Nutrition Research and Practice 2015;9(3):268-277

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Efficacy of mid-upper arm circumference in identification, follow-up and discharge of malnourished children during nutrition rehabilitation

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BACKGROUND/OBJECTIVES: Although it is crucial to identify those children likely to be treated in an appropriate nutrition rehabilitation programme and discharge them at the appropriate time, there is no golden standard for such identification. The current study examined the appropriateness of using Mid-Upper Arm Circumference for the identification, follow-up and discharge of malnourished children. We also assessed its discrepancy with the Weight-for-Height based diagnosis, the rate of recovery, and the discharge criteria of the children during nutrition rehabilitation.
SUBJECTS/METHODS: The study present findings from 156 children (aged 6-59 months) attending a supplementary feeding programme at Makadara and Jericho Health Centres, Eastern District of Nairobi, Kenya. Records of age, weight, height and mid-upper arm circumference were selected at three stages of nutrition rehabilitation: admission, follow-up and discharge. The values obtained were then used to calculate z-scores as defined by WHO Anthro while estimating different diagnostic indices.
RESULTS: Mid-upper arm circumference single cut-off (< 12.5 cm) was found to exhibit high values of sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio at both admission and discharge. Besides, children recorded higher rate of recovery at 86 days, an average increment of 0.98 cm at the rate of 0.14mm/day, and a weight gain of 13.49gm/day, albeit higher in female than their male counterparts. Nevertheless, children admitted on basis of low MUAC had a significantly higher MUAC gain than WH at 0.19mm/day and 0.13mm/day respectively.
CONCLUSIONS: Mid-upper arm circumference can be an appropriate tool for identifying malnourished children for admission to nutrition rehabilitation programs. Our results confirm the appropriateness of this tool for monitoring recovery trends and discharging the children thereafter. In principle the tool has potential to minimize nutrition rehabilitation costs, particularly in community therapeutic centres in developing countries.

Nutrition Research and Practice 2015;9(3):268-277; doi:10.4162/nrp.2015.9.3.268; pISSN 1976-1457 eISSN 2005-6168

Keywords: Malnutrition, nutrition rehabilitation, MUAC, weight-for-height, recovery

INTRODUCTION

Studies show that malnutrition affects the lives of many children, especially those from developing regions, and contributes to over 50% of child deaths globally [1,2]. Severe acute malnutrition (SAM) is the most lethal form of malnutrition and is normally defined by a very low weight-for-height (below WHZ < -3SD of median WHO standard) or visible severe wasting or by the presence of oedema [3]. Nevertheless, for children aged 6-59 months, Mid-Upper Arm Circumference (MUAC) < 115 mm is the most commonly used indicator of severe acute malnutrition and in essence most nutrition rehabilitation interventions usually admit only those children with moderate acute or mild malnutrition while the severe cases are given specialised treatment before admission to the rehabilitation programmes [4,5].

MUAC is gaining popularity over "weight-for-height based diagnosis (WH)" as a tool to follow-up children during nutrition rehabilitation [6,7]. This is because, MUAC has only one measurement, while WH needs two, it uses lighter and cheaper materials, and no reference tables are required (unlike WH based diagnosis). These elements further explain the potential value of MUAC for community screening in large populations [7,8]. WH seems to only confirm cases of severe acute malnutrition in children presenting a very low MUAC. Besides the advantages, MUAC also became an important tool for

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Received: May 13, 2014, Revised: September 12, 2014, Accepted: September 16, 2014

regions with high illiteracy levels, i.e. a characteristic that fits the requirements of Community Therapeutic Care (CTC) of acute malnutrition [9,10]. In addition, it has been adopted by many agencies and community therapeutic care centres (CTCs) in recent years [11-13].

Furthermore, undernutrition in children can be a lethal condition which requires immediate nutrition attention and medical support [2,8]. Therefore, it is very important to identify frail children as early as possible in order to adequately treat them through nutrition support programmes [7,12,14]. However there is no standard indicator for such identification and there is not enough evidence for using one indicator in the follow-up of children during rehabilitation. Therefore, this study has two objectives related to the types of identification where MUAC could be beneficial: First, Comparison of MUAC, WH and a multi-component indicator (MUAC adjusted for age and gender) to identify malnourished children for nutrition rehabilitation. In the presence of pathognomonic symptoms, during marasmus and/or kwashiorkor, rapid diagnosis is possible [15]. Conversely in children with no clinical signs WH and MUAC have been the two anthropometric indices most often used in identification of malnourished children [10,16-19]. WH and MUAC are proxies of an individual's nutritional status which reflects indirectly the catabolism of lean tissue and fat which occurred in undernourishment [12,14]. Nevertheless their use as screening tools for undernourished children differs considerably. The WH definition of undernourishment relies on the normal distribution of the anthropometry in a reference population. In this case, severe acute malnutrition (SAM) is defined by WHZ < -3 and moderate acute malnutrition (MAM) by WHZ -3 to < -2 [3,7,8], with these cut-offs being age and sex specific. On the other hand, for MUAC based diagnosis, a single cut-off is applied independently of the age and sex. Here, severely malnourished is defined as 110 mm while moderately malnourishment is defined by > 110 to 120 mm, in 6-59 months old children. Recently these cut-offs have been adjusted to 115 mm and 125 mm respectively [11]. Nevertheless, using MUAC and WH globally provides similar prevalence rates of acute malnutrition [7,20]. Besides, it is surprising to note that only a proportion of about 40% of malnourished cases identified by one indicator will also be identified by the other [7,20,21]. This is an interesting observation as these two indicators are assumed to assess the same problem and should identify children for a common treatment. However, in practice, the use of one indicator will lead to misdiagnosis of some cases while using the two independently should increase the case load. Consequently, since they detect different populations it can be hypothesized that these populations require different management approaches. In order to address this, we analyze the discrepancy between MUAC, WH and a multi-component indicator (MUAC adjusted for age and gender) in their identification of malnourished children for nutrition rehabilitation.

