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Safety of Using Mid-Upper Arm Circumference as a Discharge Criterion in Community-Based Management of Severe Acute Malnutrition in Children Aged 6–59 Months

Paul Binns, Valid International

Nancy Dale, University of Tampere Medical School

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Contact Information

Food and Nutrition Technical Assistance III Project (FANTA)
FHI 360
1825 Connecticut Avenue, NW
Washington, DC 20009-5721
T 202-884-8000
F 202-884-8432
fantamail@fhi360.org
www.fantaproject.org

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Abstract

Until recently, the World Health Organisation (WHO) recommended a percentage weight gain of more than 15% for discharge of children admitted to nutrition programs treating severe acute malnutrition (SAM) with a low mid-upper arm circumference (MUAC < 115 mm). When following this recommendation, children who are most severely malnourished receive less treatment than less severely malnourished children. Studies have shown that using a MUAC of ≥ 125 mm as a discharge criterion eliminates this problem; however, there are concerns over the safety of using this MUAC threshold. This study assessed the safety of using MUAC ≥ 125 mm as a discharge criterion for community-based management of SAM in children aged 6–59 months admitted with MUAC < 115 mm.

This standards-based trial was undertaken in Ministry of Health facilities for the outpatient treatment of SAM located in Lilongwe District, Malawi. Treatment was provided as part of a wider community-based management of acute malnutrition (CMAM) program that also provided inpatient care facilities at local hospitals and community-based support services through the identification, referral, and follow-up of children with acute malnutrition. The study enrolled 257 children aged 6–59 months with uncomplicated SAM, defined as a MUAC < 115 mm without bilateral pitting oedema. The children were discharged from treatment as cured when they achieved a MUAC of 125 mm or more for two consecutive visits. After discharge, the cured children were followed up every 2 weeks at home for a period of 3 months. The study found that a MUAC discharge criterion of 125 mm or more represents a safe discharge criterion as it is associated with an acceptably low relapse rate to SAM (1.9%) and death (1.3%) within 3 months of discharge. The total percentage of children experiencing a negative outcome (3.2%) was below the 10% standard ($p = 0.0013$) established for the study. Children with a negative outcome had all achieved a weight-for-height z-score (WHZ) > -2 on discharge. Children admitted with lower MUACs had higher proportional weight gains ($p < 0.001$) and longer lengths of stay in the program ($p < 0.0001$). These results are consistent with MUAC ≥ 125 mm being a safe discharge criterion and eliminates the problems observed with using proportional weight gain for discharge.

Introduction

The use of mid-upper arm circumference (MUAC) as a general tool (i.e., for case-finding, referral, admission, monitoring, and discharge) has the potential to simplify the practical application of community-based management of acute malnutrition (CMAM) services, facilitating their delivery within the integrated management of childhood illness (IMCI) framework.

In 2006, the use of MUAC for case-finding, referral, and admission to CMAM services was accepted by the World Health Organisation (WHO), the World Food Programme (WFP), the United Nations Standing Committee on Nutrition (UNSCN), and the United Nations Children’s Fund (UNICEF), and thus MUAC is now widely used in CMAM programs for these purposes (WHO/WFP/UNSCN/UNICEF, 2007).

The use of proportional weight gain as a discharge criterion for MUAC admissions, recommended in the WHO/UNICEF Joint Statement of 2007 (WHO/WFP/UNSCN/UNICEF, 2007), has proven to be problematic, with the most malnourished cases often receiving the least amount of treatment. This has led to the consideration of MUAC as an alternative discharge criterion (Goossens, 2012; Dale, 2013).

A consultation between academics and non-governmental organisations in December 2012 (ENN, 2012) concluded that there were concerns over the safety of using MUAC as a discharge criterion, with a weak evidence base on sustainable recovery, relapse, and survival rates to support its use. More specifically, concerns were raised about the application of MUAC discharge criteria to children who were stunted. Published evidence was assessed as inadequate to inform programming.

There is also currently a lack of evidence on the relationship between the rate of weight gain and rate of MUAC gain, although recent studies referenced in the consultation suggest a close relationship (e.g. Roberfroid, 2012; Seal, 2012 – both unpublished). Describing the relationship between weight gain and MUAC gain would potentially inform the development of tools to allow MUAC-only monitoring during the process of recovery from SAM.

Objectives

The objectives of this study were to:

1. Evaluate the safety of using MUAC as a discharge criterion in community-based management of uncomplicated SAM in children aged 6–59 months.
2. Describe the length of stay when MUAC is used for both admission and discharge in community-based management of SAM in children aged 6–59 months.

Additional analysis:

- Identify patterns of MUAC gain and weight gain during the treatment episode.
- Provide data to inform decisions regarding the feasibility of using MUAC-based monitoring tools and, if appropriate, provide candidate tools for further testing.

Methodology

The study design was a standards-based trial that was based on established standards for the outpatient treatment of children aged 6–59 months (i.e., case fatality rate during treatment < 5%, relapse rate post-discharge < 10%) (Collins, 2006; Ashworth, 2006). Previous studies indicated that the majority of post-discharge mortality occurs within 3 months of discharge (Roy, 1980; Collins, 2006). For the purposes of this study, a standard of < 10% over a 3-month period was taken to include both relapses and non-accidental, non-violent death as negative outcomes, effectively making the study standard more stringent than the established standard.

Five outpatient health facilities run by the Government of Malawi Ministry of Health (MoH) located in Lilongwe District participated in the study. A research team from Valid International, composed of a research coordinator, a registered nurse, and a community mobilisation officer, trained MoH staff in study protocols and assisted directly in the measurement and treatment of all study subjects.

The Malawi National Guidelines for Community-Based Therapeutic Care (Ministry of Health, 2006) formed the standard of care, with a change of MUAC admission criterion for the outpatient treatment for SAM from MUAC < 110 mm to MUAC < 115 mm. This change was in line with the planned revision of National Guidelines for CMAM to meet the recommendations of the UN Joint Statement of 2007.

The study enrolled children aged 6–59 months with uncomplicated SAM, defined as a MUAC < 115 mm and no medical complications and no bilateral pitting oedema. Children with MUAC < 115 mm with concurrent bilateral pitting oedema and/or medical complications were referred to inpatient care according to the National Guidelines protocol, but were admitted to the study if inpatient care was refused by the carer or on return from inpatient care.

Subjects were enrolled between March 2011 and March 2012 from Lilongwe District, Malawi. Children whose carers did not provide informed consent or were resident outside of Lilongwe District were excluded from the study, but were provided with care according to the Malawi National Guidelines. Non-residents of Lilongwe District were excluded because health workers were not able to follow up cases post-discharge across district borders (for logistical reasons) and national borders (many treatment beneficiaries were residents of Mozambique). No payment was given to families for participation in the research.

On enrolment to the study, the child's weight was measured to the nearest 100 grams using a Salter™ scale (child was weighed naked or wearing light undergarments), height was measured to the nearest millimetre using a standard paediatric height board, supine length was measured for children under 24 months of age, and MUAC was measured to the nearest millimetre using a non-elastic, colour-coded standard MUAC tape (UNICEF supply code S0145620 'MUAC, Child 11.5 Red/PAC-50'). All children underwent an appetite test to confirm the appropriate consumption of ready-to-use therapeutic food (RUTF) required to be admitted for treatment as an outpatient. Children failing the RUTF appetite test were referred to inpatient care, but admitted to the study if inpatient care was refused by the carer or on return from inpatient

care. At each visit during treatment, the child was given a ration of RUTF according to his or her weight as described in the Malawi National Guidelines.

Routine medications on admission included a broad-spectrum antibiotic and vitamin A. Each child was assessed for malaria using a Paracheck™ rapid diagnostic test for malaria (98.2% sensitivity, 99.3% specificity) and treated with lumefantrine/artemether if tested positive. In the absence of a Paracheck™, the patient was treated empirically for malaria if he or she presented with a fever of unknown origin. In accordance with national protocol, each carer and child was routinely offered serial testing for human immunodeficiency virus (HIV) using the Determine HIV-1/2 assay (99.8% sensitivity, 99.4% specificity) and, if tested positive, Uni-Gold Recombigen HIV assay (98.5% sensitivity, 99.5% specificity). All HIV-positive cases meeting the enrolment criteria were included in the study and referred for treatment, although it was not monitored whether the children went on to receive treatment for HIV.

Study subjects were requested to attend outpatient treatment for SAM on a weekly basis. At each clinic visit, the child was measured for weight and MUAC and his or her appetite for RUTF was tested. At the second visit, de-worming treatment was given according to national protocol. Folic acid was usually not available at the study sites; however, given the amounts of folate provided by the RUTF, this was not considered a significant limitation and was not monitored during the data collection.

Due to the rotation of MoH clinical staff in attendance at the health centre, each of the measurements of weight, height, and MUAC was conducted by a single observer from the research team so as to minimise observer errors. If the status of the child had not improved or had deteriorated during any subsequent visits, he or she was referred to the MoH clinician for further assessment according to the national protocol. Any child absent from treatment was followed up at home by a health surveillance assistant (HSA) or community volunteer and encouraged to return for treatment.

The child was discharged from treatment when he or she achieved a MUAC of 125 mm or more for two consecutive visits. On discharge, the child was additionally measured for height and was given a 14-day supply of RUTF. If there was a supplementary feeding program (SFP) available in the health area, the child was referred to it. A study subject was also discharged from the study if the child died, defaulted (was absent for three consecutive visits), or was non-cured (had not reached discharge criteria after 4 months of treatment) according to national protocol.

All admissions and discharges from the study were approved and verified by the Valid International research team. Any child discharged from the study as non-cured was assessed according to Malawi National Guidelines discharge criteria prior to the cessation of treatment.

