 Anthropometric predictors of mortality in undernourished adults in the Ajiep Feeding Programme in Southern Sudan\textsuperscript{1–3}

Abel H Irena, David A Ross, Peter Salama, and Steve Collins

ABSTRACT

Background: Various nutritional assessment tools are available to assess adult undernutrition, but few are practical in poorly served areas of low-income countries.

Objective: The objective was to assess the relation between mid-upper arm circumference (MUAC), weight, body mass index (BMI), and clinical assessment for edema in predicting mortality in adults with severe acute undernutrition.

Design: Demographic and anthropometric data that were collected in an observational study of 197 adults were analyzed. Participants were aged 18–59 y and were admitted to a therapeutic feeding center in Ajiep, Southern Sudan, during the height of the 1998 famine. Receiver operating curves were calculated and compared.

Results: The mean (±SD) age of the participants was 40.1 ± 10.8 y, and the mean (±SD) MUAC, weight, and BMI (in kg/m\textsuperscript{2}) were 16.4 ± 1.3 cm, 35.1 ± 5.2 kg, and 12.6 ± 1.5, respectively. The area under the receiver operating curve for MUAC (0.71) was higher (\(P = 0.01\)) than those of BMI (0.57) and weight (0.51). Mean age, weight, and BMI on admission did not differ between survivors and nonsurvivors (\(P > 0.17\)). MUAC and edema were independently associated with mortality. For every 1-cm increase in admission MUAC, the odds of subsequent mortality decreased by 58\% (adjusted OR: 0.42; 95\% CI: 0.28, 0.63; \(P < 0.001\)).

Conclusions: In this study, which was conducted at the height of a major famine among adults with extremely severe grades of undernutrition, MUAC and edema were better indicators of short-term prognosis than was BMI. Further studies are needed to define a critical MUAC threshold for the diagnosis of acute adult undernutrition. Am J Clin Nutr doi: 10.3945/ajcn.112.055095.

INTRODUCTION

Although the frequency in which famines occur has decreased, an unacceptability high number of adults suffer from undernutrition (1, 2). The global HIV/AIDS pandemic has also increased the importance of adult malnutrition to public health (3–6). In children, improved understanding and classification of undernutrition has enhanced the management of malnutrition (7, 8). Simple but effective screening tools and criteria are enabling nutrition programs to offer appropriate treatment to malnourished children in accordance with their nutritional status (7, 9, 10). On the other hand, limited data are available on the classification of adult undernutrition, and this detracts from the effectiveness of treatment programs (11).

The choice of anthropometric indicators for screening depends on the purpose and context in which case detection is taking place (12). In the resource-limited context of famine relief, easy-to-use, objective, and acceptable diagnostic methods are vital. Given that the central aim of therapeutic nutritional interventions in famine is to prevent death, screening and diagnostic tools must be able to identify patients at increased risk of mortality and be feasible with the limited resources available (13, 14). In addition, the choice of threshold values for intensive nutritional therapy must reflect the staff and infrastructure available—resources that are generally severely constrained in areas where adult undernutrition prevails.

Several indicators are available to measure adult undernutrition. However, midupper arm circumference (MUAC), weight, BMI, and edema are practical tools in most severely resource-constrained situations. Powell-Tuck and Hennessy (15) assessed the nutritional status of adults acutely admitted to surgical, medical, and orthopedic wards of Royal London hospitals and assessed the in-hospital mortality predictive power of weight loss, MUAC, and BMI. They found weight loss to be the most significant predictor of mortality followed by MUAC, whereas BMI was not found to be a significant predictor of mortality. Gustafson et al (16) prospectively followed adults with HIV and tuberculosis within a general population under demographic surveillance before and after a war in Guinea Bissau and found that MUAC predicted mortality in addition to tuberculosis and HIV exposure.

