phase of the programme [54]. Not listed is an initiative to address the issue of women work load that has been identified in our study as independent predictor of recovery and of non-recovery from MAM. However, we did not anticipate the inverse relationship of children with mothers reporting the heaviest workload having a better chance of recovery from MAM. It is well documented that increased women's workload in traditional rural Sub-Saharan society negatively affects their child's health condition and that if time is made available better child health outcomes can be achieved (for example, through providing improved water sources

nearer to the home) [70–72]. Our finding suggests the opposite: that a child's outcome is negatively affected by a reduction in mothers working time, and that the effect of this reduction is not compensated by the possible increase in time for caring for the child [73]. Indeed, the heavy workload in this context may just be a proxy of better food availability and diversification resulting from the women's farm production or non-farming income [73]. Anecdotal information collected in Jimma indicated that cash crop revenue that is usually managed by men is rarely used for improving household food security but for investments such as improving household assets and quality of housing, with income from women more likely to be allocated to food. It is also worth mentioning that others have found a similar paradoxical relationship between labour saving and children nutrition status in Ethiopia. A retrospective study carried out in rural Ethiopia suggested that labour saving technology is associated with increased fertility in women, being associated with an increased malnutrition rate [74,75].

4.5 General trend of cohort average anthropometric indices

The timing of development of SAM and the trend in cohort average anthropometric indices both point towards persisting vulnerability during the first 3 months of follow up, which is ironically the period of best food security in most part of Ethiopia, including in Jimma [21,76] duiring this study. This is an indication that increase in food availability may arrive too late to prevent deterioration. It is likely that the deterioration in nutrition status started at the beginning of the hunger season, meaning well before August, and culminated at the time when children were enrolled. A study in another part of Ethiopia has shown that the cyclic period of food insecurity and nutritional deterioration may be as long as 6 months [76]. This finding supports Jimma zone's eligibility for MAM preventive interventions such as blanket supplementary feeding (BSFP) or alternative approaches to be implemented from the peak of hunger season to the start of the harvest. However, data on the effectiveness of the current BSFP packages are inconsistent given the persistence of high incidence of MAM and SAM during the intervention [41,63,77,78]. Feasibility of other approaches should be considered, discussed in section 4.4, where a targeted intervention according to MUAC threshold may be more appropriate.

The pattern observed may also indicate that food security may not be the only factor in play and suggest possible roles for infectious diseases in the delayed response to food security improvement. In our study a decrease in the occurrence of new episodes of SAM and an increase in the overall average of anthropometric indices related to wasting coincided with a drop in the frequency of the symptoms of common infectious disease (namely diarrhoea, fever and cough). This hypothesis of the negative effect of infection on growth has previously generated research evaluating the potential impact of antibiotic mass treatment on growth. To date mass antibiotic treatment has not demonstrated any benefit on growth of children aged under 5 [79,80]despite a recent review of published studies confirming the negative role of diarrhoea episodes on growth [81]. The absence of an effect of antibiotic mass treatment calls for more research to identify environmental factors that could explain this phenomenon. The hypotheses to explore should include, among others, the role of micronutrient deficiencies, enteric environmental dysfunction, staple crops consumed and utilisation of harvest products [82–84].

4.6 Relationship between MAM and stunting

Given that Jimma zone was classified as food secure, we did not anticipate having such a high prevalence of stunting among children in our cohort. Surprisingly, two thirds of the children were stunted, suggesting the existence of chronic inadequate intake of nutrients and especially that of nutrients related to linear growth. There is no data on the level of stunting for Jimma in the Ethiopia Demographic Health Survey (EDHS) since it

does not provide disaggregated data at the zonal level. However, compared with the stunting prevalence of 41% for Oromia region observed during 2011, and stunting estimates ranging from 38.3%-46.8% observed in 3 woredas of Jimma zone during the ENGINE baseline survey in 2013, the prevalence of stunting was much higher among children of our cohort [14,21]. This higher prevalence of stunting at enrolment suggests that stunted children are disproportionally more affected by MAM than non-stunted children. This is not surprising because it is well-known that stunted children have reduced muscle mass and lower capacity to resist nutritional and infectious shock [85–87]. This finding also suggests value in further research exploring MUAC as a candidate for use in community based programmes aimed at addressing both MAM and stunting in this particular context.