Once discharged as cured, the child was followed up every 2 weeks for a 3-month period by an HSA trained in the study protocols. At each follow-up visit, the child was assessed for illness (cough, fever, diarrhoea, or vomiting) and his or her MUAC was measured by the HSA. Any child who had relapsed (MUAC < 115 mm or bilateral pitting oedema) or had deteriorated clinically was referred back to the health centre for the appropriate assessment and treatment. Relapsed children were considered eligible for readmission to the study if they met study eligibility

criteria. Any child absent from his or her home for two consecutive home visits was verified as being lost to follow-up by consulting with neighbours and other members of the local community regarding the whereabouts of the family. The accuracy of the MUAC measurements and clinical status of the child during follow-up was verified in the community by a member of the Valid International research team. Verification visits were made randomly to children in the follow-up phase of the study and visits were conducted in all cases when relapse was detected or loss to follow-up had occurred. Where death occurred, a post-mortem follow-up visit was made for verification and to obtain as detailed a history as possible regarding the events leading up to the death.

Study constraints included occasional interruptions in the MoH supply of routine medicines and RUTF. The National Health Sciences Research Committee (NHSRC) was consulted and ethical approval given to continue with the study. No preferential treatment was given to study subjects compared with non-study subjects.

Data Collection and Analysis

Data were collected on a paper form (*Figure 1*) designed for the study and then entered into an EpiData Version 3.1 database using interactive checking for range and legal values and double-entry verification for all entries. Statistical analysis was done using the R Language for Data Analysis and Graphics (Ihaka, 1996). Height-for-age, weight-for-age, and weight-for-height z-scores were calculated according to the WHO Child Growth Standards (WHO: Department of Nutrition for Health and Development, 2006). The Kruskal-Wallis non-parametric test (a two-sided test) was used for comparisons of lengths of stay and percent weight gain by categories of MUAC at admission and height at admission. This non-parametric procedure was used in preference to, e.g., a *t*-test because it is robust to deviations from normality and because median length of stay is a more useful measure of the average length of treatment episodes than is the mean length of stay, which can be influenced by extreme values from, for example, a handful of complicated cases. The null hypothesis for the Kruskal-Wallis test is that the data in each categorical group have the same distribution as the variable of interest. Safety of the MUAC ≥ 125 mm was tested using a single-sided exact binomial test with the alternative hypothesis that the proportion of subjects experiencing relapse or death in the post-discharge follow-up period is below 10%.

Figure 1 : Data collection forms for a single study subject

ADMISSION DETAILS: THERAPEUTIC FEEDING PROGRAMME

Record Number: [redacted] Reg. No: 15/34/0354/03/11/OTP

Date of admission: 23/03/11 Age (months): 28

Sex (M/F): M

Routine admission Medication:

Vitamin A: YES/NO: YES Albendazole: YES/NO: YES W/2 Treatment code: R NR

Amoxicillin: YES Readmission: [redacted] Previous registration No: [redacted]

Fansidar: YES

Data collected by: [redacted] Data entry 1: [redacted] Data Entry 2: [redacted]

Admission Record

FOLLOW UP: OUTPATIENT THERAPEUTIC FEEDING PROGRAMME

Record No: [redacted] REG No: 15/34/0354/03/11/OTP

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Date	23/03/11	29/03/11	05/04/11	12/04/11	19/04/11	26/04/11	03/05/11	10/05/11	17/05/11	24/05/11	31/05/11	06/06/11	13/06/11	20/06/11	27/06/11	04/07/11
Anthropometry																
Weight (kg)	7.9	7.8	8	8	8	8.6	8.1	8.5	8.8	9.1	8.7					
Height (cm)	76.5															
MUAC (cm)	11.4	11.5	11.7	11.8	11.9	11.9	11.7	12.0	12.0	12.0	12.6					
Oedema (+, ++, +++)	0	0	0	0	0	0	0	0	0	0	0					
Triceps skinfold 1 (mm)	5.2	5.3	4.9	5.0	4.9	5.1	5.0	4.9	5.1	6.2	5.4					
Triceps skinfold 2 (mm)	5.2	5.2	4.8	4.9	5.0	5.1	5.0	4.7	5.1	6.1	5.2					
History																
Diarrhoea (# days)	0	0	0	0	0	0	0	0	0	0	0					
Vomiting (# days)	0	0	0	0	0	0	4	0	0	0	0					
Fever (# days)	0	0	0	1	0	0	7	0	0	0	0					
Cough (# days)	0	0	0	0	0	0	0	0	0	0	0					
OUTCOME	OK	OK	OK				OK	OK	OK	OK	OK					

name HSA: [redacted]

OUTCOME: A=absent O=defaulter (3 consecutive visits) NRU=transfer to NRU X=died D=discharged cured MUAC > 12.5cm for 2 weeks

Data collected by: [redacted] Data Entry 1: [redacted] Data Entry 2: [redacted]

Handwritten notes: LTF 20 20 20 23 23 23 23 23 23 23 23 23 23 46

Clinic Visits

POST DISCHARGE FOLLOW-UP: MUAC RESEARCH STUDY

Name: [redacted] Registration Number: [redacted]

Date of Admission: 23/03/2011 Name of Community wkr: [redacted]

Village & TA: [redacted]

Address details (continued overleaf): [redacted]

Month on discharge	1	2	3	4	5	6
Date	15/03/11	29/03/11	12/04/11	27-07-11	10/08/11	24/08/11
Anthropometry						
MUAC (cm)	12.6	12.0	11.9	12.2	12.4	12.4
Oedema (+, ++, +++)	0	0	0	0	0	0
History: In the last two weeks, has the child experienced any of the following:						
Diarrhoea (# days)	0	0	0	0	0	0
Vomiting (# days)	0	0	0	0	0	0
Fever (# days)	1	2	2	0	2	1
Cough (# days)	0	0	0	0	2	0
SFP ration received	No.	Y	Y	Y	Y	0
Physical Examination						
Name of Examiner	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
OUTCOME	OK					
Additional Questions						
HC visits in past 2 wks (Y/N)		N	N	N		Y
Reason			laziness of caregiver			
Notes			the child is not improving		child is improving	

* A = absent (explain) LTFU = Lost to follow up x = Died (explain cause) OTP = referral to OTP HC = referral to health centre for medical treatment

Follow-up Visits

Results

The study enrolled 257 children aged 6–51 months between February 2011 and March 2012; 115 (44.7%) were male and 142 (55.3%) were female. Although the study protocol included children up through 59 months, none of the children were older than 51 months. Of the children enrolled in the study, 125 (48.6%) did not present with any concurrent illnesses (defined as diarrhoea, vomiting, fever, or respiratory symptoms), while 18 (7.0%) presented with complications severe enough to require transfer to inpatient care prior to enrolment in the study. One hundred forty (54.5%) children were tested for HIV on admission and, of those children, 19 (7.4%) tested positive for HIV. (HIV prevalence of those tested was 13.6%.)

Figure 2 shows the number of children enrolled by month during the study. This pattern of admission reflects the historical pattern of SAM admissions into CMAM programs in Lilongwe and matches expectations of SAM incidence derived from historical admissions, historical survey data, and local agricultural and disease calendars.

Figure 3 and *Figure 4* describe the study cohort, and *Table 1* gives further details of the cohort at admission. *Figure 3* shows the population profile of the children disaggregated by age and sex. Year-centred age groups were used since ascertaining exact age in months proved difficult in the study context [MSF Nutrition Guidelines, 1995]. *Figure 4* shows the height at admission of the enrolled children, with the median height being 67.4 cm.

Figure 5 presents the anthropometric status of the study subjects at admission in terms of MUAC, weight-for-height z-score (WHZ), height-for-age z-score (HAZ), and weight-for-age z-score (WAZ), according to the WHO Growth Standards (WHO, 2006). Only 1.6% of the recruited subjects did not have a WHZ < -2, HAZ < -2, or WAZ < -2 on admission, and 52.9% of admissions were malnourished by all indicators (i.e., by MUAC, WHZ, HAZ, and WAZ). *Figure 6* summarises the anthropometric data in a Venn diagram (Venn, 1880).

