The predictive power of changes in Weight-for-Height versus Mid Upper Arm Circumference for acute malnutrition

Fortune Maduma

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Master dissertation submitted in partial fulfilment of the requirements for the degree of Master of Science in Nutrition and Rural Development
Main subject: Human Nutrition, Major: Public Health nutrition
Certification and declaration

I, Fortune Maduma hereby declare that this Master’s dissertation is a result of my original work under the supervision of Dr. Dominique Roberfroid (ITM) and Prof. dr. Patrick Kolsteren. I vow that this work has not been submitted to any university or elsewhere. The sources of information from work done by others have been duly accredited through references to the authors. Only the author and promoters of this work are given permission to copy parts of this work for personal use. Copyright laws do apply in case of any other use of the result of this work.

Ghent University, September 2014

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Abstract

Background: Anthropometry plays a key role in the identification and follow-up of malnourished cases. Based on anthropometry which is the most practical way to detect malnutrition in decentralised settings; it is however unfortunate that the most reliable case definition of malnutrition is yet to be established.

Objective: This study aims at examining the discrepancy of diagnosis between weight-for-height and MUAC; assessing the predictive power of weight-for-height and MUAC changes for acute malnutrition and also testing MUAC’s validity for acute malnutrition.

Study design: A longitudinal study was conducted.

Methods: Growth monitoring data for children aged between 6 to 59 months from Bangladesh was used to study the performance of anthropometric indicators. Validity tests of sensitivity, specificity, predictive values and likelihood ratios were used to estimate the performance of the MUAC and weight-for-height in detecting acute malnutrition.

Results: Out of the 961 malnourished children who were detected using either MUAC or weight-for-height, only 30% (n=293) were detected by both MUAC (MUAC<125mm) and weight-for-height (WHZ <-2). Though the positive predictive values of weight-for-height changes for weight losses greater than 5% of body weight were low, they were almost twice as much as those of MUAC (38.95% as compared to 22.05%). MUAC had a low sensitivity (30.84%) to identify children (6 to 59) detected by the “gold standard”. MUAC also showed a lower specificity for females; stunted children and children below the age of 24 months.

Conclusion: MUAC could under detect malnutrition in children between 24 to 59 months as revealed by its lower sensitivity towards children identified by the “gold standard” used in this study. MUAC’s bias towards females, stunted children and younger children (6 to 23 months) was also confirmed by this study. Most of the children identified as malnourished after a significant weight loss were those close to the cut-offs. This indicates that anthropometric cut-offs are only arbitrary and that the growth curve of each child is essential in making sound conclusions on nutrition status.
Acknowledgements

To Dr. Dominique Roberfroid and Prof. dr. Patrick Kolsteren: I am grateful for such a wonderful introduction into the world of research. I really appreciate the time you set aside out of your busy schedule to guide me in the study. I feel honoured to have received your guidance, may you continue your good work and I wish you well in your future endeavours.

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Dedications

To my beloved wife Xoliswa Priscilla Inga Botya Maduma: Thank you very much for your love and support during my study period in Belgium. For nothing would have been that has been, without you.

To my little “bundle of joy” Unathi Sonwabiso Maduma: Thank you for the sweet smiles and the amazing giggles that you shared with me during the trying time of the research.

To my Parents: Mr and Mrs KSRH Maduma: Thank you for support and encouragement through all the highs and lows that I have been through. Thank you for the strong foundation that you have given me in my life, it is priceless.
Table of Contents

Certification and declaration........................................................................................................... i
Abstract........................................................................................................................................... ii
Acknowledgements........................................................................................................................... iii
Dedications ......................................................................................................................................... iii
List of tables....................................................................................................................................... vi
List of figures..................................................................................................................................... vi
List of abbreviations ........................................................................................................................ vii
CHAPTER 1 INTRODUCTION ......................................................................................................... 1
  1.1 Background ............................................................................................................................... 1
  1.2 Study Rationale ........................................................................................................................ 2
  1.3 Hypothesis ................................................................................................................................ 3
  1.4 Objective of the Study ................................................................................................................ 3
  1.5 Organization structure of the Dissertation ............................................................................. 3
  1.6 Source of References ............................................................................................................... 4
CHAPTER 2 LITERATURE REVIEW ............................................................................................. 5
  2.1 Anthropometric indicators and Nutrition status ................................................................. 5
  2.2 Choosing an appropriate anthropometric indicator ............................................................ 6
  2.3 Weight for height ..................................................................................................................... 7
  2.4 Challenges of using Weight for Height .................................................................................. 8
  2.5 Mid Upper Arm Circumference ............................................................................................ 8
  2.6 Challenges of using MUAC tape ......................................................................................... 10
  2.7 MUAC and WHZ compared. ................................................................................................. 11
CHAPTER 3 METHODOLOGY ...................................................................................................... 13
  3.1 Study Area .............................................................................................................................. 13
  3.2 Study Population .................................................................................................................... 13
  3.3 Study Design .......................................................................................................................... 13
  3.4 Data Entry and Data management ....................................................................................... 14
  3.5 Statistical Analysis ................................................................................................................ 15
  3.6 Limitations of the study ......................................................................................................... 15
CHAPTER 4 RESULTS .................................................................................................................. 16
  4.1 Sample Characteristics ........................................................................................................... 16
  4.2 Data Exploration ..................................................................................................................... 17
4.2.1 Weight for height versus MUAC on Acute Malnutrition Prevalence ..............18
4.2.2 Agreement of MUAC and MUAC/age Z score with Weight-for-height.........19
4.3 Predictive Values of MUAC and Weight-for-height changes for weight loss........20
4.4 MUAC Validity to detect Acute Malnutrition ........................................21
  4.4.1 MUAC Validity to detect Acute Malnutrition: stratified by age range ..........22
  4.4.2 MUAC Validity to detect Acute Malnutrition stratified by gender .............23
  4.4.3 MUAC Validity to detect Acute Malnutrition: stratified by stunting .........23
  4.4.4 Agreement of MUAC and Weight-for-height with weight Loss ...............24

CHAPTER 5 DISCUSSION..................................................................................25
  5.1 Discrepancy of diagnoses between MUAC and Weight-for-height.................25
  5.2 Predictive value of MUAC and weight-for-height changes for weight loss .......26
  5.3 Performance of MUAC in detecting children identified by the “Gold standard” ....26
  5.4 Appropriateness of MUAC as an indicator of acute malnutrition ..............27

Chapter 6 Conclusion and recommendations ................................................28
  6.1 Conclusions ...................................................................................................28
  6.2 Recommendations for Programs and Research ............................................28

References .........................................................................................................29

Annexes ...........................................................................................................1
  Annex 1. Terms used in assessing the appropriateness of case detection methods ....1
  Annex 2. Justification for WHZ Z score of less than [27] .................................1
  Annex 3. Graph showing the number of times females had recordings ...............2
  Annex 4. Graph showing the number of times males had recordings .................3
  Annex 5. Summary Statistic for data .................................................................3
List of tables