Our study has also shown that linear growth is negatively affected by MAM status, confirming the relationship between wasting and stunting [34]. Other studies have also shown that linear growth varies according to the evolution of MAM during that period, with deterioration to SAM leading to worsening linear growth and reversal of SAM leading to improvement, thus confirming a relationship between energy storage and linear growth [34,88,89]. This evidence suggests that the drive to reverse stunting should be integrated with programmes that address acute malnutrition, especially in countries that continue to experience recurrent hunger seasons.

Researchers have recently reported differing responses to interventions according to age-group (above or below the age of two years) [90]. In this study, the phenomenon is also observed for linear growth, with children two years or older experiencing a smaller deficit in linear growth compared to the younger children, for whom stunting was accentuated. This finding confirms emerging evidence that there is less of an impact of environmental factors such seasonal hunger and infection on linear growth on children aged older than 2 years compared to younger children [91–94]. It may be that nutrient requirements for sustaining optimal linear growth are more easily met with family food for older children than first thought, meaning nutritional interventions addressing acute and chronic malnutrition may still have an impact when implemented beyond the 1000-day window. Food with different nutrient compositions may be needed to target younger and older children accordingly [95–99].

4.7 Study limitations

The present study was designed to describe the evolution of children with MAM in a food secure setting with health services according to national policies during the post-harvest period. We envisaged enrolling children who had been declining in terms of weight and muscle mass during a period of acute malnutrition, and not infants born with low birth weight who had not recently deviated from their growth pattern. The proportion of low birth weight due to premature delivery or intrauterine growth retardation is known to be around 11% of infants for the Jimma zone [100,101]. Thus, the first and main limitation of this study is that we could not get reliable data on birth weight and past growth pattern, potentially falsely classifying some children as having MAM when they may have been low birth weight children not experiencing a recent weight loss episode. Unfortunately, the lack of quality growth monitoring data makes this misclassification unavoidable. However, we suspect that the proportion of such children would not have significantly altered our conclusions. The second limitation is that resource constraints precluded a longer duration of follow up. It may have been more appropriate to follow the cohort over a full year to explore how children who did not recover during the period of best food security fared when entering the next hunger season. We recommend future research addressing the same question should start with a cohort of children considered well-nourished, recruited at the end of the best food security season and followed up throughout the hunger

season and the following best food secure period. Indeed, we may have underestimated the level of adverse outcomes including mortality by covering only the period with reduced nutritional risks, and therefore our results should be interpreted as the 'best case' scenario. Finally, we cannot generalise our results to all woredas classified as food secure in Ethiopia. For ethical reasons we chose woredas with functioning health services, including CMAM programmes for SAM treatment. Again, we feel our results represent the best scenario since it is doubtful that there are many woredas having better health facility coverage than those we selected [102–105].

5 Conclusion

Our results indicate that children with MAM during the post-harvest season in a food secure zone experience an unacceptably high incidence of SAM and low recovery rate. This highlights the need to re-assess the current strategy for addressing MAM in areas classified as food secure. The results suggest that the current approach of not having a targeted intervention to address MAM in this context place children with MAM at excessive risk of adverse outcomes. As the study was implemented during the best period for food security, we were not expecting such a high rate of deterioration and assumed that in food secure areas there would be sufficient food in households to ensure recovery from moderate acute malnutrition, yet for close to half of these children this recovery is not happening. It is likely that if the study was implemented during the hunger period, the rate of deterioration to SAM would have been even higher, with a concomitant increase in mortality. It is concerning to learn that such a high proportion of children with MAM will enter the next hunger season in such a vulnerable condition, with likely consequences of increased risk of SAM and death. In line with recent trends of nutrition status in Ethiopia at the national and regional level it is clear that food security at the woreda level does not necessarily equate to nutritional security at household and individual level. Both preventive and curative approaches should be considered, particularly aimed at children with low MUAC, taking into account feasibility within the resource constraints of middle and low income public health programming.

6 Policy implications and recommendations

We suggest that the findings of this study provide sufficient evidence to back a number of propositions for policy adjustment. Recommendations are grouped into five broad categories.