We analyzed data from the 1998 Ajiep feeding program in southern Sudan to assess the predictive power of MUAC, weight, BMI, and edema values on admission for subsequent mortality. This study was conducted as part of an operational therapeutic feeding program in a context in which the HIV burden was low. We hope that the findings from this study will inform the selection of appropriate tools to diagnose adult undernutrition in both famine and nonfamine contexts.

\textsuperscript{1}From Valid International (AHI and SC); MRC Tropical Epidemiology Group, London School of Hygiene & Tropical Medicine, London, United Kingdom (DAR); and UNICEF Zimbabwe, Republic of Zimbabwe, South Africa (PS).

\textsuperscript{2}The therapeutic feeding center was managed through core funding from Concern Worldwide and several other bilateral funding sources.

\textsuperscript{3}Address correspondence to AH Irena, Valid International, 841 Northampton Drive, Silver Spring, MD 20903. E-mail: abelhailu@yahoo.com. Received January 9, 2013. Accepted for publication April 18, 2013. doi: 10.3945/ajcn.112.055095.
Subjects and methods

Study type and setting

In 1998, a major famine occurred in southern Sudan (17, 18). According to burial surveillance systems in major towns, crude mortality rates were frequently between 20 and 30/10,000 daily—20–30 times the threshold used to define an emergency (14). This article describes the results of an observational study of an adult therapeutic feeding center implemented by Concern Worldwide in Ajiep from October 1998 to January 1999. Criteria for admission into the therapeutic feeding program were primarily MUAC-based. Admission criteria were adults with an MUAC <16.0 cm or adults with an MUAC between 16.0 and 18.5 cm who were not able to stand or had diarrhea. Adults with MUAC ≥18.5 cm could also be admitted if the staff judged them to be at particularly high risk of death for some other reason.

The principles of the therapeutic regimen were identical to those for children. In phase 1, which generally lasted 1–4 d, 8 meals/d (including 2 meals overnight) of high-energy milk (F-75; Nutriset) were given for a total of 60 mL/kg per day (100 mL F-75 contains 75 kcal). Complications such as dehydration, hypoglycemia, dysentery, respiratory infection, and malaria and helminthes infection were treated in this phase; oral rehydration and oral antibiotics were used in preference to intravenous therapy whenever possible. Patients were generally rehydrated with ReSoMal (Nutriset), a low-sodium rehydration salt, unless the patient had profuse watery diarrhea; in this case, regular oral rehydration salts were used. In phase 2, 6 meals of F-100 (Nutriset) (100 kcal/100 mL), a standard therapeutic milk recommended by WHO for the second-stage management of severe acute malnutrition, were given in combination with a high-energy porridge called SP-450 (19); 10–12% of total calories were derived from protein and 20–30% from fat in this phase. Patients were generally fed to appetite in this phase, and local foods were added. Treatment of iron deficiency anemia was commenced in this phase from 7 d after the admission date. Patients with dysentery were generally managed in the center if they were able to tolerate oral antibiotics, and strict precautions against cross-contamination were implemented. In situations in which intravenous treatments could not be avoided, patients were transferred to a field hospital run by another nongovernmental organization.

Data collection

Trained health workers obtained patient identification information and anthropometric measurements at admission and throughout the patient’s stay in the therapeutic unit. Weight in subjects wearing minimal clothing was measured to the nearest 100 g with Soehnle digital electronic scales (DE-71522; Soehnle Professional GmbH) that had previously been calibrated against known weights in the United Kingdom. Height to the nearest 0.1 cm was assessed by using Oxfam metal adult height boards. MUAC was measured to the nearest 1 mm on the left arm, midway between the olecranon and the tip of the acromion process of the scapula, by using adult MUAC tapes. Pitting edema was coded by using a modified classification of Beattie et al (0 = absent, 1 = minimal edema on the foot or ankle that was demonstrable but not visible, 2 = visible on foot or ankle, 3 = demonstrable up to knee or beyond and/or throughout the body (anasarca)] (20).