Table 1. “Relative importance of key properties of case-detection methods in different contexts” [16], [24], [25] ................................................................. 6

Table 2. Classification of Nutrition Status by weight-for-height [13] ......................................................... 7

Table 3. MUAC Cut off Points with corresponding colour and interpretation [26] .......................... 10

Table 4. Comparison of MUAC and weight-for-height ................................................................. 12

Table 5. Standards used in computing the validity tests .......................................................... 15

Table 6. Positive Predictive values of MUAC and Weight-for-height changes for weight loss > 5% of body weight ................................................................. 20

Table 7. Validity tests on MUAC using weight-for-height less than -2 Z scores with weight Loss greater than 5% of body weight as gold standard ......................................................... 21

Table 8. Validity tests on MUAC: stratified by age range ......................................................... 22

Table 9. Validity tests on MUAC: stratified by gender .......................................................... 23

Table 10. Validity tests on MUAC: stratified by stunted and non-stunted ................................ 24

List of figures

Figure 1. The standard tape and the insertion tape. Source: [32] ................................................. 9

Figure 2. Flow Chart showing selection of children for analysis ............................................. 14

Figure 3. The number of times individuals had recordings .................................................... 16

Figure 4. Box and whisker plots showing the variation of MUAC ........................................ 17

Figure 5 Children diagnosed as Malnourished at least once (MUAC< 125mm) ...................... 18

Figure 6. Children diagnosed as Malnourished at least once (Weight-for-height< -2) ........... 19
# List of abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACF</td>
<td>Action Contre la Faim</td>
</tr>
<tr>
<td>CHW</td>
<td>Community Health Worker</td>
</tr>
<tr>
<td>CMAM</td>
<td>Community based Management of Acute Malnutrition</td>
</tr>
<tr>
<td>DALY</td>
<td>Disability Adjusted Life Years</td>
</tr>
<tr>
<td>H/A</td>
<td>Height for Age</td>
</tr>
<tr>
<td>MAM</td>
<td>Moderate Acute Malnutrition</td>
</tr>
<tr>
<td>MUAC</td>
<td>Mid Upper Arm Circumference</td>
</tr>
<tr>
<td>MUAC/A</td>
<td>Mid Upper Arm Circumference for Age</td>
</tr>
<tr>
<td>MUAC/H</td>
<td>Mid Upper Arm Circumference for Height</td>
</tr>
<tr>
<td>NPV</td>
<td>Negative Predictive Value</td>
</tr>
<tr>
<td>PPV</td>
<td>Positive Predictive Value</td>
</tr>
<tr>
<td>SAM</td>
<td>Severe Acute Malnutrition</td>
</tr>
<tr>
<td>SAS</td>
<td>Statistical Analysis System</td>
</tr>
<tr>
<td>SSR</td>
<td>Sitting height to Standing height Ratio</td>
</tr>
<tr>
<td>UNHCR</td>
<td>United Nations High Commissioner for Refugees</td>
</tr>
<tr>
<td>UNICEF</td>
<td>United Nations Children’s Fund</td>
</tr>
<tr>
<td>W/A</td>
<td>Weight-for-Age</td>
</tr>
<tr>
<td>W/H</td>
<td>Weight for Height</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organisation</td>
</tr>
<tr>
<td>WHZ</td>
<td>Weight for Height Z score</td>
</tr>
</tbody>
</table>
CHAPTER 1 INTRODUCTION

1.1 Background

The prevalence of wasting in children under the age of 5 years during the year 2012 was 51 million while that of severe wasting was 17 million worldwide. Around 71% of these children resided in India while 28% were from Africa [1]. Given the fact that malnutrition is estimated to contribute to over 50% of child deaths [2], it is therefore clear that “severe malnutrition in children is an important public health problem”[3]. According to Tekeste et al, if malnutrition were to be eliminated then “child mortality and morbidity (i.e., loss of disability-adjusted life-years [DALYs] averted)” would be reduced by one third [4]. The increased vulnerability towards morbidity and mortality that malnourished children have necessitates early diagnosis and treatment [5]. Besides its contribution to mortality, malnutrition in the “first 2 years of life also leads to irreversible damage, including shorter adult height, lower attained schooling, reduced economic productivity, reduced adult income, and decreased off spring birth weight”[6]. “The prevention of maternal and child under nutrition is a long term investment that will benefit the present generation and their children” [6].

In order to tackle the big problem of child malnutrition one of the biggest steps has been the establishment of guidelines for the treatment of severe acute malnutrition by World Health Organisation (WHO) in the year 1999 [7]. According to [8], the approach recommended by WHO has been life saving as demonstrated by the high survival rates [8]. Based on anthropometry which is the most practical way to detect malnutrition in decentralised settings, it is however unfortunate that the most reliable case definition of malnutrition is yet to be established.

Currently Mid Upper Arm Circumference (MUAC) and weight-for-Height (WHZ) are the 2 most commonly used anthropometric indicators to assess acute malnutrition; they are predominantly used alternatively with the checking for presence of bilateral pitting oedema. A Mid-Upper Arm Circumference (MUAC) of less than 115 mm and a weight-for-height Z-score (WHZ) of less than -3 Z scores have been used as the cut-off points for severe acute malnutrition (SAM). MUAC and weight-for-height have often been used in combination especially in the last decade but lately some agencies have preferred MUAC over weight-for-
MUAC has been preferred over weight-for-height due to its simplicity, affordability, acceptance by children and its claimed efficiency [5], [10]–[12].

MUAC and weight-for-height unfortunately correlate poorly, they seem to classify different children as malnourished with a limited degree of overlap [12]–[14]. According to Roberfroid agencies working on the treatment of severe acute malnutrition have been puzzled as to which indicator to trust more [12]. A 2 stage screening procedure has been used by many agencies: At first community volunteers identified malnourished cases using MUAC and referred the cases to a treatment facility, where the cases were confirmed using weight-for-height. However some children referred by community volunteers did not meet the admission criteria based on weight-for-height and this led to many children being turned away from the treatment facilities [15].

Weight-for-height has not been favoured over MUAC for screening in communities because it requires the use of “look up tables”, involves some mathematical reasoning, uses equipment that is more expensive and the fact that community nutrition volunteers find it difficult to use [16]. On the other hand, though MUAC is simple to use, the efficiency of its single cut-off points to effectively and uniformly assess malnutrition has been questioned. MUAC has been found to be more biased towards children from 6 to 24 months [11], [15]. Most studies that have tried to measure the performance of anthropometric indicators have used cross sectional data which is not informative on the evolution of the malnutrition being detected. It is this limitation of cross sectional data that prompted the search for a longitudinal study that could be explored to understand the development of malnutrition as reflected by the anthropometric indices.