6.1 Required updates in CMAM protocols

The current National CMAM guideline was developed in 2006 and published in March 2007, before the country adoption of the 2006 WHO growth standards and just after WHO had recognised MUAC to be an independent criterion for admission into therapeutic feeding programmes [4,54,106]. The best evidence available at that time led experts involved in the development of these protocols to adopt MUAC <11.0cm or oedema as admission criteria and MUAC >11.0cm and percentage weight gain (≥20%) as discharge criteria. Since then new consensus and evidence regarding these criteria have emerged and support the following proposed changes:

1. ***Criterion for admission to OTP: MUAC based admission criterion should shift from MUAC <11.0cm to MUAC <11.5cm***

   The high incidence of deterioration to SAM of children with MUAC <11.5 cm suggests that a more effective approach for managing these children is required. Several findings support the statement

that children with MUAC<11.5cm are suffering from SAM and require management with OTP protocols. Firstly community-based studies show these children have an increased risk of dying [107]. Secondly, there is evidence that CMAM protocols improve long term survival of recovered SAM children compared to other children of the same community [108]. Thirdly, WHO has already issued the recommendation to shift from <11.0cm to <11.5 cm [4,106]. This increased MUAC admission criteria will enable the 12.5% most at risk for deterioration to receive an appropriate, evidence-based treatment.

2. ***Criterion for discharge from OTP: Children admitted based on MUAC criterion should be discharged using the criterion MUAC≥12.5cm.***

   At the time of the development of the current national protocols for the management of SAM, there was no data on the use of MUAC for monitoring response to therapeutic feeding. The dominant experts' opinion was that MUAC could not be used for monitoring the response to SAM treatment. Examining evidence that emerged after 2005 during a series of meetings organised by WHO in Geneva from 2010 and 2012, the Nutrition Advisory Group concluded that MUAC can be used for monitoring response and graduating from treatment and recommended that the use of percentage weight gain be dropped [55–57,109]. WHO has adopted the recommendation and the change is endorsed in the updates on the management of severe acute malnutrition published by WHO in 2013. This update recommends a shift to using MUAC ≥12.5cm as the criterion for discharging children from treatment [109]. Furthermore, it has been shown that if percentage weight gain is used as a discharge criteria the most malnourished children risk being discharged before full recovery, being further associated with increased post-discharge mortality [55–57,109]. This finding is supported by data presented by this study

6.2 Required update in approach for managing MAM in food secure settings in Ethiopia

Jimma zone is not eligible for the Enhanced Outreach Services/Targeted Supplementary Feeding (EOS/TSF) programme in Ethiopia. We recommend a strategy to address this current lack of a targeted intervention for children with MAM in food secure settings:

Advocate for admission of children who have 'advanced' MAM but are not eligible for SAM treatment (i.e. those with MUAC 11.5 cm to <12.0 cm) to EOS/TSF during the most vulnerable period of the year (July to November) in settings considered food secure.

We believe that the momentum created by the Scaling Up Nutrition (SUN) movement and the ongoing move led by WFP to shift to the use of the same specialised food products for both SAM and MAM, should support an adoption of a policy allowing the admission of children suffering from advanced MAM into SFP in a food secure setting. This policy can be restricted to settings with known cyclic seasonal hunger and high prevalence of stunting above a certain cut-off (e.g. >30%) despite globally having food surplus during post-harvest season. This measure will help Ethiopia reach its target of reducing the stunting prevalence to 30% by 2015 and to 20% by 2020 [110]. Such an approach was carried out by MSF in Burkina Faso, leading to a cure rate of 95.6% and a length of stay in the programme of 32.5 days (Cohuet, Sandra, personal communication, Vienna MAM meeting). To minimise the additional cost for the country of such a measure, this admission criterion can be restricted to the period of highest vulnerability, which for Jimma zone is from July to

November. This would support development of a revised list of woredas being eligible for periodic EOS/TSP.

6.3 Required update in approach for preventing MAM in food secure settings in Ethiopia

In the current Ethiopia nutrition policy and programming environment, there are many policies being implemented in agriculture, health and nutrition that contribute to the prevention of undernutrition [110]. Given the potential of the food security programmes and that of strategies included in the National Nutrition Programme, we would like to emphasise the following recommendations:

1. ***Integrate household food security assessment with the existing routine deworming and vitamin A campaigns preceding the hunger season and ensure that all households identified as at risk of food insecurity are linked to the food security schemes implemented in the area e.g. the Productive Safety Net Programme (PSNP), the Household Asset Building Programme (HABP) or the Complementary Community Investment Programme (CCI).***

   Several evaluations have shown that many of the food security programmes implemented in Ethiopia have been effective in reducing the prevalence of all forms of undernutrition [110,111]. Thus, the persistence of cyclic deterioration of nutrition status during the hunger season in Jimma zone and similar settings may vastly benefit from a targeted approach and enhanced collaboration between the health sector and agriculture.

