THE ASSESSMENT AND TREATMENT OF SEVERE ADULT MALNUTRITION

Thesis submitted to the University of London in partial fulfilment of the degree of MD

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Abstract

This thesis examines the assessment and treatment of severe adult starvation during famine. The author collected data from 573, 98 and 1059 severely malnourished adults, admitted to therapeutic feeding centres in Baidoa (Somalia) during 1992-3, Ayod (Sudan) during 1993 and Melanje (Angola) during 1993-4. The data collected are unique, recording recovery from extremes of adult starvation hitherto undocumented in the medical literature. All the centres were very rudimentary in nature, with no beds, running water, electricity or equipment for special investigations. Mortality rates in the Somalia centre were 21%; war disrupted the collection of outcome data in the centres in Sudan and Angola. The thesis assesses the relative merits of Body Mass Index, Middle Upper Arm Circumference and clinical signs, for screening adult admissions into therapeutic feeding centres. The analysis demonstrates that the use of Body Mass Index is inappropriate for this role and the discussion proposes a combination of clinical signs and Middle Upper Arm Circumference as an alternative.

The thesis also examines the effect on rehabilitation of two diets differing primarily in their protein content (one diet with 156g protein and 16.5Mj of energy day⁻¹, the other with 81g of protein and 16.5Mj of energy day⁻¹). Twenty five percent of oedematous patients given the lower protein diet during the initial phase of treatment recovered, compared with only 48% who received the higher protein diet during the initial phases of treatment. This is a three-fold decrease in mortality amongst this group of patients.

The extreme levels of social disintegration, violence and death during the fieldwork prevented the execution of prospective highly controlled research. This is always true of the extreme famines where severe acute adult malnutrition is commonest and such difficulties have discouraged scientists. This is a sad state of affairs, as the extreme human suffering that occurs during famine has not received sufficient scientific attention. There is still a great need for research to assist the assessment and treatment of severe adult malnutrition. Although the conclusions of this thesis are tentative, in the absence of other data examining screening cut-offs based upon evidence gathered during famine, these are the best we have.
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<td>AED</td>
<td>Acute energy deficiency</td>
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<tr>
<td>AMA</td>
<td>Arm muscle area</td>
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<td>BMI</td>
<td>Body mass index</td>
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<tr>
<td>CAMA</td>
<td>Corrected arm muscle area</td>
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<tr>
<td>CDC</td>
<td>Centre for disease control</td>
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<td>CED</td>
<td>Chronic energy deficiency</td>
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<td>DPA</td>
<td>Dual photon absorptiometry</td>
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<tr>
<td>DXA</td>
<td>Dual-energy x-ray absorptiometry</td>
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<tr>
<td>FFM</td>
<td>Fat free mass</td>
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<td>FM</td>
<td>Fat mass</td>
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<td>HEM</td>
<td>High-energy milk</td>
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<td>Ht-for-Age</td>
<td>Height for age</td>
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<td>ICRC</td>
<td>International committee of the Red Cross</td>
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<td>IDA</td>
<td>International Drug Agency</td>
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<td>IDECG</td>
<td>International Dietary Energy Consultative Group</td>
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<tr>
<td>IDP</td>
<td>Internally displaced person</td>
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<tr>
<td>IFRC</td>
<td>International federation of the Red Cross</td>
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<td>MDM</td>
<td>Medecin Du Monde</td>
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<td>MPLA</td>
<td>Movement Patriotic Liberation Angola</td>
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<td>MSF</td>
<td>Medecins Sans Frontieres</td>
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<td>MUAC</td>
<td>Middle upper arm circumference</td>
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<td>NGO</td>
<td>Non governmental organisation</td>
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<td>OLS</td>
<td>Operation Lifeline Sudan</td>
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<td>PEM</td>
<td>Protein Energy Malnutrition</td>
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<td>SAM</td>
<td>Severe primary adult malnutrition</td>
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<td>SFC</td>
<td>Supplementary feeding centre</td>
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<td>SH/S</td>
<td>Sitting height : stature ratio (Cormic index)</td>
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<td>SPLA</td>
<td>Sudan people's liberation army</td>
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<tr>
<td>TFC</td>
<td>Therapeutic feeding centre</td>
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<td>TSF</td>
<td>Skin fold thickness</td>
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<td>UNITA</td>
<td>The National Union for the Total Independence of Angola</td>
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<td>WFP</td>
<td>World food programme</td>
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<td>Wt-for-Ht</td>
<td>Weight for height</td>
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I also thank Concern Worldwide who employed me for the first three years during which time the data presented in this thesis were collected.
Chapter 1  Foreword – The thesis

Section 1.01 Objectives

Severe adult malnutrition is commonly encountered during famine-relief operations. There have however, been few studies into the problems associated with treating severely malnourished adults during famine and consequently, little guidance is available to field workers thus engaged. There is at present, no definition or classification of acute adult malnutrition and no specific treatment guidelines for the condition. This makes the screening and selection of admissions into therapeutic feeding centres and the dietary treatment of those admitted, problematic. The objective of this work is to improve the processes of patient selection into adult Therapeutic Feeding Centres and the dietary management of those admitted. The thesis aims to:

- Clarify the definition of severe adult malnutrition and propose a working definition that can be used to guide future research
- Assess the usefulness of different indicators of adult nutritional status
- Assess the effectiveness of two dietary regimes for treating severely malnourished adults during an emergency relief programme.

The core data presented were collected from severely malnourished adults during the height of famines in Somalia, South Sudan and Angola.

The thesis falls into two distinct parts. The first, comprising three studies, examines the definition of severe adult malnutrition and the selection of inpatients into adult therapeutic centres. As a starting point, the hypothesis that: A Body Mass Index (BMI) is a useful indicator for the selection and assessment of malnourished adults presenting to an adult therapeutic centre during the height of a major emergency, is examined. The first study investigates the risks of mortality associated with low BMI. It examines whether there is a lower limit of BMI below which recovery is not possible and whether there are other BMI thresholds associated with a markedly worse prognosis. The use of BMI as the core indicator in this study reflects the recognition that BMI is useful in the assessment of chronic protein energy malnutrition in adults. The second study investigates the
risks associated with clinical signs in severe adult malnutrition. The third study attempts to compare the efficiency of Middle Upper Arm Circumference (MUAC) as an alternative indicator of severe adult malnutrition.

The second part of the thesis examines the treatment of severe adult malnutrition during famine-relief programmes. The study was prompted by the recognition that severely malnourished adults in the Concern adult therapeutic centres, when given the standard recovery diet suffered extremely high mortality rates. The hypothesis that: A protein intake little above maintenance is more appropriate in the initial treatment of severe adult malnutrition than diets with higher levels of protein, is examined. This hypothesis reflects recent successes with the use of lower-protein rehabilitation diets in the treatment of severely malnourished children in hospitals. The study compares mortality and rates of weight gain in two groups of patients given different levels of protein during their treatment.

Section 1.02 Organisation of this thesis

The thesis consists eight chapters. The first contains this foreword. The second presents an outline of the importance and relevance of severe acute adult malnutrition, highlighting the relative neglect of the condition during the past 45 years. The third describes the background, general methods and relevant methodological issues of relevance to this study. Chapters 5 – 8 contain the bulk of the thesis, each describing an individual study, including aims, a brief literature review, specific methods, results and a discussion. Chapters 4, 5 and 6 are concerned with the definition, classification and assessment of severely malnourished adults during famine and chapter 7 with their treatment. Chapter 9 draws together these various studies providing overall conclusions and a framework for the classification of severe adult malnutrition. Future research priorities are highlighted. Supplementary data are presented in the four appendices.

Section 1.03 The originality and the contribution to medical practice.

This is the first systematic examination of the usefulness of BMI and MUAC in adult patients suffering from severe, acute malnutrition. The findings that a BMI of less than 10 kg m\(^2\) is compatible with recovery, redefines the accepted limits of human response to starvation. Many practical and theoretical limitations of BMI as a screening tool for severely malnourished adults
during famine are identified. These, and the demonstration of the usefulness of clinical signs and potential for MUAC, are hitherto unrecognised and of practical significance, clearly indicating where the need for more research lies. The comparison of the effect of dietary protein levels in the treatment of severe malnutrition under “field conditions” is unique and has not to date been repeated in either adults or children. The demonstration of the large decrease in mortality associated with a lower protein diet, given during the initial phase of rehabilitation, has important implications for all future therapeutic feeding programmes.
Chapter 2 Introduction

The chapter starts with a discussion of the definitions used in this thesis. It goes on to describe the epidemiology and worldwide importance of severe acute adult malnutrition. It contrasts the large scale of this problem with the low emphasis placed upon on alleviating the condition. The evidence reviewed indicates that the treatment of severely malnourished adult during emergency relief programmes is frequently insufficient. The paucity of the recent scientific literature bears witness to the lack of attention paid by the scientific community towards this issue. The epidemiology of the condition, which usually occurs in situations of war and social disintegration, is identified as an important reason behind this mismatch.

Section 2.01 Definitions

This thesis is concerned with severe, acute, primary adult malnutrition. In contrast to child malnutrition where definitions of acute and severe are accepted, there is no satisfactory definition, or classification, of severe, acute, malnutrition in adults. The following four sections attempt to clarify this definition, as used in this thesis.

2.01(a) “Acute and chronic” malnutrition

In children two patterns of malnutrition, stunting and wasting, are recognised. (Waterlow 1972; Waterlow, Buzina, & et al. 1977) Different processes produce these two patterns and they are assessed using separate anthropometric indices. Acute nutritional deficit produces wasting, characterised by a reduction in weight for height (Wt-for-Ht), or middle upper arm circumference (MUAC). Prolonged nutritional insults result in stunting, characterised by a reduction in height for age. Weight for age is a composite index that reflects both wasting and stunting. (Gomez & et al. 1955) Wasting and stunting are associated with different functional consequences and consequently weight for height and height for age relate to different risks. Weight for height is a powerful discriminator of the risk of short-term mortality, whereas height for age relates to the risk of longer-term mortality. (Bairagi 1981; Briand et al. 1989) The importance of using the correct indicator and cut-off, for the correct purpose; nutrition screening in stable situations, or screening entries into feeding centres during famine for example, is stressed in the academic literature (Bairagi
et al. 1985; Chen, Chowdhury, & Huffman 1980; Habicht 1980; Smedman et al. 1987) and implemented at field level. (Boelaert et al. 1995; Hakewell & Moren 1991; Young 1992)

Anthropometric assessment of adults is more problematic. Despite metabolic differences between chronic and acute malnutrition, (James, Ferro-Luzzi, & Waterlow 1988; Keys 1950a; Shetty 1984; Waterlow 1986) the absence of linear growth removes the power of a height variable to discriminate between the two. Since the Second World War, anthropometric studies of adult malnutrition have been accorded low priority. (Shetty, James, & Ferro-Luzzi 1994) In contrast to the large volume of literature dating back to the 1960s on the use of anthropometry in children, the use of anthropometry for the assessment of adult malnutrition dates from only the last decade. In the 1980s, the meetings of the International Dietary Energy Consultative Group (IDECG) took several important steps to provide a basis for contemporary studies into chronic adult malnutrition. The most important was the creation of a more precise definition of chronic adult malnutrition, called chronic energy deficiency CED. This entailed the clear differentiation of CED from acute energy deficiency (AED). CED was defined as: "A steady state at which a person is in an energy balance although at a cost either in terms of increased risk to health or as an impairment of functions and health". (James, Ferro-Luzzi, & Waterlow 1988) This clearly differentiated it from AED that was defined as: "A state of negative energy balance, i.e. a progressive loss of body energy". (James, Ferro-Luzzi, & Waterlow 1988)

The differentiation of acute and chronic adult malnutrition is important, as the two conditions entail different adaptations and different risks (see 4.07(a) iv). The use of the term "energy deficiency" by the IDECG and in most of the subsequent literature on chronic adult malnutrition is however rather unhelpful in acute malnutrition. Although the oxidisation of body tissue to provide energy is an important aspect of starvation, to call the condition "energy deficiency" overly focuses attention upon this single aspect. Particularly in severe acute malnutrition, but also in chronic malnutrition, this can obscure the importance of protein catabolism and deficiencies of micronutrients and minerals. (Golden 1995) In acute severe adult malnutrition, deficits of these nutrients are likely to play very important roles in the pathogenesis of the condition (see Section 7.05) and for this reason the term acute malnutrition, rather than acute energy deficiency, is preferred. In the interest of compatibility with other authors however, chronic adult malnutrition is referred to as chronic energy deficiency (CED).
2.01(b) “Primary” malnutrition

In this thesis, the term malnutrition is used to denote a clinical condition comprising several overlapping syndromes. In adults, wasting, a decrease in body mass, is common to all these syndromes, whereas in children, a failure of growth is the unifying feature. In any individual, the most important cause is an inadequate supply of energy or other nutrients, relative to metabolic demands. The reasons for this mis-match of supply and demand can be classified as either primary or secondary. Primary malnutrition develops when nutrient intake is insufficient to cater for normal physiological needs. In children this maybe due to either, the absence of sufficient food, or to the inappropriate preparation of food, for example a diet with an insufficient nutrient density. In adults, primary malnutrition is invariably due to an absence of sufficient food. Primary adult malnutrition is the subject of this thesis.

Secondary malnutrition occurs when an underlying disease process increases metabolic demands or decreases food intake or both. Wide ranging metabolic, hormonal and cytokine-related abnormalities are involved. These are different to that seen in primary malnutrition and are beyond the scope of this thesis.

2.01(c) Severe adult malnutrition

In children, classifying wasting and stunting using many different anthropometric measurements has been well studied and reviews are available. (Waterlow 1972; Waterlow 1993) It is accepted that the validity and usefulness of a nutritional indicator depends on the degree to which it reflects health consequences and in children there has been much work assessing the linkage between anthropometric indices, morbidity and mortality. The most significant of these studies have been prospective in design, involving the follow up of cohorts of children who had previously undergone anthropometric assessment. These have yielded data enabling the relationship of the different indices (mainly Wt-for-Ht, MUAC, Wt-for-Age, Ht-for-Age and growth velocity) and mortality and morbidity patterns to be assessed. (Bairagi 1981; Bairagi et al. 1985; Briend et al. 1989; Briend & Zimick 1986; Chen, Chowdhury, & Huffman 1981; Smedman et al. 1987; Vella et al. 1994) After several years of such research, the strengths and weaknesses of the different childhood nutritional indicators are reasonably understood and rational choices, matching indicator with intended use, can be made. This provides famine-relief workers with well-defined anthropometric and clinical guidelines facilitating the process of selecting child patients for feeding centres. Although these have to be interpreted with common sense in order to match the number of
admissions to the available resources, the definitions of severe and moderate child malnutrition are valuable aids to the rational operation of child feeding centres.

In adults, the history of anthropometry for the classification of malnutrition is very recent. Although measurements of body weight in malnourished adults have been made for over a century, weight and height measurements have very rarely been recorded systematically. This has precluded any anthropomorphic classification of adult malnutrition. It was only at the IDECG meeting in the late 1980s, that a classification of adults CED in terms of physiological parameters, rather than socio-economic, ones was accepted (see 2.01(a)). (James, Ferro-Luzzi, & Waterlow 1988) Subsequently anthropometric assessment of adult CED has been common and a classification based upon BMI has been proposed and to an extent validated (see 4.03(a)). By contrast, the study of acute adult malnutrition has been neglected. To the authors knowledge, excepting one work from the IDP camps in Southern France during 1944, (Zimmer, Weil, & Dubois 1944) there has been no other systematic collection of anthropometric data from severely malnourished adults before this work. In the absence of data from severely malnourished adults, there has been a tendency to extrapolate findings from chronically malnourished adults or those with secondary malnutrition and apply them to severe adult malnutrition. (Boelaert et al. 1995; Ferro-Luzzi & James 1996; Young 1992) This has occurred despite the general acceptance that adaptations to acute and chronic malnutrition are different. (James, Ferro-Luzzi, & Waterlow 1988) There are many reasons why such extrapolations are theoretically unsound and these are examined in 4.03(e) and 6.05(e). Such extrapolations can be dysfunctional, serving to mislead inexperienced famine-relief workers. For example, in Baidoa during the famine in 1992 the 16 kg m$^2$ BMI cut-off that currently appears in two of the largest relief agency field manuals (Boelaert et al. 1995; Young 1992) would have selected almost all of the adult population, estimated at 50,000. (CDC 1992) At that time, numbers of adult therapeutic places available in the town was 150. (Collins 1993a) Any centres attempting to follow such guidelines would have immediately filled with admissions not requiring specialised treatment to survive. Furthermore, as the majority of severely malnourished adults are weaker they are often pushed to the back of queues. The result of following such guidelines would therefore have been a centre filled with the less severely malnourished, not requiring specialised treatment to survive, whilst those in real need remained outside forced to fend for themselves.

In practice during emergency relief programmes, such unhelpful definitions of what constitutes severe adult malnutrition are seldom followed. The concept of severity therefore remains vague
and inconsistent, founded upon subjective appreciation of increased mortality risks by the admitting clinicians (see 2.04(c)).

2.01(d) A working definition of severe adult malnutrition

For the purpose of this thesis, there are several important points that characterise severe adult malnutrition (SAM):

• The malnutrition is “primary” malnutrition occurring in any post-pubertal individual because of a lack of food. It is not malnutrition secondary to some other diseases, although these might complicate and exacerbate the condition.

• It is an “acute” condition where dietary intake is insufficient for metabolic demands, resulting in a continuing loss of body tissue.

• It is “severe” in that if untreated it leads quickly to death.

Beyond these rather general criteria, it is not possible at this stage of the thesis to better define severe adult malnutrition and one of the central aims of this work is to improve the definition and classification of the condition.

Section 2.02 The epidemiology of severe adult malnutrition

Primary SAM in young and middle aged adults rarely exists outside of famine. (Jellife 1966) This is a very different distribution to severe childhood malnutrition and adult CED, both of which are more geographically and temporally widespread, occurring in many developing countries even during “normal” times. Child malnutrition and adult CED therefore occur in situations of greater stability, facilitating research and long term studies with adequate experimental control and follow-up. This has fostered a large and ever increasing volume of research into these subjects. By contrast, the socio/economic disintegration that provides the backdrop for severe adult malnutrition greatly impedes research (see 3.03(a)). Controlled trials are difficult or impossible to organise and often the follow up of even a small number of inpatients is prevented by the circumstances (see 6.04(a) i). This is an important factor explaining the limited amount of research into SAM. The small volume of research does not reflect the importance of SAM as a global health problem. Famines are still common. In 1992, at the start of this study, it was estimated
that up to 40 million people were at risk of starvation in Africa alone. (Meegan 1992) During the two years of fieldwork for this MD, there were severe famines in Somalia, South Sudan, and Angola. Subsequently the author has worked in famines affecting millions of adults and children in Liberia, the Democratic People’s Republic of Korea, the Democratic Republic of the Congo, South Sudan, Burundi, Sierra Leone and Haiti.

In Baidoa (Somalia) between August 1992 and February 1993, the Somali Red Crescent Society reported that adults accounted for 8,900 of the total 15,105 deaths recorded by the death-truck workers responsible for collecting bodies (Somali Red Cross & Crescent 1993) (see Figure 1).

Figure 1

Monthly body count in Baidoa town August 1992 - January 1993 (town population approximately 60-85,000). Figures taken from the records of the Somali Red Crescent Society “death-truck” which collected unclaimed bodies (those not buried by relatives) for burial. The definition of child or adult used by the Somali Red Crescent workers is not known.

Figure 1 shows that after September the majority of all deaths were reported to be adult. It can also be seen that the ratio of reported adult to child deaths varied over the period shown, and that children tended to die earlier on during the evolution of a famine than adults. Unfortunately,
workers on the death-truck were paid according to the numbers of bodies they buried, and in December, it was found that their figures were grossly inflated. Whether this distortion was taking place throughout the period of data collection is unknown. In the opinion of the author, the extremely high number of deaths before November, when rows of dead bodies lined the streets, would have resulted in less incentive for the death-truck workers to inflate figures in order to increase earnings. Given such high mortality, the relative importance of deaths spuriously added to the true total by the collectors, would also have been less during the earlier phase of data collection. Also, any exaggeration of the numbers of dead for financial gain would not be expected to demonstrate a change in the ratio of child to adult deaths as the workers were paid the same price for all bodies. Thus, although the ICRC figures must be viewed with caution, they probably do reflect two important facts: 1. Children died before adults and 2. High rates of adult mortality persisted despite the fact that reasonable quantities of food and resources were available in the town.

The only other available data comes from two small Centre for Disease Control (CDC) mortality surveys carried out in the town during April and November/December 1992. (CDC 1992; Moore et al. 1993) These reported very high rates of mortality during this period, with some of the highest mortality rates ever recorded in a civilian population. (Centre for Disease Control 1992) They included estimates that 75% of the under-five population had died by the end of November 1992. (CDC 1992; Moore et al. 1993) These data, presented in Table 1, must also be viewed with caution. The CDC study was based upon a small sample size (47 households) and had wide confidence limits around the mean mortality rates. In addition, the sampling methods used probably over-represented displaced people in the town; a group that suffered higher mortality rates than the resident population (De Waal 1993) and the retrospective methods for mortality estimations probably over-estimated the number of deaths. (Collins 1993b) Their further analysis, based upon a sub sample of only 212 adults and 19 under fives (see Table 1), came to the conclusion that there had been no improvement in the deaths rates during November. This conclusion was very different to the impressions of those of us living and working in Baidoa at that time, who witnessed a dramatic decrease in the numbers of dead people lying in the streets. It also contradicted the Somali Red Crescent Society data presented in Figure 1, which showed a five-fold reduction in the total number of bodies during November.
Despite the difficulties in interpreting these data, it appears likely that during the autumn of 1992 there had been extremely high mortality rates with an early peak in child mortality followed by a relatively greater number of adult deaths. This interpretation makes theoretical sense and accords with the impressions of workers in the field. Children can withstand starvation for less time than adults, as their energy stores are smaller relative to their energy requirements. In the severe famine that occurred in Baidoa, the extremely high cumulative child death rate over the summer meant that by October there were fewer children left to die. At this time, there was still almost no provision of nutritional relief for adults and consequently their death rate was increasing. The combination of these two effects meant that the number of adult deaths in comparison to those of children became relatively greater. Similar peaks in child mortality occurring earlier in the evolution of famines and wars have been described before, in the Warsaw ghetto during 1942 (Winick 1979) and during many recent refugee emergencies. (Toole & Waldman 1990)

A similar pattern of mortality was recorded in Melanje, Angola during the famine in late 1993. Data from the Concern Grave-watching programme, set up by the author in November 1993 during the first three weeks of the Concern operation in the town, (Collins 1993c) are presented Figure 2. This programme identified 21 cemeteries in the town and positioned one worker in each to record the number of people buried. These workers filled in a return classifying deaths by sex, reported age at death, and reported cause of death. A system of random checks was instituted to try to improve data quality supervision of these workers and during the first month of the programme, the author visited all but one of the sites. In most cases the reported number of deaths correlated with the numbers of recent graves. However, beyond this basic verification supervision was problematic due to transport difficulties and the close proximity of some of the cemeteries to the front line and mine fields. These data are therefore rough and must be interpreted with caution. The reported age is imprecise, based upon the opinions of the relatives

Table 1

<table>
<thead>
<tr>
<th>Numbers</th>
<th>Deaths</th>
<th>8-Month total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>April - Oct</td>
<td>Nov - Dec</td>
</tr>
<tr>
<td>All ages</td>
<td>No.</td>
<td>death rate</td>
</tr>
<tr>
<td></td>
<td>(10,000⁻¹ day⁻¹)</td>
<td>(10,000⁻¹ day⁻¹)</td>
</tr>
<tr>
<td>Aged &lt; 5yrs</td>
<td>63</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>17.2</td>
</tr>
<tr>
<td>Aged &gt; 5yrs</td>
<td>349</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>212</td>
<td>23.4</td>
</tr>
<tr>
<td></td>
<td>137</td>
<td>16.9</td>
</tr>
<tr>
<td></td>
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</tbody>
</table>
and friends burying their dead. A bias towards under-reporting child deaths is also likely, as in Melanje infants were often buried around the family yard. The reported cause of death were unverified, again based upon the opinion of relatives and provide no more than a rough idea as to the proportion of the deaths overtly involving malnutrition.

Despite the severe limitations, the data presented in Figure 2 provide some interesting information. As in Baidoa, the percentage of adult deaths appears to be higher than child deaths with only 23% of the deaths occurring in those reportedly aged less than 10 years and 38% in those aged less than 20 years. This ratio of child to adult deaths is different to the expected population pyramid, wherein approximately 15-20% of the population would be expected to be under five. (1985) Anecdotal reports, collected by the author during December 1993, indicate that the child death rate had previously been perceived by the population as much higher. This perception is supported by the estimates that in December 1993 the percentage of the population under five was very much lower than expected. (World Food Programme 1993)

Poor quality data from emergencies, as described above, is a common problem complicating the study of SAM. Despite this several re-occurring themes emerge:
• During severe famine, high adult mortality is a serious problem

• Adult mortality tends to occur at a later stage of the evolution of a famine than does child mortality

• In severe famine, by the time relief operations are operating effectively adult mortality often constitutes the greatest public health problem

Section 2.03 The focus of emergency relief programmes

The previous section has argued that malnourished adults constitute a large proportion of the nutritional problem during famine-relief programmes. This fact, although recently recognised in the literature, (Davis 1996) is not reflected in the design and orientation of famine-relief programmes.

In Baidoa the international response to the crisis started in June 1992, but because of fighting and looting, relief was mainly limited to “wet selective feeding” until the US army intervention in mid December 1992. Malnourished children were rehabilitated either in supplementary feeding centres providing two meals of milk, biscuits, and “Unimix”, porridge each day, or in 24 hour TFCs serving 6-8 meals per day. The Supplementary Feeding Centres (SFCs) were run by a nurse and provided oral rehydration, basic medical care, and referral to the hospital, MSF Inpatient Department (IPD) or to TFCs. The TFCs, usually organised by two nurses, with the back up of a doctor on call (the author), were quasi-medical inpatient departments. In addition to the special diets and basic nursing care, these centres provided intense supervision, active oral and nasogastric or occasionally intra-venous rehydration. Basic antibiotics such as ampicillin, cotrimoxazole and metronidazole, antihelminthics, malaria treatment and prophylaxis, vitamins and minerals were also given. In sharp contrast, up until the end of October, the only service for starving adults were the ICRC community kitchens. These kitchens had no medical input and, although supposed to provide 8.4 MJ of energy (one plate of rice and beans) a day, they were plagued by looting and shortages of supplies. Even when food was available the lack of supervision and care meant that the sheer physical struggle needed to maintain a place in the queue often resulted in the thinnest going without food.