Second, Comparison of MUAC and WHZ in follow-up and discharge of malnourished children during nutrition rehabilitation. Admission and follow-up of undernourished children on the basis of MUAC alone is a relatively new strategy that has been considered by many agencies [12]. Although there exists a pool of evidence on the response of undernourished children selected on basis of WH, a similar response is less documented for undernourished children admitted on the basis of MUAC. As MUAC and WH identify different populations [7,20-22], we hypothesize that undernourished children identified by MUAC alone, and not by WH, respond differently to nutrition rehabilitation. Previous research shows that MUAC responds to nutrition therapy even when home-based [23,24] or even in the case of rehabilitation of moderately malnourished children [7,25]. In addition, the global daily MUAC gain is between 0.2-0.4 mm during nutrition rehabilitation and this is significantly influenced by the initial nutrition status and stature of the child. Although in many studies the MUAC gain is consistent with this global range, as nearly all studies assessed MUAC during rehabilitation by using WHZ as the inclusion criteria [4,6,14]. Still there is limited evidence on the nutritional rehabilitation of malnourished children selected on basis of low MUAC alone. During rehabilitation of malnourished children the relationship between changes in MUAC and changes in weight are a function of age, sex, and height at inclusion and conditions that are associated with increased mortality risk [7,16,20]. Too our knowledge, there is no study describing the utility of MUAC as a monitoring tool during nutrition rehabilitation [4]. Hence, we address this concern by analyzing the responses of children admitted on basis of MUAC throughout the rehabilitation in relation to the generic admission and follow up using WHZ.

Given these two objectives, the current study attempts to respond to the following five questions: 1) Is MUAC useful in clinical identification and follow-up of malnourished children?; 2) What is the difference between MUAC and WH in the identification and follow up of malnourished children?; 3) How effective is MUAC single cut-off for all?; 4) What is the rate of recovery of children selected on the basis of MUAC alone compared to those selected using WH and multi component indices ?, and 5) What is the discharge criterion for the children selected on the basis of MUAC alone?

SUBJECTS AND METHODS

Location and setting

We present data from 2 Health Centers in the Eastern District of Nairobi, Kenya, i.e. Jericho and Makadara, who participated in a Joint World Food Program (WFP) and Ministry of Health Supplementary Feeding Programme, between October 2010 and September 2011. They are among the 20 Health Centers implementing the program. Their inclusion is based on their location, which is situated in the midst of the largest slums of Kenya, and even Africa. These locations are characterized by a high population density, impaired food intakes and an overall food insecurity, which are key determinants of malnutrition [26]. This further lend support for establishing a supplementary feeding programme targeted to children from this neighborhood.

Subjects and data collection

During the period of the study the programme had a total of 1,278 children. The data for children between the ages of 6-59 months was obtained following a clear inclusion and exclusion criteria as described in the study profile shown in Fig. 1. Records of inpatient and children brought in were included

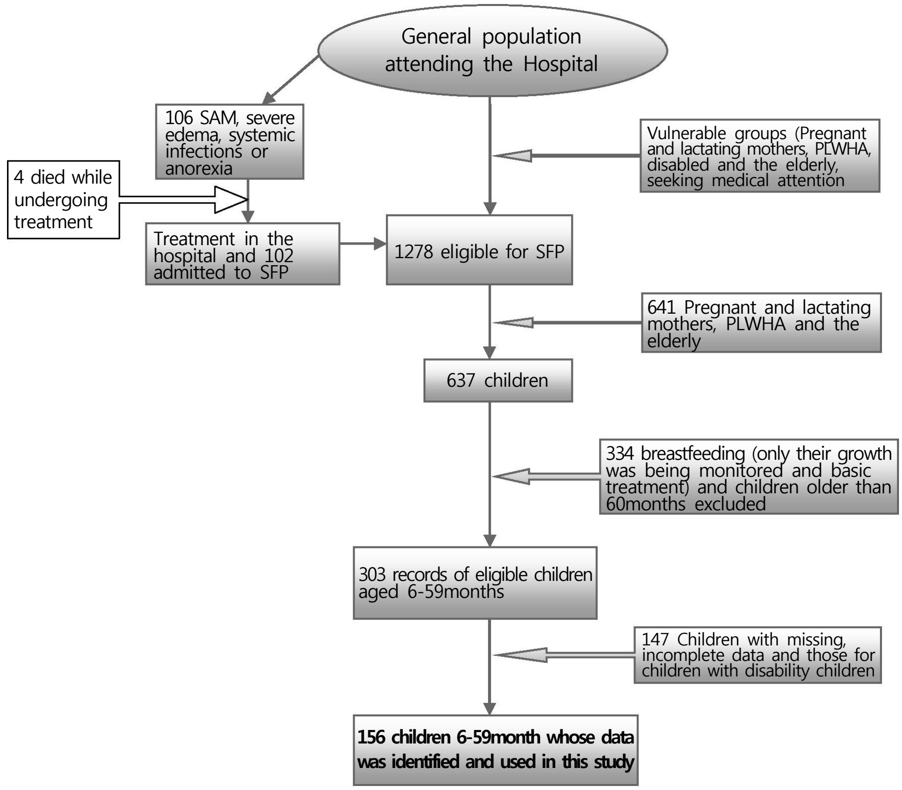

Fig. 1. Study profile of the study and sample selection

except severely malnourished or children with other complications who needed more specialized attention. A consistent inclusion criterion was adopted to select the data for the children included in the study. Data of selected children were only included when data on nutritional anthropometry clearly describes age, sex, weight, height, MUAC and subsequent dates of admission, as well as visits during the follow-up and discharge, default or death. These data refer to all children with complete admission, follow-up and discharge data. Exclusion criteria are: children outside the 6-59 months age range; data without information on the admission and /or discharge criteria, date of birth, admission, weight, height or MUAC; Data for children with other notable conditions or disability which impact on normal growth.

During the period of data selection we monitored the key elements of data collection to ensure that admission, follow-up and discharge measurements were taken and that the key data were captured for all the children attending and recorded in a special card. To minimize data collection errors, only data collected by qualified and experienced public health and nutrition professionals attached to the health facility were included.