Figure 2 : Number of children enrolled by month over the duration of the study

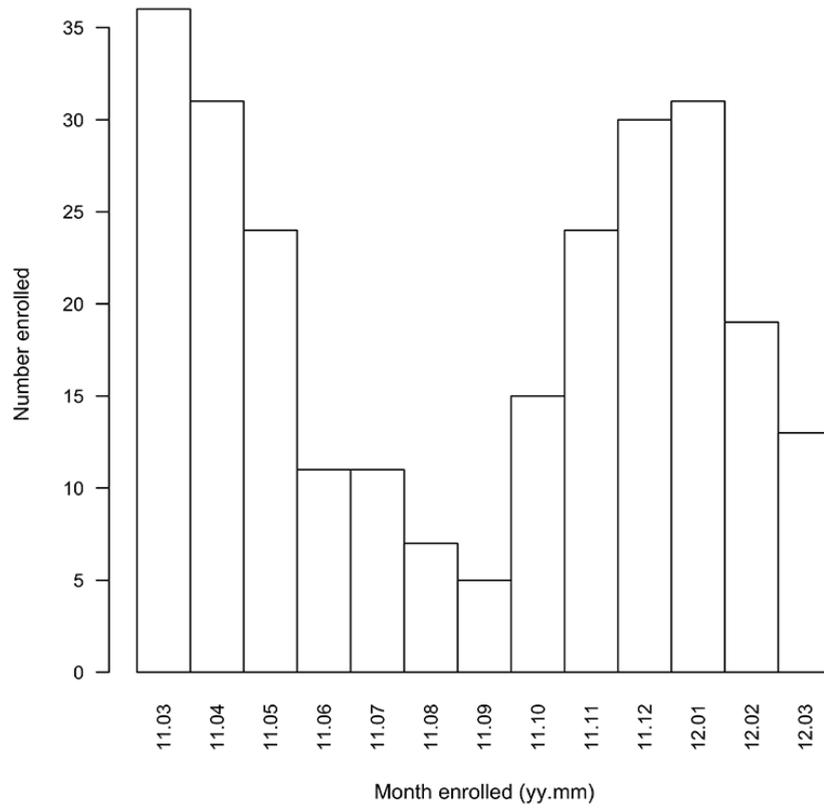


Figure 3 : Population profile of children admitted into study

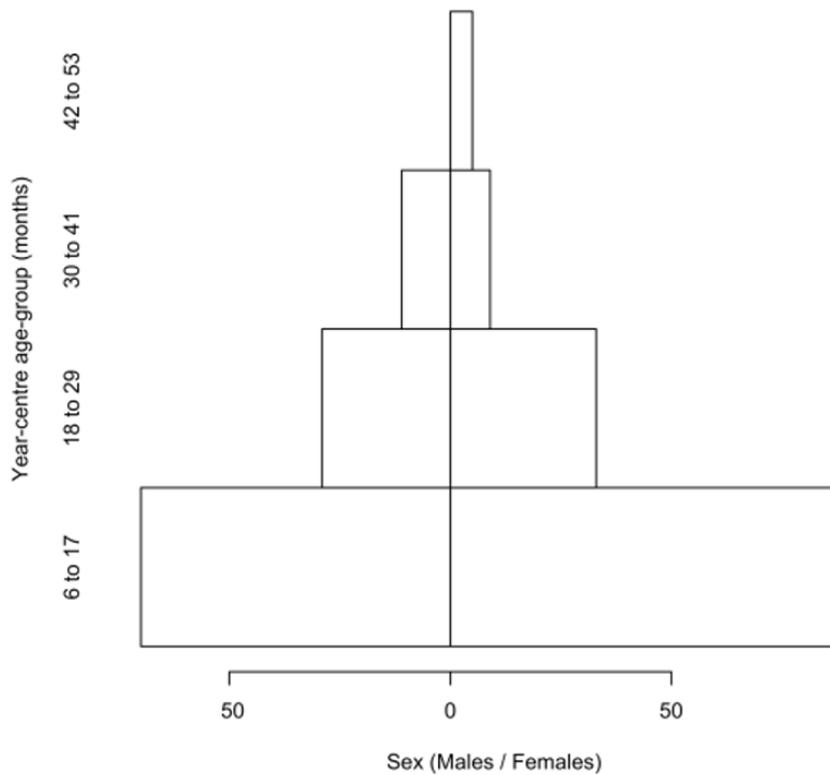


Figure 4 : Number of children enrolled by height at admission

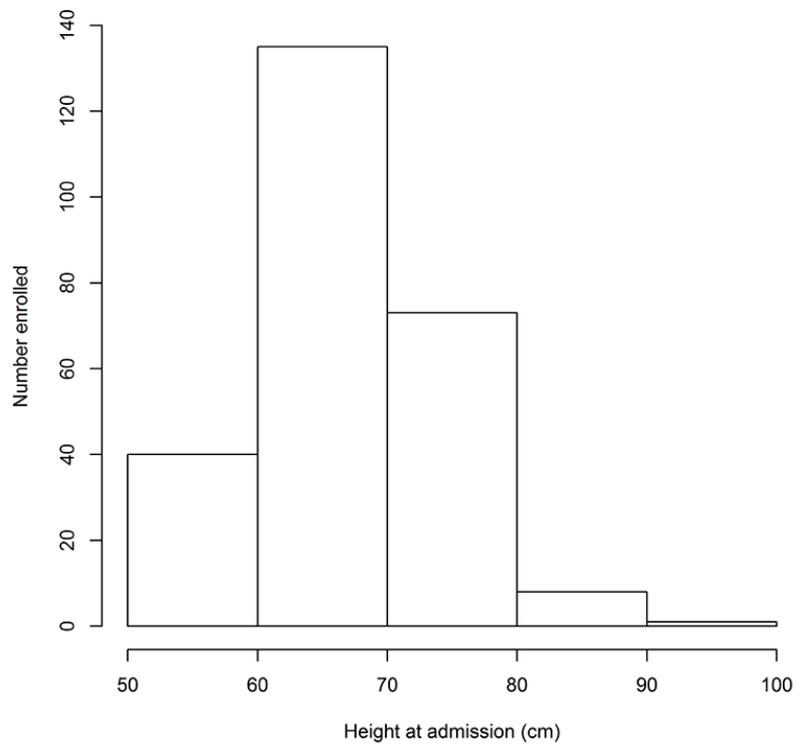


Table 1 : Attributes of study cohort at admission

Attribute	Details	n	Percentage
Enrolled	Number of cases	257	100.0%
Refusals to participate in study	Number of children	0	0.0%
Sex*	Males	115	44.7%
	Females	142	55.3%
Age at admission (months)*	Minimum	6	
	Lower quartile	10	
	Median	14	
	Upper quartile	21	
	Maximum	51	
Height at admission (cm)	Minimum	53.30	
	Lower quartile	62.50	
	Median	67.40	
	Mean	67.56	
	Upper quartile	72.20	
	Maximum	92.50	
Admission criteria	MUAC < 115 mm only	248	96.5%
	MUAC < 115 mm with nutritional oedema	10	3.9%
Requiring inpatient care **	Number of children	18	7.0%
	Median duration of inpatient episode for those admitted to inpatient care (days)	7.00	
Concurrent illness***	None recorded	125	48.6%
	Diarrhoea	56	21.8%
	Vomiting	23	8.9%
	Fever	69	26.8%
	Respiratory illness	77	30.0%
	Malaria	83	32.3%
HIV status on admission****	Positive*****	19	7.4%
	Negative	121	47.1%
	Not known (caregiver did not consent)	117	45.5%