2 The distribution of pre-prepared cooked food to targeted populations
This division of resources between adults and children did not reflect the relative numbers of cases of adult and child starvation. In October, when the available evidence suggested that adult that approximately 75% of deaths were adult (see Section 2.02), there were several thousand child supplementary places and several hundred child therapeutic places available but no specialised rehabilitation facilities for adult. The famine in Somalia, although severe, was not qualitatively different from other famines. In all severe famines adults starve and die. Experienced aid workers report however, that specialised services for severely malnourished adult have not been a feature in previous famine-relief programmes. Prior to the Baidoa centre, the author can find no evidence of specialised adult therapeutic services included in famine-relief programmes since the end of the Second World War. In Melanje (Angola) during 1993, the patterns of mortality were again similar (see Section 2.02) with a relative excess of adult mortality at the beginning of the humanitarian intervention. In Melanje however, based upon previous experiences in Baidoa, Concern were far quicker to set up specialised adult feeding facilities and within two weeks of commencing the programme over 1000 adult were admitted into a specialised adult feeding centre.

The large numbers of adults treated successfully in the Concern adult centres (see Chapter 4 and Chapter 7), indicate that many lives might be saved if famine-relief programmes pay more attention towards adults. Yet still adult nutritional services are implemented late or ignored completely. The author considers that an important function of this thesis and the publications that it has given rise to, is to highlight of the need and importance of adult therapeutic care. It is hoped that this will stimulate both more rational prioritisation of famine-relief programmes and research to facilitate this.

Section 2.04 Research into severe adult malnutrition

2.04(a) Primary acute severe adult malnutrition

Descriptions of famine and adult malnutrition exist in some of the earliest writings, (Aykroid 1974) and in “The Biology of Human Starvation”, Keys et al. list over 400 famines, dating back to 1708 BC, for which documentary evidence is available. (Keys 1950a) The history of formalised scientific

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3 A mixture of Corn and Soya flours with oil, with or without the addition of minerals and vitamins (see 7.03(c) and Table 19).

4 In October 1998, the author was asked by Concern to set up adult feeding centres in Agip, South Sudan. Here, despite the extremely high mortality rates amongst adults and a large emergency famine relief intervention for the previous three months, there were no specialised adult feeding centres.
study into the subject dates back into the 19th century, with detailed clinical descriptions of the victims of famine and anorexia nervosa appearing in medical journals and monographs. (Gull 1888; Porter 1899; Stephens 1895) Many studies during the two world wars provided additional data concerning the effects of severe malnutrition on adults. (Burger, Sandstead, & Drummond 1945; Debray et al. 1946; Mollinson 1946; Stapleton 1946; Winick 1979; Zimmer, Weil, & Dubois 1944) Several studies of mild to moderate malnutrition present in professional fasters, (Benedict 1907; Benedict et al. 1919) German civilians after the Second World War, (McCance & Widdowson 1951) and volunteer conscientious objectors in the USA (Keys 1950a) have supplemented these data. This early research focused upon clinical aspects of malnutrition. Anthropometric assessment with measurements of weight, and occasionally height, was usually only included as a part of individual clinical case histories. Systematic records of heights and weights from large numbers of people from populations at extreme grades of emaciation are very rare as there were almost no epidemiological studies on adult populations suffering from severe acute malnutrition (see 4.03(e)). Since the end of the Second World War, scientific attention has shifted towards the malnourished child. In the last 45 years, there have been few clinical and no epidemiological studies of severely malnourished adults.

The most important reason for this inattention is that SAM only really occurs during famine and war, usually co-existing with extreme social disintegration and armed conflict. This makes study difficult, unpredictable and dangerous. The high mortality and extreme suffering characteristic of such situations also makes research more "ethically" challenging, with a powerful compulsion to act to address the immediate circumstances, rather than study to improve efficiency at some time in the future. This, and the relative inexperience of most famine-relief volunteers (see 2.01(c)), means that few workers devote time to research. Although understandable, this "action mentality" poses difficulties for those who wish to research in such situations as extra resources are rarely made available by programme managers.

The combination of social upheaval, armed conflict, massive need and low resources makes research difficult, and sometimes impossible. This is particularly true of prospective, randomised, blinded study designs which, to the knowledge of the author, have never been performed during famine conditions. Even epidemiological studies are often problematic and of a poor quality. For example the CDC study in Baidoa, sampling just 47 households, was the only epidemiological survey carried out in the whole of the Bay region of Somalia during one of the most severe famines ever recorded (Section 2.02). It is unthinkable that similar mortality rates in any stable situation would elicit such a limited scientific input.
Further problems for researchers are created by the physical danger of working in such environments. For example during the 1992 / 1993 famine in Somalia, violence claimed the lives of several expatriates and many local aid workers. During the past 7 years the author has been caught in crossfire, had his team kidnapped, experienced armed attacks on his house and had colleagues murdered. This is common when working in wars and famines and there is evidence of a substantially increased risk of death or serious injury amongst aid workers. (Schouten & Borgdorff 1995; Sheik et al. 2000) Consequentially there is reluctance on the part of scientists to work in such places and those researchers who do are usually those with fewer family commitments and responsibilities. Such people tend to be younger and by virtue of that fact, less experienced. This inexperience, combined with difficulties in communicating with distant supervisors, promotes lower standards of research. However, established academics in developed countries rarely understand such restrictions. (Caballero 1989) The difficulties of producing research that meet the high epistemological standards required during peer review for reputable scientific journals discourage publication and therefore funding of research programmes.

The result of these constraints is an almost complete absence of contemporary research into SAM. To the knowledge of the author, this work represents the first study for over 45 years attempting to research SAM during an emergency. Given the extent of the adult mortality and morbidity associated with large-scale emergencies (see Section 2.02) this represents a serious omission.

2.04(b) Secondary adult malnutrition

Valuable additional data has also been obtained from patients with severe malnutrition secondary to pre-existing systemic disease. (Heymsfield et al. 1984) However such research, although useful, is by itself not sufficient. There are major, clinically relevant, differences between primary and secondary malnutrition and between acute and chronic malnutrition. The processes of screening, diagnosis and management of severely malnourished adults are situation specific. For example, the instruments and techniques required for the assessment of a single patient in a western hospital differ to those required when poorly trained health workers screen thousands of people for entrance into a TFC. The quality of water and sanitation, the availability of famine foods, many of which are poisonous, the incidence of infectious disease and the irregular and variable supplies of relief food, all modify the presentation and management of severe primary adult malnutrition in ways that do not occur in secondary or chronic malnutrition. These differences necessitate research into primary malnutrition during famine.
2.04(c) Indicators for screening: a research priority

Section 2.02 argued that the provision of assistance to malnourished adults is one of the major tasks facing emergency famine-relief programs. At the height of a famine, when large numbers of people are competing for scarce resources, accurate targeting of emergency relief supplies is essential if impact is to be maximised. During the initial phases of famine-relief operations, resources are inevitably scarce and competition for them intense and there maybe thousands of adults crowding for admission to a single adult therapeutic centre. In dealing with such high demand for limited resources, screening admissions to feeding centres, in order to separate those who require special treatment in order to survive, from the majority who do not, is necessary. Violence is common in the pressurised atmosphere characteristic of these situations and when it occurs it is always the most severely malnourished, too weak to hold their own, who loose out. To minimise the risk of fights and riots, screening must therefore be as efficient and fast as possible.

Screening of children is carried out using anthropometric indicators based upon measurements of weight, height, and MUAC. (Hakewell & Moren 1991; Ville de Goyet, Seaman, & Geijer 1978) For adults, anthropometric indicators with cut-off values appropriate to severe famine do not exist. The lack of an appropriate screening tool to differentiate quickly between those requiring specialised assistance and those who do not, poses difficulties for famine-relief workers. In their absence, admission to adult feeding centres is somewhat arbitrary, based upon the subjective impression of the admitting clinician. These staff are often junior medical or nursing personnel who, in response to appeals and press reports of tragedy, volunteer to work with an aid agency for three to six months. Often they have little or no previous experience of similar situations. A good example is that of the author, who had never treated malnourished patients before being posted to Baidoa to provide medical and nutritional support to a feeding programme covering 450 therapeutic and over 10,000 supplementary patients. In the absence of clear guidelines, this limited staff experience means that rational patient selection is not guaranteed. Although, to the authors knowledge data do not exist, this combination of inappropriate guidelines and limited staff experience must have a negative effect on efficiency. Given the fierce competition for scarce resources during famine, and the very high mortality amongst severely malnourished adults not treated in specialised centres, this sub-optimal efficiency must translate into many potentially avoidable deaths.

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5 For example, on the day the Concern Worldwide adult feeding centre opened in Melanje (Angola) in November 1993, in the region of 2000 adults turned up to try and gain admission.

6 See previous note.
The development of indicators to enable the rapid screening of adult admissions to feeding centres is therefore a research priority. This screening is a different role to that of epidemiological evaluation of malnutrition at a population level or to the monitoring of an individual's response to treatment. The different demands placed upon an indicator in each of the roles have important consequences for the characteristics of a suitable indicator. These characteristics of indicators suitable for such differing roles have been well described by Habicht (Habicht 1980) and are briefly presented below.

**i. Surveillance**

In the epidemiological roles of assessment, monitoring and surveillance at the population level, the prevalence of malnutrition is the important parameter. The appropriateness of a nutritional indicator for such studies lies in its ability to reflect the true prevalence of malnutrition in a population. The objective of such epidemiological surveys is to provide knowledge in order to aid decision making at a community level and there are no immediate benefits for the individuals surveyed. (Sackett & Holland 1975) The numbers defined by the indicator are not related to the numbers requiring treatment and the cut-off points used can therefore be determined universally and do not need adjusting according to the resources available. So long as the estimated prevalence of malnutrition reflects the true prevalence in the population, a lack of sensitivity and specificity in the identification of individuals is unimportant. Errors in the determination of an individual's nutritional status (i.e. variation not dependent on nutritional status) are not problematic, so long these are normally distributed within the population. If this is the case, the data obtained can be standardised using a correction factor based upon the mean population error. The use of such correction factors allows the prevalence in malnutrition in different populations to be compared. This is not the case for indicators used in screening individuals (see below and 4.03(c) i and 6.05(a)).

**ii. Screening**

A very different set of criteria applies to the selection of an indicator for screening. Here the specificity and the sensitivity of the indicator for identifying individuals who require individual assistance, and the ease and speed of use of the indicator, are the important criteria of

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7 To reflect changes in true prevalence, the sum of the sensitivity (the ability of the indicator to correctly identify individuals who are positive for the condition) and specificity (the ability of the indicator to correctly identify individuals who are negative for the condition) at the chosen cut-off point, must be greater than 1. The greater this sum the more that changes in the indicator reflect changes in the true prevalence of the disease. (Habicht 1980)
appropriateness. The purpose of screening is to select individuals at increased risk and treat them. Thus the numbers defined by the indicator are those that need immediate treatment. (Sackett & Holland 1975) In emergency relief programmes, the appropriate indicator cut-off point is often that which selects exactly the number of individuals that can be treated with the resources at hand. (Habicht 1980) Such cut-off values cannot therefore be determined universally but must be tailored to suit the resources available in each particular situation. (Habicht 1980) In practice, the cut-off levels used in screening are based upon universal standards tailored to meet specific circumstances. (Ville de Goyet, Seaman, & Geijer 1978) Non-nutritional factors that change the indicator reduce both its sensitivity and specificity. This decreases the ability of the indicator to differentiate correctly between those individuals that require special intervention and those that do not. In contrast to the case of epidemiological indicators, such errors cannot be corrected for using a population mean value and require the extent of that variation to be individually assessed and allowed for. In practice this is rarely feasible (see 4.03(c) i and 6.05(a)).

**iii. Clinical monitoring**

The appropriateness of a nutritional indicator for the clinical monitoring of individual patients once they have been admitted to a feeding centre is based upon criteria that are different again. The requirements of an indicator for this role is sensitivity to changes in nutritional status, rather than either an ability to reflect prevalence or sensitivity and specificity in the identification of individuals at risk. For example, weight is neither a good indicator of prevalence of malnutrition nor useful in screening. It is however, a good and widely used indicator of the progress of an individual once admitted to a centre.
Chapter 3 Background to the studies and core methods

Section 3.01 Background

3.01(a) Concern Worldwide

The field research for this thesis was undertaken in Somalia during 1992&3, South Sudan during 1993 and Angola during 1993. During the fieldwork, the author was employed as a relief doctor by the Irish charity Concern Worldwide. Concern Worldwide is a non-governmental, non-profit organisation, based in Dublin Ireland. Emerging out of church relief programmes during the Bifaran war in 1967, Concern has expanded and secularised and now engages in a variety of developmental and relief work. The organisational aim is to provide relief and assistance to the poorest, most disadvantaged people in the world. At the time of writing, they work in approximately 20 countries, focusing upon relieving poverty through long term, sustainable programmes that improve local capacity through the facilitation and development of local resources. However, in the past few years the increased donor emphasis upon emergency response and the scale and media exposure of several humanitarian emergencies has forced Concern to become more active in emergency relief operations. In particular they have been involved in emergency responses in Somalia, Sudan, Angola, Rwanda, the Congo, Liberia, Sierra Leone, Afghanistan and the Democratic Peoples Republic of Korea.

The organisation has a strong volunteer ethos and the majority of their field staff, particularly in developmental programmes, are volunteers. These people receive only basic expenses based upon the local cost of living for their services. This was also the case for the majority of emergency staff who volunteered for 3 – 6 months and are paid living allowances plus £500 to cover mortgage expenses etc at home. However the extreme expansion in the numbers of emergency staff required and the "rights based" approach to humanitarian assistance (see the Sphere Project(1999) ), requiring greater professionalism, has fostered change in the organisation. Concern, along with many other relief NGOs have been forced to develop their core human resource capacity with professional workers whilst trying to maintaining the volunteer ethos. The huge elasticity in demand for staff and the absence of formal career paths have
hindered this process and Concern are not alone amongst aid NGOs in finding this organisational
development a difficult and challenging process.

3.01(b) **Concern adult feeding programmes where data were collected**


Study 1 took place in Baidoa, the town at the epicentre of the 1992 famine in Somalia. The famine
was caused by the civil war that followed the overthrow of the president Siad Barre in 1990. The
Bay region of the country was particularly badly affected, and by the autumn of 1992, tens of
thousands of people had migrated to Baidoa, the regional capital, in search of food. The death
rate among these people was one of the highest ever recorded in a civilian population (CDC 1992;
Moore et al. 1993) (see Table 1).

A large emergency food-aid programme started in Baidoa in August and rapidly expanded during
the next few months. The structure of this food distribution programme was unusual as, until the
end of December 1992, the conflict prevented an adequate general-ration distribution. In the
absence of a general-ration, relief agencies were forced to adopt a extensive wet-feeding strategy,
distributing pre-cooked food direct to beneficiaries in selective feeding centres and kitchens. The
primary beneficiaries of these programmes were children. By the peak of the programme, in
December 1993, 20,000 children were receiving either wet “supplementary” (approximately 8 MJ
day\(^{-1}\)) or wet 24 hour therapeutic rations (> 800 kJ kg\(^{-1}\) day\(^{-1}\)) each day.

By contrast, no specialised supplementary or therapeutic services were available for adults until the
end of October, when the Concern adult feeding centre opened. In the absence of specialised
adult feeding, all adults no matter how ill, were expected to survive given a once daily wet ration
from the ICRC adult kitchens. These kitchens had no medical input and, although supposed to
provide 8.4 MJ of energy (one plate of rice and beans a day), were plagued by looting and
shortages of supplies. Even when food was available, the lack of supervision and care meant that
the physical struggle of maintaining a place in the queue was often too much for the most severely
malnourished who frequently went without food and died.

On October 25\(^{th}\), Concerned opened Bardalli adult TFC and on November 4\(^{th}\), the author joined
the programme as the doctor in charge of medical and nutritional care.
The centre consisted of nine shelters constructed out of local sticks, imported monoflex plastic sheeting roofs and mud floors. These provided room for 140 inpatients and 140 family attendants who helped with the day to day care of their relatives. Separate shelters were designated for new admissions, those with severe oedematous malnutrition, those with dysentery and those suspected of having pulmonary tuberculosis. The staff consisted of the author, up to two expatriate nurses, depending upon evacuations and sickness, three local nursing staff and approximately 30 other helpers and cooks. These staff distributed the food and oral rehydration solution (ORS), encouraged patients to eat and drink, and helped feed those who were unable to feed themselves. High levels of supervision with one staff member to eight patients were maintained during the daytime. At night, frequent gun battles and attempts at hostage taking meant that supervision by expatriate workers was impossible.

The data included in studies 1, 3 and 4 were collected in the Baidoa centre from the beginning of November 1992 until the author's departure in March 1993.

**ii. Ayod, South Sudan (March – April 1993)**

Study 2 is based upon data collected in Ayod, South Sudan, during March and April 1993. Ayod is a small town in the West Nile province of Sudan, approximately 150 miles north of Juba. Although previously a colonial administrative centre, today the town consists of grass huts with one permanent building. Since the beginning of the war between the Khartoum government in the north of the country and the Sudan people's liberation army (SPLA) in the south, the town and surrounding area have experienced frequent, sporadic armed conflict. During early 1993, after a bloody split between the Torit (predominantly Dinka) and Nasir (predominately Nuer) factions of the SPLA, intense fighting again flared up in the area. This intra-SPLA fighting caused destruction of cattle and crops and massive displacement into the town. Although the extreme insecurity in the area precluded population estimates, it is likely that this displacement swelled the towns' population from approximately 1000 up to 15-20,000. (World Food Programme - Operation Lifeline Sudan 1993)

In March 1993, after the World Food Programme (WFP) opened the airstrip in the town and started general-ration distributions, Concern staff visited the town for an assessment mission. They were confronted with a very serious situation; widespread severe malnutrition in adults and children, obvious cases of bloody diarrhoea and many people obviously close to death. As the French NGO Medicine Du Monde (MDM) were in the process of starting feeding programmes...
for the under-fives, it was decided that Concern target specialised feeding for those aged five years and over.

On the 20th March, two Concern nurses arrived and started to construct a compound and two days later the author arrived to help implement inpatient care. By the end of the month, the programme was feeding 1,200 adults and adolescents, of which 70 were inpatients. Transport of staff and materials to and from the centre was a major constraint. Ayod was three hours flying time from the Operation Lifeline Sudan (OLS) base in northern Kenya and the airstrip was short and uneven, only accommodating planes carrying less than 7 MT. The scale of the OLS operations at the time also meant that there was great competition for planes between the various sites and in general only one aid flight was possible each day.

The logistic difficulties and the early phase of the relief operation in Ayod, meant that the conditions in the centre were far more rudimentary than in Baidoa. The centre was constructed out of grass and sticks with the use of some monoflex plastic. The food was cooked outside on open fires and the medicine given out from a cardboard box during the “ward rounds”. The medication available came from a basic IDA drug kit that contained cotrimoxazole, metronidazole and ampicillin as the only antibiotics. Despite these huge constraints, the response to treatment was usually good and within a week, the number of deaths in the centre had been reduced from several each day to almost none. Tragically, during the first week of April, the village of Ayod, including the Concern adult centre where the study was taking place, was attacked. The villagers were forced to flee and all Concern staff, including the author, were evacuated. When Concern workers were able to return to Ayod, the centre had been destroyed and the occupants had either fled or been murdered.

iii. Melanje, Angola (November – December 1993)

Some of the data included in study 3 come from the Concern adult and adolescent feeding programme in Melanje, Angola. Melanje is a large provincial capital approximately 300 miles to the east of Luanda. The town has always been under the control of the government Movement Patriotic Liberation Angola (MPLA). However, after the resumption of the civil war in Angola in 1992, it was surrounded by “The National Union for the Total Independence of Angola” (UNITA) forces and was shelled frequently. This UNITA action cut off all road access and meant that the flow of almost all food from the surrounding countryside into Melanje all but ceased. Consequently, the population was forced to rely on food flown in from Luanda supplemented by
the little they could grow in the small amount of agricultural land within the town. In addition, the fighting caused substantial numbers of people to leave their homes and seek refuge inside the government-protected area. Consequently, the town’s population, previously estimated at 250,000 increased to approximately 400,000 with the influx of around 150,000 – 200,000 internally displaced people (IDPs). (Government of Angola 1993; World Food Programme 1993)

The fighting, displacement and land blockade meant that the population’s food stocks were extremely low and it was estimated that 85% of the population were dependent on food-aid. This all arrived by air, via the World Food Programme (WFP) air-bridge, however, shortages of fuel, planes, congestion in Luanda and poor air-traffic control in Melanje meant that the quantities provided were insufficient. In December, it was estimated that less than 40% of the minimum needs of the town were being supplied. Predictable the result was an extremely high prevalence of malnutrition, estimated in November at 34% of all children between 6 and 59 months as moderately or severely malnourished (<-2 z-scores), with 20% of them severely malnourished (<-3 z-scores and 14% <-2 z-scores. (World Food Programme Melanje & MSF Belgium 1993) The author arrived in November 1993, during the first week of the first Concern operation, with an assignment to assess the situation and initiate appropriate responses. At that time, there were no mortality statistics available and one of the first tasks was to set up a cemetery surveillance programme and attempt to obtain some basic mortality data. The initial results of this programme are presented in Table 2, and showed that the workers watching the graves reported that over 76% of all bodies buried in the cemetery were over ten years. At that time, almost all the targeted feeding services were targeted towards children. CARITAS operated 73 centres of which only 2 are for adults and the government 17 centres, all for children. Recognising the large disparity between needs and services, Concern set up the Upokha adult and adolescent supplementary/therapeutic feeding centre. The centre opened on December 7th 1993. On the first day, there were crowds of several thousand adults and adolescents attempting to gain admission. These people were screened and registered during the following week and within 7 days, the centre was providing a ration of approximately 13 MJ day\(^{-1}\) to 1,100 patients. Initially the centre provided only daytime care, however, the poor state of health of many of the beneficiaries meant that within a few days, night time services including food and blankets were instituted.
Table 2

Reported age of death amongst 811 subjects buried in Melanje between November 27th 1993 and December 16th 1993. Data collected from the 21 cemeteries included in the Concern cemetery surveillance programme.

<table>
<thead>
<tr>
<th>age (years)</th>
<th>number of deaths</th>
<th>percentage of total deaths</th>
<th>cumulative percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9</td>
<td>187</td>
<td>23%</td>
<td>23%</td>
</tr>
<tr>
<td>10-19</td>
<td>136</td>
<td>17%</td>
<td>40%</td>
</tr>
<tr>
<td>20-29</td>
<td>108</td>
<td>13%</td>
<td>53%</td>
</tr>
<tr>
<td>30-39</td>
<td>116</td>
<td>14%</td>
<td>68%</td>
</tr>
<tr>
<td>40-49</td>
<td>105</td>
<td>13%</td>
<td>80%</td>
</tr>
<tr>
<td>50-59</td>
<td>62</td>
<td>8%</td>
<td>88%</td>
</tr>
<tr>
<td>60-69</td>
<td>41</td>
<td>5%</td>
<td>93%</td>
</tr>
<tr>
<td>70-79</td>
<td>18</td>
<td>2%</td>
<td>95%</td>
</tr>
<tr>
<td>80-89</td>
<td>14</td>
<td>2%</td>
<td>97%</td>
</tr>
<tr>
<td>90+</td>
<td>24</td>
<td>3%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Section 3.02 Methods

3.02(a) Subjects

Unless stated all subjects were patients at Concern Worldwide adult feeding centres. The profile of the populations included in the individual studies are included in the appropriate sections (see 4.04(a) 5.04(a) 6.04(a) and 7.03(a) ). In addition, study three includes two groups of more normally nourished adults (see 6.04(a) ).

3.02(b) Measurements, equipment and precision

In Somalia, the weight of the patients, in minimal clothing, was assessed using a set of standard ‘Hanson’ spring scales. The scales were calibrated in Baidoa and later upon return to London, using known weights. The results were similar at each site. In the useful range of 20 - 50 kg linear regression analysis indicated that there was a constant, linear increase in error (r = 0.99), with the true weight being expressed by the equation:

“True weight (kg) = (1.013987 * scale weight (kg)) + 0.707”
During analysis, the correction factor derived from this equation was used to correct each weight measurement used in the study. Locally constructed height boards and standard, non-stretchable tailors' tape measures were used to measure the height of patients.

In South Sudan and Angola, the weight of the patients in minimal clothing was assessed to the nearest 100 g, using Soehnle digital electronic scales, previously calibrated against known weights in the UK. These scales proved to be accurate and required no correction factors to be applied to the weights obtained. The heights were assessed using Microtoise stadiometers, recorded to the nearest 5 mm. All height measurements were made with the patients standing with their heels together, and legs and back as straight as possible.

MUAC was assessed on the subject's left arm hanging down loosely by their side, mid way between the olecranon and the tip of the acromion process of the scapular. A standard non-stretchable tailor's tape measure, read to the nearest 5 mm, was used.

3.02(c) Clinical data collection and coding.

i. Collection

In Baidoa, upon admission, patients were registered, weighed, and had their height measured by trained local enumerators, supervised by a specially trained nurse or the author. An admission BMI was calculated. A rapid clinical screen, assessing degree of pitting oedema, ascites, anaemia, level of hydration, dysentery, diarrhoea, signs of chest infection and ability to stand was performed by myself or an expatriate nurse. Individual treatment cards were then issued to each patient and this basic data recorded in them and in the centre's register. The clinical condition and weight of each patient was monitored during rehabilitation and the outcomes recorded.

In Sudan and Angola, data was not collected on patient's cards but was entered directly into the centres' register books.

ii. Data coding

'Admission BMI' was a BMI calculated from weight measurements taken within two days of admission. Pitting oedema was coded using the classification of Beattie et al., (Beattie, Herbert, & Bell 1948) (0 = absent, 1 = minimal oedema on the foot or ankle that was demonstrable but not visible, 2 = visible on foot or ankle, 3 = demonstrable up to knee, 4 = demonstrable up to inguinal
ligament & 5 = anasarca). Pitting oedema, recorded as present but unquantified, was assumed to be moderate (grade 3). Periorbital oedema was separately graded as 0 (absent), 1 (mild), 2 (moderate) and 3 (severe), with 'present but unquantified' oedema assumed to be grade 2. Ascites was graded as 0 (absent), 1 (mild), 2 (moderate) and 3 (severe), with 'present but unquantified' oedema assumed to be grade 2. Severe oedematous malnutrition was defined as either pitting oedema greater than grade 2, periorbital oedema greater than grade 1, or any ascites. Apparent dehydration was defined as sunken eyes, decreased urine output or dry mucous membranes. Missing data values were coded as not present. Many patients left the centre spontaneously, especially immediately before and during the planting season. If this defaulting was recorded on the cards and the patient had been otherwise well, these defaulters were coded as survivors. If no note was made as to the fate of the patient on the treatment card they were coded as "lost to follow up" and excluded from any survival analyses. Patients who were discharged to the MSF referral in patient department were followed and their discharge category in that centre recorded on the cards.