1.2 Study Rationale

According to World Health Organisation (WHO), the anthropometric tool to be used in identification of malnutrition during emergencies and in community screening is the MUAC tape [17]. This however leaves out some children who may be classified as malnourished by weight for height who may be having the same risks as those identified by MUAC. None of these 2 has been identified as a gold standard. At present it remains unknown which indicator identifies true cases of malnutrition. Most studies that have tried to compare MUAC and weight-for-height performance have mostly used cross sectional data while a few studies using longitudinal approach have focused on mortality prediction. According to WHO, “wasting or thinness indicates in most cases a recent and severe process of weight loss”[18].
Following this fact of the association between wasting and recent weight loss it is therefore the interest of this study to objectively gauge the indicator which better predicts malnutrition following a recent event of significant weight loss.

1.3 Hypothesis

I. There is a discrepancy of diagnosis between weight-for-height and MUAC

II. MUAC and weight for height as standards for assessing wasting are sensitive to a weight loss of greater than 5% of body weight.

III. A weight-for-height less than minus 2 Z scores with recent weight loss of greater than 5% body weight is a sensible definition of acute malnutrition.

1.4 Objective of the Study

- To examine the discrepancy of diagnosis and characteristics of the children who are identified as malnourished by weight-for-height versus MUAC.

- To test the predictive power of weight-for-height and MUAC changes for body weight losses greater than 5% in children between 6 to 59 months.

- To evaluate the performance of MUAC to detect malnutrition in children identified by weight-for-height as malnourished and also having a recent body weight loss greater than 5%.

1.5 Organization structure of the Dissertation

This Dissertation is divided into 5 chapters. Chapter 1 gives a general an overview the challenge on malnutrition and its detection using anthropometric indicators. It also gives the Study rationale, Hypothesis and study objectives. Chapter 2 reviews literature on the anthropometric indicators and their use. The next chapter describes the methodology applied in the study. Chapter 4 presents the results of this study while Chapter 5 includes the discussion of the results, the study limitations. The conclusion and recommendations can be found in chapter 6.
1.6 Source of References

Web of science, PubMed and Google scholar were used to retrieve publications on the subject of study. Key words used include anthropometry, mid upper arm circumference, weight for height, children, malnutrition, wasting and stunting. Different combinations of these keywords were applied.
CHAPTER 2 LITERATURE REVIEW

2.1 Anthropometric indicators and Nutrition status

“From an anthropometric perspective, nutritional status can be seen as the output of a health production function, where nutrient intake is one input, but where other individual, household, and community variables also feature”[19]. Jelliffe D.B, defined anthropometry as the “measurement of physical dimensions and gross composition of the body (height, weight, mid-upper arm circumference, age, sex)”[20]. The term “anthropometric status” is sometimes used interchangeably with “nutrition status”, but this is not correct and it should be clearly understood that these 2 are indeed different [14]. “Nutritional status refers to the internal state of the individual as it relates to the availability and utilization of energy and nutrients at the cellular level”[14], [21]. It is however not possible to directly observe the nutrition status of individuals, clinicians therefore rely on measurable indicators of this state.

The simplicity and convenience of anthropometries makes them useful in their application as indicators of nutrition status [14]. According to Gorstein J and Akre J, anthropometric indicators are less accurate than clinical and biochemical techniques in assessing individual nutritional status [22]. However, in many field situations resources are limited and it is not practical to use biochemical techniques especially in emergencies, anthropometry is therefore useful for identifying individuals who are malnourished in such settings [22]. Anthropometry is vital for screening children and for monitoring their response to nutrition interventions [21]. “At the population level, anthropometry has been used to assess the nutrition status within a socioeconomic group, community, country or a region and to study both the causes and consequences of malnutrition” [23]. This form of monitoring enables both the targeting and the designing of health and nutrition interventions [19].

The anthropometric indicators that have mostly been used to estimate the nutrition status of individuals include, weight-for-height (WHZ); weight-for-age (W/A); height-for-age (H/A); skin fold thickness; mid-upper-arm circumference (MUAC); mid-upper-arm circumference-for-age (MUAC/A) and mid-upper-arm circumference-for-height (MUAC/H) [18].
2.2 Choosing an appropriate anthropometric indicator

According to Myatt et al, the best anthropometric indicator will be one that can “identify individuals who are at high risk of dying if they remain untreated but would be likely to survive if treated in an appropriate nutrition support program”[16]. This is however not the only consideration when searching for the best anthropometric methods of detecting malnutrition other essential properties such as the simplicity and cost of the method are important. All these considerations however ultimately depend on the “context in which the case detection is taking place” [16]. The relative importance of the properties depending on context is demonstrated in Table 1.

Table 1.“Relative importance of key properties of case-detection methods in different contexts” [16], [24], [25]

<table>
<thead>
<tr>
<th>Property</th>
<th>Epidemiologic survey/surveillance</th>
<th>Screening and case detection in the community</th>
<th>Case-finding in clinical context</th>
<th>Diagnosis in clinical context</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simplicity</td>
<td>++++</td>
<td>++++</td>
<td>_</td>
<td>_</td>
</tr>
<tr>
<td>Acceptability</td>
<td>++++</td>
<td>++++</td>
<td>+</td>
<td>_</td>
</tr>
<tr>
<td>Cost</td>
<td>++++</td>
<td>++</td>
<td>_</td>
<td>_</td>
</tr>
<tr>
<td>Objectivity</td>
<td>++++</td>
<td>++++</td>
<td>++++</td>
<td>++++</td>
</tr>
<tr>
<td>Quantitativeness</td>
<td>++++</td>
<td>++++</td>
<td>_</td>
<td>_</td>
</tr>
<tr>
<td>Independence of age</td>
<td>++++</td>
<td>++++</td>
<td>_</td>
<td>_</td>
</tr>
<tr>
<td>Precision(Reiability) (individual)</td>
<td>+</td>
<td>++</td>
<td>++++</td>
<td>++++</td>
</tr>
<tr>
<td>Accuracy(individual)</td>
<td>+</td>
<td>++</td>
<td>++++</td>
<td>++++</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>+</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Specificity</td>
<td>+</td>
<td>++++</td>
<td>++++</td>
<td>++++</td>
</tr>
<tr>
<td>Predictive Value</td>
<td>+</td>
<td>++</td>
<td>++++</td>
<td>++++</td>
</tr>
</tbody>
</table>

NB: Scoring of importance: – irrelevant, + minor, ++ moderate, +++ major, ++++ crucial as modified by:[16], original analysis by [25] - An explanation of the terms used in Table 1 is given in Annex 1.
2.3 Weight for height

Height and weight have been commonly used in assessment of nutrition status. According to WHO, weight for Height can be determined by comparing a child’s weight and height to the standardized age and sex-specific growth references [26]. To establish the child’s growth or growth failure and the general nutritional status a Z score system is used. The Z score system “expresses anthropometric values as several standard deviations (SDs) below or above the reference mean or median value” [27]. As the growth standards are age and sex specific so are the Z-scores, this allows the estimation of children's growth status by combining sex and age groups. Individual children’s Z-scores can be computed to produce summary statistics which can include means, standard deviations, and standard error and these can then be used to classify the growth status of a population [26].

Using weight-for-height Z scores, the nutrition status of children can be classified into three different categories, these are; adequate, moderate acute malnutrition (MAM) and Severe Acute Malnutrition (SAM). The cut off points for the classification are as shown in Table 2 below.