2. ***Strengthen the Community-based Nutrition activities for the prevention and treatment of MAM in the community.***

   The Community-based Nutrition programme (CBN) includes a package of activities implemented by Health Extension Workers and community-based volunteers, aimed at preventing malnutrition and managing cases not meeting referral criteria. Monthly growth monitoring, monthly group health and nutrition counselling and home visits for children with growth faltering are among the activities. Although, the scale-up plan was to cover the entire country with this programme by 2013, at the time of the study the programme was not yet functioning optimally in the two study woredas [110]. A study in Burkina Faso has shown that appropriate and child centred counselling may be a cost-effective and sustainable approach for prevention and management of MAM [9]. CBN activities could be strengthened by developing a specific module and related job-aid materials for counselling children experiencing growth faltering or suffering from MAM.

6.4 Advocacy for the integration between acute and chronic programming in food secure settings in Ethiopia

In Ethiopia several regions classified as food secure still have high levels of stunting and our data have shown that seasonal episodes of acute growth faltering play a significant role in the stunting process [17,34]. A technical briefing paper recently published by the Emergency Nutrition Network summarised all the existing evidence and concluded that combating SAM is likely to contribute significantly to reducing the prevalence of stunting [34]. Currently, the SUN movement of Ethiopia has only defined targets for the reduction of underweight and stunting and not wasting. Thus, we recommend that an advocacy paper be written to

emphasise the need for integrating acute and chronic undernutrition programming, and for the inclusion of a 2020 target for MAM and SAM.

6.5 Follow on research

To further strengthen the evidence from our study, we advise the following areas be considered for further research:

1. Cost-effectiveness of CBN in nutrition rehabilitation of children with MAM during pre-harvest and post-harvest season in comparison with alternative approaches including linkage to food security schemes, TSF, CMAM and cash transfers.

2. Outcomes of MAM during the hunger season in food secure woredas experiencing seasonal hunger with high quality community nutrition and health services. Two cohorts would be beneficial: one of healthy children and another of MAM children, recruited at the beginning of the hunger season and followed up throughout the hunger and best food security seasons.

3. Identification of the food security profile, dietary diversity profile, disease profile, environmental characteristics and household income of the period associated with the best growth velocity and the lowest incidence of SAM (December and January).

7 References

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8 Annexes:

8.1 Distribution of Outcomes when using WHO MUAC operational definition of MAM and SAM

Supplementary table 1 shows that overall when the WHO criteria were used, more than a quarter of the cohort deteriorated to SAM (MUAC <11.5cm) and only 51% recovered without experiencing an episode of SAM. Only just over a quarter of those who developed SAM had reached MUAC ≥12.5cm by the end of the follow up.

Supplementary table 1: Distribution of outcomes based on the WHO MUAC based operational definitions

	All children†		SAM Children	
Outcome	**n**	**%**	**n**	**%**
Recovered and never SAM	394	51.0		
Non-responder (never SAM but no recovery)	134	17.3		
Total SAM (at least 1 episode)	222	28.7		100.0
SAM at week 28			39	17.6
SAM at least once but recovered			59	26.6
SAM at least once but MAM at last follow up			110	49.6
SAM at least once but died			7	3.1
SAM at least once but lost to follow up			7	3.1
Lost to follow up	22	2.9		
Died (Never SAM)	1	0.1		
Total	773	100.0		