**iii. Data entry**

All data were entered in duplicate into a PC and validated for entry error using EPI-INFO version 6. (Dean et al. 1990)

**3.02(d) Data analysis**

All data entry and analysis were completed using EPI-INFO. v6.02 (Dean et al. 1990), Logistic (Dallal 1988) and curvefit professional V1. (Hyams 1993) Graphics were presented using Microsoft excel V5. (Microsoft Corporation 1994)

**i. The use of means, medians and geometric means**

In describing and comparing data such as the BMI and MUAC, a combination of means, medians and geometric means are used. If the data distributions approximated to a 'normal distribution', population means are quoted and if the distributions were skewed, population median values were used. As the sample sizes are relatively large and the statistics used relatively robust against departures from normality, a visual assessment of the distribution was used to assess approximation to normality. (Kirkwood 1992) In the case of 'lognormal' or approximately
lognormal distributions, a logarithmic transformation was used to normalise the data according to the method described in Kirkwood 1992, (Kirkwood 1992) and the 'geometric mean' quoted.

**ii. Use of Odds ratios**

Odds ratios were used for the presentation of the chances of mortality associated with BMI, famine oedema and clinical signs. Odds ratios were considered preferable to 'relative risk' as, within the cohort of patients admitted and followed up in the Baidoa centre, there were many patients that were lost to follow up. The reasons for these 'lost to follow up' was not known. Some patients would have been removed from the centre in order to allow them to die at home, other would have defaulted when they felt well enough to return home, especially when the planting season came. The selection of patients for whom there is data cannot therefore, be considered as random and the baseline for the study could not be the determination of exposure. Instead, the baseline for the study is the outcome, i.e. dead or alive. Those who died are equivalent to cases and those who lived equivalent to controls. The analysis of the risks of mortality is therefore treated as a case control study, nested inside the wider cohort study rather than a cohort study in it's own right.

**iii. Use of logistic regression**

Logistic regression analysis was used to assess the association of clinical features at presentation and dietary regimes with mortality. The use of logistic regression enabled other variables, potential confounders of the relationships of interest, to be included and controlled for in the analysis. This was performed by the “Logistic” computer package, using the multiple logistic regression model:

\[
\log \left( \frac{P(Y=1 | x_1, \ldots, x_p)}{P(Y=0 | x_1, \ldots, x_p)} \right) = b_0 + b_1 x_1 + \ldots + b_p x_p \] (Dallal 1988)

Where Y is a binary response variable such as died/survived and X1, . . . , Xp are explanatory variables. The explanatory variables included diet, BMI or oedema together with other potential confounders such as age, sex, date of admission, level of hydration etc. Variables that were not independently associated with mortality were eliminated from the models in both backwards and forward stepwise fashions using estimation techniques.
iv. Receiver operating characteristics (ROC) curves

This thesis uses ‘receiver operating characteristics’ curves (ROC) to examine the ability of an indicator to discriminate between patients with differing prognoses. These curves plot true positive rate (sensitivity) against the false positive rate (100-specificity) and are a useful means of assessing the trade off between sensitivity and specificity in a screening test. The values plotted to make the curve are obtained over a range of cut-off points. An ideal indicator has a sensitivity of 100% and a false positive of 0%. Such a point is at the top left-hand corner of a ROC curve. A random indicator has a straight-line plot passing through the origin with a slope of one. These basic parameters are presented in Figure 3. For assessing the performance of BMI in the prediction of mortality, the curves were constructed from the sensitivities and specificities obtained from 2*2 tables for BMI cut-off values of 10 kg m$^{-2}$ to 13.5 kg m$^{-2}$.

![ROC Curve](image)

**Figure 3**

*Receiver operating characteristic curve for near ideal and random indicators. The point “X”, at 100% sensitivity and 0% false positives represents the optimal performance of an ideal indicator.*
Section 3.03 Methodological issues

3.03(a) Constraints

All of the field work for this MD took place within war zones. This placed severe constraints on the quantity and quality of the data collected and the degree of control that was possible. In addition, each study site has specific constraints.

In Baidoa, the site of studies one, three and four, the frequent gun fighting, bandit attacks on expatriate staff houses, attempts at hostage taking, and military occupations that occurred during the study period, disrupted data collection. The frequency with which patients were weighed and the quality of the clinical data that was collected varied depending upon circumstances. For example, for much of the month of December 1992, the threat of an escalation of the war in Baidoa accompanying the American intervention forced the evacuation of all but the author and three other of concern’s expatriate staff. The author was left as sole supervisor for three therapeutic and four supplementary feeding centres with a workload that did not allow sufficient time to adequately supervise data collection and patient care in adult TFC. The high incidence of expatriate illness and resulting evacuations on medical grounds, contributed to the problems. All the expatriate staff working in the Baidoa adult centre, including the author, were medically evacuated at one time or another during the study period. This often left the centres short on supervision and forced the author to devote extra time to activities other than data collection.

The study in Ayod S. Sudan, originally aimed to investigate the use of MUAC and BMI as prognostic indicators for adults admitted to the therapeutic centre. As a result of the sacking of the village and murder of the inpatients (see 3.01(b) ii), the study was terminated before follow up data on the functional consequences associated with different indicator cut-offs could be obtained.

The Angolan data in study three, came from Melanje, a city surrounded by a hostile army and only accessible by air. The shelling of the city, particularly at night, and the threat from snipers and land mines, prevented adequate night-time supervision. The huge size of the centre, approximately 1,100 adult patients, the predominance of outpatients and the insecurity situation, meant that defaulters could not be followed up. This, again, prevented any analysis of the functional consequences associated with indicator cut-offs.
3.03(b) **Subject selection**

All subjects, were either inpatients or outpatients of adult feeding centres, in Somalia, South Sudan or Angola. As these were selected populations, with all subjects having presented and been admitted to a TFC and as such, they cannot be taken as representative of the general population. The effects of selection bias, resulting from differences in the frequency of presentation between certain sub-groups is difficult to evaluate. In Somalia, there is some evidence that men were preferentially transported to the centres (see 4.07(b)). In Sudan and Angola, the effects of this bias remain unknown.

Selection bias therefore complicates the interpretation of many of the data presented here. This weakens the ability of the studies to assess the appropriateness of indicators in the screening of adult patients to TFCs during famines. To assess such screening indicators, ideally, a study relating these nutritional indices to the risk of mortality in the general population is required. Such a population-based study could establish functional cut-off points that apply to the general population. Such studies have been used in stable, development settings, such as the ICCDR studies in Bangladesh, to assess child nutritional screening indicators. However, famines always involve massive social upheaval and large numbers of afflicted people and these, combined with the armed conflict that has characterised almost all famines during the last ten years, make such broad-based population studies unfeasible. Consequently, no such studies have yet been performed for any nutritional indicator in either adults or children during the height of a famine. Given these difficulties, studying selected feeding centre populations is a reasonable alternative. It is certainly better than the almost complete absence of information on the use and suitability of adult nutritional indicators in famine, that existed when the current work was started.

The admission criteria for each centre are reported in the specific methods section of each study (4.04(a), Section 5.03 i, Section 7.03). These admission criteria were necessarily variable. The demands placed upon the centres, the often-limited resources and staff, war and violence, sometimes forced the admission criteria to be tightened in order to avoid becoming swamped with admissions. The criteria quoted are the baseline criteria before any such restrictions were made. The existence and quality of alternative medical care also played an important role in patient selection, sometimes forcing the centres to admit some patients who were not primarily nutritional cases. For example, during October and November 1992, there were no alternative medical centres in Baidoa and 16 patients with BMI greater than 13.5 kg m\(^2\) and medical rather than

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8 The exception is the data from Concern workers and adult women in Somalia, included in study 3.
nutritional problems were admitted. Their data were excluded from analysis. This practice stopped in mid-December 1992 when a medical inpatient unit was opened in Baidoa enabling us to refer patients with primarily medical problems. In general, only patients with a measured BMI below 13.5 kg m$^2$, or those with famine oedema were admitted. Less severely malnourished people were referred to supplementary kitchens. Data from patients with BMIs $>13.5$ kg m$^2$ and no oedema were excluded from all analysis unless otherwise stated. In Melanje and Ayod, the alternative medical care was extremely rudimentary and some medical patients were included in the centres.

The potential inclusion of some primarily medical patients in the analyses is of most relevance in studies 1 and 4 where outcome is relevant to the study aims. The data for these two studies come from Baidoa. In this site, for four of the five months of the study, all primarily medical were referred away from the centre to the MSF Holland inpatient department in the town. During the first month when such referrals were not possible, the relative completeness of the data set, including inpatient registers and individual inpatient cards usually completed by the author, allowed most primarily medical cases to be excluded. For studies 2 and 3, the effect of the inclusion on medical patients is unknown. This is of less importance, as outcome is not under consideration in these studies. However, it is likely that concurrent disease does alter the relationship between MUAC and BMI. This is discussed in 6.05(c).

### 3.03(c) Controls

Study 4 aimed to assess the effectiveness of two diets in the treatment of severe adult malnutrition by comparing two groups of patients receiving different diets. There were however, many problems with the study design and implementation. In particular confounding factors surrounding allocation of patients to the diets during the dietary treatment, the use of ORS and actual dietary intake make interpretation tentative. These are discussed in Section 7.05.

### 3.03(d) Measurement errors and training

Conditions in the study sites were disorganised and confused, with extremely high rates of mortality and morbidity (see 3.01(b)). Often at the start of programmes, there were few trained staff to cope with the very high levels of unmet need amongst the population. Workloads were therefore high and time available for supervision, low. These conditions promoted errors of
precision, accuracy and reproducibility in the assessment of height, weight, MUAC and clinical data. They also precluded any assessment of food intake (see 7.03(b)).

Several attempts were made to reduce and to quantify measurement errors. In all sites the registrars responsible for weighing, measuring and assessing MUAC were literate and were trained before and during the studies. However, the need to set up centres quickly, the high workloads, and the few experienced workers available limited their training and supervision.

In Baidoa, almost all the clinical data from the adult TFC was collected and recorded by the author, a medical doctor. In the Angolan TFC, although the author screened most of the admissions for oedema and gross nutritional status, the collection and recording of oedema and ascites was performed by local nurses. These people were trained and supervised by an experienced expatriate nurse who had also worked in the Somali centre. During the study period, Melanje was a besieged town under artillery attack, the town’s food supply had been inadequate for many months and the population had been doubled by the many malnourished people displaced from the countryside. These difficult circumstance, coupled with the need to set up nutritional centres quickly in the face of widespread severe malnutrition and death, meant it was impossible to give the local staff comprehensive training before the centre opened.

Given these constraints, problems with the quality of the data collected in all the study sites cannot be ruled out. This must make the interpretation of results more tentative. However, random errors in data collection would have been accounted for by the statistical methods used. Systematic errors were potentially far more serious and several steps were taken to avoid introducing systematic errors into the data. Systematic errors in the precision of the scales used in Baidoa were identified and a correction factor built into the analyses (see 3.02(b)). Scale calibration in Angola and South Sudan revealed no such systematic errors in precision.

In Somalia, an assessment was made of the accuracy and reproducibility, with which the height, weight and MUAC measurements were performed. In the TFC a composite error of reproducibility, consisting of both “intra” and “inter” observer errors was calculated by comparing repeat BMI assessments made on the same patients separated by a three-hour period. The BMI assessments were done in a blinded fashion with the registrars involved not knowing the results of the previous estimations. The index is composite because the registrar that made the first measurement was not recorded.
The errors recorded were normally distributed in the 107 subjects assessed, with a mean error of 0.115 kg m$^{-2}$ and similar magnitudes of error for each registrar ((ANOVA) $F = 0.79$ d.f. = 1, 106, $p = 0.38$). No systematic errors were identified. These data are presented in Figure 4.

**Figure 4**

*The distribution of errors of reproducibility in BMI assessment in 107 patients measured and weighed by the two registrars in the Baidoa adult TFC. The mean error was 0.115 kg m$^{-2}$, (registrar 1 = 0.15 kg m$^{-2}$ and registrar 2 = 0.06 kg m$^{-2}$ (ANOVA $F = 0.79$ d.f. = 1, 106, $p = 0.38$).*

MUAC in children is known to associated with inter and intra observer errors in reproducibility. (McLaren 1986) In Somalia the reproducibility of the MUAC assessments performed upon the study group of Concern staff were assessed by repeating 67 of the measurements. These showed that the mean error between the two MUAC measurements was 0.022 cm (S. D. 0.277), equivalent to a percentage error of 0.074%. The mean BMI error for the same subjects was 0.014 kg m$^{-2}$ (n = 66, S. D. 0.283), equivalent to a percentage error of 0.05%. Both the MUAC errors and the BMI errors were normally distributed. In Angola and Sudan, no such assessments of error were made.
i. Conclusions

Many methodological problems complicate the interpretation of the data presented in this thesis and weaken many of the conclusions drawn. The data do however provide “conjectures” as to the limits of human adaptation to starvation, the usefulness of BMI and MUAC for assessing adult malnutrition and the desirable level of protein in rehabilitation diets. These conjectures provide a hitherto non-existent base of empirical data and being clearly stated, are amenable to the possibility of refutation. Such development of conjecture based upon empirical methods is at the centre of good scientific method. (Popper 1960) Despite the many methodological problems, they represent an advance in the subject, laying a foundation for future investigations into the management of severe adult malnutrition during famine and war.
Chapter 4 Study one: Is BMI a useful tool for the assessment of severe adult malnutrition during famine?

Section 4.01 Aims

To investigate whether BMI is a useful tool for the assessment of severely malnourished adults and adolescents during famine. To examine the risks of mortality associated with different levels of BMI, in patients admitted to a TFC during the height of a severe famine and explore the potential of BMI as a screening tool in these situations.

In particular, the questions of, whether a lower limit of BMI, beyond which recovery is not possible, exists and whether there are specific thresholds of BMI, below which patients require specialised rehabilitation in order to survive, are examined. Practical aspects of the use of BMI are also investigated.

Section 4.02 Introduction

This study took place in the concern adult TFC in Baidoa, the town at the epicentre of the 1992 famine in Somalia. For a description of the background to the famine, centre and study see 3.01(b) i. One of the most difficult operational problems was deciding who to admit and who to turn away. Reviews of literature by Concern's Dublin office and attempts to gain advice from other nutritionists, at the time proved, unhelpful. In then field, nobody was able to provide us with realistic admission criteria for such a centre and, despite the presence in Somalia of a very many experienced famine-relief workers, nobody had experience of running such a centre. This subsequent research project has revealed that this was because our centre was probably the first such adult TFC since the liberation of the concentration camps at the end of the Second World War.

Under the extreme conditions present in Baidoa at that time (see Section 2.02 and 3.01(b) i), a useful indicator for screening adult admissions, was one that could rapidly differentiate between those who require treatment and those who did not. Central to this was the ability of the indicator to reflect risk of mortality. It was also important that the measurements required were easy to
obtain under the very difficult conditions that existed. If they were not, the high demand for the centre and the limited numbers of trained staff, would mean that the indicator would not be used.

The concept of the usefulness of BMI, the subject of this study, is a combination of BMI’s ability to reflect risk of mortality in starving adults and the ease with which it can be used during emergency feeding programmes. In particular, the ability of BMI to differentiate between three grades of malnutrition; those who will survive without specialised therapeutic care; those who require specialised nutritional support to survive and those who will not survive whatever were considered important.

Three basic questions were asked:

- Is there a level of BMI below which recovery is not possible?
- Is there a level of BMI below which, prognosis is worse and specialised treatment required?
- Are the measurements required feasible under the conditions that prevail in a TFC during the height of a famine?

Section 4.03 Literature review

4.03(a) BMI in the assessment of chronic malnutrition in adults

BMI (wt (kg) m\(^{-2}\)), sometimes called de Quetelets index, was originally promoted as an indicator for the assessment of obesity in adults. (Garrow & Webester 1985) In obese adults the relationship between grades of obesity, defined by BMI, and morbidity and mortality has been well investigated and the evidence for an increased risk of morbidity and mortality above a BMI 30 kg m\(^{-2}\) is now generally accepted. (Byers 1996) In 1988, the use of BMI was extended and three BMI cut-off, 18.5, 17 and 16 kg m\(^{-2}\) were proposed. (James, Ferro-Luzzi, & Waterlow 1988) This classification has since provided a useful framework for the analysis of height and weight data from malnourished adult populations. It is also attractive since it conformed to the three grades of childhood malnutrition originally proposed by Gomes et al (Gomez & et al. 1955) and the three grades of adult obesity proposed by Garrow. (Garrow 1993)

The evidence for functional consequences of these lower BMI cut-offs is however, problematic. Some of the large-scale population based studies in developing countries, have indicated that the relationship between risk of mortality and BMI is “U” or “J” shaped. In simple bivariate analysis, mortality appears to increase below a BMI of 18.5 or 19 kg m\(^{-2}\). (Ferro-Luzzi et al. 1992; James 1994;
Kushner 1993; Waaler 1984) However, when the effects of confounders, such as cigarette smoking and concurrent sub-clinical disease, are excluded from the models, this excess mortality mostly disappears. (Iribarren et al. 1995; Kushner 1993; Manson et al. 1995) This lack of evidence most probably reflects the low proportion of the population in developed countries with BMI values under 18.5 kg m\(^2\) and no concurrent illness, rather than the absence of an increased mortality at low levels of BMI. In theory therefore, data from populations in developing countries, where a far higher proportion of the population have BMIs below 18.5 kg m\(^2\), might be expected to provide good evidence of the functional consequences of low BMI. Such evidence is, however, scarce.

Few longitudinal studies of the relationship between low BMI and mortality or morbidity exist and the retrospective, cross sectional design, of most hinders interpretation. An exception comes from a prospective study of the relationship between low BMI and mortality in Indian labourers. This ten-year follow up of a cohort of 792 Indian labourers provides evidence of an increase in mortality in subjects with low BMIs. In this study, men with a BMI below 16 kg m\(^2\) exhibited mortality rates almost three times than those with a BMI greater than 18.5 m\(^2\) (higher (CMR 32.5% compared to a CMR of 12.1%). (Reddy 1991) However, the mortality rates quoted are unadjusted for age and concurrent disease and it is not possible to differentiate between excess mortality directly attributable to CED and that attributable to other risk factors. Recently a 5 year follow up of a cohort of adults in Papua New Guinea reports an increased mortality and morbidity of adults with low BMI, even after the effects of concurrent disease are controlled for. Preliminary results indicate that those with CED (BMI< 18.5kg m\(^2\)) had a relative risk of mortality of 1.87 and a relative risk of subsequently reporting morbidity of 3.00 when compared to the non-CED group. (Duffield 1998)

4.03(b) BMI and body composition

The use of BMI as an indicator of adult malnutrition has arisen out of an appreciation of its usefulness in obesity. Consequently to date, almost all the data on the relationship between the index and body composition are from adequately nourished populations. These data have been reviewed by Norgan. (Norgan 1994a) In obesity, it has been shown that when a person puts on weight, the added tissue has a roughly constant ratio of fat to lean tissue. This results in a strong relationship between BMI and body fat content, with correlation coefficients in the region of 0.955. (Webster, Hesp, & Garrow 1984) This provides a theoretical rational for using the index as a screening tool for excess adiposity. (Lazarus et al. 1996) However, newer more accurate newer methods of body composition analysis such as Dual-energy X-ray Absorptiometry (DXA) or bio-
electrical impedance, have shown that BMI cannot explain a significant proportion of the variation in body fat content and there is a wide range of body fat percent for any given BMI. (Roubenoff, Dallal, & Wilson 1995; Smalley et al. 1990) For example, a BMI of 20 kg m\(^2\) in an adult woman corresponds to a range of 13-32% body fat. (Hortobagyi, Israel, & O'Brien 1994) The relationship between BMI and percentage fat is also sex dependent and at any given BMI, women have a higher percentage of body fat. (Forbes 1987; Gallagher et al. 1996; Norgan 1994a; Ross et al. 1994)

The relationship between body composition and BMI in adult under-nutrition is less clear. Of the few studies available, some from developing countries have questioned the use of BMI as a classification of CED. (Immink, Flores, & Diaz 1992) Of particular interest in the current context are questions over the premise that the composition of tissue laid down during weight gain is constant. This appears not to be true at low levels of body fat. Forbes has argued that the composition of tissue lost or gained varies according to the initial level of fatness and there is less fat in tissue change, at lower levels of fatness. Models of this effect suggest that below a body fat content of approximately 8%, equivalent to a BMI of 18 kg m\(^2\) in men, BMI falls more quickly than the % fat. (Forbes 1987) Although there is some empirical data to support this model, the small selective sample of only 164 Caucasian women, is insufficient to determine how applicable the model is to men or to other ethnic groups.

In severe acute malnutrition the relationship between BMI and body fat content is important, and although disagreements continue, the availability of body fat appears to be a central limiting factor in the survival of the severely malnourished. (Forbes 1983; Kerr, Stevens, & Robinson 1978; Korcok 1981; Leiter & Marliss 1982) These data are discussed in 4.03(e) iii.

### 4.03(c) Determinants of BMI

In health body shape, age and sex are determinants of BMI, independent of nutritional status. Given the steep gradient of BMI cumulative frequency plots in third world adult populations, (James & Francois 1994) even small effects caused by non-nutritionally based variables, can produce substantial changes in the nutritional status of large numbers of people as defined by BMI. (Norgan 1994b)
**i.Body shape**

BMI is dependent on stature and BMI values decline as height increases. In the 1983 metropolitan Height-Weight tables, the ideal ranges of body weight in women corresponds to a BMI of 21.4 - 27.4 kg m\(^{-2}\) in the shortest and 18.8 to 24.8 kg m\(^{-2}\) in the tallest. (Kushner 1993) Inter-ethnic differences in body shape, particularly with regards to the relationship between BMI and the SH/S ratio or sitting height stature ratio (sitting height (SH) / total height (S)) are also well documented. African and Australian Aboriginal phenotypes tend to have longer legs in comparison to their trunk and therefore a lower SH/S ratio, whereas the legs of Asians and Far Eastern populations are proportionally shorter. These differences result in worldwide variation in the SH/S ratio from 0.48 in Australian aborigines (Norgan 1994c; Norgan 1994b) up to 0.55 in the Japanese. (Norgan 1994c) This has a considerable bearing on BMI which, at the extremes of the range of SH/S ratio, are equivalent to a variation of almost 5 kg m\(^{-2}\) in BMI (see Figure 5). This probably explains much some of the differences of 3 kg m\(^{-2}\) in mean adult BMI values found in populations around the world. (Eveleth & Tanner 1976)

![Figure 5](image)

*Figure 5*

*The effect of varying sitting height: stature ratio (SH/S) on the relationship of Body Mass Index and SH/S ratio in a 70 kg, initially 1.75 man (reproduced from Norgan 1994(Norgan 1994d)*
Correction for this variation in SH/S ratio, using a correction factor based upon the mean SH/S ratio value for the particular population, is possible. In this way, comparisons between ethnic groups can be made and BMI remains useful for population monitoring and surveillance (see 2.04(c) i and 6.05(a)).

Considerable intra-population variation in SH/S ratio also exists. In an aboriginal population studied by Norgan, the intra-population range for SH/S ratio was 0.41 - 0.54 (mean 0.48, S. D. ± 0.02). (Norgan 1994b) This is larger than the world-wide variation in population mean values of SH/S ratio(Norgan 1994c) and is equivalent to a 4 kg m\(^2\) intra-ethnic variation in the range of BMI, dependant on shape and independent of nutritional status. This, non-nutritional variation, weakens the relationship between BMI and "true" nutritional status in any particular individual and can only be corrected for by the concurrent estimation of individual SH/S ratio values. If the individual SH/S values are not corrected this variation lowers both the sensitivity and specificity of BMI as a screening indicator of individual nutritional status. The practicalities of routinely measuring sitting height during an emergency programme are discussed in 4.07(e).

\textit{ii. age}

Adult body size, shape and composition vary with age, (Borkan & Norris 1977; Forbes & Halloran 1976; Gallagher et al. 1996; Mazariegos et al. 1994; Noppa et al. 1980; Norgan 1994a; Rolland-Cachera et al. 1991; Stoudt et al. 1965; Strickland & Ulijaszek 1992; Wang et al. 1994) and these change alter the significance of BMI and also the ease with which the requisite height measurements can be taken. The adolescent growth spurt produces a rapid increase in length that is not matched by weight increases. This causes high rates of change in the mean BMI with increasing age in adolescents and young adults. This may explain some of the extremely low BMIs found in anorexic patients (see 4.03(e) ii). Increased prevalence of spinal disease (predominantly osteoarthritis and osteoporosis) that decrease subjects capacity to stand straight to have their heights measured makes the application of BMI difficult or impossible in an increasingly large proportion with increasing years. (Todorovic 1998) These changes in BMI with age have been well-documented developed country populations (see Figure 6). (Rolland-Cachera et al. 1991)

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the metropolitan Height-Weight tables are often used as the basis for the determination of "ideal" body weights based upon risk of mortality
Figure 6

*BMI centiles by sex and age in the French population* (Rolland-Cachera et al. 1991)

In addition to the influence on body shape, age also affects body composition. Adults tend to lose FFM and increase FM with age (Forbes & Reina 1970) and these changes alter the functional significance of BMI at different ages. In people aged over 85 levels of BMI > 30 kg m², considered as grade 1 obesity and associated with increased morbidity and mortality in younger adults, are beneficial. Conversely levels below 20 kg m², a level where mortality is at it lowest in younger adults is associated with a considerable lower five years survival rate in people aged 85 and over (see Figure 7). Lead-time and socio-economic biases contributes to this effect, however even when concurrent disease and socio-economic factors are controlled out, the effect appears to
remain. Changes in body composition, with a decrease in body fat with age might be relevant factors (see 4.03(b) and 4.03(e) iii).