Table 2. Classification of Nutrition Status by weight-for-height [13]

<table>
<thead>
<tr>
<th>Nutrition Status</th>
<th>Classification based on Weight for Height Z-score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate</td>
<td>&lt;2 to &gt;-2 Z score</td>
</tr>
<tr>
<td>Moderate Acute Malnutrition (MAM)</td>
<td>≤ -2 but ≥ -3 Z score</td>
</tr>
<tr>
<td>Severe Acute Malnutrition (SAM)</td>
<td>&lt; -3 SD</td>
</tr>
</tbody>
</table>

The use of Weight-for-height below -3 to classify severe acute malnutrition was justified by WHO based on 2 main reasons which are; 1) “The fact that children who fall below the Z score of -3 are at an elevated risk of death as compared to the children who are above this cut off point” and 2) “There is evidence that in populations which are well nourished, children with a z score below -3 almost cannot be found” [26]. Annex 2 summarises all the reasons for justification of use of Z score of -3 to categories severe acute malnutrition.
2.4 Challenges of using Weight for Height

The instrument used to measure height among children under the age of 5 years is a height board. The height board is a bulky tool to carry around as is the requirement in the conduction of community assessments and nutrition surveys. For ideal measurement of height 3 individuals are required as compared to one in the measurement of MUAC. On the other hand weighing scales require calibration before use and this further complicates the use of weight-for-height as an anthropometric indicator.

To identify the weight-for-height Z score of each child, “look up” tables are used and this requires use of some basic mathematical concepts which most community health workers cannot perform. According to Ross et al, this makes weight for height not ideal for rapid screening [28]. Some Children become agitated and show some degree of being uncomfortable while others cry during the measurement of weight and height [29]. The agitation and discomfort during measurement of height could possibly contribute to lack of precision in the measurement.

2.5 Mid Upper Arm Circumference

“Human arms contain subcutaneous fat and muscle mass. Under conditions of reduced food intake, lower levels of subcutaneous fat and muscle mass tend to correspond to a decrease in the mid-upper-arm circumference”[30]. The mid upper arm refers to the midpoint between the olecranon (tip of elbow) and the acromion (tip of shoulder). To measure the circumference of the mid upper arm, the midpoint is first located using a string then a flexible graduated measuring tape (MUAC tape) is placed around the mid upper arm [26]. MUAC is measured on the left arm [13].

The use of MUAC dates back to 1958 where it was used in community surveys [31], [32]. According to [33] one of the major issues that prompted the trials of MUAC was the need for age independent anthropometry that could be used in the regions which were most affected by malnutrition [33]. In the 1960s people did not value keeping of birth dates, it had little importance socially hence it was difficult to know the correct birth dates [31], [32]. Even if one individual could know their birth dates it was not possible to verify by documentation. The challenge of failure to establish birth dates pressed the need for anthropometry that could be used without needing to verify age [33].
During the era of development of age independent anthropometry 2 categories of such anthropometry were established: Precise age independent and age independent [33]. MUAC was categorised as “precise age independent”, meaning that taking of MUAC did not require knowledge of exact month or week of birth but required an approximate age categorisation [33]. “However, in 1993, a WHO Expert Committee concluded that age independence is not reflected in the true pattern of mid-upper arm growth, recommended the use of MUAC-for-age, and presented age- and sex-specific MUAC reference data developed with observations obtained from a representative sample of children in the USA aged 6-59 months” [34]. Onis et al also established that the use of MUAC-for-age reference data was essential in order to correctly interpret MUAC with regard to nutritional status[34].

Many different MUAC tapes have been used but the best design which is still in use was developed by Zerfas J in the 1970s, and is called the Insertion tape. The insertion tape was designed to overcome some measurement problems which had been experienced. One of the major problems was aligning of the tape around the arm. The innovation brought the following advantages, “The tape inserts into itself to allow: 1) good control around the upper arm or other circumference; 2) correct alignment around the arm and of the reading scale and 3) a clear, direct, window reading” [32]. Picture 1 below shows the standard and the insertion.

![Figure 1. The standard tape and the insertion tape. Source: [32]](image)

The latest MUAC tape in use was introduced by UNICEF in 2009 and in addition to the already preferred insertion tape, 3 distinct colours were added. These colours correspond to cut-offs which are illustrated in table 3 below:
<table>
<thead>
<tr>
<th>Colour</th>
<th>Cut off points</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>&lt; 115 mm</td>
<td>Severely Acute Malnutrition</td>
</tr>
<tr>
<td>Yellow</td>
<td>115 mm to &lt;125 mm</td>
<td>Moderate Acute Malnutrition</td>
</tr>
<tr>
<td>Green</td>
<td>&gt;125 mm</td>
<td>Well nourished</td>
</tr>
</tbody>
</table>

Source: World Health Organisation [26].

The use of MUAC has recently been endorsed by the WHO for the community-based management of acute malnutrition (CMAM) [9]. Currently the MUAC tape is being used by various organisations and governments as a standalone tool for identifying severe acute malnutrition (SAM) and moderate acute malnutrition (MAM). The main reasons behind preference of MUAC over other indicators are that it is claimed to be cheap, so simple to learn that even illiterate community health workers (CHWs) learn to use it effectively with minimal training and the fact that it does not need reference table which are sometimes difficult to interpret to many people [16]. In addition the MUAC is easily carried around as it is not bulky as compared to other tools such as height boards and it is also well accepted by children [16]. The above mentioned reasons make the MUAC tape particularly useful as a screening tool for acute malnutrition during emergencies and also for routine community level screening [16].

2.6 Challenges of using MUAC tape

As most agencies are already using MUAC for screening and admitting children into nutrition programs there is an unknown risk for children who would otherwise be identified by weight for height as malnourished. According to Myatt and Duffield, children who are more affected by choosing to use MUAC over weight for height are those with shorter trunks and longer legs as they are the least categorised as malnourished by MUAC [35]. Myatt and Duffield further state the need for longitudinal studies to assess the mortality risk of the children who are diagnosed as severely malnourished by weight for height but depicted as normal by MUAC [35].

In the recent years there has been confusion on how to discharge children who are admitted based on MUAC. The most used discharge criterion has been that of 15% weight for all children whose admission was based on MUAC [13]. Unfortunately this criterion of discharge has not worked well as children with a lesser degree of malnutrition have been
favoured to stay longer in the treatment programs in order to achieve this 15% weight gain, while those with a higher degree of malnutrition quickly reach this discharge criterion even whilst still fulfilling the admission criteria based on MUAC [11]. Discharge based on MUAC has been recommended by WHO as from November 2013, however WHO puts it clearly that though this is a strong recommendation, it is based on weak evidence [7]. There is therefore need to take advantage of the enormous number of already existing nutrition rehabilitation programs to gather evidence on discharging children based on MUAC [12].