A physician conducted a clinical examination and initiated both routine treatment and specific treatment of any complications that had been diagnosed. Treatment was monitored by using standard patient monitoring cards on which patient identifiers and nutritional and medication information were recorded. There were 5 outcome categories in this observational study: 1) cured (resolution of clinical symptoms and consistent weight gain), 2) death (any death during treatment or within 2 wk after defaulting from the treatment center), 3) transfer to another feeding center, 4) referred to a hospital for further treatment, and 5) defaulted (absent for >7 d without having been medically discharged or referred).

Statistical analysis

Data were initially checked for inconsistencies and for missing values. Missing data for admission variables were minimal: 5 for height, and 3 for admission weight. These data for patients were not included in the analysis. Admission data were mainly used in the analysis, because the intention was to assess the effect of patients’ nutritional status at admission on treatment outcomes and the relation between the different admission anthropometric measures. BMI was calculated as weight (kg)/height (m) squared. Outlier values of BMI, weight, and MUAC, > and <3 SD from their means were dropped. The distribution of admission anthropometric data was checked by comparing calculated skewness values with a critical skewness value for the sample size (for a 2-sided ). This analysis showed that all 3 anthropometric indicators were approximately normally distributed. One-factor ANOVA, a t test (for normally distributed variables), and a Kruskal-Wallis test (for nonnormal distribution) were calculated to assess differences in admission anthropometric measures by sex and by outcome.

Because the relation between MUAC, weight, and BMI may be confounded by edema, comparisons and regression lines were calculated stratified by edema status. Sensitivity and specificity for subsequent mortality were assessed for various threshold values of weight, BMI, and MUAC after stratification by edema status. Receiver operating curves, AUCs, and discriminatory values were calculated and compared.

Logistic regression was used to assess the effects of sex, age, MUAC, weight, BMI, or edema on admission on risk of mortality. The likelihood ratio test and associated P values were calculated. Adjusted and unadjusted ORs, 95% CIs, and P values were calculated. STATA 11 (StataCorp) was used for the analysis.

Results

A total of 469 patients, aged 2 mo to 77 y, were treated in the Ajiep therapeutic feeding center between 9 October 1998 and 14 January 1999. Of these, completed data for 197 adults aged between 18 and 59 y were available and analyzed for this study. The mean (±SD) age of the adults was 40.2 ± 10.8 y. More than two-thirds of the subjects were women (n = 138, 70%). No statistically significant differences in mean BMI (P = 0.55) or mean MUAC (P = 0.09) were observed by sex.
Relation between MUAC, BMI, and weight

Mean (±SD) age and anthropometric values (weight, height, BMI, and MUAC) by sex are shown in Table 1. On average, the men (n = 59) were heavier and taller than the women (n = 138; P < 0.001). Neither MUAC on admission (ANOVA: P = 0.7) nor BMI on admission (ANOVA: P = 0.8) differed significantly by sex.

Mean (±SD) MUAC, weight, and BMI values are shown in Table 2 by edema status. In both men and women, mean MUAC, weight, and BMI were higher in edematous than in nonedematous patients (P < 0.001).

The receiver operating curves for MUAC, weight, and BMI—adjusted for edema status—are shown in Figure 1. MUAC had better sensitivity and specificity in predicting mortality than did BMI, with weight having the lowest (P = 0.01). The most discriminatory threshold was determined as the anthropometric threshold, with the highest value for sensitivity plus specificity; <15.6 cm for MUAC and <12.0 for BMI.

Analysis of treatment outcome showed that 145 patients (74%) exited the feeding center as cured, 22 (11%) died, 10 (5%) defaulted, and 19 (9.7%) were transferred out. Baseline variables are compared between survivors and those who died in Table 3. Survivors had a significantly higher admission MUAC than did nonsurvivors (P = 0.002). There was only very weak evidence (P = 0.19) that the mean BMI was different between survivors and those who died. More than half of those who died had edema (13/22, 59.1%; P = 0.001). In contrast, BMI on admission was not significantly associated with subsequent mortality (P = 0.2). No significant interaction was found between MUAC and edema in predicting mortality (P = 0.34). After adjustment for edema and MUAC, men had a higher odds of death than did women, and this difference was nearly statistically significant (adjusted OR: 2.8; 95% CI: 1.07, 7.40; P = 0.04).