From the above discussion, it is clear that age must be taken into account when interpreting BMI and deciding if BMI is a relevant nutritional indicator. (James & Francois 1994)

Figure 7

key: (all values in kg m\(^{-2}\))

\[ \geq 28, \quad \ldots \ldots \quad 26 - 27.9, \quad \ldots \ldots \quad 24 - 25.9, \quad \ldots \ldots \quad 22 - 23.9, \quad \ldots \ldots \quad 20.0 - 21.9, \quad \ldots \ldots \quad < 20.0 \]

Five year survival curves according to Body Mass Index in subjects aged 85 years and over. Reproduced from Mattila, K. et al, 1986 (Mattila, Haavisto, & Rajala 1986)

**iii. Gender**

The same BMI cut-off points for CED have been proposed for both men and women. (Ferro-Luzzi et al. 1992; James 1994; James, Ferro-Luzzi, & Waterlow 1988) These are however, tentative, based on limited data of the functional consequences of low BMI (see 4.03(a) ). Data from developed countries indicate that sex differences in the relationship between BMI and body
composition exist (see 4.03(b)) and have been used to argue for sex specific cut-offs for obesity. (Hortobagyi, Israel, & O'Brien 1994) In other studies on obese subjects, sex specific functional consequences of BMI cut-offs have been demonstrated with respect to risk of disease, (Delpeuch et al. 1994; Strickland & Ulijaszek 1992) levels of blood markers (Folsom et al. 1994) and significance of genetic differences. (Harris, Tambs, & Magnus 1995) These finding are however not universal. (Negri et al. 1992; Tuomilehto 1991) Given the importance of body fat during severe starvation (see 4.03(e) iii), sex differences in body fat at any given BMI are likely to result in sex specific BMI cut-offs. This appears to be the case in the data reviewed by Henry (see 4.03(e)), but data are at present scant. This study attempts to shed light on this issue.

iv. Ethnicity

Ethnic variations in body shape, particularly the SH/S ratio have been explored above. In addition to this effect, ethnic differences in body composition may mean that the nutritional significance specific BMI levels also varies between different ethnic groups. In particular, there appears to be substantial inter-ethnic variation in the percentage of body fat at any given BMI (for examples see Figure 8). Survival in starvation is intimately related to body fat content (see 4.03(e) iii) and this inter-ethnic variation may well result in BMI cut-offs having different functional significance for different ethnic groups. Such differences may result in different BMI cut-offs for different ethnic groups.

10 With the increasing availability of newer, highly accurate techniques for estimating body composition such as neutron activation and dual photon absorptiometry these differences are becoming ever more precisely quantified. To date all these studies using such sophisticated technology have been performed on relatively well nourished ethnic subgroups living in developed countries and now validation has been attempted upon those suffering from CED or AED in the developing world. (Wang et al. 1992; Wang et al. 1994)
Figure 8

Body Mass Index and body fat in adults from different parts of the world. Data from studies on 226 Italian men aged 38 +/- 7.4 and 76 women aged 37 +/- 5.5 years; 482 Ethiopian and Somali men aged 33.4 +/- 13.1 years; 255 Ethiopian women aged 36.1 +/- 12.1 years; 18 New Guinea men aged 31.3 +/- 8.2 years and 90 women aged 29.4 +/- 5 years. The mean +/- 2 S. D. lines refer to data from 5072 UK soldiers studied by Durnin et al. (1984) and predominantly aged 17-34 years. Most of these estimates of body fat in the Italian and New Guinea studies were from body density and the others from skinfold thickness measurements. Reproduced from James et al. 1988.

(James, Ferro-Luzzi, & Waterlow 1988)

4.03(d) The use of BMI to screen severely malnourished adults

To date all research into the use of BMI in the assessment of malnutrition has focused upon the assessment of chronic malnutrition in stable populations. This role is primarily that of the epidemiological surveillance of chronic malnutrition at a population level. This is a very different role to that of screening individuals suffering from acute malnutrition, in order to regulate admissions to feeding centres. The demands placed upon an indicator for surveillance are not the same as those for screening (see 2.04(c)). The common assumption, in contemporary NGO field manuals and recent academic articles, (Boelaert et al. 1995; Ferro-Luzzi & James 1996; Young 1992) that BMI is also an appropriate indicator for screening during famine, has not been tested. Indeed BMI cut-offs for screening adult admissions to feeding centres, extrapolated directly from the definition of severe adult CED, can be highly inappropriate. The cut-off of 16 kg m⁻², that appears in two of the largest relief agency field manuals, (Boelaert et al. 1995; Young 1992) would, in Baidoa during the end of 1992, have selected almost all of the adult population, estimated at 50,000. (CDC 1992) At that time, numbers of adult therapeutic places available in Baidoa was only 150.
Obviously few out of the 50,000 were admitted to adult TFC, however, many did survive given only a basic general-ration or one cooked meal a day. This indicates that 16 kg m\(^2\) BMI cut-off did not reflect a degree of starvation that required specialised treatment.

Such non-specific cut-offs are unhelpful for screening. The 16 kg m\(^2\) threshold for severe CED was proposed for the surveillance of the nutritional status of populations and relates to the risk of long-term functional consequences in the absence of intervention. (Ferro-Luzzi et al. 1992; James, Ferro-Luzzi, & Waterlow 1988; James & Shetty 1994; Naidu & Rao 1994) In famine, such long-term functional consequences are largely irrelevant and it is the ability to ascertain the immediate risks of mortality and degree of nutritional support that individuals require, that are important. There is no reason to suppose that the BMI cut-off that relates to long-term consequences is the same as one that relates to such short-term consequences. Until now, there have been no data from adults in famine available and the usefulness of BMI for screening in such circumstances remains untested. This study aims to do that.

4.03(e) Previous investigations into the limits of human response to starvation

i. Evidence from famine victims

Some of the earliest height and weight data from severely malnourished adults was recorded by doctors working for the colonial medical service in Madras during the famine of 1877. Although there is little data from individuals, some composite data for those that died does exist. Porter reportedly recorded the weights and heights of 30 non-oedematous and 13 oedematous male subjects who died of starvation. The mean BMIs at the time of death were reported as 13.6 kg m\(^2\) and 18 kg m\(^2\) in the non-oedematous and oedematous subjects respectively (Porter 1899). Interpretation of population means in the absence of information on the shape of the population distribution must however be tentative. If there is a fixed BMI threshold below which life is unsustainable, the distribution of the BMI values would be expected to be positively skewed.\(^{11}\) In a skewed distribution the geometric mean, or the median, are describe the population better than the mean. In a positively skewed distribution, these are lower than the mean. The mean values reported above are therefore of limited values in establishing the lower limit of BMI compatible with survival. The records do however record the interesting observation that the men who died

\(^{11}\) This was the case in the Baidoa data (see 4.06(a) ii).
had lost a greater proportion of their body weight than the women, with both sexes dying at a mean body weight of 77 lbs.

Several studies into adult malnutrition took place during the 1st world war. All appear to have been clinical studies primarily concerned with famine oedema (see review by McCance et al. 1951 and Keys 1950( Keys 1950a; McCance & Widdowson 1951 ) ), and height and weight data were not usually recorded. At the time of the Second World War, adult malnutrition was again common and several studies were performed. Reports from the Warsaw ghetto(Winick 1979) , France, (Debray et al. 1946; Zimmer, Weil, & Dubois 1944) the concentration & prisoner of war camps, (Leyton 1946; Lipscomb 1945; Mitchell & Black 1946; Mollinson 1946; Murray 1947; Vaughan & Pitt Rivers 1945) Holland during 1944-5, (Burger, Sandstead, & Drummond 1945) and in post war Germany(McCance & Widdowson 1951) have been studies for this review. In these studies although weight and height data were rarely collected in a systematic fashion some relevant information, particularly percentage of the original body weight that was lost, are available.

Frenchmen transferred from the Nazi concentration camps to the Salpietre hospital in Paris were frequently reported to have experienced a reduction in body weight of 30 kg approximately 40% of their normal body weight. (Debray et al. 1946) Given a mean BMI for a normal European population of 22 kg m\(^{-2}\) this represents levels of BMI in the region of 13 kg m\(^{-2}\). One 19 year old male is reported to have been repatriated to France from the camps with a BMI of 9.5 kg m\(^{-2}\) (Ht 172 cm, wt 28 kg) however no note is made as to whether he survived. (Debray et al. 1946) In the internment camps of the unoccupied zone of France, weight losses of up to 49% were recorded in both male and female internees. The distribution of weight loses were positively skewed (see Figure 9) and women exhibited greater weight loss than men (median values 25 - 30 % in women and 18-22% in men. The high prevalence of famine oedema in the camps (48% in men and 52% in women) and the failure to differentiate between oedematous and non-oedematous patients in the weight data, means that these figure are likely to underestimate the true extent of the weight losses. (Zimmer, Weil, & Dubois 1944)
Figure 9

Distribution of the percentage of physiological weight in male and female inmates in the internment camps in the occupied zones of France during 1942. Not given in the text but the population of the camps were stated elsewhere to be approximately 10,000, divided up into individual camps of approximately 2,500 people. (Zimmer, Weil, & Dubois 1944)

In Belsen concentration camp, even greater estimates of weight loss, as a percentage of previous body weight were recorded (see Table 3). Extreme as some of these weight losses appear, the author states them to be an underestimate of the degree of emaciation seen in the concentration camp. Mollinonon reports that the most severely emaciated patients had been too ill to be weighed and because of this the data in Table 3 were recorded some days after the start of treatment, presumably after some increase in weight had occurred. (Mollinonon 1946)
Table 3

Loss of body weight in 10 patients liberated from Belsen concentration camp (Mollinson 1946)

<table>
<thead>
<tr>
<th>case</th>
<th>weight</th>
<th>original weight</th>
<th>weight loss</th>
<th>weight loss (% of original weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>m42</td>
<td>35.0</td>
<td>80.0</td>
<td>45.0</td>
<td>56.3</td>
</tr>
<tr>
<td>f116</td>
<td>25.0</td>
<td>50.0</td>
<td>25.0</td>
<td>50.0</td>
</tr>
<tr>
<td>fx1</td>
<td>34.0</td>
<td>63.0</td>
<td>29.0</td>
<td>46.0</td>
</tr>
<tr>
<td>m37</td>
<td>39.0</td>
<td>67.0</td>
<td>28.0</td>
<td>41.8</td>
</tr>
<tr>
<td>f114</td>
<td>35.1</td>
<td>56.0</td>
<td>20.9</td>
<td>37.3</td>
</tr>
<tr>
<td>fx4</td>
<td>39.9</td>
<td>62.0</td>
<td>22.1</td>
<td>35.6</td>
</tr>
<tr>
<td>m35</td>
<td>32.0</td>
<td>50.0</td>
<td>18.0</td>
<td>36.0</td>
</tr>
<tr>
<td>f111</td>
<td>31.0</td>
<td>47.0</td>
<td>16.0</td>
<td>34.0</td>
</tr>
<tr>
<td>f124</td>
<td>33.2</td>
<td>48.0</td>
<td>14.8</td>
<td>30.8</td>
</tr>
<tr>
<td>f101</td>
<td>33.0</td>
<td>47.0</td>
<td>14.0</td>
<td>29.8</td>
</tr>
</tbody>
</table>

Amongst the records written by the doctors in the Warsaw ghetto during 1942 - 1944 are occasional weight and heights data. Eighteen patients aged between 16 and 42 years (mean 27 years) were recorded as having weight losses of 50% of their original body weight resulting in a mean weight of 32 kg. (Apfelbaum-Kowalski 1979) Unfortunately, neither the height nor the sex of the subjects are available from these records. However if the mean BMI of these subjects is assumed to have been in the middle of the normal range (18.5 - 25 kg m^2) a 50% reduction in weight would result in a mean BMI of approximately 11 kg m^2. Such an estimate seems reasonable and when combined with the mean weight of 32 kg gives a mean height of 1.7 m, a reasonable value for a mixed Caucasian population. One record where height and weight data exist is of a woman aged 30 years with a reported weight of 24 and height of 1.52, equivalent to a BMI of 10.4 kg m^2 (Fliederbaum et al. 1979)

Records from the Dutch winter famine of 1944-5 contain more anthropometric data from both survivors and non-survivors. In these data, collated by Henry, (Henry 1990; Henry 1993) the mean values of BMI in both survivors (17.4 kg m^2, n = 16) and non-survivors (13.3 kg m^2, n = 5), are considerably higher than those estimates from the Warsaw ghetto (see above). A possible explanation for these differences could be the low ambient temperature during the Dutch winter combined with the lack of fuel for heating. Such an explanation is consistent with the many observations that hypothermia and an inability to control body temperature are usual in malnutrition (Keys 1950a; Winick 1979) and the reports of higher death rates from starvation that
occur during the winter months. (Zimmer, Weil, & Dubois 1944) 4.07(a) provides further discussion of possible reasons for these differences, pertaining to the current data.

Despite several severe post war famines, in particular in India and the African continent and the frequent studies that have taken place during these famines, height and weight data from severely malnourished adults do not appear to have been recorded.

**ii. Evidence from Anorexia nervosa**

Extremely low levels of BMI are relatively common in anorexia nervosa. Early studies of adolescent girls include descriptions of a BMI of 8.7 kg m^2 (Stephens 1895) in a 16 year old measured and weighed at autopsy 56 hours after death, and 9.9 kg m^2 (Gull 1888) in a 14 year old who survived. This century several series of anorexic nervosa patients with extremely low BMI have been reported. Based upon data collected from adult women with anorexia nervosa and extreme emaciation (see Table 4), Berkman argued that a reduction of greater than 50% of the original body weight was the critical level below which recovery was less likely.

**Table 4**

*Height and weight data on 4 adult female anorexic patients (LTF = lost to follow up). Adapted from Berkman et al 1947* (Berkman, Weir, & Kepler 1947)

<table>
<thead>
<tr>
<th>Case number</th>
<th>Age years</th>
<th>Weight kg</th>
<th>Height m</th>
<th>BMI kg m^2</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24</td>
<td>22.7</td>
<td>1.6</td>
<td>9.1</td>
<td>Lost to follow up</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
<td>23.2</td>
<td>1.6</td>
<td>8.8</td>
<td>died</td>
</tr>
<tr>
<td>7</td>
<td>32</td>
<td>27.0</td>
<td>1.6</td>
<td>10.6</td>
<td>recovered</td>
</tr>
<tr>
<td>18</td>
<td>31</td>
<td>27.3</td>
<td>1.6</td>
<td>10.9</td>
<td>Lost to follow up</td>
</tr>
<tr>
<td>mean</td>
<td>26.3</td>
<td>25.1</td>
<td>1.6</td>
<td>9.9</td>
<td>-</td>
</tr>
</tbody>
</table>

Similar extremely low levels of BMI have been reported in several other series of patients with anorexia nervosa (see Farquharson (1941) (Farquharson 1941; Farquharson & Hyland 1938) and Ljunggren et al. (1961) (Ljunggren, Ikkos, & Luft 1961) and Bruckner et al. (1938). (Bruckner, Wies, & Lavietes 1938)

Many factors promote low values of BMI in patients with anorexia nervosa. Age is a determinant of BMI (see 4.03(c) ii) and adolescents, in whom the incidence of anorexia nervosa is highest, have lower BMIs than adults. Adolescent anorexies would therefore, be expected to survive at lower
levels of BMI than adults (see 4.03(c) ii). The relatively high quality, albeit energy deficient diets, characteristic of the early phases of the disease, (Beumont, Russell, & Touyz 1993) would produce some sparing of lean tissue and micronutrient reserves, (Owen et al. 1998; Sapir et al. 1972), facilitating a more complete utilisation of energy stores before death occurred (see 4.03(e) iii). The higher socio-economic conditions associated with anorexia would tend to decrease the prevalence of infectious disease. There is also some evidence that at comparable degrees of emaciation, patients with anorexia nervosa suffer less severe immunosuppression than people with other forms of protein energy malnutrition. (Bessler et al. 1993; Golla et al. 1981) A relatively reduced prevalence of infectious disease compared to famine victims would also decreasing the free radical load thereby conserving anti-oxidants and promote survival at lower BMIs in anorexics, reducing the relative risk of mortality at any given BMI. The reported tendency towards dehydration in anorexic patients might also contribute to depressed weights in anorexic subjects. (Bruckner, Wies, & Lavietes 1938)

In 1990, CJK Henry reviewed some of the above data together with some additional sources obtained from professional fasters. He concluded that a BMI of approximately 12 kg m$^{-2}$ was around the lowest limit compatible with life, refining the estimate with sex specific cut-offs of 13 kg m$^{-2}$ for men and 11 kg m$^{-2}$ for women. (Henry 1990; Henry 1993) As Henry himself points out the proposed cut-offs were tentative, based upon sparse data from diverse sources, and designed more to stimulate further research rather than provide cut-offs for use in famine-relief programmes.

The limit of adaptation of 13 kg m$^{-2}$ for men is largely extrapolated from the data collected by Buerger et al. during the Dutch winter famine (see above). The conditions that prevailed during the time of this data collection were extremely harsh, with a cold ambient temperature, little fuel for heating and a breakdown of social services and infrastructure. It is possible that these factors prevented survival at levels of BMI that would, in less harsh circumstances, have been compatible with recovery. The figure of 11 kg m$^{-2}$ for women is far less clear cut and there is substantial variation in BMIs both within the group that survived and those that died. In contrast to the male data, the majority of the female subjects are anorexics nervosa sufferers living in western societies.

\footnote{Anti-oxidant status has been shown to correlate with risk of mortality in severely malnourished children. (Golden & Randath 1987)}
iii. The lower BMI limit of human response to starvation

The above data suggest that a reduction of greater than 50% of normal body weight, equivalent to a BMI of approximately 12 kg m\(^2\), is the lowest limit of BMI compatible with life. The available evidence does however contain substantial individual variation in this absolute limit. Support for limit of 50% loss of normal body weight also comes from studies of body composition in normally nourished subjects and those suffering from secondary malnutrition. Heymsfield has demonstrated that at a body weight approximately 50% below normal in men and between 50% and 60% below normal in women, body fat reserves are effectively exhausted. As weight loss proceeds towards this point, an increasing proportion of the bodies' energy needs must come from the catabolism of fat free mass. Each gram of FFM produces approximately only 4 kJ, Between 20 and 25% of FFM is protein (Heymsfield et al. 1984). This is much less than the 30 kJ available from each gram of fat (adipose tissue consists of 80% triacylglyceride, 18% water and 2% protein (Heymsfield et al. 1984)). If FFM were the sole metabolic fuel, between 0.5 - 1 kg of FFM would have to be catabolised each day in order to meet resting energy requirements alone. Survival times at this rate of FFM loss in individuals with pre-existing FFM depletion would be extremely short.

Studies of the percentage of energy derived from protein (P-ratio), support these findings. (Payne & Dugdale 1977) Although the P-ratio is usually a fixed constant in any particular individual, there is evidence of a "pre-terminal" sudden increase in protein catabolism during a prolonged fast. (Henry, Rivers, & Payne 1988) This would be expected with a switch to FFM as the sole metabolic fuel.

The sparse data from starving adults is also compatible with exhaustion of fat stores being a limiting factor in the adaptation to starvation. An analysis of the timing of deaths in the Irish hunger strikers indicated that loss of fat was an important factor in the timing of their deaths. (Leiter & Marliss 1982; Leiter & Marliss 1983) Post mortems records of subjects that died of starvation or anorexia also indicate the almost complete absence of fat reserves. (Stephens 1895; Winick 1979; Zimmer, Weil, & Dubois 1944)

This model of protein and fat stores limiting adaptation to starvation is based upon data gathered from populations in developed countries. The background conditions in these countries are however very different to those seen in famine. The hygienic surroundings, high quality foods and food supplements available and usually acute starvation superimposed upon well-nourished pre-morbid states, all reduce the importance of other factors that limit adaptation to starvation. In
The breakdown of environmental hygiene, contaminated food and toxic famine foods all increase exposure to infection and damage by free radicals. In addition, starvation is prolonged and superimposed upon pre-existing nutritional deficiencies and the diets eaten before and during the evolution of malnutrition frequently deficient in a whole range of nutrients. These factors would increase the frequency with which micro-nutrient deficiency, infection, poor anti-oxidant status and free radical damage disrupt normal adaptation before all available fat stores were used up. Conversely, the superimposition of acute starvation upon a background of adaptation to chronic starvation might predispose individuals to greater adaptation. These issues are further discussed in 4.07(a).

The result of these differences is that malnourished people in famine are likely to die from different causes than those starving under clinical conditions in western countries. Rather than respiratory or cardiac insufficiency caused insufficient energy or muscle as an endpoint to starvation, infection and/or metabolism dysfunction are frequently the terminal events. Given such different end-points, universal stipulation of BMI limits to starvation appears to be theoretically unrealistic. This assertion is examined in the rest of this chapter.

4.03(f) Triage and BMI limits of human adaptation to starvation

During famine-relief programmes demand for food and basic medical attention greatly outstrips the resources available. Selective feeding centres, important interventions to reduce excess mortality, cannot be too large or crowded. If they are they cannot function effectively and case fatality rates and the lengths of time patients stay, increase. Efficient patient selection to limit numbers is therefore essential. At present, there are no tools available to screen severely malnourished adults. Such selection requires that those patients that need specialised feeding in order to survive, are differentiated from those that will survive on a general-ration and those who will not survive whatever. BMI is potentially useful at both ends of this spectrum. If there are BMI thresholds below which prognosis is considerably worse, BMI could be used for the selection of patients for specialised for therapeutic feeding. At the most severe end of the spectrum of starvation, identifying patient that are beyond help no matter what therapy is given, would also be useful. Although distasteful, resource restrictions are such that a triage tool is often valuable in targeting scarce resources towards those for whom they can do some good. The more severe

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13 In a modern world, the need for such triage, in the treatment of a slowly evolving condition that, if caught early is so easily treatable, is an obscene failure. However, the collective will of the international community to prevent famines before they happen, or even to promptly intervene before the horrors of widespread death from starvation supervene, is sadly lacking. The reality of famine relief programmes is still usually “too little too late”.

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admissions require most staff, resources and time. If those for whom there was no possibility of survival could be screened out prior to admission, the efficiency with which therapeutic care could be targeted would be increased. A requirement of any indicator used for this role is a very high degree of specificity. This is essential to help ensure that only those who are beyond help are excluded from curative treatment. In the context of famine-relief programmes, accurate identification of the level of BMI below which recovery is not possible, has, therefore, more than a theoretical importance. If there are BMI thresholds related to prognosis, at either the upper or lower ends of the spectrum of severe adult malnutrition, they would be extremely useful.

The literature contains little data as to the relationship between BMI and mortality in severe acute adult malnutrition. Extrapolations from adults with CED will not do (see 4.03(d)). At the most severe grades of starvation BMI data are almost non-existent and at present it is not possible to specify, with any degree of certainty the BMI limits to survival (see 4.03(e)). This study attempts to address these issues.

**Section 4.04 methods**

**4.04(a) Subjects.**

Data were collected on 573 patients with a reported age of 15 years and over, admitted to the Concern Worldwide Adult Therapeutic Centre, Baidoa, between 25th October 1992 and the end of March 1993. The reported ages of those admitted were between 15 and 80 years (mean 34). It is unlikely that these reported ages are accurate as people were generally unsure of their exact ages and no local calendar was available to verify the ages given. Analysis of the distribution of the age data revealed clustering around ages divisible by five, suggesting that reported ages were often given to the nearest five years. 46% of those admitted were male.

The criteria for admission varied depending upon the available space in the centre, and the existence of other medical facilities in Baidoa (see 3.03(b)).
4.04(b) Treatment in the centre

i. Supervision

High levels of supervision, with staff patient ratios of 1:9 or less, particularly during the first few days after admission, were maintained. These staff distributed the food and WHO formula oral rehydration solution (ORS, composition: sodium chloride 3.5g/l, trisodium citrate 2.9g/l, potassium chloride 1.5g/l and glucose 20g/l). They encouraged patients to eat and drink and helped feed those who were unable to feed themselves.

ii. Rehydration

Patients were orally rehydrated using the WHO formula ORS. This was prescribed upon an "ad libitum" basis, with all patients encouraged to drink as much as possible.

iii. Dietary treatment

There were 6-8 meals each day. The diets used consisted of high energy milk ((HEM), made from dried skimmed milk, vegetable oil and sugar), sweet tea, rice, oil, beans, biscuits and local fruits, especially bananas. During the first few days after admission the HEM component was diluted with WHO formula ORS. Two therapeutic regimes were used in the centre. A high protein regime wherein patients were offered 156g protein and 16.5 MJ (16% of energy from protein, P:E ratio 9.5 g/MJ), and a low protein regime wherein patients were offered 81 g protein and 16.5 MJ (8.5% of energy from protein, P:E ratio 5 g/MJ). For a detailed discussion of the diets see 7.03(c).

iv. Medical treatment

Oral antibiotics were needed by the majority of the patients upon admission, with many patients remaining on an antibiotic throughout their stay in the centre. Penicillin V or ampicillin, were the first line antibiotics for pulmonary infections; cotrimoxazole and metronidazole for dysentery and persistent diarrhoea. Chloramphenicol was the second line antibiotic.
4.04(c) **Discharge criteria**

Discharge criteria were predominantly clinical: Freedom from infectious disease, a good appetite, constant weight gain, and the ability to walk and care for themselves, were all necessary conditions for discharge. The presence of minimal pedal oedema did not preclude discharge so long as all the above criteria were fulfilled. Upon discharge all patients were issued with a “rehabilitation pack” containing a sheet of plastic, hoes, seeds, a machete, pots and pans, a blanket, a water containers and some cloth. Transport to the patients’ home village was provided.

For additional methods see core methods see Section 3.02

**Section 4.05 Results**

4.05(a) **General inpatient data.**

Of the 573 admissions for whom data were collected, 413 (72%) survived, 122 (21%) died, and 38 (7%) were lost to follow-up. Those lost to follow up were excluded from the analysis of mortality. Mean reported age of those that died was 36 years (95% C. I. = 33-39), slightly older than the survivors whose mean age was 33 years (95% C. I. = 31.5 - 34.5, ANOVA F = 3.1, p = 0.08 ). 46.4 % of those admitted were male and the gender composition of those that died did not differ from survivors (likelihood ratio test = 1.5 p = 0.2). 19 % of deaths occurred within 48 hours after admission, 48% within the first week and 27% during the second week after admission (see Figure 10). Mean time to discharge was 30.8 days, (34.6 days in oedematous patients and 30.2 days in marasmic patients).
There was a bi-phasic relationship between age and BMI at admission in the non-oedematous patients. Below a reported age of 25 there was a significant relationship between admission BMI and age (regression co-efficient BMI on age = 0.24, β-coefficient 0.14, F statistic = 7.315 d. f. 1, 120, p < 0.05). No such relationship existed in patients with a reported age of 25 and above (regression co-efficient BMI on age = 0.11, β-coefficient 0.01, F statistic = 2.43 d. f. 1, 189, p > 0.1), see Figure 11. The relationship between age and BMI appeared to be similar for both sexes.
Figure 11

The relationship between age and BMI on admission. Regression line "A" is a regression of admission BMI on age for patients with a reported age of less than 25 years $n = 121$, regression coefficient = 0.24, slope = 0.14, and intercept = 9.4. The regression line "B" is of admission BMI upon age for patients with a reported age of 25 years or more $n = 190$, regression coefficient = 0.11, slope = 0.015, and intercept = 12.55.