Data entry, documentation and Statistical analysis

EpiData platform was used for data entry [27]. Besides EpiData platform allows detection of errors (e.g. double entry verification), generation of identification numbers of different elements of the sample and encryption at the initial stages.

After entering the data another colleague was involved for cross-checking to detect any errors or omissions that might have occurred. After this second stage the data set was screened for the third time in order to develop the final data set, which was exported to STATA [28].

Nutritional indices of malnutrition were first calculated using WHO Anthro (Version3.2.2; Department of nutrition WHO, 2011). WH, WA and MUAC were compared to the WHO reference standards (WHO, 2011) to produce the Z-scores for all anthropometric measurements.

Descriptive characteristics of the sample were computed among which mean age, weight, height, MUAC and other anthropometric indices for all children and for each gender. Since, the selection of the sample included only children with admission, follow-up and discharge data, we also computed the discharge characteristics of the sample.

Using WHZ < -2 and MUACZ < -2 as the golden standard, the sensitivity, specificity, positive predictive value, negative predictive value, likelihood ratios, accuracy, Kappa and diagnostic odd ratios of single MUAC cut-off < 12.5 cm were estimated at admission and discharge, for each gender and in total. Sensitivity was defined as the percentage of true positive for malnutrition that were identified when MUAC single cut-off < 12.5 cm, MUACZ < -2 or when WHZ < -2. The proportion of the children who would otherwise be missed during identification with a single MUAC cut-off < 12.5 cm, WHZ < -2, MUACZ < -2 or WAZ < -2 was also calculated.

Table 1 below outlines the criteria for diagnostic indices.

Table 1. 2 × 2 table of comparing diagnostics accuracy

Screening indicator results	True malnutrition as defined by WA < 75%, > 60% of media or WH < 90%, > 85 of median		Total
	Positive	Negative	
Positive	A (True positive)	B (False positive)	A + B
Negative	C (False negative)	D (True negative)	C + D
Total	A + C	B + D	N = (A + B + C + D)

Key: sensitivity = A/A + C; specificity = D/B + D; PPV = A/A + B; NPV = D/C + D

The average gain in MUAC and Weight during rehabilitation was computed for each gender and for combined group. The duration taken by children from admission was calculated as the average difference between point of discharge and admission. The time for recovery for children identified as malnourished on basis of MUAC, MUACZ, WHZ or WAZ was compared.

We also calculated the positive likelihood ratio (+ LR) and negative likelihood ratio (-LR) from the data collected. + LR and -LR was calculated as the probability of a person who has the disease testing positive divided by the probability of the person who does not have the disease testing positive, and vice versa in the case of -LR (Table 3). This is an important parameter to evaluate the utility of MUAC and WHZ for use in identification of frail children. When + LR is close to 1, there isvery little practical utility as post and pretest probability are very similar while when -LR is close to 1 then there is very little utility to exclude the diagnosis (Bayes' Theorem).

Another important indicator is the diagnostic odds ratio (DOR) which provides the test performance used in diagnosis. DOR is normally independent of prevalence and easier to understand by which it can be used to compare the performance of MUAC single cut-off (< 12.5 cm) and WHZ < -2. It is usually defined as the ratio of odds of positivity in a disease relative to the odd of positivity in the non-diseased or simply the ratio of + LR to -LR.

DOR values range from 0 to infinity where the higher values of DOR indicates better discriminatory test performance with 1 representing a no discrimination and values below 1 point to improper test interpretation. The value of DOR increases if sensitivity and specificity is close to perfection.

Finally, the evolution of MUAC, Weight and Height during the whole period of rehabilitation was compared using polynomial smoothing curve.

RESULTS

Sample descriptive and baseline statistics

Of the 303 children 6-59 months old eligible only data for 156 children who attended SFP were selected as presented in Fig. 1. Data from 147 children excluded were mainly for those with missing details such as dates of birth or age, any of the three key measurements (MUAC, weight, height) and/or respective gender at admission, follow-up or discharge data as well as those with disability.

Table 2 depicts the characteristics of the sample at admission and discharge for different gender and for combined group during the rehabilitation. At admission 59% were females, with mean age of 15.73 months ± 10 while males (41%) had mean age 19.23 ± 13.35 months. Generally males were relatively heavier and taller, at 8.92 ± 2.03 kg and 76.50 ± 11.01 cm respectively, than females, at 8.05 ± 1.17 kg and 73.0 ± 7.32 cm respectively.

Mid Upper Arm Circumference for male and female at admission were 13 ± 0.67 cm and 12.79 ± .59 cm respectively. While the WHZ was -1.17 ± 1.52 and -1.05 ± 1.30 for male and female respectively. For the whole group, there was a significant change in anthropometric measurements (weight, height and MUAC) between admission and the discharge of the children from the programs ($P < 0.001$).

The mean weight and height gain during nutrition rehabilitation was 1.03 kg (CI 0.9-1.17; $P < 0.001$) and 2.42 (CI 1.96-2.89) respectively. However there was no significant difference in gain