†The 111 children with MUAC<11.5cm at enrolment not included

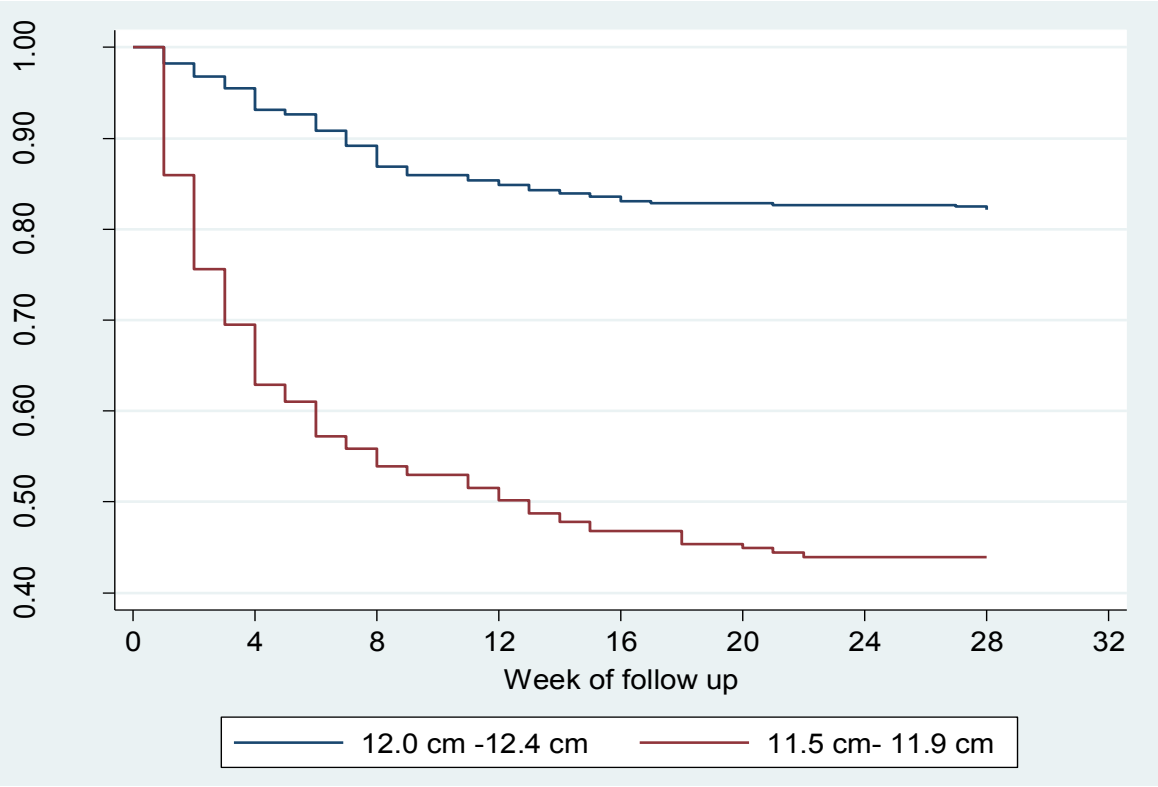
8.2 *Deterioration to SAM: incidence, cumulative probability and predictors when using WHO MUAC operational definition of MAM and SAM*

Supplementary table 2 shows that the incidence of SAM was very high among children of the cohort when WHO case definition was used with 16 children out of 100 children deteriorating to SAM every month in children who had MUAC between 11.5 cm and 11.9 cm at enrolment.

Supplementary table 2: Incidence of Severe Acute Malnutrition when using WHO MUAC-based case definition of MAM and SAM

Outcome	**N**	**No. of episodes (n)**	**Follow-up time (100 person-months)**	**Incidence (100 person - months)**	**95% CI**
All	769	218	37.9	5.74	5.03-6.56
>=12.0 cm	556	99	30.6	3.23	2.65-3.93
11.5 -<12.0 cm	213	119	7. 3	16.28	13.60-19.49

The Kaplan Meier curves below show that the proportion of children who deteriorated to SAM increased sharply in the weeks immediately after enrolment. The deterioration rate decreased from the 8th week of follow up for children with MUAC between 12.0cm and 12.4 cm but remained high until the 16th week of follow up for those with MUAC between 11.5 cm and 11.9cm at enrolment. The difference between the two curves was statistically significant (p<0.001).



Supplementary figure 1: Cumulative probability for deteriorating to SAM (MUAC<11.5cm or oedema)

Supplementary table 3 below shows that in addition to MUAC, Weight-for-height/length, child feeding practices, food security condition and receiving routine Vitamin A supplementation predicted deterioration to SAM using the WHO case definition of SAM (<11.5cm).