**ii. Survivors**

The distribution of the admission BMI values in survivors was positively skewed. Amongst non-oedematous survivors ($n = 262)$, the median BMI at admission was 11.9 kg m$^{-2}$ in the young adult group. This was significantly lower than the older adult group where the median BMI on admission was 13.0 kg m$^{-2}$ (Kruskal-Wallis $H = 26.238$ d. f. = 1 p < 0.0001). Amongst the oedematous survivors ($n = 51$), the median admission BMI for young adults was 13.7 kg m$^{-2}$. This was not significantly lower than the median admission BMI of 14.6 kg m$^{-2}$ (Kruskal-Wallis $H = 2.05$ d. f. = 1 p < 0.15) in oedematous older adults.
iii. Non survivors

In contrast to these survivors, the levels of BMI at admission of those who died did not differ between older and younger adults (ANOVA $F = 1.74$, d. f. 1, 58, $p = 0.2$). The following data on the relationship between BMI at presentation and death are therefore not stratified by age.

Section 4.06 BMI data.
Table 5 summarises anthropometric data recorded upon admission to the centre. The prevalence of some degree of famine oedema upon admission to the centre was 23.7% (136 / 573). The prevalence of severe famine oedema upon admission was 16.1% (92 / 573), and there were no differences in the prevalence between men and women (Yates corrected $\chi^2 = 1.07$, $p = 0.85$). The presence of severe famine oedema was associated with a higher BMI at admission (Kruskal-Wallis $H = 29$, $p < 0.001$). This was greater in male than in female patients (partial $F$ statistic = 5.3 $p < 0.001$).

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14 In 4.3% of the 573 admissions aged 15 years and over, for which data is available oedema was recorded as unquantified and therefore coded as grade 3 (see 3.02(c)).
Table 5
Data recorded upon admission to the Concern adult therapeutic centre in Baidoa Somalia, November 1992 - April 1993. p < 0.001 ANOVA, **, p < 0.005 Kruskal-Wallis †, p = 0.01 Kruskal-Wallis ‡, p = 0.067 Yates corrected.

<table>
<thead>
<tr>
<th></th>
<th>Admissions with marasmus or mild famine oedema</th>
<th></th>
<th>Admissions with moderate or severe famine oedema</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n means male female difference (male : female)</td>
<td>n means male female difference (male : female)</td>
<td></td>
</tr>
<tr>
<td>age, years</td>
<td>479 32 35 -3</td>
<td>92 35 37 -2</td>
<td></td>
</tr>
<tr>
<td>weight, kg</td>
<td>370 37.2 31.5 5.66*</td>
<td>83 42.0 33.7 8.334*</td>
<td></td>
</tr>
<tr>
<td>height, m</td>
<td>339 1.68 1.57 0.115*</td>
<td>79 1.7 1.6 0.093*</td>
<td></td>
</tr>
<tr>
<td>BMI survivors (kg/ m²)</td>
<td>263 12.9 12.7 0.2</td>
<td>51 15.4 13.5 1.966 †</td>
<td></td>
</tr>
<tr>
<td>BMI non-survivors (kg m²)</td>
<td>37 12.3 11.5 0.839 **</td>
<td>24 14.8 13.7 1.062</td>
<td></td>
</tr>
<tr>
<td>Case fatality rate</td>
<td>442 18% 21% -3%</td>
<td>92 48% 27% 21% ‡‡</td>
<td></td>
</tr>
</tbody>
</table>
4.06(a) **BMI and the risk of mortality**

**i. All admissions**

BMI values for those that died did not differ significantly between older and younger adults. Therefore, the results for the risk of mortality associated with specific BMI cut-offs, are not stratified by age. BMI values upon admission to the Centre were bimodally distributed, depending upon the presence or absence of oedema. A peak in mortality around a BMI of 11 kg m\(^2\) corresponded to the mortality associated with marasmus, another around 15.5 kg m\(^2\) to mortality associated with oedematous malnutrition. The chances of death, related to thresholds of admission BMI, are presented in Figure 12.
Figure 12

*The chances of mortality below different thresholds of admission BMI for oedematous (N=75) and marasmic patients (N=218)*
**ii. Marasmic patients**

In female marasmic patients, the level of BMI at admission reflected the chances of mortality, which increased sharply below a admission BMI threshold of 11.0 (Odds ratio = 7.88, corrected $\chi^2 = 13.8$, D. F. = 1 $p < 0.0005$). No such threshold was observed in male patients where the slight increase in chances of mortality with decreasing BMI was not significant (Odds ratio for each decrease of 1 kg m$^{-2}$ = 1.4 Likelihood ratio = 1.3 d. f. = 1 $p = 0.25$) (see Figure 13).

![Figure 13](image)

*The risk of mortality associated with various BMI cut-offs in Marasmic patients (N males 103, females 107)*

**iii. Oedematous patients**

The relationship between admission BMI and mortality in oedematous patients was very different to that seen in marasmic patients. Figure 12 presents the chances of death for all admissions, stratified by the presence or absence of oedematous malnutrition. The form of this relationship differed between male and female oedematous patients. Oedematous male patients suffered increased mortality at levels of admission BMI greater than 14.5 kg m$^2$. This pattern was not seen in female patients (see Figure 14)
Figure 14

The risk of mortality associated with admission BMI cut-offs in oedematous patients, stratified by sex (n = 75).
4.06(b) **The lowest BMI compatible with life.**

Figure 15 presents data on BMI at admission amongst survivors with marasmus or mild famine oedema.

The geometric mean and minimum admission BMI in the older adult group were 13.2 m²kg⁻¹ (95% CI = 12.9 - 13.5) and 10.4 m²kg⁻¹. Younger adults had BMIs approximately 1 kg m⁻² below those recorded in patients aged >= 25 years. Geometric mean and minimum BMIs in this group were 12.1 m²kg⁻¹ (95% CI = 11.8 - 12.4) and 9.6 m²kg⁻¹. Mean and minimum BMI values were similar for both male and female patients, once the severity of famine oedema was controlled for.

Weight loss, due to loss of oedema during the initial phase of treatment, reduced many patients’ BMIs still further. The lowest BMIs recorded in survivors were 10.1 m²kg⁻¹ for older, and 8.7 m²kg⁻¹.
kg for younger adults. 22% (n=43) of survivors aged >= 25 years, and 49% (n=59) of survivors aged between 15 and 24 years, had BMIs on admission below 12, the level previously considered the lowest compatible with life. The survival rate amongst those admitted with BMIs below 11.0 m^2/kg, was 65% for older adults (n=23) and 82% for younger adults (n=34). Mean BMI on discharge was 15 m^2/kg.

4.06(c) Famine oedema and the risk of mortality.

Mortality rates were higher in patients presenting with severe famine oedema (see Table 5). This was common, seen in 16% of all admissions and 28% of those that subsequently died, and associated with a poorer prognosis (odds ratio = 2.4, Yates corrected χ^2 = 11.7 p < 0.001). This association was stronger in male than female patients (Wolfs' χ^2 = 4.59, p < 0.05). The poor prognosis seen in patients with severe famine oedema was predominantly a result of the increased mortality in patients presenting with pitting oedema. Pitting oedema was independently associated with mortality, (Odds ratio for each increase in grade = 1.5, likelihood ratio test 22.2 p < 0.001). Figure 16 shows that male patients had a poorer prognosis at severe grades of pitting oedema than female patients (odds ratio for each increase in oedema grad (male) = 1.7, likelihood ratio test 23.5 p < 0.001, (female) = 1.3, likelihood ratio test 4.4 p < 0.05). Minimal pitting oedema was not associated with an increased risk of death in either sex.
Figure 16

Section 4.07 Discussion

4.07(a) The BMI limit in human starvation.

These data show that the level of emaciation compatible with life is much lower than previously thought. The BMI data from survivors is positively skewed with the numbers surviving quickly decreased below a BMI of 12 kg m\(^2\). The progressively increasing mortality in female marasmic patients with decreasing BMI, below 12 kg m\(^2\) (see Figure 13) explains some of this skew. However, the inability of the most severely emaciated patients to stand did not allow for BMI assessment of many of the most emaciated patients. This systematic under-sampling those at the lower end of the BMI spectrum would have introduced a bias into these data, also positively skewing the data presented in Figure 15. The true mean and minimum BMI values in the centres are therefore lower than those recorded here. There are several potential explanations for such low BMI values.

i. Variation due to body shape

Conceivably, such low BMI values could be in part due to a tall, long legged, phenotype. This phenotype occurs in some east African ethnic groups, notably Nilotic peoples, such as the Dinka of southern Sudan and the Samburu of northern Kenya and Australian Aborigines. (Eveleth & Tanner 1976; James, Ferro-Luzzi, & Waterlow 1988; Norgan 1994c; Norgan 1994b) The BMI values in Somalis, a Cushitic people, have however been recorded as lying within the normal range of 19-21. (Branca & Abdulle 1993) Complimentary BMI data, collected in the spring of 1993 from 164 of Concern's local Somali workers in Baidoa, and 642 adult Somali women living in the villages surrounding Baidoa, also recorded mean BMIs within the normal range (mean BMI = 20.7 kg m\(^2\) and 19.9 kg m\(^2\) respectively, see Table 27.)

Although the mean population BMI for Somalis lies within the normal range, it is still conceivable that intra-population variation in BMI, independent of nutritional status, could account for the extremely low levels of BMI seen in this population. In Aborigine populations it has been demonstrated that there is large intra-population variation in the sitting height stature ratio (sitting height (SH) / total height (S) or SH/S ratio). In a group of 349 Aborigine adults the SH/S ratio was 0.48, with a standard deviation of 0.02 and range of 0.41 - 0.54. (Norgan 1994b) Such variation is equivalent to standard deviation of ± 7 cm in the height of a population with a mean
height of 170 cm, giving 95% confidence limits of 156 cm - 185 cm. As height is a square term in the calculation of BMI, this error is further magnified. In a population with a mean BMI of 12 kg m\(^2\) and height of 170 cm, the 95% confidence limits of BMI dependant solely on SH/S ratio and independent of nutritional status is 10.1 kg m\(^2\) - 14.25 kg m\(^2\). No SH/S ratio data on adult Somalis appears to exist, however, there is no reason to suppose that intra-population variation in SH/S ratio should be any less than in Aborigine populations. Such variation in individual BMI could explain both the low levels of BMI in patients that survived and also the poor predictive qualities of BMI marasmic patients (see Figure 17). These issues are also discussed in 6.05(a).

**ii. Temperature**

Survival at these extremely low BMIs would have been aided by the warm climate that existed in Baidoa throughout the period that the centre was operating. Much of the previous data concerning the limits of survival during famine comes from colder climates. (Henry 1990; Henry 1993) Given the inability of severely malnourished people to thermoregulate, (Burger, Sandstead, & Drummond 1945; Keys 1950a; Leyton 1946; Winick 1979) the limits of survival are likely to be lowest in warm climates. Indeed reports from the camps in the unoccupied zone of France during 1942 describe a tripling of the mortality rates during the winter months. (Zimmer, Weil, & Dubois 1944)

**iii. Dehydration**

The dehydration present in many of the admissions to the centre would have reduced admission BMIs. The magnitude of this effect cannot be accurately estimated, as the clinical evaluation of the grade of dehydration in the severely malnourished is difficult. The normal signs of dehydration, such as sunken eyes, decreased skin elasticity, changes in heart rate and reduced peripheral perfusion, can all occur in severely malnourished independently of the state of hydration. It is likely however, that the reduction of admission BMIs due to dehydration was not a major effect, as the inability of most severely dehydrated people to stand, meant that they did not have their BMIs estimated immediately upon admission.

**iv. Adaptation to starvation**

Previous exposure to CED may have facilitated survival at such low BMIs. Habituation to CED has also been described in Indian labourers who, with a mean BMI of 16.6, were able to function as wage earning labourers. (Shetty 1984) By contrast, similar BMIs, rapidly induced in 32
previously well nourished volunteers during the Minnesota experiments, resulted in extremely poor physical and psychological states. (Keys 1950a) The precise mechanism for such adaptation remains unknown and several studies have failed to show much evidence of metabolic adaptation. One possible mechanism is that the acute reduction in the numbers of muscle cells and the increased the ratio of collagen in lean tissue induced by and previous exposure to under-nutrition to some extent persists after recovery. (Stini 1973) Such changes would reduce the resting metabolic requirements of an individual thereby adapting them to future periods of under nutrition. The absence of any way of assessing body composition during this study means such discussions necessarily fall largely outside the scope of this thesis.

v. The availability of small amounts of food

The gradual nature of the reduction in food intake over a period of two years and the sporadic availability of some food would have helped to spare protein reserves in some of our patients. (Sapir et al. 1972) It has been demonstrated that even a small amount of carbohydrate, in the order of 7.5 g kg$^{-1}$, will, by reducing the requirements for short chain carbon intermediaries for anaplerosis, reduce nitrogen loss. (Owen et al. 1998) Such protein sparing would help promote complete exhaustion of fat reserves before FFM became incompatible with life.

4.07(b) Sex difference in adaptation.

The results of this study indicate that men and women responded differently to starvation. Women with famine oedema had a better prognosis than men with equivalent grades of oedema (see Figure 16), whereas severe marasmus appeared to mark a worse prognosis in women than in men (see Figure 13). No differences in admission BMIs, the minimum BMIs in those who survived, or the frequency of famine oedema were observed (see 1.01(a)). These data should be interpreted with caution. The inpatients at the centre were a selected population, people who had either, walked, been carried by friends and family, or been transported to the centre by aid workers. The greater numbers of male medical admissions, many of whom could not walk far, is possibly a reflection of an increased tendency to carry male patients to the centre. If there was such a selection bias, with male moribund patients more likely to present than female ones, the effect would be expected to be greatest at the lower levels of BMI, where the inability to walk was more usual. Consequently, mean female BMI could have been artificially raised and sexual differences in the lower limit of BMI compatible with recovery obscured.
The evidence that women withstand starvation better than men has been summarised by Keys (1950). The finding in this study, that the presence of famine oedema is associated with a better prognosis in women, is in keeping with previous observations. (Gopalan & Krishnaswamy 1975; Keys 1946; Knack 1950; Widdowson 1976) Data on gender differences in the prevalence of famine oedema appear equivocal. Amongst more than 3000 inmates in the internment camps of France during 1942, 48 percent of men and 52% of women were affected by famine oedema, although ascites only occurred in the men. (Zimmer, Weil, & Dubois 1944) In other studies, famine oedema occurs less frequently in women. (Gopalan & Krishnaswamy 1975; McCance & Widdowson 1951; Widdowson 1976)

Whether the lowest level of BMI compatible with life, differs between men and women is also unclear. Previous anthropometric data are contradictory on this point. Mean weights of people that died during the Madras famine of 1877, were reported as 77 pounds for both men and women (quoted in Aykroid (Aykroid 1974) ). On the other hand, Henry, reviewing data largely collected during the Dutch famine of 1944-5, concluded that the minimum BMI compatible with life is lower in women (see 4.03(e) ). It does seem likely that women are more efficient at sparing protein during starvation than men. At any given body weight, women have a higher percentage of body fat and it has been demonstrated that the loss of body protein is inversely proportional to body fat content . (Forbes 1987) This finding is supported by examination of the percentage of energy derived from protein during starvation, the p ratio. (Payne & Dugdale 1977) C. J. K. Henry has provided evidence that during prolonged complete starvation, this ratio is a fixed constant for any given individual. (Henry, Rivers, & Payne 1988) Although similar p ratio estimations during starvation do not appear to have been made for women, it has been demonstrated that in starved rats the p ratio is lower in the females than in the males. (Widdowson 1976) The reduction in the sexual dimorphism in upper arm muscle, that occurs during prolonged human under-nutrition, (Stini 1973) further supports the hypothesis that during starvation women tend to spare protein more efficiently than men.

4.07(c) Famine oedema

The prevalence of famine oedema as a complication of severe adult malnutrition shows great world-wide variation and the 23.5% of subjects with famine oedema, observed in this study, is common (see Table 6). This is similar to the variation seen child oedematous malnutrition in where the prevalence of kwashiorkor or marasmic kwashiorkor, varies between 0% and over 90%. (Itekunigwe 1971; Waterlow 1993) In the three Concern TFCs in Baidoa during 1992 and early
1993, the famine oedema was much less than in the adults. (child prevalence = 5.7% (25/411) chi square = 24.7 Odds Ratio 3.1, \( P < 0.0001 \) (Collins 1993d)). This accords with other reports describing a higher occurrence of oedematous malnutrition as age increases. (Gopalan & Krishnaswamy 1975; Ramalingaswami et al. 1971) In this study the incidence of severe famine oedema was similar in both sexes and was associated with a markedly increased risk of death, especially in the male patients (see 4.06(c)). Ascites occurred less commonly than pitting oedema and was most often seen in the male subjects. The prevalence of ascites in severe adult malnutrition also appears to be variable. In some famines, the condition has been reported to be almost as common as pitting oedema, (Gopalan et al. 1952; Ramalingaswami et al. 1971) in others ascites is only seen in a small proportion of adults, predominantly the male patients, (Zimmer, Weil, & Dubois 1944) or not at all. (Gopalan et al. 1952) The functional significance of ascites is unclear in this study; in bivariate analysis it was associated with a marked increase in the risk of mortality in male patients, however the significance of this association disappeared when pitting oedema was added into the logistic models (see also 6.05(b)).

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Date of study</th>
<th>Prevalence of famine oedema (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collins</td>
<td>Somalia</td>
<td>1992</td>
<td>23.7</td>
</tr>
<tr>
<td>Collins</td>
<td>Angola</td>
<td>1993</td>
<td>90</td>
</tr>
<tr>
<td>Collins</td>
<td>South Sudan</td>
<td>1993</td>
<td>0</td>
</tr>
<tr>
<td>Zimmer et al.</td>
<td>France</td>
<td>1942</td>
<td>50</td>
</tr>
<tr>
<td>Mollinson</td>
<td>Germany</td>
<td>1945</td>
<td>typical finding</td>
</tr>
<tr>
<td>McCance et al.</td>
<td>Germany</td>
<td>1946</td>
<td>common</td>
</tr>
<tr>
<td>Debray</td>
<td>France</td>
<td>1945</td>
<td>100</td>
</tr>
<tr>
<td>Keys et al.</td>
<td>USA</td>
<td>1945</td>
<td>87</td>
</tr>
</tbody>
</table>

**4.07(d) BMI and the prediction of mortality**

BMI was related to the risk of short-term mortality in female but not in male marasmic patients. Figure 17 illustrates the receiver-operating characteristics for BMI in the prediction of mortality in female and male patients. It can be seen that, at low levels of BMI, the prediction of female mortality is reasonable, with 56% of deaths correctly predicted and only 14% of survivors
incorrectly identified at point “X”. This point corresponds to the threshold of 11 kg m⁻², below which there is a marked increased in the risk of death (see Figure 13). The prediction of death in adults and adolescents by BMI was broadly similar (see Figure 29). In male patients, BMI is little better at predicting death than a random indicator. For a fuller discussion of the reasons behind these problems see Chapter 5 and Chapter 6 (see also 4.07(a)).

![Graph of Receiver Operating Characteristics (ROC) for BMI in predicting short term mortality in male (n = 99) and female (n = 108) patients.](image)

**Figure 17**

_The receiver operating characteristics (ROC) for BMI in predicting short term mortality in male (n = 99) and female (n = 108) patients._

### 4.07(e) The use of BMI during severe famine.

This section discusses the practical aspects of using BMI during famine-relief programmes. The height and weight measurements required to assess BMI, were problematic during famine, as the
absence of chair, bed or stretcher-scales in these situations meant that patients had to be able to stand. The assessment of height was particularly difficult, requiring the subject to stand up straight, a central problem with the use of BMI in the elderly and deformed. (Steele & Chenier 1990) In this study, many of the most severely malnourished could not stand on admission, resulting in approximately 11% of all admissions and 33% of those who subsequently died, not having their BMI assessed on admission. These findings are not unique and several other studies reported that gross weakness, (Winick 1979) flexor contractions, (Mollinson 1946) or scoliosis (Zimmer, Weil, & Dubois 1944) prevented measurements of weight or height in a substantial proportion of the most severe cases. Recognition of this problem has prompted enquiries into other indicators of stature and researchers have demonstrated a good relationship between arm span, femur length and stature. (Feldesman 1992; Feldesman, Kleckner, & Lundy 1990; Reeves, Varakamin, & Henry 1996; Steele & Chenier 1990; Steele & Mattox 1987) However, there are several problems with the use of such proxies in the severely malnourished. Different regression equations must be used in people of different ethnic origin because of the substantial ethnic differences in the relationship between arm span (Reeves, Varakamin, & Henry 1996; Steele & Mattox 1987) or femur length (Feldesman, Kleckner, & Lundy 1990) and height. The additional mathematics required is problematic during emergency relief operations, where time and train staff are scarce. There is also significant error involved in the estimation of stature at the individual level, where the standard error of the estimate of height from arm span appears to be in the order of 2.5 - 3.8 cm. (Steele & Chenier 1990) The squaring of the height element in BMI magnifies these differences: For example, taking a stature of 1.6m and weight of 60 kg and a SEE of height from arm span of 3.00 cm, the 95% confidence limits around the estimated BMI would be 21.8 - 25.2 kg m^2. This variation would be a function of the height estimation and independent of nutritional status. Such problems may be surmountable and arm span could turn out to be a more stable measurement than height. At present these data do not exist and there is a need for research into the use of such proxies for stature, in the assessment of severe adult malnutrition.

The high incidence of adult famine oedema (see 4.07(c) ) is a serious drawback to the usefulness of BMI as an indicator in severe famine. The association between famine oedema and a poor prognosis on the one hand (see Figure 16), and increased weight on the other results in patients with severe famine oedema often having a poorer prognosis the higher the admission BMI. This is the opposite to the situation in marasmic patients (see Figure 12) and greatly reduces the ability of BMI to reflect severity of malnutrition or risk of mortality in patients with severe famine oedema.
Even in non-oedematous populations where the majority of patients can stand the height and weight measurements required in order to calculate BMI are time consuming and difficult to obtain from the most severely emaciated people. During the early phase of an emergency, when there are large numbers of people seeking treatment, this extra time greatly reduces the attractiveness of BMI as a screening tool. In the assessment of the use of BMI screening in such situations such the ease of use is extremely important. In this study, the difficulties in obtaining such measurements under the pressurised conditions that occur during the height of a famine resulted in BMI assessment frequently being omitted, especially in the more severe cases. Individual sitting height measurements required to correct BMI measurements for intra-population variation in the SH/S ratio (see 4.03(c) i), are slow and relatively difficult to perform. These would not be practical in the majority of famine-relief programmes.

One of the main conclusions from this study is that there is a need for alternative indicators for the screening and assessment of adult malnutrition. The possibility that clinical signs upon presentation may provide good screening tools for malnutrition has been investigated in children but not in adults. (McLaren, Pellett, & Read 1967; McLaren & Shirajian 1969) Chapter 5 examines the use of such models in adults under famine conditions. In children assessment of MUAC, a quick but sometimes less precise, index of nutritional status (Shakir 1975; Velzeboer et al. 1984) is often used during these early phases. There is also some research to show that MUAC maybe a useful nutritional indicator in adults, (Friedman 1991; Gassull et al. 1984; Heymsfield et al. 1984; James et al. 1994; Ohlson et al. 1956) however its use emergency feeding programmes has not yet been evaluated. Chapter 6 examines the use of MUAC for the assessment of severely malnourished adults under famine conditions.

4.07(f) Adult therapeutic care.

The provision of food and medical care in a protected inpatient environment was instrumental in the survival of those admitted. It is likely that very few would have survived outside the centre, forced to queue for food in the general kitchens. However, since the concentration camps were liberated at the end of the Second World War, adult therapeutic centres have not been a feature of emergency relief programmes. The relatively low case fatality rates, even at extreme grades of emaciation, and the fast rates of rehabilitation reported here, support the feasibility and utility of adult therapeutic centres. These should constitute a standard part of emergency feeding programmes. There is a need for more research into indicators useful in the screening and assessment of admissions to such centres.
4.07(g) Conclusions

BMI has been found to have many drawbacks limiting its usefulness in screening malnourished adults during famine. Under these conditions, BMI assessment is slow and the measurements required cannot be obtained in many patients. The index is also confounded by famine oedema, commonly seen in starving adults. Ethnic origin, age, sex and ambient temperature all affect the significance of BMI values. In particular, the large variation in BMI due to phenotype, independent of nutritional status, reduces its usefulness. In the absence of SH/S ratio estimations, the receiver-operating characteristic of BMI in the prediction of mortality, are poor.

The BMI limit below which individual survival is impossible is also dependent upon many factors. Important among these are; the availability of sources of carbohydrate, previous exposure to periods of chronic food shortage, ambient temperature, level of hydration and phenotype. In this study adults survived with admission BMI of less than 11 and adolescents with BMIs less than 10. Even using very low cut-offs values, little above these minimum values, the specificity of BMI in prediction of was only 80%. This is far too low to make the indicator useful for triage. These data strongly support the view that it is not possible to stipulate a minimum BMI value below which recovery is impossible. BMI cannot therefore, be used as a triage tool to identify patients who should be given palliative rather than curative care.

The results of this study indicate a need for research to evaluate alternative indicators, such as MUAC or clinical signs, for the screening and assessment of adult malnutrition. Clinical signs are investigated in Chapter 5 and MUAC in Chapter 6.

At these extremes of emaciation, the ability to obtain food and medical care passively is instrumental in survival, and it is very unlikely that most of these people would have survived outside a therapeutic centre. However since the concentration camps were liberated at the end of the Second World War, adult therapeutic centres have not been a feature of emergency relief programmes. The comparatively high survival rate and the reasonably fast turn around of patients at the centre, achieved in the very difficult circumstances, support the feasibility and usefulness of such centres. These should be included more frequently in emergency feeding programmes. Concern has since opened other adult therapeutic centres in south Sudan and Angola with similar success.

BMI was not shown to be a useful indicator for the assessment of SAM. At the centre we did not manage to record BMIs in 40% of all those who subsequently died and even when it was possible
to obtain an admission BMI, this correlated poorly with short-term mortality. At the lowest end of the BMI spectrum practical constraints meant that only the fittest patients, those strong enough to stand and be measured, had BMIs recorded, whilst at the higher end BMI was falsely raised by famine oedema. Consequently screening cut-offs based on BMI exhibited low sensitivity at the high specificity required from an efficient indicator.
Chapter 5 Study two:  
Clinical assessment of severe adult malnutrition

Section 5.01 Introduction

The previous study described many problems associated with the use of BMI in the assessment of severely malnourished adults during famine-relief programmes. This study examines the prediction of short-term mortality (mortality occurring within a therapeutic treatment centre) amongst severely malnourished adult and adolescent inpatients. It examines whether clinical signs at admission, either alone or used as an adjunct to BMI, may be useful in assessing severe adult and adolescent malnutrition under famine conditions.