Table 2. Background anthropometric data

Characteristic	Male: 64 (41%)			Female: 92 (59%)			Combined = Male: 64 (41%)/ Female: 92 (59%)			
	Admission (mean, SD/95%CI)	Discharge (mean, SD/95%CI)	Difference (95%CI)	Admission (mean, SD/95%CI)	Discharge (mean, SD/95%CI)	Difference (95%CI)	Admission (mean, SD/95%CI)	Discharge (mean, SD/95%CI)	Difference (95%CI)	*P*-value
Age (Months)	19.23 ± 13.35	22.18 ± 13.54	2.96 (2.5 to 3.3)	15.73 ± 10.0	18.44 ± 9.96	2.71 (2.44 to 2.98)	17.16 ± 11.6	19.98 ± 11.7	2.81 (2.59-3.03)	< 0.001
Weight (kg)	8.92 ± 2.03	10.16 ± 2.31	1.13 (0.86 to 1.09)	8.05 ± 1.17	9.02 ± 1.64	0.97 (0.84 to 1.09)	8.41 ± 1.9	9.44 ± 2.0	1.03 (0.9-1.17)	< 0.001
Height (cm)	76.50 ± 11.01	79.04 ± 10.49	2.54 (1.82 to 3.26)	73.0 ± 7.32	75.34 ± 7.49	2.34 (1.72 to 2.97)	74.43 ± 9.2	76.86 ± 9.0	2.42 (1.96-2.89)	< 0.001
MUAC (cm)	13 ± 0.67	13.90 ± 0.59	0.90 (0.74 to 1.06)	12.79 ± .59	13.83 ± 0.44	1.03 (0.91 to 1.15)	12.88 ± 0.6	13.86 ± 0.5	0.98 (0.88-1.07)	< 0.001
WHZ	-1.17 ± 1.52	0.46 ± 1.30	0.72 (0.34 to 1.07)	-1.05 ± 1.30	-0.35 ± 1.11	0.70 (0.47 to 0.93)	-1.12 (-0.9 to-1.34)	-0.40 (-0.21 to -0.59)	-0.7 (-0.5 to -0.9)	< 0.001
WAZ	-1.83 ± 1.01	-1.32 ± 0.95	0.51 (0.29 to 0.77)	-1.50 ± 1.04	-1.06 ± 0.92	0.44 (0.32 to 0.55)	-1.63 (-1.47 to -1.8)	-1.16 (-1.01 to -1.31)	-0.47 (-0.36 to -0.58)	< 0.001
HAZ	-1.88 ± 1.68	-1.92 ± 1.44	-0.04 (-0.21 to 0.30)	-1.32 ± 1.57	-1.53 ± 1.41	0.21 (-0.37 to 0.04	-1.53 (-1.29 to -1.81)	-1.69 (-1.46 to -1.91)	0.14 (-0.00 to 0.28)	0.97*
MUACZ	-1.75 ± 0.72	-0.99 ± 0.62	0.76 (0.59 to 0.91)	-1.44 ± 0.69	-0.62 ± 0.53	0.83 (0.72 to 0.94)	-1.57 (-1.46 to -1.68)	-0.77 (-0.67 to -0.87)	-0.8 (-0.71 to -0.89)	< 0.001
Mean stay in SFP mean days ± SD	89.91 ± 45.58			82.47 ± 38.95			85.52 ± 41.82			

Table 3. Characteristics of malnutrition identified by MUACZ < -2SD compared to single MUAC cut-off (< 12.5 cm), WHZ < -2 and WAZ < -2

Characteristic	MUACZ < -2SD						MUACZ < -2 for all the sessions from admission to discharge		
	Singlemuac cut-off < 12.5 cm		WHZ < -2		WAZ < -2		Single MUAC < 12.5 cm	WHZ < -2	WAZ < -2
	Admission	Discharge	Admission	Discharge	Admission	Discharge			
Sensitivity (Se) %	63.4 (51-72.5)	11.1 (1-47.7)	46.3 (33.6-57.8)	44.4 (16.4-73.4)	70.7 (56.8-82.1)	77.8 (41.5-96)	48.4 (42.2-53.6)	53.1 (45.4-60.5)	68 (59.8-75.3)
Specificity (Sp)%	93.0 (88.6-96.3)	83.7 (83.2-85.6)	87.7 (83.1-91.8)	95.9 (94.1-97.7)	75.7 (70.7-79.7)	82.8 (80.5-83.9)	97.4 (96.4-98.2)	90.2 (89-91.4)	75.9 (74.6-77.1)
Prevalence % (n)	26.28 (41)	5.84 (9)	26.45 (41)	5.84 (9)	26.28 (41)	5.84 (9)	13.66 (128)	13.68 (128)	13.66 (128)
Positive predictive value %	76.5 (61.6-87.5)	3.4 (0-14.8)	57.6 (41.7-71.8)	40.0 (14.7-66)	50.9 (40.9-59.1)	21.9 (11.7-27)	74.7 (65-82.7)	46.3 (39.6-52.7)	30.9 (27.2-34.2)
Negative predictive value %	87.7 (83.5-90.8)	94.7 (94.1-96.9)	82.0 (77.7-85.8)	96.5 (94.8-98.3)	87.9 (82.1-92.6)	98.4 (95.7-99.7)	92.3 (91.3-93)	92.4 (91.1-93.6)	93.7 (92.1-95.2)
+ LR	9.116 (4.49-19.58)	0.68 (0.04-3.32)	3.77 (1.99-7.09)	10.74 (2.79-31.3)	2.91 (1.94-4.05)	4.51 (2.13-5.96)	18.67 (11.75-30.18)	5.43 (4.13-7.02)	2.82 (2.36-3.28)
-LR	0.39 (0.29-0.55)	1.06 (0.61-1.2)	0.61 (0.46-0.80)	0.58 (0.27-0.89)	0.39 (0.22-0.61)	0.27 (0.05-0.73)	0.53 (0.47-0.60)	0.52 (0.42-61.3)	0.42 (0.32-0.54)
Diagnostic Odds Ratio (+ LR/-LR)	23.18 (8.13-68.64)	0.64 (0.03-5.44)	6.17 (2.49-15.44)	18.53 (3.13-114.69)	7.51 (3.17-18.08)	16.8 (2.93-125.3)	35.25 (19.59-63.92)	10.56 (6.75-16.24)	6.68 (4.38-10.23)
The overall fraction correct = TP + TN)/ Total obs (referred simply "Accuracy") %	85.3 (78.8-90.1)	80.1 (79.1-83.7)	76.8 (70-82.8)	92.9 (89.6-96.2)	74.4 (67-80.4)	82.5 (78.2-84.6)	90.7 (89-92.1)	85.1 (83-87.2)	74.8 (72.6-76.8)
Kappa	0.60 (0.42-0.72)	-0.2 (-0.08-0.16)	0.36 (0.18-0.53)	0.38 (0.1-0.68)	0.41 (0.24-0.55)	0.28 (0.1-0.36)	0.54 (0.45-0.61)	0.41 (0.32-0.49)	0.29 (0.23-0.35)

between males. Although, there was a statistically significant increase in Mid Upper Arm Circumference 0.98 cm (CI 0.88-1.07; $P < 0.001$), the increase was not significantly different between male and female. However this finding is in contrast to earlier studies that report that females respond better than males [7,29,30]. The results also point to significant increase in Z scores (WHZ, MUACZ and WAZ) ($P < 0.001$) which depicts the recovery of malnourished children due to rehabilitation, which are key to examining the recovery of malnourished children [11,16,24].