The new recommendations by WHO of using the same criteria for discharge as in admission is also helping to avoid a challenge of rejected referrals in nutrition rehabilitation programs which used both MUAC and Weight for height on admission. Before realising the huge overlap on the children identified by MUAC and weight for height most agencies allowed community screening to be done using MUAC because of its simplicity but maintained the use of Weight for height to admit into the rehabilitation programs. This led to a high percentage of community referred children to be rejected when reassessed for admission [11].

2.7 MUAC and WHZ compared.

According to Briend et al, MUAC has shown to be more sensitive than “WHZ in identifying high risk SAM children and predicting mortality, particularly in the younger age group (6–23 months)” [15], but this could be as a result of MUAC’s bias towards younger children who obviously have a higher risk of mortality. One of the idealistic requirements of an anthropometric indicator is age independency. This is because anthropometric indicators that rely on age have been shown to be more prone to random errors associated with age estimations than the random errors in anthropometry [36]. MUAC is claimed to be more age independent than weight-for-height in predicting mortality in children aged between 1 and 5 years [37][38]. Table 4 summarises the comparison of other properties between MUAC and weight-for-height.
### Table 4. Comparison of MUAC and weight-for-height

<table>
<thead>
<tr>
<th>Property</th>
<th>MUAC</th>
<th>Weight-for-Height</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simplicity</strong></td>
<td>Provides immediate classification using colour bands, allows rapid screening and is made from simple material [12]. Community volunteers learn easily to use MUAC as it does not need tables which require some basic mathematical concepts [16].</td>
<td>Height is measured using a height board which is bulky to carry around while weight scales require calibration before use. Weight for height requires basic mathematical concepts which most community health workers cannot perform, this makes weight for height not ideal for rapid screening [28].</td>
</tr>
<tr>
<td><strong>Acceptability</strong></td>
<td>The procedure of taking MUAC and the tool used has been reported to be more acceptable to children [16].</td>
<td>Children show some degree of discomfort and sometimes may become agitated during the measurement of height and weight [29].</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>MUAC tape is a simple a cheap tool and measurement can be done by one individual</td>
<td>Height measurement requires 3 people and this adds to the costs of the already expensive height measurement equipment [26].</td>
</tr>
<tr>
<td><strong>Precision</strong></td>
<td>Velzeboer et al, reported that a higher precision was observed for MUAC than for weight-for-height. However he also further emphasised that carers tend to attempt to tighten the MUAC in order to facilitate admission.[29]</td>
<td>Due to the agitation that children get during the measurements of weight and height there is higher chance of getting errors</td>
</tr>
</tbody>
</table>

Based on the different properties used to compare MUAC and weight-for-height, it is clear how MUAC has been preferred over weight-for-height. However with exception of mortality prediction none of these properties are as important as that of the indicator that better detects a “true case of malnutrition”. Unfortunately up to date the anthropometric indicator which better represents nutrition status is yet to be defined.
CHAPTER 3 METHODOLOGY

3.1 Study Area
Cox Bazaar is a region which is located in the south eastern part of Bangladesh. The region hosts Myanmar’s northern Rakhine state refugees in the UNHCR refugee camps of Kutupalong and Nayapara. As of December 2013 UNHCR had 31,690 registered refugees, while it is estimated that 30,000 to 40,000 more refugees are living unregistered in the neighbouring villages [39]. The refugees are Rohingya Muslims and they are members of an ethnic, linguistic and religious minority in Myanmar. “This population is what remains of the 250,000 refugees from Myanmar who arrived in 1991, most of whom subsequently returned home” [39]. The quality of life for these refugees is very poor especially the unregistered refugees [39].

3.2 Study Population
Children under the age of 5 years from the refugee camps of Kutupalong and Nayapara have been under monthly growth monitoring since January 2009 to date. The growth monitoring data is recorded in registers by Action Contre la Faim (ACF). Since the MUAC tape is only used for children as from 6 months, all the children who were below 6 months by the end of the selected study were therefore excluded. The final sample population considered included all the children who were between 6 months and 59 months.

3.3 Study Design
This was a longitudinal study on performance of anthropometric indicators using growth monitoring data for children between 6 months to 5 years. Data collected between June 2010 and August 2012 was considered as most of the monthly registers (98%) were available. This period was considered also because trained ACF staff took the anthropometric measurements. The sample selected for analysis are all children between the ages of 6 months to 5 years, on condition that all the required variables of; gender, date of birth, weight, height and MUAC were recorded.
3.4 Data Entry and Data management

Data from the growth monitoring registers was entered into excel according to their blocks, placing one month into a separate excel sheet. Excel was chosen because about 15% of the data had already been entered in to Excel ACF field staff. An Add-ins named “Merge table” was used to collate the data into a single sheet. Figure 2 summarises the steps taken in selecting children for the final analysis.

**Figure 2. Flow Chart showing selection of children for analysis**

Total number of Children Entered in registers (n=2,827) (F=1398; M=1429)

Total number of Children after Elimination of children above 60 months (n=2,801) (F=1385; M=1416)

Total number of Children after Elimination of children below 6 months by August 2012 (n=2,543) (F=1,258;)

Total number of Children after elimination of Children without Date of Birth, gender (n=2,524) (F=1,251;)

Total number of Children after Elimination of children with only one Entry of anthropometric data (n=2337)

Total number of Children used in Final analysis (n=2318) (F=1,138; M=1,180)

Excluded because of being above the age Limit of 60 months (n=26) (F=13;)

Excluded because of being below the age Limit of 6 months (n=258) (F=127;)

Excluded because of Missing date of birth and gender (n=19) (F=7; M=12)

Excluded because of having data on only one month (n=187) (F=103; M=84)

Excluded due to missing weight, MUAC or height values (n=19) (F=10; M=9)
3.5 Statistical Analysis

Data was converted from its cross sectional appearances to a longitudinal format using Statistical Analysis System (SAS). Basic descriptive statistics which include box plots, means, frequency distributions and individual profiles were produced using SAS. WHO-anthro macros were used in SAS to compute weight-for-height Z scores (WHZ), Height for age (HAZ) and MUAC-for-age Z score among other indices. [40], was used to compute sensitivity, specificity, PPV, NPV, positive likelihood ratio (LR+) and negative likelihood ratio (LR-). Malnutrition prevalence based on the different anthropometric indices was also produced using SAS. Table 5 summarises the validity tests computations.