Section 5.02 aim

1. To assess the performance of clinical models in the prediction of mortality occurring in severely malnourished inpatients in an adult/adolescent TFC.

2. To examine whether the predictive power of BMI in this role can be improved by the addition of clinical variables.

Section 5.03 Background literature

Much of the relevant literature is discussed in Section 4.03 and Section 6.03. This section reviews only the literature relevant to the use of clinical models in malnutrition.

i. The effects of infection

For many years, it has been recognised that malnutrition increases both susceptibility to and the severity of infection. Vitamin, mineral and other dietary deficiencies, depressed cell mediated and humeral immunity, gastric acidity, mucosal integrity and altered flora are all known to increase susceptibility to infection. (Tomkins & Watson 1989; Waterlow 1993) The situation in famine is
usually worsened by the breakdown in public health infrastructure and the congregation of displaced people in crowded and unhygienic conditions. (De Waal 1989) This combination of poor public health environment and immunosuppression means that in famine it is infection rather than absolute loss of fat or fat free mass that kills people. This is different from the situation in developed countries where exhaustion of fat or fat free mass is more often the terminal event. (Korcok 1981; Leiter & Marliss 1982)

The strong association between infection and mortality means that clinical signs are likely to be useful prognostic indicators. Clinical models for the prediction of mortality, useful in the screening of admission to child feeding centres, have been proposed. (McLaren, Pellett, & Read 1967) Although reported as effective in identifying children at a high risk of mortality, (McLaren & Shirajian 1969) these models have been criticised because of interactions between the features used, such as oedema and hypoprotinaemia, were not taken into account. (Waterlow 1972) In adults, the use of clinical models to assess nutritional status appears to have been restricted to well nourished surgical patients. (Baker et al. 1982) To date, similar assessments have not been made in severely malnourished adults or during famines.

Extreme conditions often characterise famine relief programs. The levels of need are very high and trained staff, equipment and buildings always scarce. Sometimes crowds of several thousand people may gather, attempting to gain admission to centres. Such centres may readily become over-filled, disorganised and dysfunctional if patient selection and prioritisation is not efficient. Tools to assess patients must be quick, simple and reliable, even when used by minimally trained staff, who maybe barely literate. This study investigates the effectiveness of two assessment tools, BMI and models using readily ascertainable clinical signs, during the height of a major famine.

Section 5.04 Subjects and methods

5.04(a) Subjects

This retrospective cohort study involved clinical record data of 393 patients admitted to the Concern Worldwide Adult Therapeutic Centre, Baidoa, Somalia, between November 4, 1992, and March 15, 1993 (see Chapter 3 :3.01(b) i, Section 3.02 . Criteria for inclusion in this retrospective analysis were: a BMI at admission of 13.5 kg/m2 or less or any signs of oedematous malnutrition; a reported age of 15 years or older; the presence of an inpatient treatment and clinical data card,
and no record that the patient was admitted because of medical criteria alone. Of these 393 patients, 10 (2.5%) were excluded owing to the absence of outcome data. 383 patients who met the admission criteria and for whom outcome data was available were included in the study. The mean reported age of these 383 subjects was 33.0 with no significant age difference between the sexes ($t = 1.32$, d. f. = 380 $p = 0.19$). 48.4% of those admitted were male. Mean BMI at admission was 12.7 kg m$^{-2}$ (SD 2.0); mean weight was 34 kg (SD 7.2). Mean admission BMI of survivors was 12.6 kg m$^{-2}$ and 12.9 kg m$^{-2}$ for non-survivors (see Table 7).

### Table 7

**Characteristics of the study population**

<table>
<thead>
<tr>
<th>Category</th>
<th>All patients</th>
<th>Survivors</th>
<th>Non-survivors</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>383</td>
<td>292</td>
<td>91</td>
</tr>
<tr>
<td>Mean Age (self-reported in years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (self-reported in years)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum 15.0</td>
<td></td>
<td>15.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Mean = 33.0</td>
<td>Mean = 32.7</td>
<td>Mean = 33.8</td>
<td></td>
</tr>
<tr>
<td>SD = 16.0</td>
<td>SD = 14.8</td>
<td>SD = 16.5</td>
<td></td>
</tr>
<tr>
<td>Maximum = 89.0</td>
<td>Maximum = 89.0</td>
<td>Maximum = 80.0</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males = 185</td>
<td>Males = 140</td>
<td>Males = 45</td>
<td></td>
</tr>
<tr>
<td>Females = 197</td>
<td>Females = 152</td>
<td>Females = 45</td>
<td></td>
</tr>
<tr>
<td>Missing = 1</td>
<td>Missing = 0</td>
<td>Missing = 1</td>
<td></td>
</tr>
<tr>
<td>BMI at admission (kg m$^{-2}$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum 9.0</td>
<td>Minimum 9.0</td>
<td>Minimum 9.3</td>
<td></td>
</tr>
<tr>
<td>Mean = 12.7</td>
<td>Mean = 12.6</td>
<td>Mean = 12.9</td>
<td></td>
</tr>
<tr>
<td>SD = 2.0</td>
<td>SD = 2.0</td>
<td>SD = 1.9</td>
<td></td>
</tr>
<tr>
<td>Maximum = 24.0</td>
<td>Maximum = 24.0</td>
<td>Maximum = 17.6</td>
<td></td>
</tr>
<tr>
<td>Missing = 87</td>
<td>Missing = 48</td>
<td>Missing = 39</td>
<td></td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum 19.2</td>
<td>Minimum 21.0</td>
<td>Minimum 19.2</td>
<td></td>
</tr>
<tr>
<td>Mean = 34.0</td>
<td>Mean = 34.0</td>
<td>Mean = 34.1</td>
<td></td>
</tr>
<tr>
<td>SD = 7.2</td>
<td>SD = 7.2</td>
<td>SD = 7.4</td>
<td></td>
</tr>
<tr>
<td>Maximum = 59.5</td>
<td>Maximum = 59.5</td>
<td>Maximum = 53.4</td>
<td></td>
</tr>
<tr>
<td>Missing = 42</td>
<td>Missing = 21</td>
<td>Missing = 21</td>
<td></td>
</tr>
</tbody>
</table>

**5.04(b) Methods**

Details of the centre are presented in 3.01(b) i, and details of the supervision, rehydration, medical treatment and discharge criteria in 4.04(b). Methodological problems are described in Section 3.03.)
**i. Data collection**

Details of data collection and coding are presented in 3.02(c). During this study, the level of supervision of data collection was variable. Occasionally, expatriate access to the Centre was restricted for part of a day due to the gun fighting, bandit attacks, attempts at hostage-taking, and military occupations that occurred in Baidoa during the study period. In addition, the author (SC) was absent from the Centre due to illness requiring medical evacuation and for rest and recuperation, for approximately three weeks during the nineteen-week study period. During this time data collection was supervised by an experienced expatriate nurse.

**ii. Data analysis**

Bivariate (i.e., two-by-two table) and multivariate logistic regression analysis were used to assess the association of clinical features at presentation with mortality in the centre. Variables that were not independently associated with mortality were eliminated from the logistic models in a backwards stepwise fashion using estimation techniques. The odds ratios of the three signs independently associated with death (severe oedema, inability to stand, and apparent dehydration) were used to construct a predictive model. If a patient exhibited none of the signs, their score was zero. If they exhibited one sign, their score was the odds ratio associated with that sign. If more than one clinical sign was present, their score was the sum of the odds ratios associated with each sign. The sensitivity and specificity of predicted mortality at score intervals of 0.5 were calculated and receiver operator characteristic (ROC) curves plotted. ROC curves plot sensitivity against 100-specificity and are a useful means of assessing the ability of an indicator to discriminate between healthy and diseased persons or, in this case, between patients with differing prognoses (see 3.02(d) iv). A simpler model, using a count of clinical signs, was also constructed. In this model, the score for each patient was the number of three relevant clinical signs exhibited.

The association between BMI and survival was explored in a systematic manner. A series of 'indicator' variables was created using successively higher BMI cut-points at intervals of 0.5 kg m\(^2\) (i.e., variables were created to indicate whether an individual BMI was below 10.0, 10.5, 11.0, 11.5, 12.0, 12.5, and so on). Each indicator was tabulated against survival. The indicator with the most significant positive association (BMI < 11.0 kg m\(^2\), odds ratio = 2.44, 95% C.I. = 1.11-5.32, Yates corrected chi-square = 5.22, p < 0.05) was then included in the predictive model.

A simulation exercise was undertaken to validate the methods used to construct the models. Each run of the simulation involved splitting the dataset into 2 parts by randomly selecting (using a
pseudo random number generator) approximately one half of the available records as a training
dataset and using the other half of the data as a validation dataset. The odds ratios and
uncorrected chi-squares for the association between predictor variables and death were calculated
using the training dataset. Sums of odds ratios and sign-counting models were then constructed
using those variables with significant positive associations with death, defined as any variable
having an odds ratio of greater than 1.0 and an uncorrected chi-square of greater than 3.84 (p <=
0.05). Models constructed using these variables were then tested on the validation dataset. The
simulation was run 1000 times.

All data entry and analysis were performed using EpiInfo, (Dean et al. 1990) Logistic(Dallal 1988)
and Microsoft Excel. (Microsoft Corporation 1994) (see 3.02(d)).
**Section 5.05 Results:**

**5.05(a) Clinical signs at presentation and prognosis**

91 of the 383 patients (23.8%) included in the study died. Median time to death was 8 days (range 1-53 days).

**Table 8**

Variables independently associated with survival

<table>
<thead>
<tr>
<th>Category</th>
<th>Survivors</th>
<th>Non-survivors</th>
<th>Unadjusted odds ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>292</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>Inability to stand</td>
<td>7%</td>
<td>19%</td>
<td>2.96 (1.40 - 6.26) †</td>
</tr>
<tr>
<td>Dehydration</td>
<td>22%</td>
<td>43%</td>
<td>2.73 (1.60 - 4.66) †</td>
</tr>
<tr>
<td>Severe oedema</td>
<td>19%</td>
<td>36%</td>
<td>2.45 (1.41 - 4.27) *</td>
</tr>
<tr>
<td>Dysentery</td>
<td>29%</td>
<td>38%</td>
<td>1.50 (0.88 - 2.53)</td>
</tr>
<tr>
<td>Anaemia</td>
<td>21%</td>
<td>25%</td>
<td>1.28 (0.71 - 2.31)</td>
</tr>
<tr>
<td>Diarrhoea</td>
<td>34%</td>
<td>37%</td>
<td>1.18 (0.70 - 1.99)</td>
</tr>
<tr>
<td>Chest infection</td>
<td>58%</td>
<td>57%</td>
<td>0.97 (0.58 - 1.61)</td>
</tr>
</tbody>
</table>

† Corrected Chi-square = 9.00, p = 0.005
†† Corrected Chi-square = 15.01, p < 0.001
* Corrected Chi-square = 10.94, p = 0.001

Table 8 presents the clinical sign variables that were independently associated with survival and the ORs associated with these variables. Severe oedema, inability to stand, and apparent dehydration were independently associated with mortality. Ascites was not associated with survival.

Table 9 presents the sensitivity and specificity for the prediction of death in all patients (n = 383) for all combinations of clinical models created using oedema, inability to stand and apparent dehydration. The most discriminatory model (i.e. the model with the greatest sum of specificity and sensitivity) was that based on the presence of any one of these three signs. This model predicted 77% of deaths at a specificity of 59%.
Table 9

The prediction of death amongst all patients (n = 383) by clinical signs

<table>
<thead>
<tr>
<th>Sign(s)</th>
<th>Numbers of deaths predicted to die</th>
<th>Number of survivors predicted to die</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>De</td>
<td>39</td>
<td>63</td>
<td>43%</td>
<td>78%</td>
<td>70%</td>
<td>38%</td>
<td>81%</td>
</tr>
<tr>
<td>Od</td>
<td>33</td>
<td>55</td>
<td>36%</td>
<td>81%</td>
<td>70%</td>
<td>38%</td>
<td>80%</td>
</tr>
<tr>
<td>Ns</td>
<td>17</td>
<td>21</td>
<td>19%</td>
<td>93%</td>
<td>75%</td>
<td>45%</td>
<td>79%</td>
</tr>
<tr>
<td><strong>Combined using AND</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Od &amp; Ns</td>
<td>3</td>
<td>3</td>
<td>3%</td>
<td>99%</td>
<td>76%</td>
<td>50%</td>
<td>77%</td>
</tr>
<tr>
<td>De &amp; Ns</td>
<td>8</td>
<td>4</td>
<td>9%</td>
<td>99%</td>
<td>77%</td>
<td>67%</td>
<td>78%</td>
</tr>
<tr>
<td>De &amp; Od</td>
<td>9</td>
<td>12</td>
<td>10%</td>
<td>96%</td>
<td>75%</td>
<td>43%</td>
<td>77%</td>
</tr>
<tr>
<td>De &amp; Od &amp; Ns</td>
<td>1</td>
<td>1</td>
<td>1%</td>
<td>100%</td>
<td>76%</td>
<td>50%</td>
<td>76%</td>
</tr>
<tr>
<td><strong>Combined using OR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Od or Ns</td>
<td>47</td>
<td>73</td>
<td>52%</td>
<td>75%</td>
<td>69%</td>
<td>39%</td>
<td>83%</td>
</tr>
<tr>
<td>De or Ns</td>
<td>48</td>
<td>80</td>
<td>53%</td>
<td>73%</td>
<td>68%</td>
<td>38%</td>
<td>83%</td>
</tr>
<tr>
<td>De or Od</td>
<td>63</td>
<td>106</td>
<td>69%</td>
<td>64%</td>
<td>65%</td>
<td>37%</td>
<td>87%</td>
</tr>
<tr>
<td>De or Od or Ns (any one sign)</td>
<td>70</td>
<td>121</td>
<td>77%</td>
<td>59%</td>
<td>63%</td>
<td>37%</td>
<td>89%</td>
</tr>
<tr>
<td><strong>Any two signs</strong></td>
<td>18</td>
<td>17</td>
<td>20%</td>
<td>94%</td>
<td>77%</td>
<td>51%</td>
<td>79%</td>
</tr>
</tbody>
</table>

De = Dehydration, Od = Oedema, Ns = Inability to stand
Figure 18 shows the ROC curves for the prediction of short-term mortality using the sum of odds ratios clinical model and BMI. The prediction of death by the sum of odds ratios of severe oedema, inability to stand and apparent dehydration performed at the highest level of sensitivity and specificity. Prediction of death using BMI alone in these patients (n = 383) yielded results that were worse than random. When BMI was used in a sub-population, selected to include only marasmic patients who could stand (n = 218), performance was similar to the clinical model, predicting 46% of deaths at a specificity of 85%. When use of BMI was further restricted to include only marasmic females who could stand (n = 108), BMI performed better than the clinical model, predicting 56% of deaths at a specificity of 87%. 
The ROC curve for the model constructed by counting clinical signs was identical to that produced using the sum of the odds ratios clinical model. Addition of a BMI marginally improved these models. ROC curves for these models are presented in Figure 19.
The prediction of short-term mortality by counting clinical signs with and without a BMI threshold ($\leq 11.5$ kg $m^2$), in 383 adult and adolescent inpatients.

Section 5.06 Discussion

The risks of mortality associated with apparent dehydration, inability to stand and famine oedema were independent of each other. A patient presenting with more than one of these signs therefore had a risk of mortality equivalent to the sum of the risks of all the signs that were present. A scoring system based upon the sum of the odds ratios of these three signs, predicted 77% of deaths at a specificity of 59%. A simplified model, using only the presence or absence of the 3 clinical signs, predicted deaths in a near identical fashion (see Figure 19). The three clinical signs used were quick and easy to elicit in all patients and the application of the model involved only counting. Consequently the model can be readily taught to local workers and is suitable for use in the field, even during the early phases of a famine relief programme.

The capacity of BMI to predict death was limited. Only in female marasmic patients who could stand, did BMI perform better than the clinical models. When non-marasmic patients and those
unable to stand were included (i.e. the entire patient cohort), the prediction of mortality using BMI was worse than random (see Figure 18). The assessment of BMI was also difficult and time-consuming. Dehydration present among patients admitted to the centre reduced admission BMIs. Because apparent dehydration was also a sign of poor prognosis, its presence tended to make BMI a better predictor of death in the centre. The inability of most severely dehydrated people to stand meant that they could not have their BMI estimated within 2 days of admission and were therefore not included in the BMI prognostic models. It is therefore likely that the reduction of admission BMIs due to dehydration was not a major effect.

The presence of severe oedema was associated with a poor prognosis and increased admission BMI. This confounding meant that the ability of BMI to predict death among patients with oedema was worse than random. Because severe oedema was common, BMI was not useful as a prognostic indicator when applied to the entire centre population.

These results indicate that at the extremes of emaciation seen in adult therapeutic feeding centres, clinical illness is a better indicator of prognosis than the degree of wasting as defined by BMI. A model using the presence or absence of readily discernible clinical signs is useful in identifying patients at high risk of death. The high-risk patients identified by these models can then be moved to specialised areas within feeding centres with the most motivated staff, more medical supervision and if necessary higher care-giver:patient ratios.

This is a different role to that of screening admissions for entry into feeding centres, a research priority in severe adult/adolescent malnutrition. (Collins 1993a) Rather than identifying inpatients with a poor prognosis, a screening indicator must differentiate between those in the general population who are likely to respond to treatment if admitted to a feeding centre, but who will die if not admitted. The specificity and sensitivity requirements for screening are different to those required for prognostic indicators. To be useful in famine relief programs, where there are often large crowds of people attempting to gain entry into feeding centres, a screening indicator must have a high specificity. This is not the prime requirement for a prognostic indicator. This study has demonstrated that the sign-count model is sensitive for predicting death within a therapeutic feeding centre. It has not assessed its potential for use as a screening tool to exclude individuals from admission to feeding centres.

This potential use for screening admissions to therapeutic feeding centres needs to be investigated further. Although the model is somewhat non-specific for identification of patients who would die despite having been given treatment in the centre, it is likely that in the absence of treatment,
many more of the individuals identified would have died. The model might therefore be more specific if used for screening. Despite this effect, it is likely that the relatively low specificity of the clinical model proposed here means that on its own it is not well adapted for screening. To increase the model's specificity for identifying malnourished individuals at greater risk of dying, an indicator of nutritional status would need to be added to the model or combined with it in a two stage screening procedure to improve specificity. MUAC shown in Chapter 6 to be a useful indicator of adult nutritional status might be suitable (see pages 105-134). Addition of MUAC would differentiate between those with clinical illness but no malnutrition, better treated in medical units, from those with both illness and malnutrition, best treated in specialised feeding centres.

By weighting the model appropriately, having an MUAC below a certain threshold could be made a necessary prerequisite for selection. This would ensure a high prevalence of malnutrition in the population assessed by the sign-count part of the model.

Within this selected population, the specificity of the clinical signs for identifying death among persons who did not receive treatment would be high, fulfilling the requirement for screening. Use of this single model would be equivalent to application of a 2-stage screening procedure.

Such a two-stage system is similar to that employed by the author when confronted by large crowds of malnourished adults. In such situations, a rapid visual inspection and a very brief clinical examination are under-taken outside the centre to assess the fat in the upper arms. This is followed by more involved anthropometric and clinical inspection inside. In this “ad hoc” system, the initial screen outside the centre increases the prevalence of those requiring urgent assistance that are allowed through the gates to be assessed by a more time consuming clinical examination. In this selected population, the higher prevalence of life-threatening malnutrition makes the relatively low specificity of the clinical screen less important. The sign count model proposed here, combined with an MUAC cut-off, would formalise this method, making it more useful to workers with less experience. The threshold of both MUAC and clinical score chosen as a screening cut-off will depend upon the context and the relative balance of resources and needs. (Habicht 1980)

Emergency relief programs must ensure that the majority of a population has access to the minimum requirement to maintain life. This requires prioritising lower-input interventions with a large coverage of the vulnerable population over high-input services treating a relatively few, providing at least 8786 kJ from grains, legumes, and vegetable oil; adequate water; sanitation; basic
health care; and dry supplementary feeding, must, therefore, form the basis of any relief program. (Project team 1999) Therapeutic feeding centres are only efficient and effective if these basic prerequisites are in place. This hierarchy of interventions constitutes a form of triage. During the initial stages of famine, need will usually outstrip the available resources and the focus should be on ensuring that the general ration is adequate before targeted feeding centres are established. At this stage, those too malnourished to survive on this basic support will die. As resources increase it becomes possible to undertake therapeutic feeding, although initially clinical triage may be necessary. For example, in Wau town in South Sudan during June - August 1998, over 100 therapeutic centres would have been required to treat the estimated 16,000 children adults requiring therapeutic feeding. (Buchanan-Smith et al. 1999) At that time, there was only one a single 24-hour therapeutic feeding centre with a maximum capacity of 400 patients. In this context, given the limited means available, selecting only those patients with a good chance of survival would have optimised the efficient use of resources. In this study, the combination of two relevant clinical signs predicted death at sensitivities of greater than 95%. In Wau, the combination of these two signs would have been a useful triage tool determining the bottom end of the spectrum of severity that the centre would admit. Relief programs are rarely totally overwhelmed and it is important that the existence of a triage tool does not undermine international will to provide sufficient humanitarian assistance during emergencies.

Screening and prognostic indicators are also different to markers of improvement during treatment. In this study, maintenance of fluid balance and hydration, disappearance of oedema and a steady increase in weight in the absence of increasing oedema, were all markers of improvement (see Section 4.05, Section 4.06 and Section 7.04)

Ideally, a study evaluating the relationship between clinical signs and the risk of mortality in a general population suffering from famine is required to establish relevant clinical screening criteria. However, conducting such broad-based population studies is probably not feasible during famine and none have yet been undertaken in these conditions, for any nutritional indicator, in either adults or children. Given these difficulties, evaluating prognostic models in selected feeding centre populations is a feasible alternative. It is certainly better than the current absence of information on prognostic indicators in famine.

In conclusion, counting simple clinical signs is a useful method of assessing prognosis in severe adult and adolescent malnutrition. The addition of an anthropometric indicator may improve the performance of these models. However, difficulties in obtaining BMI estimations and its
inappropriateness in many cases make it unlikely to be useful at the height of a famine. MUAC might prove to be more useful in this context and a combination of MUAC and clinical models might also be useful in screening admissions to therapeutic feeding centres. More work on identifying relevant clinical signs and combining them with MUAC in such models is required.
Chapter 6 Study three: MUAC and the assessment of severe adult malnutrition

Section 6.01 Aim

To compare the use of BMI and MUAC in the assessment of SAM.

Section 6.02 Introduction

The results of study 1 indicated that there are many problems involved in the use of BMI for the assessment of severely malnourished adult during famines (see Section 4.07). This study attempted to investigate the use of MUAC assessment as an alternative to BMI. It took place in Ayod, a small village in South Sudan, during March - April 1993 and Melanje, a regional capital in Angola, during November-December 1993. Supplementary data from Somali women attending village food distributions in the Bay region of Somalia, during 1993, are also included. The aim was to examine the potential usefulness of MUAC and BMI in the assessment of severely malnourished adults during the height of a famine. The aim was for this to be achieved by comparing estimations of MUAC with those of BMI and relating each to short term outcomes such as mortality and length of stay in the centres. Methodological issues surrounding this aim are discussed in Section 3.03. Unfortunately in both sites it was impossible to evaluate short-term outcome and only the comparisons of MUAC and BMI are presented here. In South Sudan, during the second week of April SPLA forcers loyal to John Garang attacked Ayod, forcing the villagers to flee and Concern to evacuate all staff. Tragically when Concern workers were able to return to Ayod, the centre had been destroyed and the occupants had either fled or been murdered. In the Angola study, the majority of patients were outpatients and there was a high incidence of self-discharges. The size of the city and the insecurity during the study period precluded follow-up of these patients once they ceased to attend the centre.
Section 6.03 Background literature

This section reviews the evidence indicating that MUAC might be a useful indicator of adult malnutrition during famine.

6.03(a) Body Mass Index (BMI)

For a discussion of the literature relevant to the use of BMI in the assessment of acute malnutrition, see Section 4.03.

6.03(b) Middle upper arm circumference (MUAC)

i. Child MUAC

In children, MUAC has been demonstrated as useful in the assessment of nutritional status. (Briend & et al. 1986; Burgess & Burgess 1969; Jelliffe & Jellife 1969; Shakir 1975; Velzeboer et al. 1984; WHO 1986) It is efficient at predicting mortality and, in some studies, MUAC alone (Alam, Wojtyniak, & Rahaman 1989; Briend & Zimick 1986; Vella et al. 1994) or MUAC for age, (Chen, Chowdhury, & Huffman 1980) predicted death better than all other anthropometric indicators. This advantage of MUAC was greatest when the period of follow up was short. (Briend, Wojtyniak, & Rowland 1987) Debate continues over whether the increased sensitivity and specificity of MUAC in predicting death is due to the confounding effects of age as MUAC is known to preferentially select younger children. It is thus possible that the higher mortality in younger children from non-nutritional causes is the factor behind MUAC predictive qualities. However, the inclusion of age in logistic models used to evaluate the predictive power of MUAC, made little difference to its performance, (Alam, Wojtyniak, & Rahaman 1989; Briend & Zimick 1986; Vella et al. 1994) indicating that preferential section of younger children is probably not of prime importance. The measurement of MUAC is easy to perform even on the most debilitated children and measurement techniques can be taught readily to minimally trained health workers. (Velzeboer et al. 1983) It is thus potentially suited to screening admissions to feeding centres during emergency aid operations. However, the use of MUAC in emergencies is still controversial, and disagreement over the preferential selection of younger children, the levels of cut-offs used, the efficiency of a two phase screening process and poor reproducibility in the measurement continue. (Bern & Nathanail 1995; Lindtjorn 1985; McLaren 1986; Ross et al. 1990; Ross, Berry, & Taylor 1986)
Consequently, some humanitarian relief agencies remain sceptical about the use of MUAC in emergencies. (Diskette 1995)

**ii. Adult MUAC**

At present during famines, MUAC is only recommended for use in children between 1 and 5 years of age and is not used routinely in the assessment of adult malnutrition. (Boelaert et al. 1995; Hakewell & Moren 1991; Young 1992) However, measurements of adults mid-arm circumference are known to reflect changes in adult body weight. (Ohlson et al. 1956) Estimates of arm muscle area (AMA) or corrected arm muscle area (CAMA), corrected for humerus cross-sectional area, can also be derived from MUAC and measurements of triceps skin-fold thickness (TSF). These have been incorporated into diagnostic schemes for adult malnutrition in hospitals (Gassull et al. 1984) and used as prognostic indicators in the elderly and cancer patients. (Friedman 1991; Heymsfield et al. 1984) In the elderly, CAMA area is reportedly a more sensitive indicator of changing nutritional status than BMI (Potter et al. 1995) and a CAMA threshold of $\leq 16.9 \text{ cm}^2$ has been shown to sensitively predict impending death. (Friedman 1991) Heymsfield demonstrated that in secondary malnutrition once AMA fell to 9-11 cm$^2$ death was imminent. Post mortem examination of these patients, revealed no other immediate reasons for death other than profound wasting. (Heymsfield et al. 1984) This AMA level therefore appears to represent a threshold, below which the amount of FFM is incompatible with life.