Diagnostic relationship of single MUAC cut off (< 12.5 cm) with other indices (MUACZ < -2, WHZ < -2SD, and WAZ < -2)

Table 3 indicates the sensitivity, specificity and other diagnostic measures of malnutrition defined by the single MUAC cut-off < 12.5 cm, WHZ < -2SD, and WAZ < -2SD in relation to malnutrition defined by MUACZ < -2 at admission, follow-up and discharge.

According to the findings there are no statistically significant differences in sensitivity and specificity when single MUAC cut-off (< 12.5 cm), WHZ < -2SD and WAZ < -2SD were compared with MUACZ < -2SD at both admission and discharge except for discharge at WAZ < -2SD. However, in general WAZ < 2SD led to significantly higher values of sensitivity than single MUAC cut-off < 12.5 cm but low specificity than WHZ < -2 which was even much lower. These trends are indicative of the change in capacity to correctly identify those frail children for rehabilitation and those ready for being discharged from the programme, as shown by Roy *et al*. [16].

Single MUAC cut-off < 12.5 cm gave statistically higher PPV values than WHZ < -2 WAZ < -2 in relation to MUACZ < -2 at admission but indifferent values at discharge.

The + LR of single MUAC cut-off < 12.5 cm in relation to malnutrition defined by MUACZ was found to be significantly higher at 18.67 (CI 11.75-30.18) than for WHZ < -2 and WAZ < -2 at 5.43 (CI 4.13-7.02) and 2.82 (CI 2.36-3.28) respectively. Further, the diagnostic odds ratio of malnutrition defined by single MUAC cut-off < 12.5 cm in relation to malnutrition defined by MUACZ < -2 was found to be 35.25 (CI 19.59-63.92) which was significantly higher than for WHZ < 2 and WAZ < -2 at 10.56 (CI 6.75-16.24) and 6.68 (CI 4.38-10.23) respectively.

The accuracy (simply the percentage agreement) of single MUAC cut-off < 12.5 cm and malnutrition defined by MUACZ was higher than for WHZ < -2 and WAZ < -2. Nevertheless these agreement values were only significant at discharge and not at admission. The kappa value was found to be higher for single MUAC cut-off and WHZ < -2 than WAZ < -2 but indifferent at admission and discharge.

Table 4 contains the sensitivity, specificity and other diagnostic measures of malnutrition defined by the combined indicator MUAC single cut-off < 12.5 cm, MUACZ < -2SD and WAZ < -2SD) in relation to positive malnutrition defined by WHZ < -2 at admission, follow-up and discharge. According to these findings WHZ < -2SD generated low values of sensitivity and high values of specificity (sensitivity was 50.6%, 20.6%, 48.44% and specificity 87.7%, 96.2%, 97.4% for MUAC < 12.5 cm, MUACZ < -2 and WAZ < -2 respectively).

We also obtained higher NPVs than PPVs for WAZ < -2 at 86.4% (80.1-91.1) than for MUACZ < -2 (46.3% (CI 39.6-52.7)) and single MUAC cut-off < 12.5 cm at 28.6% (CI 22.8-34.3). In contrast the NPVs was higher when WHZ < -2 was compared with single MUAC cut-off < 12.5 cm (94.8% (93.7-95.9)) than MUACZ < -2 (92.4% (CI 91.1-93.6)) and WAZ < -2 (80.5% (CI 79.3-81.4)). Additionally, although the difference in NPVs on admission and discharge was statistically significant, i the PPV differences between admission and discharge were not significant except for the single MUAC cut-off < 12.5 cm. Furthermore, according to the findings the + LR and -LR were

Table 4. Characteristics of malnutrition identified by WHZ < -2 compared to single MUAC cut-off (< 12.5 cm), MUACZ < -2, and WAZ < -2