* The distributions of age and sex are shown in Figure 2

** Referrals to inpatient care for stabilisation prior to enrolment in the study as per CMAM National Guidelines

*** Does not sum to 100% due to multiple illnesses at presentation

**** Serial HIV testing according to national protocol using Determine™ and Uni-Gold Recombigen™ HIV assays

***** Prevalence of HIV in those tested was 13.6%

Figure 5 : Distribution of MUAC, WHZ, HAZ, and WAZ at enrolment

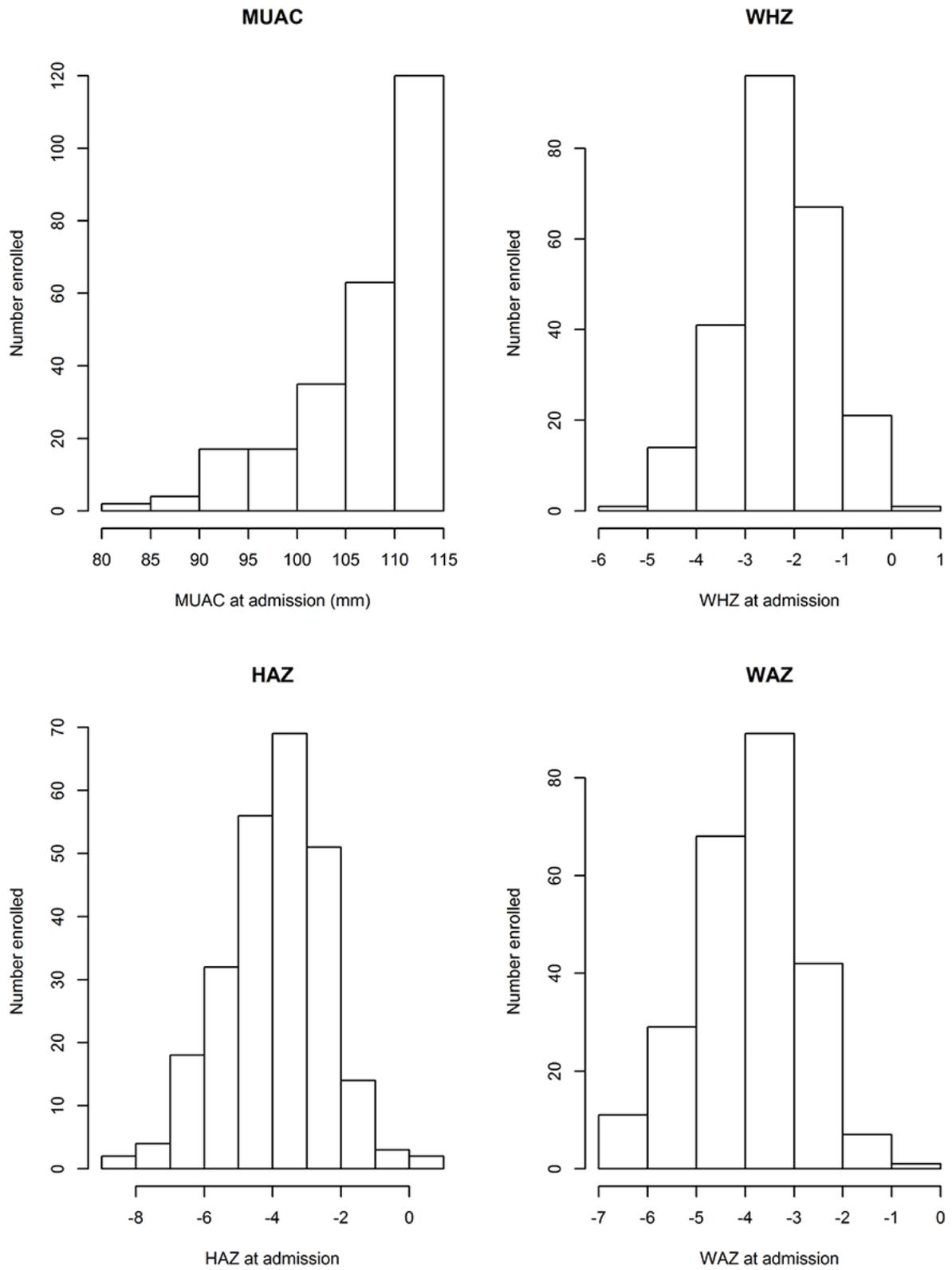
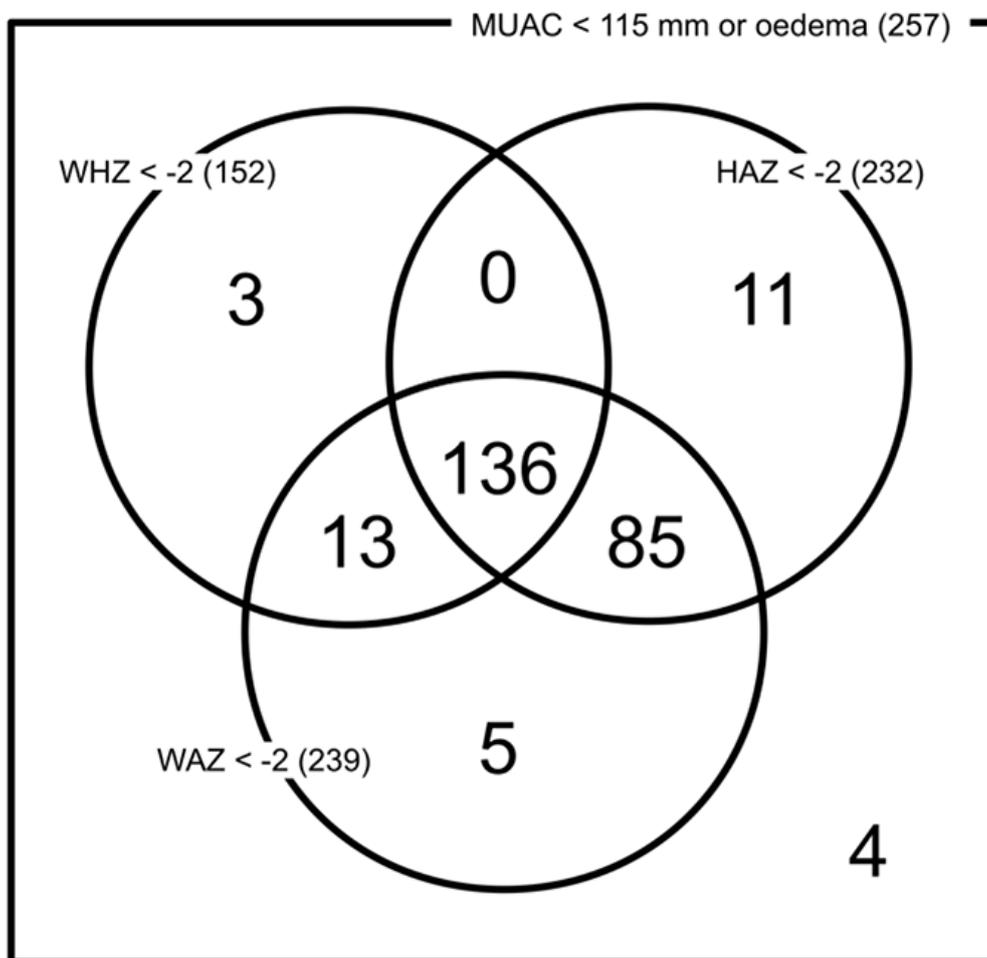


Figure 6 : Venn diagram showing anthropometric categories of all admissions*



* Admissions including children with MUAC < 115 mm without oedema and children with MUAC < 115 mm with oedema whose carer refused NRU care and were thus eligible for outpatient treatment according to the Malawi National Guidelines.

The majority (c. 90%) of study subjects were stunted (see *Figure 6*). Children recruited to the study with a height at admission below 65 cm showed a higher proportional weight gain and a longer median length of stay under treatment than taller children. These children were no more likely to be discharged as ‘non-cured’ than taller children (relative risk [RR] = 0.93, 95% CI = 0.77–1.13, chi-square = 0.33, $p = 0.5667$). There was no more association with negative outcomes at 3 months post-discharge for children with height at admission below 65 cm than for taller children (RR = 1.22, 95% CI = 0.21–7.09, Fisher’s exact test [single-tailed with $H_A : = RR > 1$], $p = 0.5798$).

Table 2 describes the treatment given to the study subjects. A high proportion of subjects (93%) received antibiotics, while 65% received the full national CMAM protocol of medicines.

Figure 7 describes the treatment outcomes achieved in the study and the subsequent exclusions from follow-up. More than 63% of enrolled subjects were cured within 4 months, while 14.0% defaulted, 3.9% died during treatment, and 18.7% were non-cured. The cure rate for the study did not meet the Sphere minimum standard of > 75 % (The Sphere Project, 2011). Defaulter and mortality rates met Sphere minimum standards (< 15% and < 10%, respectively), thus the low cure rate was largely due to the high non-cure rate. The median attendance rate for cured patients (as a percentage of the total number of weekly visits required of all subjects by the study protocol during treatment) was 87%.

Eight children were excluded from the follow-up portion of the analysis for the following reasons:

- I. The follow-up was discontinued because of site closure.
- II. Children moved to another district and were unable to be followed.
- III. Children were lost to follow-up because they were from outside of the health district and had provided an incorrect address upon registration in order to qualify to receive care.

Table 2 : Treatment given in program

Treatment	Value	Percentage
RUTF*	257	100.0%
Vitamin A	203	79.0%
Antibiotics**	238	92.6%
Albendazole***	108	42.0%
Lumefantrine/Artemether Combination	82	31.9%
Received full CMAM protocol****	168	65.4%
Referred for inpatient care*****	35	13.6%

* Quantity given according to national protocol (average 200kcal/kg/day)

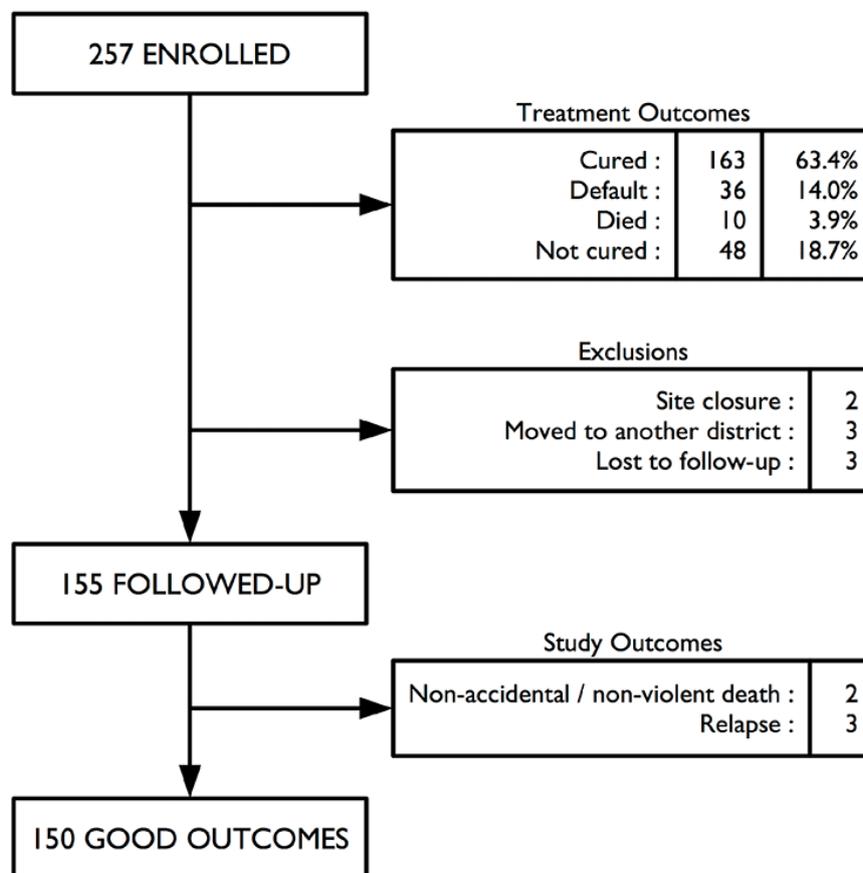
** Amoxicillin or co-trimoxazole given according to availability

*** Anthelmintics given to children \geq 12 months according to national protocol

**** According to Malawi National Guidelines

***** Children referred to inpatient care during outpatient treatment as per CMAM National Guidelines

Figure 7 : Flow diagram indicating treatment outcomes and exclusions from the study



Site closure: The study was discontinued at two health centres due to a fall to zero recruitment. Children enrolled in the study at that time had care continued according to the standards of the Malawi National Guidelines for CMAM or, if discharge had occurred, the discharge criteria were compared to ensure that this satisfied Malawi National Guidelines.

Figure 8 describes the length of stay and weight gain of cured subjects as a proportion of weight at admission by MUAC for three MUAC classes of subjects at admission. The median length of stay of all children in the study was 49 days (inter-quartile range [IQR] = 35;77). Children with lower MUAC at admission had longer durations of treatment ($p < 0.0001$, Kruskal-Wallis test), with median durations of treatment in the lowest MUAC group of 98 days (IQR = 60;105) and highest MUAC group of 42 days (IQR = 35;63). The median percentage weight gain of all children in the study was 21% (IQR = 16%;27%). Children with low MUAC had higher percentage weight gains ($p < 0.0001$, Kruskal-Wallis test), with median percentage weight gain of 42% in the lowest MUAC group (IQR = 40%;47%) and 18% in the highest MUAC group (IQR = 14%;22%).