Table 5. Standards used in computing the validity tests

<table>
<thead>
<tr>
<th>Test Indicator</th>
<th>Gold standard</th>
<th>False Positive</th>
<th>False negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUAC &lt; 125</td>
<td>WHZ &lt; -2 + weight loss &gt; 5% of body weight</td>
<td>Children detected by MUAC but not detected by WHZ&lt;-2+weight loss&gt;5% of body weight</td>
<td>Children detected by WHZ&lt;-2+weight loss&gt;5% of body weight but not detected by MUAC &lt;125</td>
</tr>
</tbody>
</table>

3.6 Limitations of the study

The growth monitoring data used for this thesis was not ideally collected for the purpose of this study. Some important measures which include giving of unique numbers to individual children were not done during data collection period. SSR which could have aided in explaining weight-for-height deviations were not collected for individuals. The reasons for exiting of beneficiaries from the program were not explained. If exiting from the program was linked to episodes of malnutrition or death due to malnutrition then this could have caused loss of information that could have been valuable for this study.
CHAPTER 4 RESULTS

4.1 Sample Characteristics
A total of 2,524 children between the ages of 6 months to 5 years had their anthropometric measurements recorded over a period of 27 months. The gender distribution showed no bias to any sex as there were 49% females and 51% males. The number of times individuals had anthropometric measurements taken is shown in Figure 3. Only 54 individuals had all the recordings in all the 27 months. Annexes 3 and Annex 4 show the same results segregated by gender. The data quality was quite acceptable as only 3% (n=64) of the children were excluded due to missing date of birth, impossible anthropometrics and being older than 60 months.

Figure 3. The number of times individuals had recordings
4.2 Data Exploration

Figure 4 shows the Box plots of MUAC in the different age groups. The plot shows that there is a small increase of MUAC as age range is increased. On comparing the means, there was a 10mm difference between the means of the 6 to 11 months and the 48 to 60 months age groups. Two lines that represent the moderate acute malnutrition (125mm) and the severe acute malnutrition (115mm) cut off points for MUAC were drawn so as to visualise if the cut-offs judge fairly across the different groups. The line representing the MAM cut-offs is very close to the first quartiles of the 6 to 11 and 12 to 23 months age groups, the first quartiles for these groups are 126mm and 127mm respectively. Meanwhile the first quartiles for the 3 older age groups are much further away from the MAM cut-offs, they are 132mm for 24 to 35 months; 136mm for the 36 to 47 months and 137mm for the 48 to 59 months age group. Annex 5 shows the summary statistics for the data.

![Figure 4. Box and whisker plots showing the variation of MUAC (age group 1= 6 to 11 months; 2=12 to 23 months; 3=24 to 35 months; 4=36 to 47 months and 5=48 to 59 months)](image)
4.2.1 Weight for height versus MUAC on Acute Malnutrition Prevalence

The rates of acute malnutrition as defined by MUAC and weight for height were explored based on age groups. Figure 5 and Figure 6 show the prevalence rates based on MUAC and weight for height respectively. Most of the children (80%, 364/450) identified by MUAC as having acute malnutrition were below the age of 24 months. In the 2 younger age categories (6 to 11 and 12 to 23) there were slightly more females (60%, 218/364) than males diagnosed as malnourished by MUAC. Severe Acute Malnutrition (SAM) and Moderate Acute Malnutrition (MAM) showed a similar pattern in that most of the children identified as acutely malnourished by MUAC below the age of 24 months. Meanwhile acute malnutrition prevalence based on weight for height was between 20% and 40% across all the age categories and did not show much bias towards a particular age group. Weight for height however did detect more males (57%, n=455) than females (43%, n=349) as acutely malnourished.

Figure 5 Children diagnosed as Malnourished at least once (MUAC< 125mm)
Figure 6. Children diagnosed as Malnourished at least once (Weight-for-height< -2)

4.2.2 Agreement of MUAC and MUAC/age Z score with Weight-for-height

Out of the 961 malnourished children who were detected by both indicators, only 30% (n=293) were detected by both MUAC (MUAC<125mm) and weight-for-height (WHZ <-2). However when MUAC was corrected for age by using MUAC for age Z scores, the agreement in the children detected by both MUAC and weight-for-height improved to 43% (n=587).
4.3 Predictive Values of MUAC and Weight-for-height changes for weight loss

A weight loss greater than 5% of body weight in children within approximately 30 days was hypothesised to be significant enough to effect detectable changes in MUAC and weight-for-height. It was therefore assessed if these children who lost more than 5% of their body weight were also detected to be malnourished by MUAC and weight-for-height after this significant weight loss. Table 6 summarises the results. The positive predictive values of weight-for-height changes for weight losses greater than 5% of body weight were almost twice as much as those of MUAC (38.95% as compared to 22.05%). The higher positive predictive values of weight-for-height changes as compared to MUAC changes was also observed after stratifying the data by age ranges. It is important to note that most of the children, who were classified as malnourished by both MUAC and weight-for-height following a weight loss greater than 5% of their body weight, were children who had previous measurements which were close to the cut-off points. 70% (180/259) of true positives for weight-for-height changes were below minus 1 Z-Scores while 71% (63/86) of true positives for MUAC were below 130mm in their previous measurements.

<table>
<thead>
<tr>
<th>Age</th>
<th>MUAC&lt;125mm (95% C.I)</th>
<th>Weight-for-height &lt; -2 Z-Score (95% C.I)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 to 59 months</td>
<td><strong>22.05%</strong> (18.03 % to 26.50 %)</td>
<td><strong>38.95%</strong> (35.22 % to 42.77 %)</td>
</tr>
<tr>
<td>6 to 23 months</td>
<td><strong>20.25%</strong> (15.99 % to 25.07 %)</td>
<td><strong>30.64%</strong> (25.45 % to 36.23 %)</td>
</tr>
<tr>
<td>24 to 59 months</td>
<td><strong>19.17%</strong> (12.56 % to 27.36 %)</td>
<td><strong>38.41%</strong> (33.97% to 43.00%)</td>
</tr>
</tbody>
</table>

The positive predictive value of MUAC changes for weight loss did not improve when MAUC was adjusted for age by using MUAC for age Z scores, it was 23.13% (95% CI: 20.66 % to 25.74 %) which is similar to that of MUAC (22.05%) without adjusting for age.
4.4 MUAC Validity to detect Acute Malnutrition

The validity of MUAC less than 125 mm to detect acute malnutrition was tested using weight-for-height less than -2 Z scores with weight loss greater than 5% of body weight as the gold standard. Weight-for-height less than -2 Z scores with 5% body weight loss were hypothesised to be a sensible definition of acute malnutrition. Table 7 summarises the validity tests on MUAC. MUAC seems to have a high probability for identifying rightly the non malnourished children as demonstrated by the high specificity (83.61%). The sensitivity for MUAC however is very low (30.84%) and the likelihood ratios also indicate that MUAC may not be useful in ruling in and ruling out malnutrition in children identified by weight-for-height less than -2 with weight loss greater than 5% of body weight. Both the negative and the positive likelihood ratios for MUAC are close to 1 and according to Hayden and Brown, such likelihood ratios are not useful to rule in or rule out a disease [41]. Out of 450 children identified by MUAC as acutely malnourished, 321(70%) neither had a previous weight loss greater 5% nor had weight-for-height less than -2 Z scores, and out of these 321 children 273(85%) were below the age of 24 months.