Characteristic	WHZ < -2						WHZ < -2 for all the sessions from admission to discharge		
	MUAC < 12.5 cm		MUACZ-2		WAZ < -2		MUAC < 12.5 cm	MUACZ < -2	WAZ < -2
	Admission	Discharge	Admission	Discharge	Admission	Discharge			
Sensitivity (Se) %	47.1 (32.4-61)	50 (2.7-97.3)	46.3 (33.6-57.8)	44.4 (16.4-73.4)	51.8 (43-56.5)	28.1 (17.5-31.1)	50.6 (40.4-60.7)	53.1 (45.4-60.4)	45.2 (41.9-47.7)
Specificity (Sp)%	86 (81.8-89.9)	94.1 (93.5-94.7)	87.7 (83.1-91.8)	95.9 (94.1-97.7)	96 (91-98.6)	99.2 (96.4-100)	87.7 (86.7-88.7)	90.2 (89-91.4)	96.9 (95.5-98)
Prevalence % (n)	21.94 (34)	1.3 (2)	26.45 (41)	5.84 (9)	36.13 (56)	20.78 (32)	15.71 (147)	13.68 (128)	30.02 (281)
Positive predictive value %	48.5 (33.3-62.8)	10 (0.5-19.5)	57.6 (41.7-71.8)	40 (14.7-66)	87.9 (72.9-95.9)	90 (55.8-99.5)	28.6 (22.8-34.3)	46.3 (39.6-52.7)	86.4 (80.1-91.1)
Negative predictive value %	85.2 (81.1-89.1)	99.3 (98.6-100)	82 (77.7-85.8)	96.5 (94.8-98.3)	77.9 (73.8-80)	84 (81.7-84.7)	94.8 (93.7-95.9)	92.4 (91.1-93.6)	80.5 (79.3-81.4)
+ LR	3.35 (1.78-6.02)	8.44 (0.41-18.37)	3.77 (1.99-7.09)	10.74 (2.79-31.3)	12.82 (4.77-41.63)	34.31 (4.82-721.79)	4.11 (3.04-5.36)	5.43 (4.13-7.02)	14.8 (9.39-23.92)
-LR	0.62 (0.43-0.83)	0.53 (0.03-1.04)	0.61 (0.46-8.0)	0.58 (0.27-0.89)	0.50 (0.44-0.63)	0.73 (0.69-0.86)	0.56 (0.44-0.69)	0.52 (0.43-0.61)	0.57 (0.53-0.61)
Diagnostic Odds Ratio (+ LR/-LR)	5.44 (2.15-13.85)	15.89 (0.39-648.34)	6.17 (2.49-15.44)	18.53 (3.14-114.69)	25.51 (7.61-94.45)	47.35 (5.63-1046.921)	7.30 (4.41-12.08)	10.46 (6.76-16.24)	26.18 (15.45-44.8)
The overall fraction correct = (TP + TN)/ Total obs (referred simply "Accuracy") %	77.4 (71-83.5)	93.5 (92.3-94.7)	76.8 (70-82.8)	92.9 (89.6-96.2)	80 (73.6-83.4)	84.4 (80-85.6)	84.5 (82.6-86.2)	85.1 (83-87.2)	81.4 (79.4-82.9)
Kappa	0.33 (0.14-0.51)	0.15 (-0.01-0.31)	0.36 (0.19-0.53)	0.38 (0.-0.68)	0.52 (0.37-0.61)	0.37 (0.19-0.42)	K = 0.29 (0.20-0.37) A = 84.40; EA = 78.21	0.41 (0.32-0.49)	0.49 (0.43-0.53)

Table 5. Duration of stay and rate of growth during nutrition rehabilitation

Group of children	Male: 64 (41%)			Female: 92 (59%)			Gain Combined = Male: 64 (41%)/ Female: 92 (59%)		
	Duration of stay (days)	MUAC gain (mm/day)	Weight gain Grams/day	Duration of stay (days)	MUAC gain (mm/day)	Weight gain Grams/day	Duration of stay (days)	MUAC gain (mm/day)	Weight gain Grams/day
All children the program	89.91 ± 45.58	0.13 (0.1-0.16)	14.1 (10.51-17.69)	82.47 ± 38.95	0.14 (0.12-0.16)	13.06 (11.25-14.87)	85.52 ± 41.82	0.14 (0.12-0.15)	13.49 (11.69-15.28)
Children admitted on basis of single MUAC cut-off (< 12.5 cm)	83.45 ± 34.42	0.19 (0.13-0.25)	12.79 (2.98-22.6)	100.26 ± 44.66	0.19 (0.15-0.24)	12.41 (10.15-14.66)	94.82 ± 41.86	0.19 (0.16-0.23)	12.53 (9.36-15.7)
Children admitted on basis of WHZ (< -2SD)	95.47 ± 35.03	0.13 (0.08-0.18)	18.78 (10.81-26.75)	101 ± 41.67	0.12 (0.07-0.18)	15.6 (10.05-21.16)	97.91 ± 37.6	0.13 (0.09-0.16)	17.38 (12.5-22.24)
Children admitted on basis of MUACZ (< -2SD)	98 ± 48.3	0.15 (0.1-0.21)	11.5 (5.92-17.08)	87.45 ± 41.49	0.2 (0.14-0.26)	13.91 (8.74-19.07)	92.85 ± 44.86	0.18 (0.14-0.22)	12.67 (9.01-16.33)
Children admitted on basis of WAZ < -2(**)	100.19 ± 40.57	0.12 (0.08-0.16)	16.76 (10.54-22.98)	96.87 ± 41.32	0.17 (0.13-0.2)	13.98 (10.45-17.5)	98.39 ± 40.65	0.14 (0.12-0.17)	15.25 (11.92-18.57)

higher when WHZ < -2 was compared with WAZ < -2 than MUAC < 12.5 and MUACZ < -2 (+ LR was 14.8 (CI 9.39-23.92); 5.43 (CI 4.13-7.02); 4.11 (CI 3.04-5.36) while -LR was 0.57 (CI 0.53-0.61); 0.52 (CI 0.43-0.61) ; 0.56 (CI 0.44-0.69) for WAZ < -2, MUACZ < -2 and MUAC single cut-off > 12.5 cm respectively), even though the differences in -LR were not statistically significant. Again, although there were differences in + LR and -LR between admission and discharge they were not statistically significant except for WAZ < -2.

The findings also indicated that the diagnostic odds ratio was higher when WHZ < -2 was compared with WAZ < -2 (26.18 (CI 15.45-44.8)) than MUACZ < -2 (10.46 (6.76-16.24)) and single MUAC cut off < 12.5 cm (7.30 (CI 4.41-12.08)) but the differences were statistically significant for WHZ < -2 and MUAC < 12.5 cm between admission and discharge. The accuracy (agreement) was found to be high for MUACZ (> single MUAC cut-off > WAZ) while kappa values were high for WAZ (> MUACZ > MUAC). Nevertheless although accuracy was significantly different between MUACZ < -2 and WAZ < -2, for Kappa this was only the case between WAZ < -2 and the single MUAC cut-off (< 12.5 cm). Additionally although the difference in KAPPA coefficients when comparing WHZ < -2 and the three anthropometric indices at admission and discharge were not significant the difference in accuracy were found to be statistically significant.