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15 Using the equation: $\text{CAMA (cm}^2\text{)} = [\text{AMC (cm)}]^2 / (4\pi - 10\text{cm}^2)$, where $\text{AMC} = \text{MUAC} - \pi \text{TSF}$. (Heymsfield, McManus, & Smith 1982)
Unfortunately, these studies did not include data on the relationship between MUAC and mortality and, although AMA and CAMA are derived from MUAC, there are important differences. MUAC is determined by several components; arm muscle, subcutaneous fat, the humerus, neurovascular bundle and skin. Although bone demineralisation and a decrease in density do occur in prolonged severe starvation percentage losses are much less than weight. It is therefore reasonable to assume that the cross-sectional area of the humerus remains relatively constant even during severe malnutrition. The percentage reduction of skin and the neuro-vascular bundle, consisting of a large proportion of collagen, is also less than that of fat or muscle protein. (Picou, Halliday, & Garrow 1966) The determinants of MUAC that change during starvation are therefore arm muscle and sub-cutaneous fat. These have both been identified as the most important determinants of survival in PEM (see section 4.03(e) iii). This central role of fat and muscle in determining survival
during starvation might mean that MUAC, a reflection of both, is more functionally relevant than CAMA, which reflects muscle mass alone. The relationship between peripheral subcutaneous fat and total body fat is however, not simple. The distribution of fat in the body varies with sex, ethnicity and age, (Bishop, Bowen, & Ritchey 1981; Heymsfield et al. 1984; Wang et al. 1994) and during under-nutrition, the amounts of subcutaneous and central fat do not change in direct proportion to each other. As starvation progresses however, the utilisation of subcutaneous fat in severe adult malnutrition (see section 4.03(e) iii) would be expected to increase the correlation between MUAC and CAMA.

**iii. Sexual dimorphism in arm circumference**

In normally nourished North American adults, sexual dimorphism in MUAC, triceps skin fold thickness and AMA exist: men have larger AMA and MUAC and women larger TSF. (Bishop, Bowen, & Ritchey 1981) This dimorphism appears around puberty (Stini 1973) and has been attributed to differences in androgenic and oestrogenic steroids increasing the bulk of skeletal muscle in men and subcutaneous fat in women. (Stini 1973; Widdowson 1976) As the TSF is larger in women the degree of sexual dimorphism in AMA is greater than in MUAC. The extent of sexual dimorphism in both MUAC and AMA however, appears to be variable, dependant on culture (James et al. 1994) and nutritional status. (Stini 1973) Dimorphism in MUAC can actually disappear in cultures where a disproportionately large physical work burden is placed upon women, particularly if this is during adolescence. (Dettwyler 1992)

**Section 6.04 Subjects and method**

**6.04(a) Subjects**

A group of severely malnourished adults in South Sudan with a low prevalence of famine oedema was chosen as a study population. The absence of oedema in this population minimised the confounding the relationship between BMI and MUAC by oedema which has previously been shown to increase body weight independently of changes in Fat and Fat Free Mass (see Section 4.07). The other study group is malnourished adults from Angolan with the majority of subjects suffering from oedematous malnutrition. This group was chosen in recognition of the importance of famine oedema as a complication of severe adult malnutrition. (Debray et al. 1946; Keys 1950a; McCance & Widdowson 1951; Winick 1979; Zimmer, Weil, & Dubois 1944)
Two groups of more normally nourished adults from Somalia are also included in the analyses. One study group was obtained by taking a systematic random sample of adult Somali women attending the Concern Worldwide general-ration distributions in the Bay region of Somalia during 1993. The other is the Concern Worldwide staff in Somalia during 1993.

**South Sudan**

During April 1993, BMI and MUAC were assessed in 98 severely malnourished Nuer adult inpatients at the Concern Worldwide feeding centre in Ayod, south Sudan. The population was suffering from acute malnutrition resulting from escalation in the war between opposing factions of the Sudanese Peoples Liberation Army (SPLA). This acute malnutrition was superimposed upon a background of chronic malnutrition, a result of the long-term war between the SPLA and the Sudanese government forces. Twenty five years of war had caused the death of almost all the cattle, the traditional source of livelihood for the Nuer. Superimposed upon this background of chronic malnutrition, patients were suffering from acute, non-oedematous malnutrition, complicated by a variety of infections commonly seen during famine, of which dysentery, respiratory infection, helminthiasis and malaria were the commonest. An epidemic of Kalar Azar was reportedly also present in the area (personal communication A. Davis, MSF Holland). All patients who could stand were measured, weighed, and had their MUAC assessed during the first week after their admission, using standard techniques (see 3.02(b)). The sacking of Ayod and the destruction of the centre with the murder of many of the inpatients in early April, ended the study and all patients were lost to follow up.

**Angola**

During November and December 1993, MUAC and BMI data were collected from adult and adolescent patients at the Concern Worldwide feeding centre (Angola (1), N =769) and Caritas adult feeding centre supported by Concern Worldwide (Angola (2), N=290), in Melanje, Angola. The city's population was suffering from acute malnutrition caused by several months of a total ground blockade of the government held town by UNITA guerrillas. Subjects were severely malnourished, suffering from acutely oedematous or non-oedematous malnutrition complicated by a variety of infections of which helminthiasis and respiratory tract infection were the commonest. The incidence of dysentery was extremely low. The majority of subjects were treated as outpatients with only those who were unable to return home at night sleeping in the centre. This
made follow up difficult, as most undertook took self-discharge and were lost to follow up once they felt better.

**iii. Somalia**

During 1993 MUAC and BMI data were collected from a sample of 642 rural Somali women attending village level general-ration distributions in the Bay region of Somalia. In addition, similar data were collected from all of Concern Worldwide's 145 local employees in regional capital, Baidoa. The sample of rural women was selected using a systematic random sampling technique, during Concern Worldwide general-ration distributions in the villages during July 1993. This distribution began in January 1993 and provided a monthly, family ration of approximately 15 kg of maize per person, delivered to the women of each family. Standard techniques were used to assess MUAC and BMI (see 3.02(b)).

**6.04(b) General methods**

See Chapter 3

**6.04(c) Analysis**

Sensitivity/specificity analysis, based upon 2x2 tables, and linear regression techniques were used to compare MUAC and BMI data. To make the results comparable with previous literature, the relationships between MUAC and BMI are presented using the regression of MUAC on BMI (regressions derived from $\text{MUAC} = b \times \text{BMI} + c$ ($b =$ slope and $c =$ intercept). Multiple linear regression techniques using EPI-Info (Dean et al. 1990), according to the method of Draper and Smith, (Draper & Smith 1981) were used to examine the relationship between BMI and MUAC whilst controlling for confounders such as oedema, sex, ethnic group and presence of acute malnutrition. Before the regression analysis was used to compare the Sudanese, Angolan and Somali data, outlying data points were removed. Outliers were defined as those with a mean BMI or MUAC greater than four standard deviations away from their respective population means. Only one data point from the Angolan data was excluded according to these criteria. Subsequently, after the initial linear regression of the groups of data, data points having (residuals) $> 4$ standard deviations away from the mean of the (residual) $^2$ were also excluded.
from further analysis. This excluded 1.13% of the 1,944 data points from further analysis. The degree to which the two indices identified the same individuals in the Sudanese data was analysed in terms of the sensitivity and specificity of MUAC in identifying those individuals below specific BMI cut-offs. In this analysis BMI was the dependent variable and the regression line $\text{BMI} = b \times \text{MUAC} + c$ was used. Integer values of BMI between 16 and 10 were assigned as cut-off points and the corresponding mean MUAC values predicted from the regression line. The choice of BMI as the reference indicator was somewhat arbitrary as, although an accepted indicator of adult CED, BMI has not yet been shown to be a criterion standard for the assessment of acute adult malnutrition (see Section 4.03). Data were analysed using EPI-Info, Microsoft Excel (Microsoft Corporation 1994) and Curvefit Professional. (Hyams 1993) See also 3.02(d).

6.04(d) Results

MUAC and BMI in adult marasmus

The MUAC and BMI values recorded from 98 marasmic patients in the South Sudan centre are presented in Table 10. Mean BMI values were higher for male than female patients (mean (kg m$^{-2}$): male 13.3, female 12.6, (ANOVA) $F = 3.26$, d.f. = 1, 96, $p = 0.07$). This result is of borderline significance. The mean MUAC was significantly higher for male than female patients (mean (mm): male 188, female 179, (ANOVA) $F = 4.24$, d.f. = 1, 96, $p < 0.05$).

BMI measurements were difficult to perform on the patients who experienced problems in standing. Many patients were very slow to step onto the scales and had great difficulty in standing up straight enough to be measured. Other inpatients could not stand at all and BMI measurements were not obtained. These patients were excluded from the study. MUAC measurements were much easier to perform on all subjects and could be taken with the patient standing, sitting or, in extreme cases, lying.

Figure 21 presents a scatter diagram of MUAC and BMI measurements with the male and female regression lines for MUAC on BMI. There was a highly significant correlation between MUAC and BMI, with a correlation coefficient of 0.88 (95% C.I. = 0.82 - 0.92, $F = 319$, d.f. = 1, 96, $p < 0.001$). Correlation coefficients were similar for male and female patients, male = 0.79 (95% C.I. = 0.64 - 0.88, $F = 65$, d.f. = 1, 39, $p < 0.001$), female = 0.92, (95% C.I. = 0.87 - 0.95, $F=$

16 Two of the 98 in the Sudanese sample, two of the 87 non oedematous Angolan, three of the 241 mildly oedematous Angolan, three of the 731 oedematous Angolan subjects, eight of the 642 Somali women and two of the 145 Concern
There was no significant difference between the sexes in the relationship expressed by the regression line of MUAC on BMI.

The proportion of the population below various cut-off values and an analysis of the sensitivity, specificity, and predictive power of MUAC with respect to BMI are presented in Table 11.

The proportions defined by the two indicators were similar, although at the lower end of the BMI range MUAC tended to define a smaller proportion of the population than the comparable BMI cut-offs. The sensitivity-specificity analysis indicated that the individuals identified by the two indices were also similar, particularly within the BMI range of 16 - 13 kg m\(^2\). The positive predictive value for the prediction of BMI by MUAC remained high for all the cut-off values. Below an MUAC of 18.5 cm (equivalent to a BMI of 13 kg m\(^2\)), the relative proportion of the population defined by MUAC and the sensitivity of MUAC in predicting BMI fell. This cut-off point corresponded to a position on the receiver operating characteristic (ROC) curve for the prediction of BMI by MUAC, where sensitivity was maximised without appreciable loss in specificity (see Figure 22).


Table 10

BMI and MUAC values in 98 severely malnourished adults belonging to the Nuer tribe in South Sudan

<table>
<thead>
<tr>
<th>sex</th>
<th>n</th>
<th>median (BMI)</th>
<th>minimum (BMI)</th>
<th>lower quartile (BMI)</th>
<th>upper quartile (BMI)</th>
<th>normal values (mean ± SD)†</th>
<th>median (MUAC)</th>
<th>minimum (MUAC)</th>
<th>lower quartile (MUAC)</th>
<th>upper quartile (MUAC)</th>
<th>normal values (mean ± SD)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>male</td>
<td>41</td>
<td>13.4</td>
<td>10.2</td>
<td>11.8</td>
<td>14.4</td>
<td>20.0 ± 2.2</td>
<td>19.0</td>
<td>15.0</td>
<td>17.8</td>
<td>20.0</td>
<td>25.6 ± 2.4</td>
</tr>
<tr>
<td>female</td>
<td>57</td>
<td>12.5</td>
<td>9.3</td>
<td>11.3</td>
<td>13.9</td>
<td>20.4 ± 2.7</td>
<td>17.5</td>
<td>12.5</td>
<td>16.0</td>
<td>19.5</td>
<td>24.8 ± 2.6</td>
</tr>
</tbody>
</table>

† Normal values based upon a sample of 5669 adults from developing countries (James et al. 1994)
Comparison of the sensitivity and specificity of MUAC and BMI cut-offs in 98 severely malnourished Nuer adults from south Sudan. The sensitivity, specificity and predictive values for the MUAC cut-offs are relative to the BMI cut-offs.

<table>
<thead>
<tr>
<th>BMI cut-off (kg/m²)</th>
<th>numbers below BMI cut-off (n)</th>
<th>proportion below BMI cut-off (%)</th>
<th>MUAC cut-off (cm)</th>
<th>numbers below MUAC cut-off (n)</th>
<th>proportion below MUAC cut-off (%)</th>
<th>sensitivity of MUAC cut-off relative to BMI cut-off (%)</th>
<th>specificity of MUAC cut-off relative to BMI cut-off (%)</th>
<th>positive predictive value of MUAC cut-off relative to BMI cut-off (%)</th>
<th>negative predictive value of MUAC cut-off relative to BMI cut-off (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>92</td>
<td>94</td>
<td>22.5</td>
<td>96</td>
<td>98</td>
<td>100</td>
<td>33</td>
<td>96</td>
<td>100</td>
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<tr>
<td>15</td>
<td>86</td>
<td>88</td>
<td>21.0</td>
<td>82</td>
<td>84</td>
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<td>95</td>
<td>50</td>
</tr>
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<td>14</td>
<td>71</td>
<td>72</td>
<td>20.0</td>
<td>68</td>
<td>69</td>
<td>87</td>
<td>78</td>
<td>91</td>
<td>70</td>
</tr>
<tr>
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<td>88</td>
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<td>14.0</td>
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<td>2</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
Figure 21

Scattergram illustrating the relationship between MUAC and BMI measurements in the S. Sudan study population, taken at the height of a severe famine (n = 98). Included for comparison are data from more normally nourished populations in developing countries. (James et al. 1994) There was a close correlation between MUAC and BMI in the Sudanese population. The slope of the regression lines of MUAC on BMI in these severely malnourished subjects were greater than those recorded in the better-nourished populations. At the most severe levels of emaciation, this difference is of practical significance, equivalent to a difference of 1 - 2.5 cm in MUAC.
Figure 22

Receiver operating characteristic curve (ROC) for the prediction of BMI by MUAC in the S Sudanese data population (n=98). The point "X", beyond which any increase in sensitivity is accompanied by a marked decrease in specificity, corresponds to a BMI cut-off of 13 kg m\(^2\).

ii. MUAC and BMI and oedematous adult malnutrition

The incidence of famine oedema in the Angolan subjects was high; 90% of subjects present with some pitting oedema and over 50% with moderate or severe pitting oedema of grade 3 or more. Table 12 & Table 13 present one-way analyses of variance, comparing mean BMI and MUAC values in 1056 of these subjects, grouped according to their grade of oedema. Table 12 demonstrates that increased severity of famine oedema (from grade 0 up to grade 5), were associated with a progressive elevation in BMI (F statistic = 20.25, p < 0.001). By contrast, Table 13 demonstrates that MUAC did not vary according to the grade of famine oedema (see, F statistic = 1.68, p = 0.14).
### Table 12

Analysis of variance for the relationship between grade of famine oedema and BMI in 1059 patients attending adult feeding centres in Melanje Angola.

<table>
<thead>
<tr>
<th>Oedema Grade</th>
<th>n</th>
<th>Total BMI kg m⁻²</th>
<th>Mean BMI kg m⁻²</th>
<th>Variance kg m⁻²</th>
<th>Std. Dev. kg m⁻²</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>101</td>
<td>1609</td>
<td>15.9</td>
<td>5.9</td>
<td>2.44</td>
</tr>
<tr>
<td>1</td>
<td>102</td>
<td>1648</td>
<td>16.2</td>
<td>5.8</td>
<td>2.42</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>2676</td>
<td>16.7</td>
<td>5.3</td>
<td>2.30</td>
</tr>
<tr>
<td>3</td>
<td>489</td>
<td>8551</td>
<td>17.5</td>
<td>6.1</td>
<td>2.47</td>
</tr>
<tr>
<td>4</td>
<td>159</td>
<td>2856</td>
<td>18.0</td>
<td>6.0</td>
<td>2.45</td>
</tr>
<tr>
<td>5</td>
<td>49</td>
<td>924</td>
<td>18.9</td>
<td>5.3</td>
<td>2.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oedema Grade</th>
<th>Minimum</th>
<th>25%ile</th>
<th>Median</th>
<th>75%ile</th>
<th>Maximum</th>
<th>Mode</th>
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<td>0</td>
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<td>15.7</td>
<td>17.2</td>
<td>25.4</td>
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<td>15.9</td>
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<td>15.4</td>
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<td>3</td>
<td>9.4</td>
<td>15.9</td>
<td>17.5</td>
<td>19.2</td>
<td>25.1</td>
<td>17.5</td>
</tr>
<tr>
<td>4</td>
<td>12.4</td>
<td>18.1</td>
<td>17.9</td>
<td>19.3</td>
<td>24.5</td>
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<td>17.6</td>
<td>19.0</td>
<td>20.6</td>
<td>24.2</td>
<td>19.2</td>
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Analysis of variance (ANOVA for normally distributed data)

<table>
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<tr>
<th>Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F statistic</th>
<th>p-value</th>
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<td>5</td>
<td>115.3</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>Within</td>
<td>6203</td>
<td>1054</td>
<td>5.885</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6780</td>
<td>1059</td>
<td></td>
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</tbody>
</table>

### Table 13

Analysis of variance for the relationship between grade of famine oedema and MUAC in 1059 patients attending adult feeding centres in Melanje Angola.

<table>
<thead>
<tr>
<th>Oedema Grade</th>
<th>n</th>
<th>Total MUAC cm</th>
<th>Mean MUAC cm</th>
<th>Variance cm</th>
<th>Std. Dev. cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>101</td>
<td>1993</td>
<td>19.7</td>
<td>5.9</td>
<td>2.42</td>
</tr>
<tr>
<td>1</td>
<td>102</td>
<td>1992</td>
<td>19.5</td>
<td>5.2</td>
<td>2.27</td>
</tr>
<tr>
<td>2</td>
<td>160</td>
<td>3175</td>
<td>19.8</td>
<td>5.0</td>
<td>2.24</td>
</tr>
<tr>
<td>3</td>
<td>489</td>
<td>9797</td>
<td>20.0</td>
<td>5.3</td>
<td>2.30</td>
</tr>
<tr>
<td>4</td>
<td>159</td>
<td>3113</td>
<td>19.6</td>
<td>4.9</td>
<td>2.22</td>
</tr>
<tr>
<td>5</td>
<td>49</td>
<td>977</td>
<td>19.9</td>
<td>6.3</td>
<td>2.50</td>
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</table>

<table>
<thead>
<tr>
<th>Oedema Grade</th>
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<th>25%ile</th>
<th>Median</th>
<th>75%ile</th>
<th>Maximum</th>
<th>Mode</th>
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<tbody>
<tr>
<td>0</td>
<td>15</td>
<td>17.8</td>
<td>19.6</td>
<td>21.1</td>
<td>27.0</td>
<td>19.8</td>
</tr>
<tr>
<td>1</td>
<td>15.2</td>
<td>18</td>
<td>19.4</td>
<td>20.8</td>
<td>28.8</td>
<td>19.2</td>
</tr>
<tr>
<td>2</td>
<td>15.6</td>
<td>17.8</td>
<td>19.6</td>
<td>21.2</td>
<td>27.2</td>
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<td>3</td>
<td>14.2</td>
<td>18.4</td>
<td>20.0</td>
<td>21.6</td>
<td>33.6</td>
<td>18.0</td>
</tr>
<tr>
<td>4</td>
<td>13.8</td>
<td>18</td>
<td>19.6</td>
<td>21.0</td>
<td>27.2</td>
<td>17.0</td>
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<tr>
<td>5</td>
<td>10.8</td>
<td>18.5</td>
<td>19.9</td>
<td>21.8</td>
<td>24.4</td>
<td>19.6</td>
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Analysis of variance (ANOVA for normally distributed data)

<table>
<thead>
<tr>
<th>Variation</th>
<th>SS</th>
<th>df</th>
<th>MS</th>
<th>F statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between</td>
<td>41</td>
<td>5</td>
<td>8.1</td>
<td>1.54</td>
<td>0.17</td>
</tr>
<tr>
<td>Within</td>
<td>5577</td>
<td>1054</td>
<td>5.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5618</td>
<td>1059</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Simple linear regression of MUAC on BMI, using the Angolan data, stratified according to the degree of oedema, indicated that the $\beta$ coefficient (slope) and the correlation co-efficient ($r$), decreased as the grade of oedema increased (see Figure 23 and Table 14). Both the $r$ and $\beta$ coefficients were smaller in the Angolan data, even when the non-oedematous group Angolan subjects were compared to the South Sudanese subjects (comparison of $\beta$: partial F statistic 9.0, d. f. 2, 182, $p < 0.001$; comparison of $r$: $z = 4.22$, $p < 0.001$). The linear regression lines did however converge around a BMI of 11.5 – 12.5 kg m$^2$ (see Figure 23).

---

17 Method for the comparison of correlation coefficients described in Clarke and Cooke, p 333 – 4 (Clarke & Cooke 1982)
The relationship between the MUAC and BMI in the Sudanese and Angolan data was examined further using multiple linear regression techniques that included the variables BMI, oedema, sex ascites and ethnic origin in models. The regression model is presented in Table 14. It demonstrates that the presence of pitting oedema was the most significant of the factors influencing the relationship between BMI and MUAC (partial f statistic = 46.21, p < 0.001). The
presence of ascites and differences in the gender composition of the two samples also exerted an influence over the relationship (ascites partial f statistic = 3.90, p < 0.005; sex partial f statistic 11.2, p < 0.001). Ethnic differences between the South Sudan (Nilotic) group and the Angolan (Bantu) group were not significant (partial f statistic 0.62, p > 0.05).

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>5</td>
<td>2471.77</td>
<td>494.35</td>
<td>157.21</td>
</tr>
<tr>
<td>Residuals</td>
<td>1150</td>
<td>3616.21</td>
<td>3.14</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1155</td>
<td>6087.98</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>β -coefficient</th>
<th>Lower 95% C.I.</th>
<th>Upper 95% C.I.</th>
<th>S.E.</th>
<th>Partial F-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI</td>
<td>16.87</td>
<td>0.57</td>
<td>0.53</td>
<td>0.62</td>
<td>0.022</td>
<td>663.98</td>
</tr>
<tr>
<td>oedema</td>
<td>2.39</td>
<td>-0.31</td>
<td>-0.40</td>
<td>-0.22</td>
<td>0.045</td>
<td>46.21</td>
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<tr>
<td>sex</td>
<td>1.35</td>
<td>-0.38</td>
<td>-0.60</td>
<td>-0.15</td>
<td>0.113</td>
<td>11.12</td>
</tr>
<tr>
<td>ascites</td>
<td>0.08</td>
<td>-0.38</td>
<td>-0.76</td>
<td>0.00</td>
<td>0.192</td>
<td>3.90</td>
</tr>
<tr>
<td>data set †</td>
<td>1.92</td>
<td>-0.18</td>
<td>-0.63</td>
<td>0.27</td>
<td>0.229</td>
<td>0.62</td>
</tr>
</tbody>
</table>

| Y-Intercept | 11.69 |

† 1 = Sudanese, 2 = Angolan

Table 14
Multi-linear regression model for the relationship between MUAC and BMI, with MUAC as the dependant variable amongst 1155 malnourished Sudanese and Angolan subjects.

iii. The relationship between BMI, MUAC and nutritional status

The subjects admitted into the S. Sudan and Angolan feeding centres were clinically all severely wasted. The very low mean MUAC and BMI values of these groups accord with this clinical observation. The Somali subjects, on the other hand, were clinically better nourished and in both cases the population means of BMI and MUAC were within the normal range (see Section 9.02). This difference in nutritional state between the Sudanese/Angolan subjects compared to the Somali subjects was used to examine whether the relationship between MUAC and BMI differed according to nutritional state. A multiple linear regression model, including variables for clinical nutritional status (defined by population group), oedema, sex and ethnic origin indicated that the relationship between MUAC and BMI might be different between normally nourished and malnourished populations. In the severely malnourished, the slope (β - coefficient) of the regression line MUAC on BMI was significantly greater than in the better nourished population.
(partial F statistic = 92, d. f. 5, 1939, p < 0.001, see Table 15). These results concord with MUAC and BMI data from other normally nourished populations in developing countries (Figure 24).

Table 15

Multi-linear regression model demonstrating the effect of malnutrition (defined clinically), on the relationship between MUAC and BMI in 1939 subjects from Somalia, Sudan and Angola. All P values are < 0.001.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>F-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>5</td>
<td>14749.19</td>
<td>2949.84</td>
<td>911.48</td>
</tr>
<tr>
<td>Residuals</td>
<td>1934</td>
<td>6259.04</td>
<td>3.24</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1939</td>
<td>21008.23</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>β-coefficient</th>
<th>Lower 95% C.I.</th>
<th>Upper 95% C.I.</th>
<th>Std. Error</th>
<th>Partial F-test</th>
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<tbody>
<tr>
<td>BMI</td>
<td>18.14</td>
<td>0.62</td>
<td>0.59</td>
<td>0.65</td>
<td>0.017</td>
<td>1332.10</td>
</tr>
<tr>
<td>clinical nutritional status†</td>
<td>0.60</td>
<td>-2.72</td>
<td>-3.28</td>
<td>-2.17</td>
<td>0.284</td>
<td>92.03</td>
</tr>
<tr>
<td>oedema</td>
<td>1.43</td>
<td>-0.36</td>
<td>-0.44</td>
<td>-0.28</td>
<td>0.041</td>
<td>75.79</td>
</tr>
<tr>
<td>sex</td>
<td>1.57</td>
<td>-0.56</td>
<td>-0.75</td>
<td>-0.36</td>
<td>0.099</td>
<td>31.43</td>
</tr>
<tr>
<td>data set‡</td>
<td>3.24</td>
<td>-0.22</td>
<td>-0.39</td>
<td>-0.06</td>
<td>0.084</td>
<td>7.01</td>
</tr>
<tr>
<td>Y-intercept</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>14.08</td>
</tr>
</tbody>
</table>

† Data sets coded as: 1 = Sudanese, 2 & 3 = Angolan, 4 & 5 = Somali
‡ Data sets coded as: 1 = Sudanese & Angolan, 2 = Somali
Figure 24

Linear regression lines for MUAC on BMI data in severely malnourished and adequately nourished populations. Angolan data from the Concern Worldwide and Caritas adult feeding centres in Melanje Angola. Included for comparison are data presented by James et al. from normally nourished populations in developing countries. (James et al. 1994)
The MUAC data were non-normally distributed with a skew to the right (see Figure 30 in the appendix). Only six of the 1,940 cases fell below 14.5 cm and examination of the regression on MUAC on BMI for all data, revealed a threshold around 14.5 – 15.5 cm, below which values appeared not to fall. This threshold meant that when a simple linear regression model for MUAC on BMI was fitted the residuals were not randomly distributed. A curvilinear, 4th degree polynomial model (MUAC = α + β1BMI + β2BMI^2 + β3BMI^3), fitted the data more closely, yielding residuals that were randomly distributed (see Figure 25). A very similar model provided the best fit in the non-oedematous data (see Figure 26).