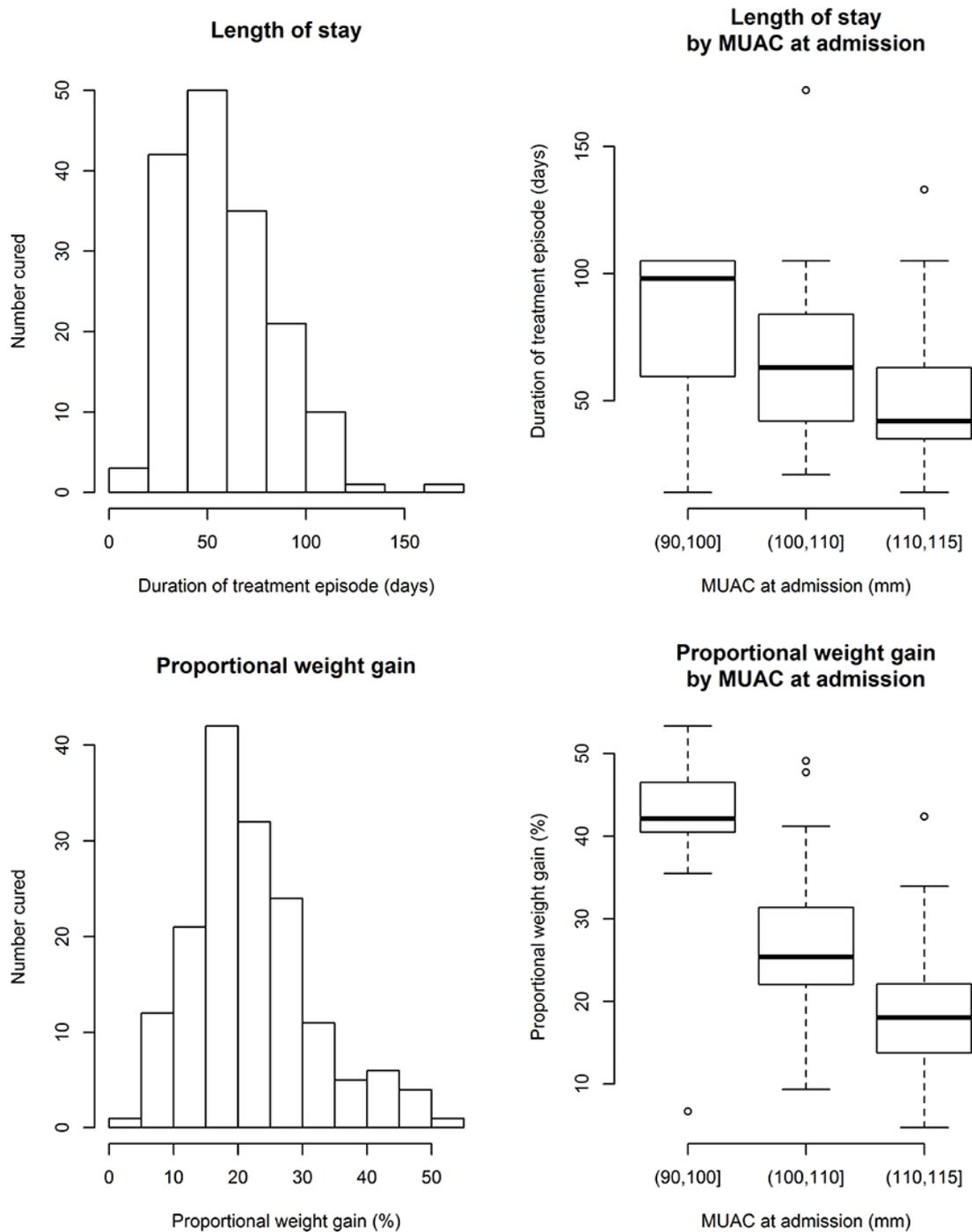
Figure 9 shows the length of stay and proportional weight gain by height at admission for two height classes of subjects. The length of stay was inversely proportional to the height at admission for the two height classes ($p = 0.0220$, Kruskal-Wallis test). Proportional weight gain

was also inversely proportional to height at admission for the two height classes ($p = 0.0003$, Kruskal-Wallis test).

Outcomes of children followed for the 3-month period after being discharged as cured from the outpatient treatment are shown in *Table 3*. The proportion of patients discharged cured and experiencing relapse to SAM or non-accidental death was below 10% ($p = 0.0013$, binomial test with alternative hypothesis that the proportion of failures is below 10%).

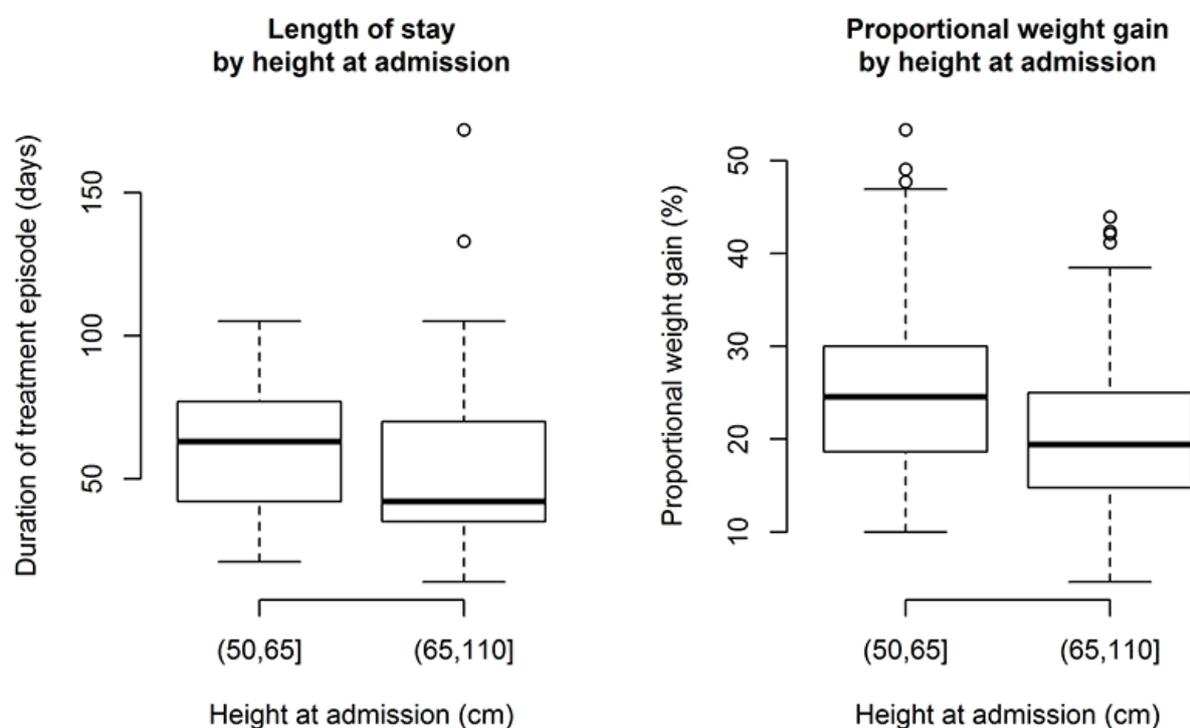
Of the 155 children followed up after being discharged as cured, 29% ($n = 45$) received SFP rations. Children who did not receive SFP rations were no more likely to experience a negative outcome than those who did receive SFP rations (chi-square = 2.11, $p = 0.1461$).

Figure 8 : Length of stay and proportional weight gain by MUAC at enrolment



For the box plots presented in Figure 8, the box extends between the upper and lower quartiles with the thick line in the box marking the position of the median. The whiskers extend to 1.5 times the interquartile distance above and below the upper and lower quartiles, and the isolated points mark the positions more extreme than the range of values covered by the whiskers.

Figure 9 : Length of stay and proportional weight gain by height at admission



For the box plots presented in Figure 9, the box extends between the upper and lower quartiles with the thick line in the box marking the position of the median. The whiskers extend to 1.5 times the interquartile distance above and below the upper and lower quartiles, and the isolated points mark the positions more extreme than the range of values covered by the whiskers.

Table 3 : Outcome of children followed up for 3 months post-discharge

Outcome	Number	Percentage (95% CI)
MUAC \geq 115 mm	150	96.8% (92.6%; 98.9%)
Non-accidental, non-violent death*	2	1.3% (0.2%; 4.6%)
Relapsed	3	1.9% (0.4%; 5.6%)
Non-accidental, non-violent death plus relapsed	5	3.2% (1.1%; 7.4%)

* No other deaths recorded including from accidental or violent causes

The study data for the children who died and relapsed during the 3-month follow-up period are shown in *Table 4*. One child who died did not experience any recorded illnesses during the week prior to her recorded death, and the second child who died was recorded to be very unwell with diarrhoea, vomiting, cough, and fever during the week prior to her death. A detailed follow-up investigation of the deaths indicated that in both cases the children had accessed medical services at a hospital prior to death.

Regarding relapses, one child was absent for four of the six follow-up visits prior to relapse, but did not have any illnesses recorded. A second child was recorded to have diarrhoea, fever, and cough the week prior to relapse, and a third child had a cough recorded for weeks 2 and 3, but no other illnesses recorded during the week prior to the relapse in week 5.

The relationships between MUAC gain and weight gain during recovery are illustrated by exemplars (Figure 10, Figure 11, Figure 12, and Figure 13). Each plot indicates periods of illness recorded in the clinical record (C = Cough, D = Diarrhoea, V = Vomiting, F = Fever). The number following each code indicates the number of days the condition was present during the week preceding the visit. MUAC gain and weight gain tend to mirror each other and both are sensitive to illness during a treatment episode.