Supplementary table 3: Predictors of occurrence of severe acute malnutrition (using WHO MUAC cut-off) based on parameters at enrolment: bivariate and Cox proportional hazards analyses †

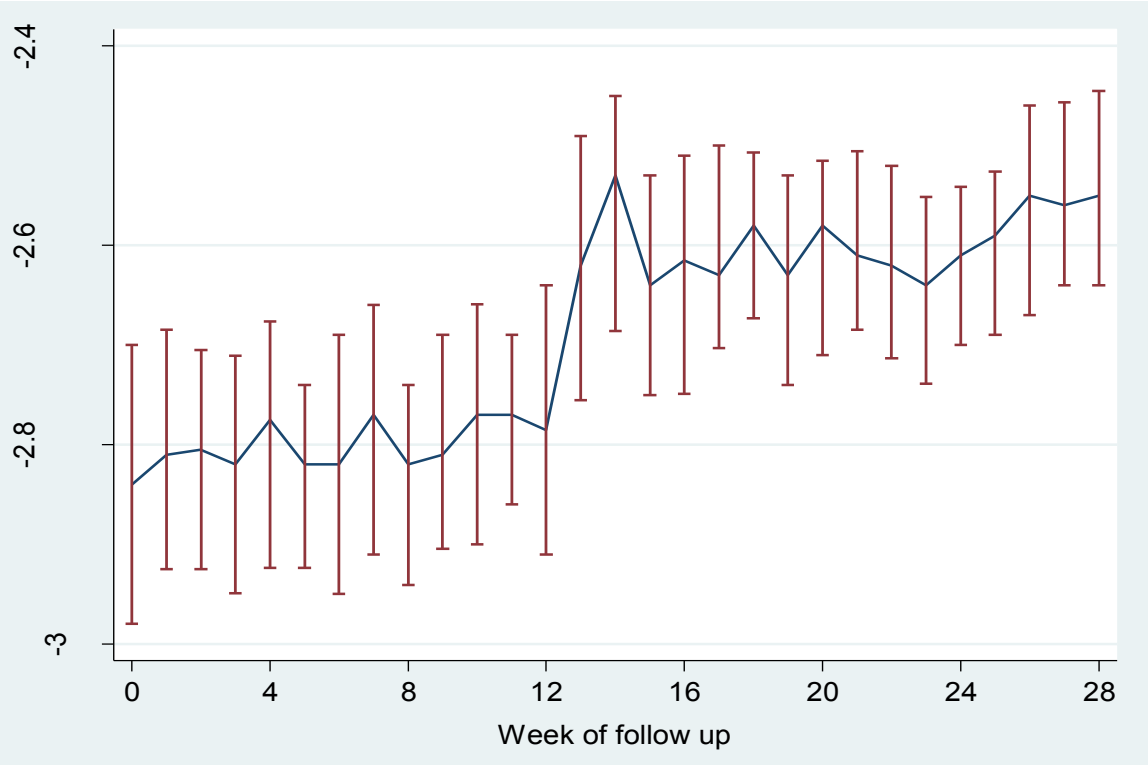
Variable	Category	n‡	% SAM	Unadjusted HR (95% C.I.)	P-value	Adjusted HR (95% C.I.)	P-value
Gender	Male	314	28.3	1.00 (base)		1.00 (base)	
	Female	456	29.2	1.04(0.79-1.37)	0.760	1.08(0.82-1.44)	0.571
Age group	≥ 24 months	332	26.8	1.00 (base)		1.00 (base)	
	< 24 months	471	30.2	1.15(0.88-1.51)	0.314	1.26(0.93-1.70)	0.143
Food insecurity	None	253	22.5	1.00 (base)		1.00 (base)	
	Moderate	266	28.2	1.26(0.89-1.78)	0.187	1.09(0.77-1.55)	0.634
	Severe	254	35.4	1.64(1.17-2.30)	0.004	1.39(0.99-1.96)	0.059
Child feeding	Lowest	148	25.0	1.00 (base)		1.00 (base)	
practices score	Middle	337	31.2	1.34(0.92-1.96)	0.131	1.51(1.02-2.22)	0.039
tertiles	Highest	288	27.8	1.16(0.78-1.72)	0.468	1.40(0.93-2.10)	0.105
MUAC category	≥ 12.0 cm	558	18.1	1.00 (base)		1.00 (base)	
	11.5 – 11.9 cm	215	56.3	4.27(3.27-5.58)	<0.001	3.74(2.82-4.97)	<0.001
WHZ category	≥-2	501	23.3	1.0 (base)		1.00 (base)	
(Z-score)	≥-3 and <-2	176	38.6	1.81(1.34-2.45)	<0.001	1.71 (1.25-2.33)	0.001
	<-3	84	39.3	1.91(1.29-2.83)	0.001	1.56 (1.03-2.36)	0.036
HAZ category	≥-2	259	24.7	1.00 (base)		1.00 (base)	
(Z-score)	≥-3 and <-2	153	28.8	1.23(0.84-1.83)	0.289	1.19 (0.79-1.79)	0.397
	<-3	357	31.6	1.43(1.05-1.95)	0.025	1.34 (0.94-1.31)	0.102
Topics covered	≥ 3	132	22.7	1.00 (base)		1.00 (base)	
by the HEW	1-2	179	31.3	1.48(0.88-1.98)	0.172	1.39(0.88-2.20)	0.156
counselling	0	461	29.5	1.48(0.94-2.31)	0.088	1.14(0.75-1.72)	0.541
Vitamin A in past	No	223	37.7	1.00 (base)		1.00 (base)	
6 months	Yes	570	25.1	0.60 (0.46-0.79)	<0.001	0.76 (0.57-1.01)	0.062