Evolution of anthropometry, Duration of stay and rate of recovery during nutrition rehabilitation

Table 5 shows that all the 156 children stayed in the rehabilitation programme for a period of 85.52 days ± 41.82 and during this period gained an average of 0.14mm of MUAC/day (CI 0.12-0.16) and 13.06 grams weight/ day (CI 11.25-14.87). However, males stayed longer and gained more weight and less MUAC compared to females. According to the findings children admitted on basis of single MUAC cut-off < 12.5 cm stayed for 94.82 ± 41.86 days in the rehabilitation and had significantly higher rate of MUAC gain compared to those

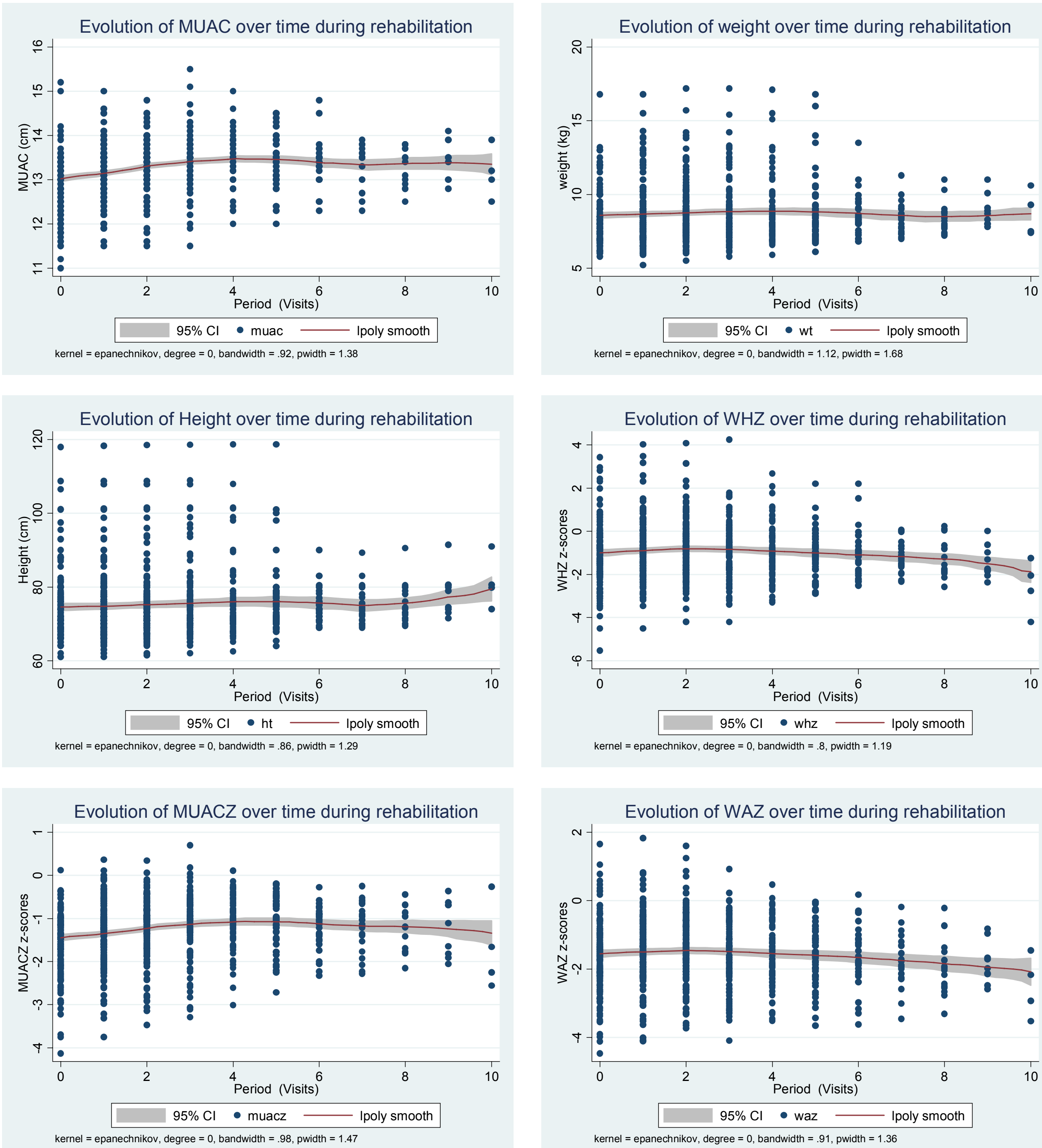

Fig. 2. Polynomial graphs showing evolution of MUAC, weight and height, WHZ, MUACZ and WAZ during rehabilitation

admitted on the basis of WHZ < -2. But this differences in MUAC gain were not significant if children were admitted on basis of MUACZ < -2 or WAZ < -2.

The polynomial graphs of MUAC, weight, height, MUACZ, WAZ and WHZ (Fig. 2) indicates that mid-upper arm cirmference and weight gains follows a systematic trend throughout rehabilitation. The increase in MUAC are substantial at initial visits, then it levels off and decreases while weight increase then stabilizes. Height does not present a particular trend on admission and the first few visits but increases as students recover which then affects the WHZ which decreases as children recover and approaches discharge. In addition, though the duration of stay in the rehabilitation programme varied based on the criteria used at the admission. There were no statistically significant differences in MUAC and weight gain between boys and girls.

DISCUSSION

The various advantages and simplicity positions MUAC as a very attractive tool for detection and follow-up malnourished children and eventually discharging them during nutrition rehabilitation. Nevertheless the use of MUAC single cut-off (< 12.5 cm) for admission, monitoring and discharging malnourished children during rehabilitation is not supported in literature.

The current study was carried out on moderately malnourished (MAM) children (Table 2) undergoing a single intervention module. And the results, expressed using changes in different diagnostic indices, show that there was a systematic change in nutritional status from admission through to discharge. Above and beyond MUAC gain (mm/day) and weight gain (g/day) was substantial which is consistent with earlier findings [31].

The capacity of MUAC to detect malnourished children was therefore, when compared with other anthropometric indices, promising for admission, follow-up, and eventually discharging the children. And this scenario is not only as regards the many advantages of MUAC, but also its ability to respond to treatment or improved dietary intervention. This finding is corresponds with earlier studies examining the changes in MUAC during rehabilitation [18,21,29]. Furthermore, the findings highlight a considerable discrepancy between the prevalence of malnutrition as defined by MUAC single cut-off (< 12.5 cm) and that defined by WAZ < -2, MUACZ < -2 and WHZ < -2 which was also the case in previous research works [7,18,29].