Figure 14 and Figure 15 show the relationship between MUAC gain and weight gain in absolute and proportional terms. Filled points in these plots are used to indicate negative outcomes (i.e., death, default, and non-cured).

Table 4 : Details of subjects with negative outcomes following discharge with a MUAC \geq 125 mm

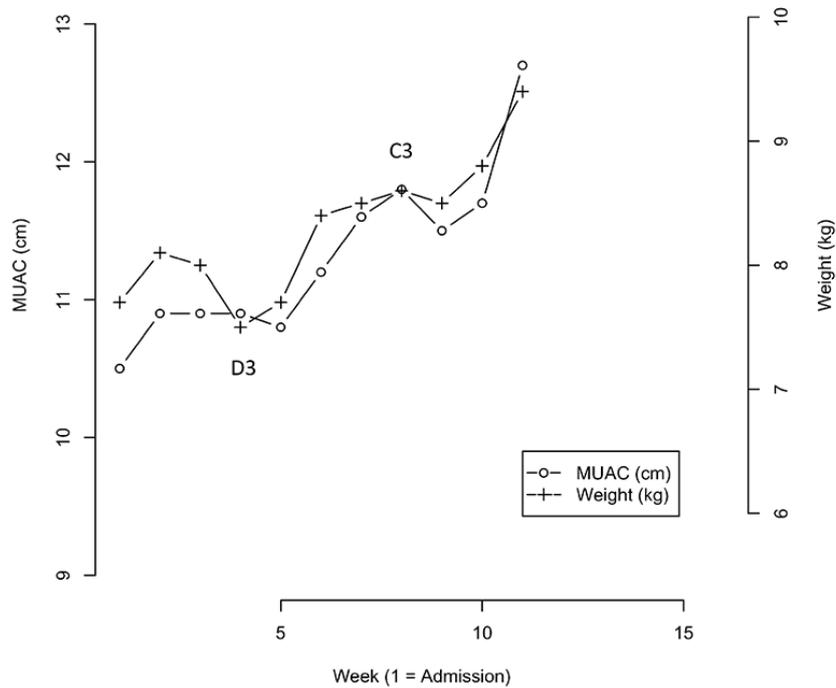
Outcome	Age at Admission (months)	Sex F/M	Admission MUAC*	Discharge		Length of stay in program (weeks)	% wt. gain	Duration of follow-up (weeks)**	Last known MUAC***	Illness in follow-up
				MUAC	WHZ					
Death	9	F	11.2 cm	12.5 cm	0.30	7	10.0%	10	13.4 cm	Diarrhoea Cough
Death	14	F	11.0 cm	12.8 cm	-0.01	15	14.7%	6	12.0 cm	Diarrhoea Vomiting Fever Cough
Relapse	14	M	11.0 cm	12.6 cm	-0.08	12	26.8%	12	11.0 cm	None recorded
Relapse	12	M	10.4 cm	13.0 cm	-0.39	5	26.8%	8	11.4 cm	Diarrhoea Vomiting Fever Cough
Relapse	9	F	11.0 cm	12.8 cm	-0.65	16	30.0%	6	11.5 cm	Diarrhoea

* No children had oedema at admission

** The follow-up visit prior to death or the follow-up visit when relapse was detected

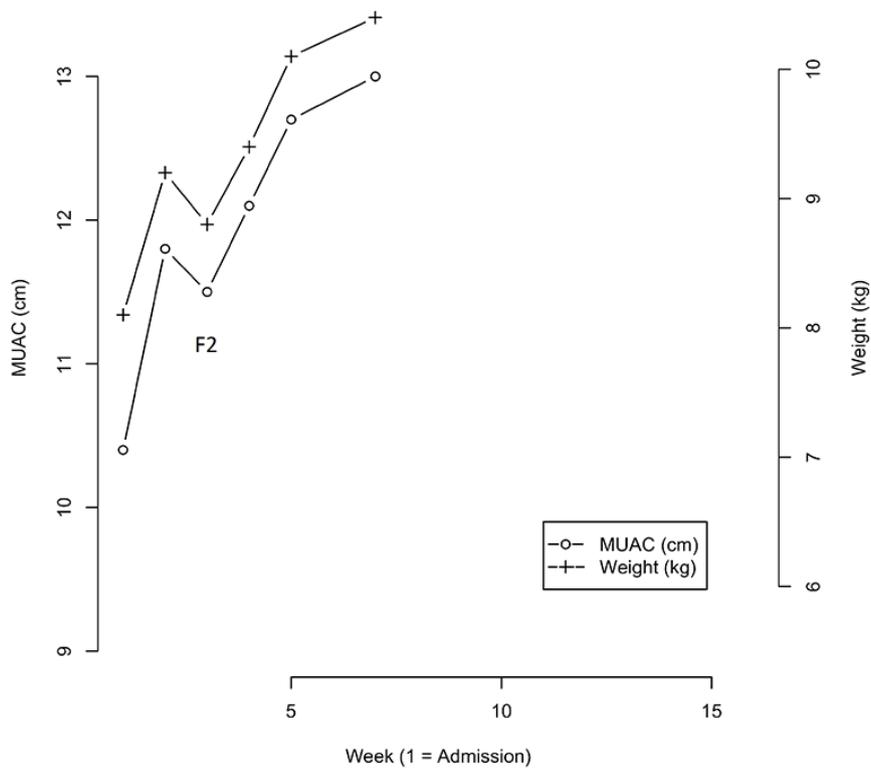
*** Last known MUAC for deaths is the MUAC recorded in the follow-up visit prior to death. Last known MUAC for relapse is the MUAC at the follow-up visit at which the relapse was detected. All relapsed cases in follow-up were referred back to the therapeutic feeding program.

Figure 10 : Graph of MUAC and weight against time in treatment



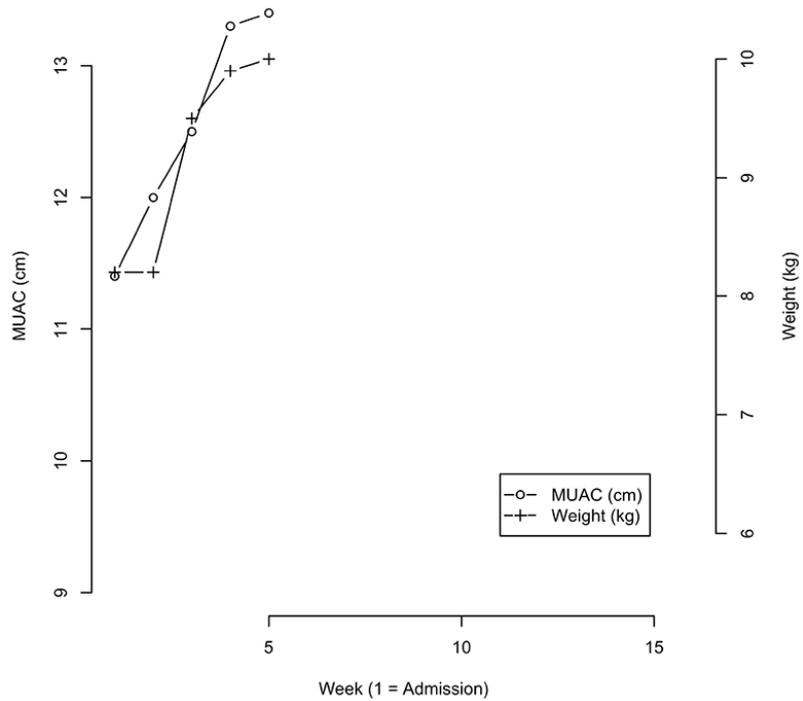
Female, 23 months, admission MUAC = 10.5cm, discharge MUAC 12.7cm, 11 weeks under treatment, systemic antimicrobials given at admission. Diarrhoea x 3 days (D3) and cough x 3 days (C3) during treatment.

Figure 11 : Graph of MUAC and weight against time in treatment



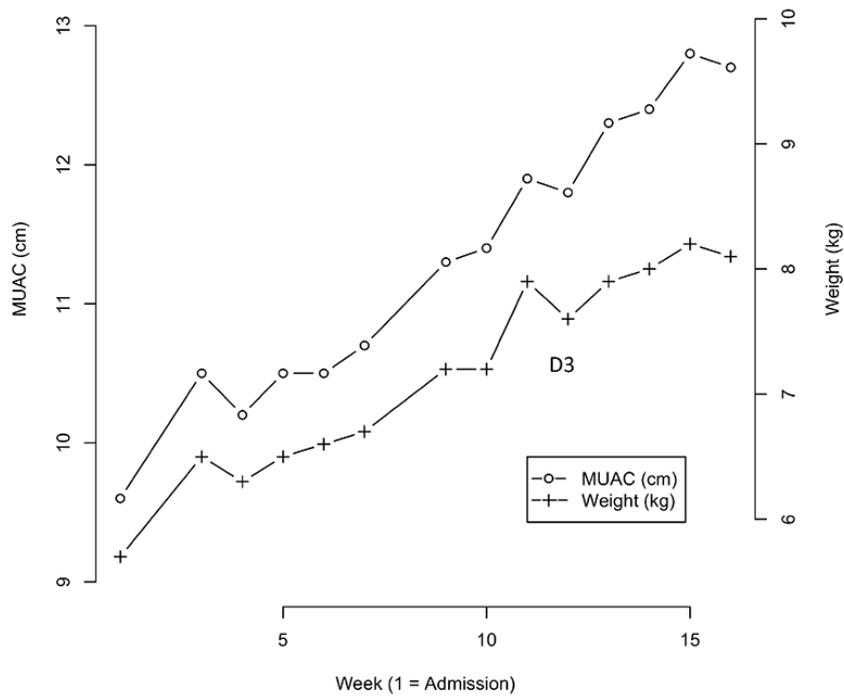
Female, 14 months, admission MUAC = 10.4cm, discharge MUAC = 13.0cm, 7 weeks in treatment, systemic antimicrobial given in week 3. Fever x 2 days (F2) during treatment.