†N in multivariable analysis: 757 with 215 events. ‡N in bivariate analysis

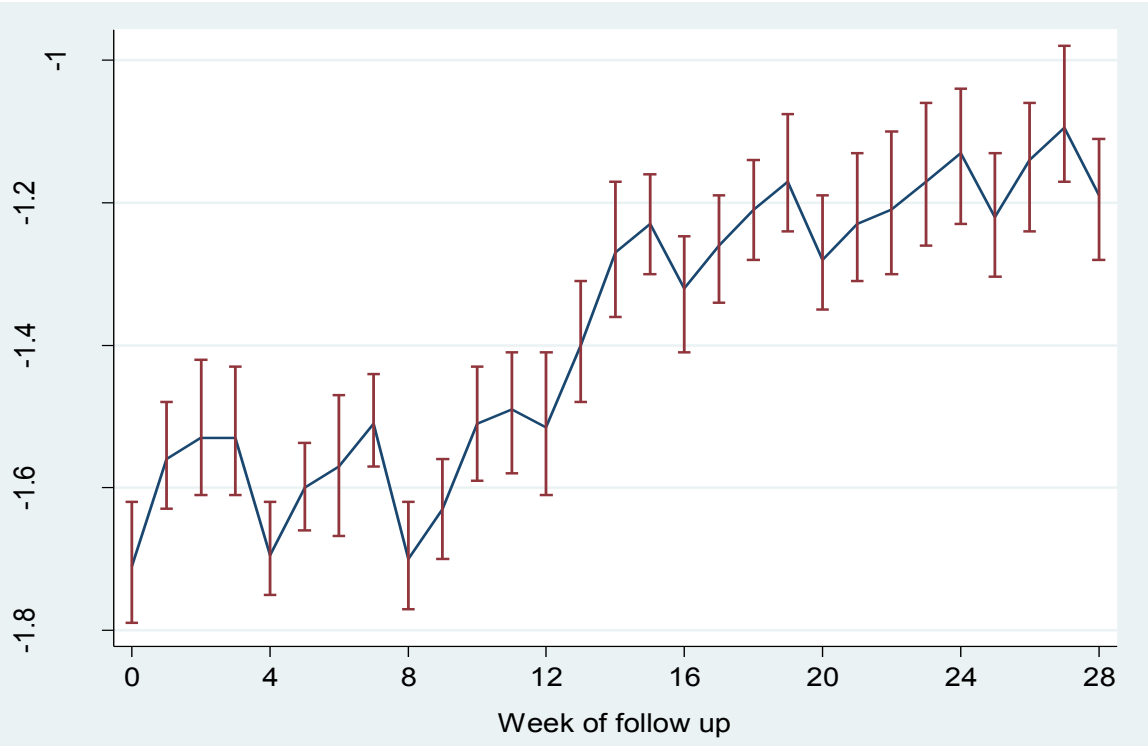
Abbreviations: CI. Confidence interval, HR, Hazard Ratio; MUAC, mid-upper arm circumference; WHZ, weight-for-height z score; HAZ, height-for-age z-score; HEW, health extension worker