Table 7. Validity tests on MUAC using weight-for-height less than -2 Z scores with weight Loss greater than 5% of body weight as gold standard

<table>
<thead>
<tr>
<th>Property</th>
<th>MUAC &lt;125 (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>30.84% (25.93 % to 36.10 %)</td>
</tr>
<tr>
<td>Specificity</td>
<td>83.61% (81.89 % to 85.22 %)</td>
</tr>
<tr>
<td>Positive Likelihood Ratio</td>
<td>1.88 (1.56 to 2.27)</td>
</tr>
<tr>
<td>Negative Likelihood Ratio</td>
<td>0.83 (0.77 to 0.89)</td>
</tr>
</tbody>
</table>

{Calculations for 6 to 59 months -True Positive 103; False Positive 321; False Negative 231; True negative 1637}
4.4.1 MUAC Validity to detect Acute Malnutrition: stratified by age range

When stratified by age range as shown in Table 8, MUAC's sensitivity for the age group of 6 to 23 months is more than twice as much as before stratifying by age range (65% as compared to 30 %). In the age group 24 to 59 months MUAC's sensitivity is much lower than that of 6 to 23 months age group (14% as compared to 65%). The negative likelihood ratio of MUAC for children between 6 to 23 months is also much improved after stratifying by age range, from 0.83 (in the combined age groups) to 0.46, but the negative likelihood ratio in the 24 to 59 months age groups is even closer to 1 (0.9) than before stratifying by age range. MUAC therefore shows better agreement with the ‘gold standard’ used for this test in the 6 to 23 months age group than in the 24 to 59 months. It is also important to note that the specificity in the 6 to 23 months age group is lower than when the 2 age ranges are combined and also lower than the 24 to 59 months age group.

Table 8. Validity tests on MUAC: stratified by age range

<table>
<thead>
<tr>
<th>Age group</th>
<th>TESTING OF VALIDITY OF MUAC&lt;125 USING WHZ&lt;-2 with Weight Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitivity</td>
</tr>
<tr>
<td>6_59</td>
<td>30.84%</td>
</tr>
<tr>
<td></td>
<td>(25.93 % to 36.10 %)</td>
</tr>
<tr>
<td>6_23</td>
<td>65.22 %</td>
</tr>
<tr>
<td></td>
<td>(55.77 % to 73.86 %)</td>
</tr>
<tr>
<td>24_59</td>
<td>14.29 %</td>
</tr>
<tr>
<td></td>
<td>(10.10 % to 19.39 %)</td>
</tr>
</tbody>
</table>

{ {6_59 months {True Positive-103; False Positive-321; false negative-231; True negative-1637} }  
6_23 months {True Positive-75; False Positive-273; false negative-40 True negative-814} }  
24_59 months {True Positive-34; False Positive-74; false negative-204; true negative 1490} }
4.4.2 MUAC Validity to detect Acute Malnutrition stratified by gender

MUAC's performance in males and females did not show any crucial differences as shown in Table 9. The only notable difference was the slightly higher specificity (88.60%) in males as compared to females (78.66%).

Table 9. Validity tests on MUAC: stratified by gender

<table>
<thead>
<tr>
<th>Age group</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold standard</td>
<td>STANDARD WL+WHZ</td>
<td>STANDARD WL+WHZ</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>33.97 % (26.59 % to 41.98 %)</td>
<td>28.09 % (21.62 % to 35.30 %)</td>
</tr>
<tr>
<td>Specificity</td>
<td>78.66 % (75.96 % to 81.18 %)</td>
<td>88.60 % (86.44 % to 90.53 %)</td>
</tr>
<tr>
<td>Positive LR</td>
<td>1.59 (1.24 to 2.04)</td>
<td>2.46 (1.84 to 3.30)</td>
</tr>
<tr>
<td>Negative LR</td>
<td>0.84 (0.75 to 0.94)</td>
<td>0.81 (0.74 to 0.89)</td>
</tr>
</tbody>
</table>

{Females-6_59 months {True Positive-53; False Positive-210; false negative-103; True negative-774} 
{Males- 6_59 months {True Positive-50; False Positive-111; false negative-128; True negative-863}

4.4.3 MUAC Validity to detect Acute Malnutrition: stratified by stunting

As shown in Table 10. The positive Likelihood ratio and specificity of MUAC were slightly higher in stunted children than in non stunted children, 3.71 compared to 2.05 and 92.91% compared to 83.88% respectively. The negative likelihood ratio and sensitivity had very small differences between the stunted and non stunted children.
### Table 10. Validity tests on MUAC: stratified by stunted and non-stunted

<table>
<thead>
<tr>
<th>Property</th>
<th>Stunted Children</th>
<th>Non Stunted Children</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensitivity</strong></td>
<td>33.07 % (27.28 % to 39.26 %)</td>
<td>26.32 % (17.81 % to 36.35 %)</td>
</tr>
<tr>
<td><strong>Specificity</strong></td>
<td>83.88 % (82.00 % to 85.63 %)</td>
<td>92.91 % (91.37 % to 94.26 %)</td>
</tr>
<tr>
<td><strong>Positive Likelihood Ratio</strong></td>
<td>2.05 (1.67 to 2.53)</td>
<td>3.71 (2.51 to 5.49)</td>
</tr>
<tr>
<td><strong>Negative Likelihood Ratio</strong></td>
<td>0.80 (0.73 to 0.87)</td>
<td>0.79 (0.70 to 0.90)</td>
</tr>
</tbody>
</table>

\[
\text{Calculations for stunted children - True Positive 83; False Positive 262; False Negative 168; True negative 1363,}\]
\[
\text{Calculations for non stunted children - True Positive-25; False Positive 91; False Negative 70; True negative 1193}]

### 4.4.4 Agreement of MUAC and Weight-for-height with weight Loss

Out of 334 children who had a weight loss greater than 5% and were also identified by weight-for-height less than -2 as acutely malnourished, 30% (n=103) of these children were detected as acutely malnourished by MUAC. However when MUAC was adjusted for age by using MUAC for age Z score the agreement went up to 71% (n=238).
CHAPTER 5 DISCUSSION

5.1 Discrepancy of diagnoses between MUAC and Weight-for-height

The agreement between MUAC and weight-for-height was only 30% (n=293) of the children identified by both indicators as malnourished, this is consistent with findings reported by Myatt et al. [16]. However when MUAC-for-age was compared with weight-for-height, their agreement was 43% (n=587). When tested on children identified by weight-for-height with previous weight loss, MUAC’s agreement remained at 30% (n=103) but MUAC-for-age showed a very high agreement 71% (238). This suggests that correcting MUAC-for-age could improve MUAC’s agreement with weight-for-height as also echoed by [42]. The findings by [15] and [11] that MUAC is more biased to children between 6 to 23 months in the detection for malnutrition was also confirmed by this study as 80% (n=364) of children identified as malnourished by MUAC were between 6 to 23 months. In addition 60% (n=218) of children identified by MUAC below 24 months were females. Weight-for-height did not show any age bias but did show a small bias towards males as 57% (n=455) of children identified by weight for height were male. Weight-for-height is suspected to be influenced by body shape [43]. It would therefore have been more useful to have sitting and standing ratios (SSR) for males and females and to explore if this could explain why weight-for-height identified more males than females.