Figure 12 : Graph of MUAC and weight gain against time in treatment



Male, 36 months, admission MUAC = 11.4cm, discharge MUAC = 13.4cm, 5 weeks in treatment, systemic antimicrobials given at admission, no illnesses recorded during treatment.

Figure 13 : Graph of MUAC and weight against time in treatment



Female, 38 months, admission MUAC = 9.6cm, discharge MUAC = 12.7cm, 16 weeks in treatment, systemic antimicrobials given at admission. Diarrhoea x 3 days (D3) recorded during treatment.

Figure 14 : MUAC gain in cm against weight gain in kg

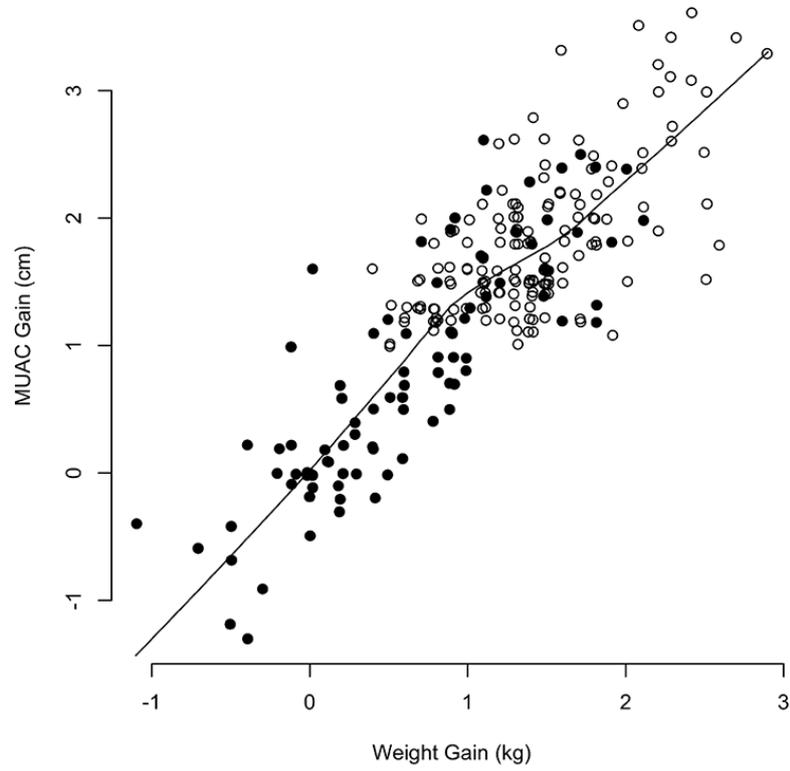
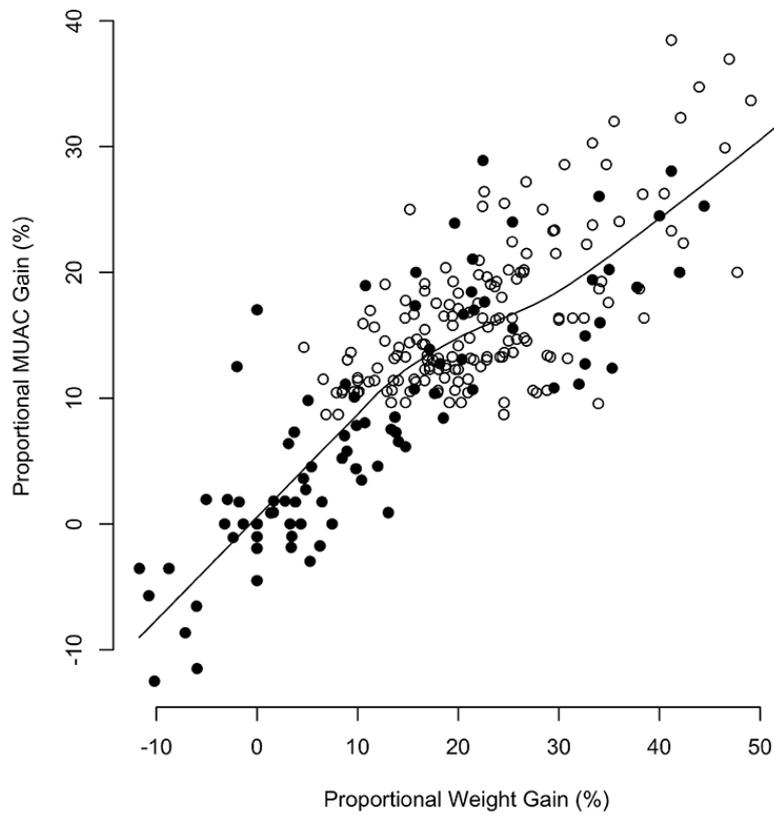


Figure 15 : Graph of proportional MUAC gain (%) against proportional weight gain (%)



Discussion

Relapses formed 1.9% and non-accidental, non-violent deaths formed 1.3% of negative outcomes post-discharge (total negative outcomes post discharge = 3.2%). Thus, the study met the standard established for relapse and non-accidental, non-violent death in the 3 months following discharge from treatment (< 10%). The post-discharge deaths were not related to relapse and were not associated with discharge with WHZ < -2. All cases with a negative outcome following discharge had a WHZ > -1 on discharge from treatment. This suggests that the MUAC criterion of ≥ 125 mm represents a safe discharge criterion for children aged 6–59 months when assessed at 3 months post-discharge.

Children recruited to the study with a height less than 65 cm showed a higher proportional weight gain and a longer median length of stay under treatment than children 65 cm or more. There was no association with negative outcomes at 3 months post-discharge for children with height less than 65 cm, thus addressing concerns that using MUAC as a discharge criterion would not be appropriate for stunted children aged 6 months or more with a height less than 65 cm.

The median length of stay for subjects achieving the MUAC ≥ 125 mm discharge criterion was 49 days. Children with lower MUAC at admission had longer durations of treatment and a higher percentage weight gain than the children admitted with a higher MUAC. This shows that the MUAC discharge criterion requires the children who are the most malnourished to remain under treatment longer and to be discharged with a higher percentage weight gain. This eliminates the problems identified with the proportional weight gain criterion (Dale, 2013) and its association with under-treatment for the most malnourished individuals.

Study findings included a high non-cure rate (18.9%), which appeared to be associated with non-compliance with treatment and which reduced the sample size available for follow-up after cure and subsequent analysis.

Figure 10, Figure 11, Figure 12, and Figure 13 illustrate the relationship between MUAC and weight during treatment for four selected study cases. In all of the exemplars presented, there is a close correlation between MUAC gain and weight gain. The changes in both weight and MUAC appear to be sensitive to episodes of illness recorded during treatment. These correlations were consistently seen in all of the cases enrolled in the study. The relationship between MUAC gain and weight gain for all cases is further illustrated in *Figure 14* and *Figure 15*.

The relationship between the MUAC on admission and length of stay and the relationship among MUAC, weight, and the sensitivity to episodes of illness raises the possibility for the development of a candidate tool for MUAC-only monitoring (*Figure 16*).