DISCUSSION

Acute adult undernutrition tends to occur in prolonged severe famines. This study was the first to document levels of BMI as low as 8.0—previously thought to be incompatible with survival. Mean BMI on admission was 12.6—well below current accepted BMI thresholds for defining severe undernutrition in adults. Studies conducted during the famine in Somalia of 1992 documented BMI values as low as 8.0 (21). The Ajiep study confirmed the conclusions of a small number of previous studies that suggest that relatively high rates of recovery are possible when treating even severely emaciated adults with therapeutic protocols, similar to those used and formally evaluated for malnourished children—based on low-protein, high-frequency regimens. The findings of higher odds of death in men than in women after adjustment for edema and MUAC, despite there being no significant difference in nutritional status on admission, is also consistent with previous studies and is likely due to the natural tendency for women to have a higher proportion of body fat that they can draw on.

Another major finding of this study is that admission MUAC was more strongly associated with subsequent risk of death than BMI. MUAC and edema were the only variables that were independently associated with mortality in our study. In addition,

### Table 1

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Total (n = 197)</th>
<th>Male</th>
<th>Female</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>197</td>
<td>59</td>
<td>138</td>
<td>-1.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>194</td>
<td>57</td>
<td>137</td>
<td>4.2</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>192</td>
<td>56</td>
<td>136</td>
<td>9.6</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>191</td>
<td>55</td>
<td>136</td>
<td>0.0</td>
</tr>
<tr>
<td>MUAC (cm)</td>
<td>197</td>
<td>59</td>
<td>138</td>
<td>-0.1</td>
</tr>
</tbody>
</table>

1/ t test.
2/ MUAC, midupper arm circumference.

### Table 2

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Male</th>
<th>Female</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edematous</td>
<td>21</td>
<td>38</td>
<td>0.8**</td>
</tr>
<tr>
<td>Nonedematous</td>
<td>38</td>
<td>16.1 ± 1.4</td>
<td>1.3**</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>19</td>
<td>36.4 ± 4.1</td>
<td>4.9**</td>
</tr>
<tr>
<td>Edematous</td>
<td>28</td>
<td>17.2 ± 1.5</td>
<td>0.9**</td>
</tr>
<tr>
<td>Nonedematous</td>
<td>110</td>
<td>16.3 ± 1.1</td>
<td>1.4**</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>28</td>
<td>13.7 ± 1.9</td>
<td>4.9**</td>
</tr>
<tr>
<td>Nonedematous</td>
<td>108</td>
<td>12.3 ± 1.3</td>
<td>4.9**</td>
</tr>
</tbody>
</table>

1/ MUAC, midupper arm circumference.
2/ t test: *P = 0.02, **P < 0.001.
the relation between MUAC and mortality showed a dose-response or incremental pattern. The odds of death decreased by a very substantial 58% for every 1-cm increase in mean MUAC on admission. In contrast, no difference in mean BMI on admission was found between survivors and those who died. BMI was initially developed as a tool to assess overnutrition and chronic undernutrition (22, 23). Although it has proven to be a useful tool in such assessments, various factors in addition to nutritional status affect the interpretation of BMI. These factors include body shape, the cormic index (sitting height to standing height ratio), edema, age, and sex (15, 20, 24, 25). MUAC, however, has the advantage of reflecting the status of predominately 3 tissues: bone, muscle, and fat—the last 2 of which are particularly sensitive to weight gain and loss (13). Edema or retained fluid increases weight and changes the interpretation of BMI (25). To our knowledge, this study was the first to also document the influence of edema on interpretation of MUAC. However, edema of the upper arms only occurs in the relatively rare condition of anasarca. In addition, MUAC was significantly and independently associated with mortality in our study.