Out of 450 children identified by MUAC less than 125 mm as acutely malnourished, 321(70%) neither had a previous weight loss greater 5% nor had weight-for-height less than -2 Z scores, and out of these 321 children, 273(85%) were below the age of 24 months. This result can be explained by proximity of the MUAC’s first quartiles of the 6 to 11 and 12 to 23 months age groups to the MUAC’s cut-off of 125mm as shown in figure 4, the first quartiles for these groups are 126mm and 127mm respectively. The single cut-off points of MUAC for the 6 to 59 age group seem to ignore the difference in the standard growth curves between males and females and the fact that MUAC increases with age as observed by Onis [34]. The efficiency in which MUAC’s single cut-offs detects malnutrition in children below 24 months and its appropriateness for the children between 24 to 59 months therefore needs further investigation.
5.2 Predictive value of MUAC and weight-for-height changes for weight loss

Though the positive predictive values of weight-for-height changes for weight losses greater than 5% of body weight were low, they were almost twice as much as those of MUAC (38.95% as compared to 22.05%). Weight-for-height changes do not depend only on weight changes but also on height changes and this could explain in part the low positive predictive value of weight-for-height changes for weight loss. About 70% of the children who were detected by both anthropometric indices as malnourished after having lost more than 5% of body weight were those children whose measurements were close to the cut-offs. As the younger children of 6 to 23 months have a smaller mean MUAC (closer to the cut-offs) as compared to the older age group of 24 to 59 months, it is therefore not surprising that MUAC shows a bias to the younger age group of 6 to 23 months.

Since MUAC for age Z score is MUAC adjusted for age, it was expected that its positive predictive value would be better than that of MUAC. However this was not the case as the positive predictive value for MUAC for age Z scores was 23.13% (95% CI: 20.66 % to 25.74 %) which was very similar to that of MUAC (22.05%) without adjusting for age. This result needs further study as it could not be explained.

Failure for anthropometric indices to detect significant weight losses indicates that anthropometric cut-offs are arbitrary and it is essential for health workers to consider as well the growth curve of each individual child in order to make sound conclusion on the nutrition status of each child.

5.3 Performance of MUAC in detecting children identified by the “Gold standard”

Taking into consideration that weight-for-height below -2 with recent weight loss greater than 5% of body weight is a reasonable gold standard for acute malnutrition; MUAC had a low sensitivity (30.84%) to identify children detected by the “gold standard”. This suggests that using MUAC may leave out many children who are malnourished out of the programs which are intended to benefit them. The purpose of community screening for malnutrition is to diagnose the condition early but with such high number of false negatives generated by MUAC this goal may not be achievable using MUAC. The positive likelihood ratio (1.88) and the negative likelihood ratio (0.83) are very close to 1 and according to Hayden and Brown such likelihood ratios are not useful for ruling in and ruling out a disease [41].
However when stratified by age ranges MUAC’s performance for the 6 to 23 months age group was very different from the 24 to 59 months. In the 6 to 23 months age group MUAC had a better sensitivity (65% compared to 14% in 24 to 59 months age group). Such a low sensitivity for the children above 2 years shows that MUAC may under detect malnutrition in this age group. The negative likelihood ratios and the positive likelihood ratio in the 6 to 23 months indicate that MUAC could be useful in ruling in and ruling out malnourished cases identified by weight for height less than -2 with weight loss greater than 5% of body weight. The discrepancy between these 2 ranges of age suggests that the single cut-offs of MUAC do not detect malnutrition uniformly between the 2 age ranges of children.

The phenomenon observed by Berkley et al that MUAC identifies more stunted was also observed in this study as 70% (370) of children identified by MUAC were stunted [44]. According to de Onis, females between 6 to 10 months with a MUAC below 125mm are considered to be within the normal range as this falls above the -2 Z score MUAC-for-age reference [34]. This finding by Onis could explain the lower specificity of MUAC in younger children, especially in females.

**5.4 Appropriateness of MUAC as an indicator of acute malnutrition**

Though MUAC is simple, of low cost, and more acceptable to children than weight for height, these properties should be considered on condition that the indicator can effectively detect malnutrition. Based on the evidence presented in this study the competence of MUAC to effectively and uniformly detect malnutrition in children between the ages of 6 to 59 months is certainly not convincing.
Chapter 6 Conclusion and recommendations

6.1 Conclusions

1. MUAC had a selection bias towards females and younger children who are below the age of 24 months. MUAC-for-age showed a better agreement with weight-for-height on the children detected to be malnourished as compared to MAUC alone.

2. The positive predictive values of both MUAC and weight-for-height towards weight loss greater than 5% body weight were low, though that of weight for height was a slightly higher than that of MUAC. Most of the children identified as malnourished after a significant weight loss were those close to the cut-offs. This indicates that anthropometric cut-offs are only arbitrary and that the growth curve of each child is essential in making sound conclusions on nutrition status.

3. MUAC’s performance in detecting malnutrition on children between 6 to 23 months and the 24 to 59 months age groups is significantly different. MUAC had a lower specificity in younger children; females and also in stunted children. MUAC also had a lower sensitivity in children above 2 years which suggests that MUAC could under detect malnutrition in this age category. For ruling in and ruling out malnutrition based on the gold standard used in this study, MUAC shows that it is useful in the 6 to 23 months age group but not in the 24 to 59 months age group.

6.2 Recommendations for Programs and Research

1. Conduct longitudinal study specifically designed to observe the performance of nutrition indicators on the evolution of nutrition status. Identification of the most efficient anthropometric indicators would improve the targeting in nutrition programs.

2. The effectiveness in which MUAC’s current single cut-offs detects malnutrition in children below 24 months and its appropriateness for the children between 24 to 59 months needs further investigation. Conducts a study to observe if different MUAC cut-offs are necessary for the 6 to 23 months and the 24 to 59 months age groups.
References


Annexes

Annex 1. Terms used in assessing the appropriateness of case detection methods

- **Simplicity**: the method can be easily administered by non clinicians;
- **Acceptability**: the method is acceptable to the subject and others;
- **Precision**: the degree of reproducibility among independent measurements of the same true value (also known as reliability);
- **Accuracy**: the proximity of a measurement to its true value;
- **Sensitivity**: the proportion of diseased subjects who test positive;
- **Specificity**: the proportion of healthy subjects who test negative;
- **Predictive value**: the probability that a person with a positive test has the disease or that a person with a negative test does not have the disease.

Annex 2. Justification for WHZ Z score of less than [27]

- Children below -3 Z scores have an elevated risk of death compared to those who are above this cut-off point.
- When fed on a therapeutic diet compared to other diets, children below -3 Z scores have a higher weight gain which results in faster recovery.
- In a well-nourished population there are virtually no children below -3 SD (<1%).
- There are no negative effects or any known risks associated with therapeutic feeding of these children applying recommended protocols and appropriate therapeutic foods.
Annex 3. Graph showing the number of times females had recordings
Annex 4. Graph showing the number of times males had recordings

![Graph showing the number of times males had recordings stratified by gender](image)

Annex 5. Summary Statistic for data

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