Figure 16 : Candidate tool for MUAC-only monitoring

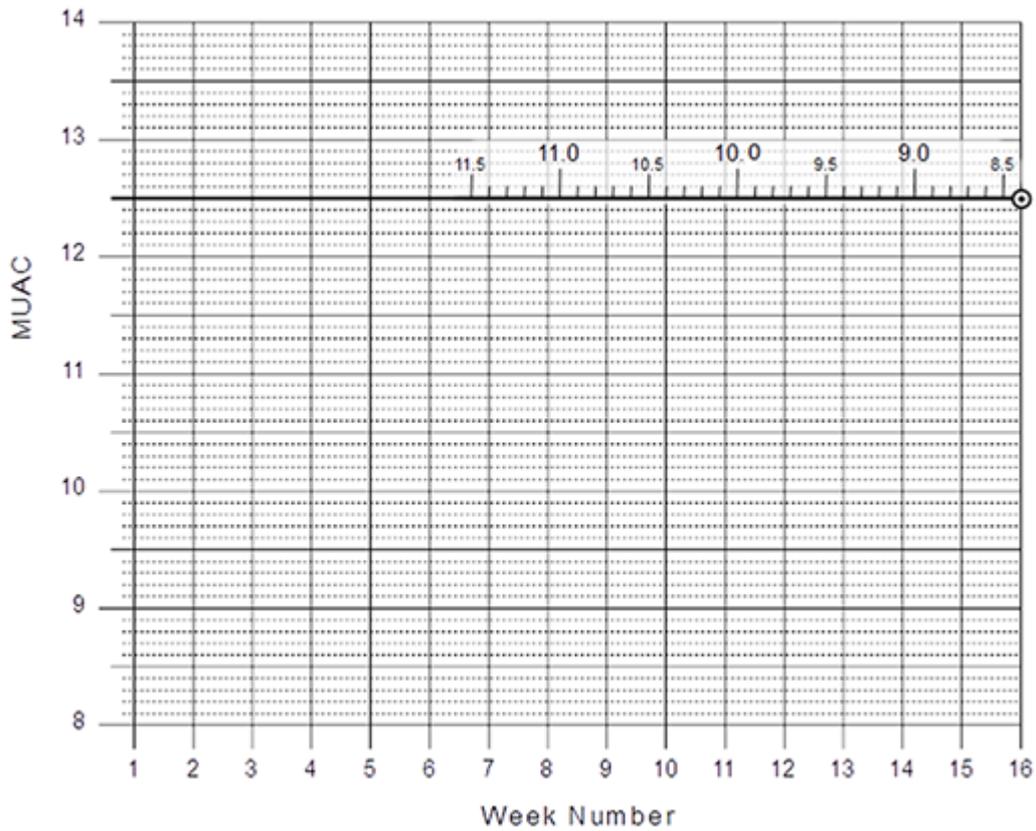
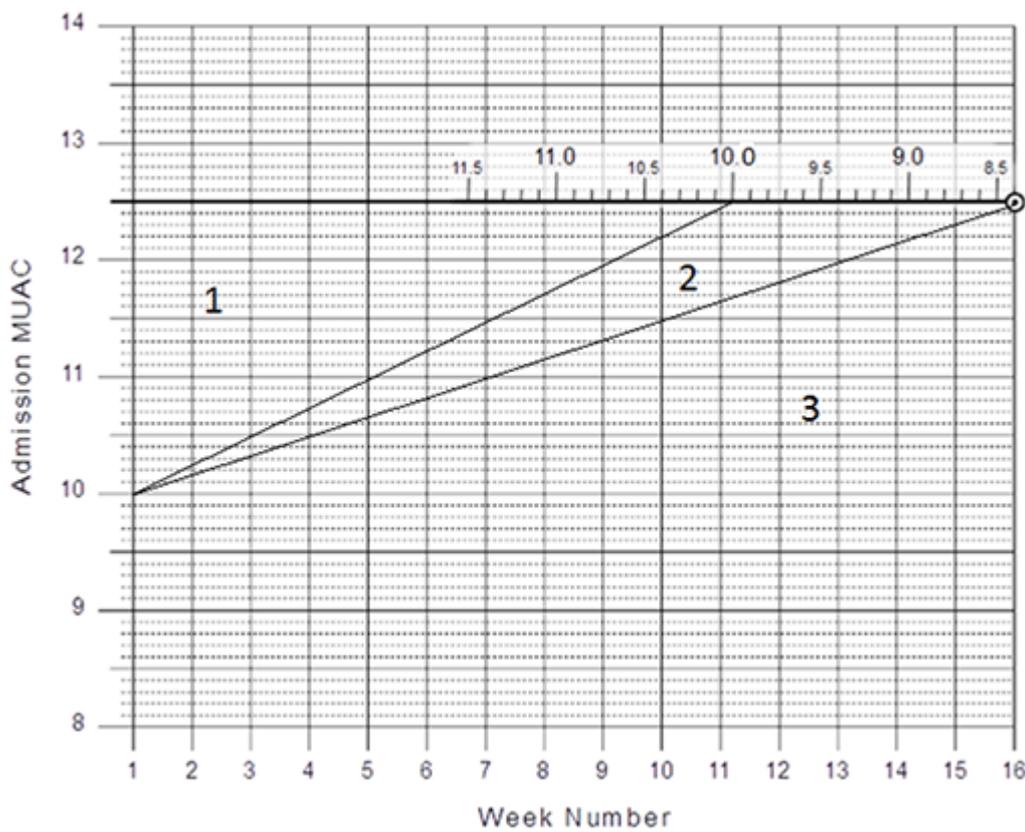


Figure 16 provides a graph of MUAC against time in treatment. A secondary abscissa (x-axis) along the top of the diagram also refers to the MUAC on admission. This axis is drawn to intersect the ordinate (y-axis) at the desired point of cure according to MUAC (i.e., 12.5 cm). On admission, the MUAC is plotted for week 1 at the appropriate intersection of the y-axis and x-axis. That point is then connected to two other points on the nomogram with straight lines. The first point to be joined is from the MUAC reading plotted in week 1 to the admission MUAC on the top axis. The top axis is derived from the median length of stay depending on MUAC on admission. The second point joins the admission MUAC in week 1 to the point marked by a target (⊙) at the junction of the top axis and week 16. The drawing of the lines divides the chart into three potential growth vectors. In the example below, the child is admitted with a MUAC of 10.0 cm.

Figure 17 : Example of MUAC tool applied to a child with an admission MUAC of 10.0 cm



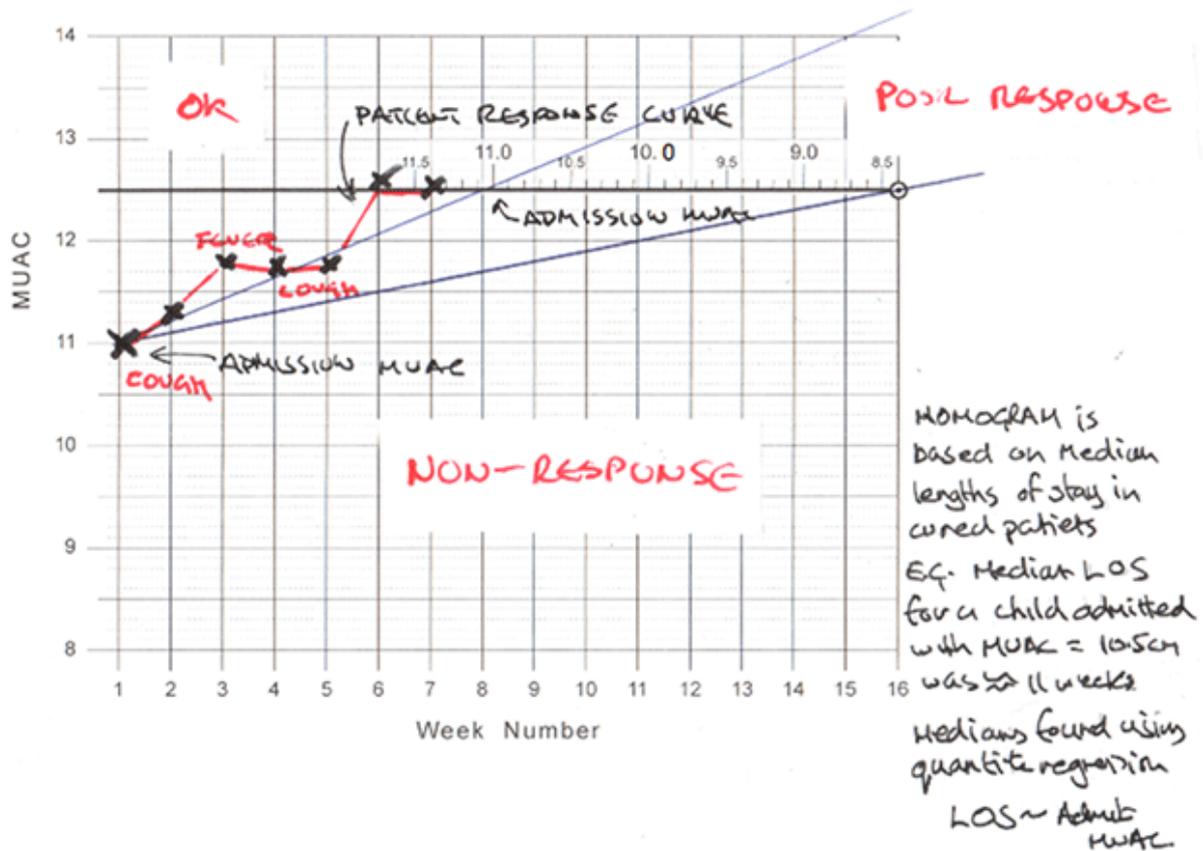
In the example in *Figure 17*, the chart is divided into three areas labelled 1, 2, and 3. On each successive weekly visit following admission, the MUAC reading is plotted on the chart using the x and y axes only.

A growth curve that remains within area 1 defines a good recovery and the child may be expected to recover at or before the expected median length of stay according to the admission MUAC.

A child with a growth curve that falls into area 2 indicates a child who will take longer than the expected median length of stay to attain cure but will still be cured within 16 weeks (typically the point at which a child would be discharged as non-cured). A child falling into this area typically requires closer clinical evaluation and is likely to be suffering from some illness (which may or may not be diagnosed) or is indicative of poor compliance with treatment protocols.

A child with a growth curve that enters area 3 is not responding to treatment appropriately and is at high risk of non-recovery, whether due to illness or non-compliance. Having a growth curve in area 3 also appeared to be highly indicative of likely default from treatment. A child in area 3 requires a full re-evaluation and possibly referral to an inpatient unit. An example using real data is shown in *Figure 18*.

Figure 18 : Example of MUAC monitoring tool using real data



MUAC growth plots using real data attained during the study appropriately detected children in need of further intervention for the treatment of illnesses or for poor compliance to treatment protocols. This MUAC monitoring tool is currently under further development through integration into simple protocols to allow its use at health facility and community levels. Integration into C-IMCI protocols may allow for improved access to treatment and case coverage through MUAC-only monitoring at the community level, with appropriate referral to health facilities when required.

It is suggested that this study be repeated in other centres to establish a multi-centre evidence base. The MUAC monitoring tool should be further developed and field tested.

Conclusions

This study suggests that the discharge criterion of MUAC \geq 125 mm on two consecutive visits represents a safe discharge criterion with acceptable negative outcomes at 3 months post-discharge in the context of Malawian MoH outpatient care facilities. Negative outcomes (death or relapse) were not associated with failing to meet accepted discharge criterion for outpatient care using the WHZ > -2 criterion. This MUAC discharge criterion was also found to be appropriate for children aged 6 months or more who are less than 65 cm in height.

Using a discharge criterion of MUAC \geq 125 mm, children admitted with lower MUAC remain under treatment for longer and achieve higher proportional weight gains. Early detection of SAM using MUAC in the community has the potential to reduce the length of stay and the associated cost of treatment.

A candidate monitoring tool developed from the study data suggests that MUAC-only monitoring is possible and can be sensitive to episodes of illness or non-compliance with treatment during recovery. Further development of this tool and field testing may provide a simple method of monitoring treatment at the community level and improve treatment coverage.

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