The single MUAC cut-off produced higher values of sensitivity, specificity when compared with MUACZ < -2 than when related to WHZ < -2 and WAZ < -2, while specificity increased at the expense of sensitivity between admission and discharge (Table 3). This points towards a higher capacity to detect the frail children for admission and those children still in need of extra attention before discharge. But, on the contrary, WHZ resulted in significantly lower values of specificity and sensitivity (Table 4) when compared with WAZ < -2, MUACZ < -2 and MUAC (< 12.5 cm). This is indicative of the appropriateness of using MUAC in identification and discharge of children during rehabilitation than WHZ < -2. These findings are in consonance with the findings by Le Thi Hop *et al.* [29] which demonstrated the relation of different MUAC cut-offs and other indices.

From the results, MUAC single cut-off (< 12.5 cm) produced higher values of positive likelihood ratio (+ LR) when compared with MUACZ. Correspondingly, the positive likelihood values (+ LR) for WHZ < -2 were higher when compared with WAZ < -2. Nonetheless, there were no significant differences between MUAC and WHZ which demonstrates that the two indices are influenced by changes in age and gender. Furthermore, negative likelihood ratio (-LR values) obtained were closer to unit when MUAC single cut-off (< 12.5 cm) was compared with WHZ and WAZ. But -LR values were far from unit when WHZ was compared to MUACZ, WAZ and MUAC (< 12.5 cm). In other words, the confirmatory power of a positive MUAC for a single cut-off (< 12.5 cm) and WHZ < -2 was indifferent but the negative test for MUAC gives more information than for WHZ. This information contradicts the assumption from previous studies that MUAC single cut-off is independent of age and gender for children below 60 months [4,6,21].

Furthermore, the average MUAC increment for the children was 0.98 cm, albeit higher in females (1.03 cm) than males (0.90 cm). This reflect the changes in the lean tissue during rehabilitation owing to the supplementary feeding as reported, also, in earlier findings [29,30]. Also, the rate of MUAC and weight gain during rehabilitation of children was 0.14mm/day and 13.06 grams/day respectively. However, children admitted on the basis of low MUAC using a single cut-off (< 12.5 cm) gained a significantly higher MUAC but their gain in weight was not different from children admitted on the basis of low WHZ (< -2SD). These changes reflect the daily responses in MUAC and weight which need to be realized to obtain a meaningful recovery of malnourished children as demonstrated in a review by Myatt *et al.* [7].

Regarding the duration of stay in rehabilitation program, the study results show that children took an average of 86 days to recover. There were also no differences in duration of stay if children are admitted using different criteria. But generally females stayed for longer in the rehabilitation to recover than their male counterparts, albeit more if admitted with single MUAC cut-off (< 12.5 cm) than WHZ < -2SD. This indicates that there are no significant differences in the cost of rehabilitation for children admitted on basis of MUAC single cut-off (< 12.5 cm) and those admitted on basis of WHZ, WAZ and MUACZ (< -2). However, since females are likely to stay longer to recovery than male when admission is based on MUAC single cut-off (< 12.5 cm), the overall cost of rehabilitation might change depending on the proportion of each gender admitted

This study also highlights the unique evolution of MUAC, weight, height and the WHZ, MUACZ and WAZ (Fig. 2). The polynomial graphs show that during rehabilitation MUAC increases steadily upon admission and during the first few visits then stabilizes and starts to decrease. However, weight increases at the initial stages and levels off after some time while height remains constant right from admission and start increasing after a number of visits. This demonstrates the capacity of MUAC to immediately respond to the treatment during rehabilitation malnourished children. This means that MUAC can be used as a good indicator of recovery and, in the short term, the weight based indices can be used in the rehabilitation while in the long term, height can be used as it takes longer to respond. As they evolve differently, all three indices are important for monitoring the trend of recovery of malnourished children in rehabilitation programs.Nevertheless, there was no significant difference in KAPPA coefficient when comparing MUAC single cut off and WHZ < -2 the degree of agreements/ accuracy was higher (90.72%) compared to WHZ < -2 (85.1%) in relation to MUACZ and WAZ.

It is important to note that the sample size, sampling and data selection criteria may have influenced the findings. Besides, data was obtained from a specific population and in a small geographical area with specific needs which is obviously likely to be the strongest limitation to the findings of this study and validation using bigger study and careful sample selection and examination of the nutritional status of the participants is inevitable.

In conclusion, the MUAC single cut-off (< 12.5 cm) was found to yield higher sensitivity and specificity than WHZ when admitting and follow up of malnourished children during nutrition rehabilitation. An average stay of 86 days as well as a MUAC and weight gain of 0.14mm/day and 13.06grams respectively, is necessary for all children to reach full recovery when admitted to rehabilitation programmes. Moreover, a higher MUAC gain per day of 0.19mm/day is recorded when children are admitted on basis of MUAC single cut-off (< 12.5 cm). In principle these findings positions the MUAC single cut-off (< 12.5 cm) as a strong candidate for admission and monitoring malnourished children as well as discharging the recovered children during nutrition rehabilitation. Similar attempts have also been presented in earlier studies that point to the appropriateness of MUAC as a tool for nutrition rehabilitation. This is in line with the requirements attached to the limited-resource settings in the developing world, i.e. the key beneficiaries of these tools, particularly the Community Therapeutic Care (CTC) of acute malnutrition.

ACKNOWLEDGEMENT

We acknowledge VLIR-UOS, Belgium, for supporting this work through the South- South Credit Allowance (SSCA) granted to the corresponding author. The authors are grateful to Kenya's Ministry of Health staff, at Majengo and Jericho Health Centres, and WFP staff who facilitated data selection and compilation. Equally we also recognize the Ministry of Health's permission to use these data for the current study.

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