In addition to being a precise and reproducible indicator, MUAC is also a far more practical tool than BMI in situations of severe and prolonged famine (10, 26). Severely emaciated adults may have trouble standing, which makes a height assessment both difficult and inaccurate. In addition, food security crises are more common in pastoralist communities with Nilotic ethnicity in the Horn of Africa. Such communities may have a mean Cormic Index (sitting height:standing height ratio) that differs significantly from reference populations, which makes complex adjustment in BMI necessary. All these factors indicate that MUAC is likely to be a better tool for assessing acute undernutrition in adults than is BMI, especially in the resource-poor areas where the great majority of famines occur.

The data from this study were derived from a therapeutic feeding center operating at the height of a famine under extremely insecure and difficult field conditions. Study participants were selected on the basis of being severely undernourished; as such, the findings may not be generalizable to a population of adults that includes moderately and/or mildly malnourished adults. In addition, sample sizes, particularly for men, were relatively small and resulted in wide CIs for the adjusted ORs. Importantly, the relations between the anthropometric and clinical indicators and mortality were measured in the presence of an active therapeutic nutritional and treatment program, so it is not possible to know which patients would have died if this program had not been in place or whether the relations between the anthropometric and clinical measures and mortality would have been the same in that situation. Finally, there are no accepted international thresholds for MUAC assessment of acute undernutrition in adults.

In the 2 published studies in adults that reported both MUAC and BMI (15, 16), MUAC was also found to be a better predictor of mortality. Those 2 studies were conducted in very different populations from those in the current study: one was a study among patients admitted to a London hospital (15), whereas the other was in patients with both HIV and tuberculosis within a general population under demographic surveillance before and after a war in Guinea Bissau (16). The current study was conducted in severely malnourished patients admitted to a therapeutic feeding program during a famine in southern Sudan. Despite the limitations of the current study that were discussed above, in combination with the findings from these 2 previous independent studies and when combined with practical considerations, we believe that the current study provides sufficient evidence to recommend MUAC over BMI as the tool of choice for measurement of acute undernutrition in adults. Further research on a population basis and from rigorously designed controlled trials within adult therapeutic feeding programs will be required to refine admission and discharge thresholds for MUAC. Such research will need to determine whether criteria should be identical for men and women, but it will be complicated by ethical considerations and the relative infrequency of severe and prolonged famines. Evidence from related disciplines, such as infectious diseases, and specifically the treatment of undernutrition associated with chronic diseases such as HIV and

TABLE 3

Anthropometric status on admission by subsequent survival

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Survived</th>
<th>Died</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Age (y)</td>
<td>162</td>
<td>40.4 ± 10.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>160</td>
<td>35.2 ± 4.8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>158</td>
<td>166.7 ± 8.5</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>157</td>
<td>12.6 ± 1.4</td>
</tr>
<tr>
<td>MUAC&lt;sup&gt;2&lt;/sup&gt; (cm)</td>
<td>162</td>
<td>16.5 ± 1.3</td>
</tr>
</tbody>
</table>

<sup>1</sup> t test.

<sup>2</sup> MUAC, midupper arm circumference.
tuberculosis, may also be useful in determining the optimal thresholds.

We thank Concern Worldwide for making the data available for this study. The authors’ responsibilities were as follows—PS and SC: set up the therapeutic center, designed the treatment protocol, managed the therapeutic feeding program, and led the data-collection effort; AHI: analyzed the data and prepared the manuscript; and DAR and SC: supervised the analysis and interpretation of the results. All authors read, critically commented on, and then approved the final manuscript. The authors declared that they had no competing interests. No donor had involvement in the design, implementation, analysis, or interpretation of the data in this study.

REFERENCES