8.3 Whole cohort trend in anthropometric indices

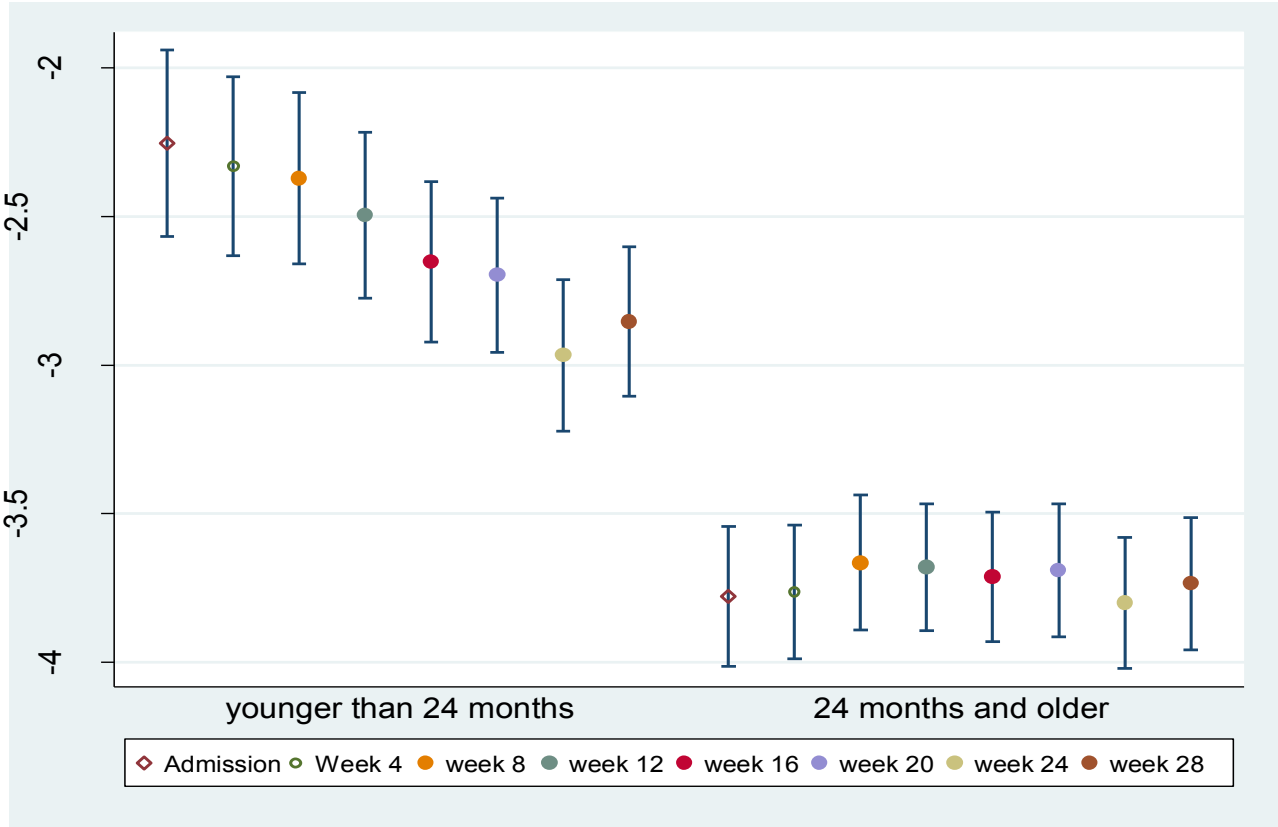
The analysis of the data for the whole cohort indicates that the weight change encountered during the first 12th weeks was insufficient for ensuring catch up from wasting. Improvement only started after the 12th week (supplementary figures 2 and 3). For the stunting process, supplementary figure 4 shows that the stunting process continued throughout the follow up period in children below 24 months but children 24 months and older remained on the same median Z-score suggesting no further aggravation of the stunting status but also no catch up. However, supplementary table 4 shows that there was also a deficit in linear growth in children 24 months and older.



Supplementary figure 2: whole cohort trend in weight-for-age Z-score over the follow up period



Supplementary figure 3: whole cohort trend in weight-for-height Z-score over the follow up period



Supplementary figure 4: whole cohort trend in height-for-age Z-score over the follow up period according to age at enrolment.

Supplementary table4: Percentage of expected age-matched length and height gains stratified by final outcome, defined using the Ethiopian operational definitions.

Variable		**% expected height gain**	
	N	Median	**IQR**
<24 months			
Recovered	258	64.6	42.8 – 96.6
Remained MAM	164	61.1	40.4 – 81.6
Developed SAM	50	45.4	29.5 – 71.9
p-value		0.003	
≥ 24 months			
Recovered	202	81.8	50.4 – 121.7
Remained MAM	103	78.0	48.0 – 110.9
Developed SAM	26	68.7	54.8 – 87.0
p-value		0.161	