![Figure 25](image)

Polynomial regression model MUAC = 39.7 + (-5.9 * BMI) + (0.50 * BMI)^2 + (-0.016 * BMI)^3 + (0.0002 * BMI)^4 describing the relationship between MUAC and BMI in all subjects (r = 0.75, Std error for the predicted y value = 2.20 n = 1940).
Section 6.05 Discussion

6.05(a) SH/S ratio and BMI

Many of the patients described above presented with extremely severe emaciation. Thirty five percent (34/98) of the Sudanese sample had a BMI below 12 kg m\(^2\), the level previously considered to be the lowest limit compatible with recovery. (James, Ferro-Luzzi, & Waterlow 1988)

The lowest BMI recorded in the centre was that of a woman who was still able to walk to the weighing scales with a BMI of 9.3 kg m\(^2\). Other patients were too weak to stand and were not weighed or measured. If the BMI could have been estimated in these patients, even lower values are likely to have been recorded.

The Nuer, a Nilotic race, have a phenotype with long legs relative to stature and consequently have low values for the SH/S ratio (see 4.03(c) i). In an extensive review of anthropometric data from around the world, the Dinka and the Samburu, both Nilotic peoples from sub-Saharan Africa, were the only populations to have mean BMIs below 18.5 kg m\(^2\). (Eveleth & Tanner 1976) This phenotype is almost certainly one of the reason why the BMIs found in the study population were so low.

SH/S ratio was not recorded in any of the centres during this study. The pressurised circumstances that surround emergency famine-relief operations mean that such measurements are unlikely to be routinely feasible. In the absence of these data, individual BMI values cannot be standardised for individual SH/S ratio. This detracts from BMI’s usefulness in the routine assessment and screening of individual admissions to feeding centres.

Using an estimated mean population SH/S ratio of 0.48 and the correction equation proposed by Norgan18 the mean BMI in the Sudanese sample increased by 2 kg m\(^2\) to a value of 15.2 kg m\(^2\). The minimum corrected BMI values at the centre were 11.6 kg m\(^2\) and 12.5 kg m\(^2\) for female and male patients respectively (see Table 16). Interestingly the corrected minimum BMI values are similar to the values of 13 kg m\(^2\) for male and 11 kg m\(^2\), suggested by Henry as the limits of BMI in starvation. (Henry 1990; Henry 1993)

\[^{18}\text{This correction is based upon the linear regression model of: BMI} = 57.2 \times \text{SH/S} - 7.4 \text{ and the equation BMIsd} = \text{BMIsd} = \text{BMI}_{0.52} + (\text{BMI}_{0.52} - \text{BMIsd}) \text{ where BMIsd} = \text{standardised BMI, BMI}_{0.52} = \text{estimated BMI at SH/S of 0.52, BMI}_{0.52} = \text{actual BMI, and BMIsd} = \text{estimated BMI at actual SH/S (see Section 9.04 ).} \]
Table 16

**BMI in the Sudanese centre, corrected mean SH/S ratio according to the method of Norgan (see footnote 18) using a SH/H value of 0.48 for the Nuer phenotype and 0.52 for the "normal" phenotype.** (Norgan 1994c; Norgan 1994b)

<table>
<thead>
<tr>
<th>Sex</th>
<th>n</th>
<th>Minimum</th>
<th>25%ile</th>
<th>Mean</th>
<th>Median</th>
<th>75%ile</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>male</td>
<td>41</td>
<td>12.48</td>
<td>14.08</td>
<td>15.59</td>
<td>15.68</td>
<td>16.68</td>
<td>19.28</td>
</tr>
</tbody>
</table>

6.05(b) **The effect of oedema**

Clinically the Angolan population was malnourished. The severity of malnutrition was however, due to the increases in weight caused by the presence of famine oedema BMI did not reflect this (see Table 12). MUAC values were less affected by famine oedema (see Table 13) although in extreme grades of famine oedema the upper arm can become swollen. This was rare and overall MUAC appeared to be a more stable reflection of decreased body mass in these subjects. Consequently, the gradient (\( \beta \) co-efficient) of the regression of MUAC on BMI was less with increasing severity of oedema (see Figure 23).

The gradient of the MUAC on BMI regression line in Angolan patients with no signs of famine oedema was less than a similar regression using the Sudanese data. The most likely explanation for this is that the diagnosis of famine oedema, especially in it's early, "pre-pitting" stage (Waterlow 1993) can be problematic and even amongst trained doctors estimations of the amount of oedema fluid are very variable. (Golden 1999) It is therefore possible that many mild cases of oedema were wrongly classified as oedema free. Ascites also poses diagnostic difficulties and several litres of free fluid in the peritoneum can be missed, especially by workers inexperienced in clinical examination and the diagnosis of ascites. These issues are discussed in 3.03(d). The convergence of the Angolan regression lines around a BMI of 13-14 kg m\(^{-2}\) (MUAC of 17 – 18 cm) is compatible with this explanation. At extremes of emaciation, the minimum amount of lean tissue necessary to sustain life is present and the weight of excess extra cellular oedema fluid must approach zero. Consequently, the confounding effect of oedema upon the relationship between MUAC and BMI would be expected to decrease with increasing emaciation and the regression lines would converge as in Figure 23. Although the point of convergence with the Sudanese
regression line appears to occur at a lower BMI, correcting the Sudanese data for SH/S ratio (see 6.05(a) ) would make the convergence points closer.

6.05(c) The effect of acute malnutrition

The presence of malnutrition appeared to exert a significant influence on the relationship between MUAC and BMI (see Table 15). At severe grades of emaciation, actual MUAC was 2 - 2.5 cm lower than the theoretical value predicted by the regression of MUAC on BMI in several better nourished populations (see Figure 21& Figure 24). There are several possible reasons for this finding. It is possible that the difference is due to ethnic differences in body shape. The common regression lines published by James et al. presented in these figures, were based upon data from many different populations and contain substantial racial variation. In some of the contributory data sets (Ethiopian, Somali, and Chinese female), the relationship between BMI and MUAC is similar to that seen in the Sudanese data (see Figure 31). The differences demonstrated between the severely and less severely malnourished groups might also be an artefact resulting from deficiencies in the study design. Although the effect of ethnicity did not appear to be significant in the multivariate model presented in Table 15, the ‘malnutrition’ and ‘ethnic’ variables were not independent. Thus, ethnic variation in the relationship between MUAC and BMI cannot be ruled out adequately by this study. It might also be that workers responsible for measuring MUAC in the different studies systematically recorded MUAC in slightly different ways.

There are however, several physiological reasons why the relationship between BMI and MUAC should vary with the presence of acute malnutrition. During acute energy deficiency, tissue with a low metabolic rate, such as sub-subcutaneous fat and skeletal muscle, is preferentially catabolised. (Heymsfield et al. 1984; Waterlow 1986) The high rates of infection in acute malnutrition during famine, (Tomkins & Watson 1989) would also increase catabolism of skeletal (peripheral) muscle. (Broom 1993; Heymsfield et al. 1984) The reduction in physical work using the arms that occurs during famine would further decrease arm muscle. The resultant accelerated loss of upper arm tissue in comparison to other tissues would reduce MUAC faster than the BMI in the acutely malnourished when compared to better nourished populations. The slope of the MUAC on BMI regression line would therefore be increased and its position shifted to the right, as malnutrition increased. This is seen in the South Sudanese data (see Figure 21).

---

19 Somalia, Papua New Guinea, India, China, Senegal, Zimbabwe, Mali and Ethiopia (James et al. 1994)
An important deficiency in these studies was the failure to record individual SH/S values. However, it is unlikely that the differences in the relationship between BMI and MUAC in severely malnourished and more normally nourished populations demonstrated here can be explained by differences in SH/S ratio. The long legged phenotype of the Sudanese population would be associated with a low SH/S ratio. Therefore observed BMI values would tend to be lower than if they had been standardised to a SH/S ratio of 0.52. The use of un-standardised BMI values would therefore mean that the MUAC on BMI regression line would lie more to the left, the reverse to that seen in Figure 21. Standardisation of the BMI values to a SH/S ratio of 0.52 would tend to shift the MUAC on BMI regression line to the right, increasing the differences between the severely malnourished and more normally nourished populations.

In the absence of other data from SAM in famine, it is parsimonious to conclude that the effect seen in Figure 21 & Figure 24 represent a physiological change rather than, or in addition, to any ethnic differences. This has important implications for the development of MUAC cut-offs for use in famine. If the relationship between MUAC and BMI does change in acute malnutrition, MUAC cut-offs appropriate to famine must be based upon data from acutely malnourished populations. Since 1992, when the attention of the scientific community was re-drawn towards severe adults malnutrition in famines, (Collins 1993a; Collins 1995) attempts have been made to extrapolate from non-acutely malnourished populations to create indicators for use in famine-relief programmes. In 1996, Ferro-Luzzi and James adjusted their theoretical estimation of the lowest BMI compatible with life down from 12 kg m$^2$ to 10 kg m$^2$ [sc192] in order to take into account the extremely low BMIs being observed in Somalia during the famine of 1992. (Ferro-Luzzi & James 1996) They proposed two new BMI and three adult MUAC cut-offs for use during famine (see Table 17). (Ferro-Luzzi & James 1996) These MUAC cut-offs were based upon MUAC Z-scores, derived from MUAC measurements on 5669 adults living in developing countries (see Table 10). Implicit in their use of Z-scores is the assumption that the distribution of MUAC values is the same in normally nourished and acutely malnourished populations. This assumption is not correct if acute malnutrition is accompanied by a physiological change altering the relationship between MUAC and tissue mass.

An increased slope of the MUAC on BMI regression line in acute malnutrition would mean that MUAC cut-offs derived from normal populations using Z-scores, would over-estimating levels of malnutrition in famine populations. The result would be a reduced specificity (and increased sensitivity) in their identification of “true” malnutrition giving a less discriminatory ROC curve. Comparing the sensitivity, specificity and predictive power of such theoretical MUAC cut-offs in
identifying BMI thresholds, with MUAC cut-offs derived from acutely malnourished subjects, gives a magnitude of this error. This comparison again assumes BMI to be a criterion standard for adult AED (see 6.04(c) ) and require a famine population with no oedema. Table 18 shows the result of this comparison. See also Figure 32 in the appendix that presents the ROC of the different MUAC indicators using the data from South Sudan.

This analysis suggests that MUAC cut-offs, derived by extrapolation from normally nourished adult populations, introduce substantial error into the assessment of SAM. A cut-off based upon the -2 Z-score had a specificity of 54% in the identification of a BMI threshold of 13 kg m$^2$, compared to a specificity of 90% for the 18.5 cm cut-off derived from acutely malnourished adult populations. If used for screening this fall in specificity would be translated into a very substantial increase in the workload of a TFC. In the absence of a sound theoretical or empirical basis, such an increase in caseload would appear to be unwarranted.
Table 17

MUAC values proposed by Ferro-Luzzi and James for the assessment of adult malnutrition during famines (Ferro-Luzzi & James 1996)

<table>
<thead>
<tr>
<th>MUAC Z-score</th>
<th>MUAC values (mm)</th>
<th>diagnostic category</th>
<th>corresponding BMI (kg m(^{-2}))</th>
<th>grade of malnutrition</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; -1</td>
<td>&lt; 230</td>
<td>men</td>
<td>&lt; 17</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>&lt; 220</td>
<td>women</td>
<td>&lt; 17</td>
<td></td>
</tr>
<tr>
<td>&lt; -2</td>
<td>&lt; 200</td>
<td>men</td>
<td>&lt; 13</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>&lt; 190</td>
<td>women</td>
<td>&lt; 13</td>
<td></td>
</tr>
<tr>
<td>&lt; -3</td>
<td>&lt; 170</td>
<td>men</td>
<td>&lt; 10</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>&lt; 160</td>
<td>women</td>
<td>&lt; 10</td>
<td></td>
</tr>
</tbody>
</table>

Table 18

The prediction of BMI by MUAC cut-off derived from non-famine populations and severely malnourished populations.

<table>
<thead>
<tr>
<th>source of indicator cut-off</th>
<th>MUAC cut-off (cm)</th>
<th>BMI cut-off (kg m(^{-2}))</th>
<th>numbers below MUAC cut-off</th>
<th>numbers below BMI cut-off</th>
<th>sensitivity of MUAC cut-off relative to BMI (%)</th>
<th>specificity of MUAC cut-off relative to BMI (%)</th>
<th>PPV of MUAC cut-off relative to BMI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>normal population</td>
<td>20.0</td>
<td>13.0</td>
<td>68</td>
<td>48</td>
<td>94</td>
<td>54</td>
<td>66</td>
</tr>
<tr>
<td>James et al.</td>
<td>17.0</td>
<td>10.0</td>
<td>26</td>
<td>2</td>
<td>100</td>
<td>75</td>
<td>8</td>
</tr>
<tr>
<td>severely malnourished</td>
<td>18.5</td>
<td>13.0</td>
<td>45</td>
<td>48</td>
<td>83</td>
<td>90</td>
<td>89</td>
</tr>
<tr>
<td>population</td>
<td>14.5</td>
<td>10.0</td>
<td>2</td>
<td>2</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
6.05(d) **BMI and MUAC in extreme malnutrition**

During starvation, the total amount of collagen and skeletal mass in the body remains reasonably constant. (Heymsfield et al. 1984; Picou, Halliday, & Garrow 1966) Therefore, in the pre-terminal stages of extreme emaciation as peripheral stores of fat and muscle non collagenous protein become exhausted, elements such as skin, bone and the neuro-vascular bundle, form an increasingly large proportion of the arm volume. This exhaustion of peripheral stores is accompanied by a relative increase in the catabolism of central, visceral protein stores and a decrease in catabolism of peripheral stores (see 4.03(e) iii). These changes would reduce the rate of decrease in MUAC compared to BMI, causing the regression line of MUAC on BMI to level off. The drop in the sensitivity of MUAC when compared to BMI, that occurred below an MUAC of 18.5 cm (see Table 11), might be a reflection of such a change at the lower end of the BMI and MUAC ranges. The near absence adult MUACs lower than 14 to 15 cm is also evidence in support this change in metabolism. The requirement to be able to stand as a criterion for entry into the study would have resulted in a selection bias partially obscuring this effect. Only those with sufficient peripheral muscle mass remaining to enable them to stand would have been selected. Although fewer than 10 patients were excluded from the Sudanese data in this way, many of them would have been those who had exhausted their peripheral stores. The number of exclusion in the Angolan data is not known. The drop in the sensitivity of MUAC at extreme grades of emaciation would therefore most likely have been greater had the whole population of the centres been measured. The paucity of data at extremely low BMI and MUAC values means that empirical support of this phenomena is sketchy. At present the relative importance of these effects is unknown and more work is required relating MUAC cut-offs to risk of short term functional consequences before MUAC cut-offs can be more firmly stipulated.

6.05(e) **The relationship between MUAC and BMI in SAM**

The opposing effects of increased peripheral catabolism during the evolution of severe acute adult malnutrition and decreased peripheral catabolism in the terminal stages means that a straight linear model of the relationship between MUAC and BMI is not likely appropriate. When fitted such a model yields residuals that are not normally distributed. An “S” shaped polynomial regression model describing the relationship between BMI and MUAC is theoretically more appropriate. Such a model, where the slope of the regression line of MUAC on BMI is increased over the BMI range 19 – 14 and levels out below 13 kg m\(^2\) and above 19 kg m\(^2\) is shown in Figure 25. The
correlation co-efficient for this model is not significantly greater than a linear model the residuals are randomly distributed. A very similar model, but with a greater increase in slope between a BMI of 19 – 13 kg m\(^2\), also provide the best fit if the oedematous patients are excluded from the analysis (see Figure 26).

![Diagram](image)

**Figure 26**

Polynomial regression model \( \text{MUAC} = 38.2 + (-6.4 \times \text{BMI}) + (0.63 \times \text{BMI})^2 + (-0.02 \times \text{BMI})^3 + (0.0.0003 \times \text{BMI})^4 \)

describing the relationship between MUAC and BMI in all non-oedematous subjects \( r = 0.82, \text{Std error for the predicted } y \text{ value} = 1.87, n = 971 \).

The levelling out of the regression line at the extremes of emaciation indicates a point where peripheral stores are exhausted and central catabolism of protein provides the main energy source. This level of MUAC may therefore represents a functional threshold below which there is an increase in the catabolism of visceral protein from vital organs such as the heart and other vital structures. This point probably corresponds to the pre-terminal increased in the P-ratio. (Henry,
Rivers, & Payne 1988) The increase in visceral catabolism will decrease the function of vital organs and increase the necessity for special therapeutic diets. Such severely emaciated patients are unlikely to survive given only a general-ration alone. The point where the regression line flattens is therefore likely to represent the threshold at which therapeutic feeding is necessary (see Chapter 7).

6.05(f) The use of MUAC in adults

In children, the use of MUAC is associated with two problems; the preferential selection of younger children as malnourished(Bern & Nathanael 1995; Smedman et al. 1987; Sommer & Loewenstein 1975) and a lack of reproducibility in MUAC measurements. (McLaren 1986) The preferential selection of younger children as malnourished results from the gradual increase in the normal MUAC between the ages of 1 and 5. (Ross et al. 1990) In older children and adolescents, the rapidly changing patterns of skeletal muscle and subcutaneous fat are likely to exaggerate this problem and it is likely that age specific MUAC cut-offs will be required. In adults the use of MUAC, is not subject to errors caused by growth, but can be affected by the redistribution of subcutaneous fat towards central areas of the body with ageing. (Euronut SENECA investigators 1991) Problems with the reproducibility of MUAC measurements are potentially more serious obstacles to the use of MUAC in adults. As in children, inter- and intra-observer errors in MUAC measurements may occur. These did not appear to be great problems with these data (see 3.03(d)) and it maybe that the larger dimension of the adult arm reduces the relative importance of these errors. The development of coloured, non-numeric, MUAC bands reflecting threshold values of MUAC with a change of colour would further reduce these problems by remove numerical errors. Given the ease with which MUAC measurements can be performed it would be feasible to refer any patients found to have an MUAC within a few mm either side of the threshold to a more experienced worker for verification. This area for referral could be designated on the band as a different coloured zone. The width of this zone would need to be based upon a more detailed examination of errors in the evaluation of adult MUAC by minimally trained workers. These problems are being investigated using data from several Concern Worldwide adult therapeutic centres.

Assessment of adult nutritional status using MUAC requires no equipment apart from a tape measure. As the index is the actual measurement itself, mathematical manipulation of the measurements obtained is not necessary. By contrast, assessment of BMI requires a height board and weighing scales that often require frequent re-calibration in the hot dusty environments in
which famines usually occur. In addition, the two measurements obtained must be mathematically transformed before being useful. All these processes are prone to error, especially during the highly pressurised circumstances characteristic of the early phases of famine-relief programs. The ease with which MUAC can be assessed therefore suit it for nutritional screening during the height of an emergency where time and skilled personnel are at a premium.

**Section 6.06 Conclusion**

There is a great need for a practical indicator with which to assess adult malnutrition, especially during the initial phases of emergency relief operations during famine. This study indicates that MUAC is well suited to such a role and its use has several important advantages over the use of BMI. However, the inability to follow up patients in all study sites and the resulting absence of outcome data prevented any analysis of the relationship between MUAC and mortality. This is a major limitation in this study and in the absence of these data, functional MUAC cut-offs based on risk of mortality cannot be presented with any degree of certainty.

At present, there is insufficient data available to stipulate with any degree of certainty functional MUAC cut-off differentiating malnourished adults that require specialised therapeutic care from those who can survive without it. This study does demonstrate that it is inappropriate to derive such thresholds by extrapolation from data recorded in normally nourished populations. There is a need for more field studies during emergency famine-relief operations, to evaluate the power of adult MUAC to predict mortality in different famine affected populations.

In severe adult malnutrition oedema is common, associated with a poor prognosis and confounds anthropometric indicators dependant on weight. At present, there are no clear guidelines as to how to assess oedema. By analysis oedema using readily definable anatomical landmarks this study goes some way to providing a useful classification of the condition. However there are still problems over the way that oedema is assessed in practice, particularly how much pressure should be applied and for how long. There is a need for further research to assess this.

At the moment, there is an urgent need for indicators of SAM for use in famine relief programmes. The recent increased interest in severely malnourished adults has resulted in many centres being opened in recent famines. Many of these are operating without guidelines, or with guidelines based upon the BMI indicators for chronic adult malnutrition or MUAC cut-offs derived from normally malnourished populations. Given this situation, the author feels that there
is a need for tentative recommendations for screening indicators, based upon what little data there is from severely malnourished adults during famine and taking due regard of theoretical considerations. Although far from perfect these are likely to be better than either an absence of guidelines or those derived without reference to data from famine. The "best guess" indicators from this study are presented in Chapter 8.
Chapter 7  Study four: The dietary treatment of severe adult malnutrition

Section 7.01 Aim

To examine the effect of dietary protein intake on the rehabilitation of severely malnourished adults

Section 7.02 Introduction

The difficulties of feeding severely malnourished adults, especially those with oedematous malnutrition, have long been recognised. (Digby 1878) During the first half of this century, these problems received considerable attention from the scientific community and, generally, diets containing relatively high levels of protein were recommended. (Beattie, Herbert, & Bell 1948; Burger, Sandstead, & Drummond 1945; Leyton 1946; Lipscomb 1945; McCance & Widdowson 1951; Mollinson 1946) In the early 1950s, scientific attention shifted towards malnourished children in whom the quantity and quality of dietary protein required for successful rehabilitation became the focus of much research. (Waterlow 1961) In particular, the importance of liver pathology in kwashiorkor was recognised. (Waterlow 1948) Recently, it was demonstrated in children with kwashiorkor, that mortality was minimal when diets containing only maintenance levels of protein (<1 g kg\(^{-1}\)day\(^{-1}\)) were given. (Golden 1993; Golden 1996) Up to the time of the Somali famine in 1992, these diets had only been tested in specialised hospital units and no field research had been performed during an emergency relief program. The difficult circumstances that exist during famines generally prevent the execution of classical, scientifically rigorous research. This has resulted in an absence of field research since the late 1940s when the concentration camps in Europe and the Far East were liberated. In its absence, results from studies performed in less severely malnourished subjects, usually in hospital settings, have been extrapolated to the very different circumstances found during war and famine. Thus, it was shown that adult subjects with BMI of 17-18 kg m\(^{-2}\) respond well to diets with P:E ratios greater than 19%. (Barac-Nieto et al. 1979) As a result, such high protein diets have continued to be recommended for the management of severe adult malnutrition. They were used in all Concern Worldwide TFCs during the Somali relief operation.
in 1992-1993. However, the adults admitted to these TFCs generally had BMI of 10-13 kg m$^2$, far less than those that had been studied, and often, they had oedema (see Chapter 4). It was observed that many of these patients, particularly those with oedema, were refusing the high protein diets. Thus, the hypothesis was advanced that the high protein diets were deleterious during the initial phase of rehabilitation. The aim of this study was to compare the immediate and short-term effects of a lower protein diet with those of the conventional higher protein diet during nutritional rehabilitation of severely malnourished adults admitted to a TFC during the emergency relief program in Baidoa.
7.03 Subjects and Methods

7.03(a) Subjects

Data were collected on 573 patients with a reported age of 15 years and over, admitted to the Concern Worldwide Adult Therapeutic Centre, Baidoa, between 25th October 1992 and the end of March 1993. The reported ages of those admitted were between 15 and 80 years (mean 34). It is unlikely that these reported ages are accurate as people were generally unsure of their exact age and no local calendar was available to verify the ages given. Analysis of the distribution of the age data reveals clustering around ages divisible by five, suggesting that reported ages were often given to the nearest five years. 46% of those admitted were male.

The criteria for admission varied depending upon the available space in the centre, and the existence of other medical facilities in Baidoa. In general, only patients with a BMI below 13.5 kg m\(^{-2}\) or patients assessed as very severely malnourished by the clinician (SC.) and too ill to be weighed and measured on admission, or patients with oedematous malnutrition were admitted. Patients with primarily medical problem were referred to the MSF Holland inpatient unit and the less severely malnourished people to supplementary kitchens (see Chapter 3 for a fuller discussion of subject selection).

7.03(b) Methods

Details of the centre are presented in 3.01(b) i, and details of the supervision, rehydration, medical treatment and discharge criteria in 4.04(b).

7.03(c) The rehabilitation diets

During their stay in the centre, patients received 6-8 meals each day. For the first month of operation, the standard higher protein diet (HP diet), used in all the other TFCs in Baidoa, was the only diet available. This consisted of 'recovery milk' [King's Food (Ermelo, Holland), a blend of dried skim milk (DSM), vegetable oil, vitamins and minerals], UNIMIX (a blend of Soya flour, oil and sugar), rice, beans and BP5 biscuits (Compact, Bergen, Norway) (Table 19). The recovery milk and BP5 biscuits were premixed fortified foods, designed especially for famine-relief and
marketed in Europe: the UNIMIX was a premixed fortified food made up for UNICEF in various factories in Africa. Patients on this diet were offered, on average, 158 g protein and 16.2 MJ per day (P:E ratio 16.4%), including 70 g oil and 137 g of lactose. The cost of this diet was approximately US $1.90 person\(^{-1}\) day\(^{-1}\). During the first few days after admission, the milk component was diluted to half strength with the WHO formula ORS containing sodium chloride 3.5g l\(^{-1}\), trisodium citrate 2.9g l\(^{-1}\), potassium chloride 1.5g l\(^{-1}\) and glucose 20g l\(^{-1}\). This reduced the total daily average offered to 129 g protein and 14 MJ (P:E ratio 15.5%). From 5 December 1992, a lower protein diet (LP diet), mixed on site from basic commodities, was also available. The LP diet consisted of 'high energy milk', a blend of DSM, vegetable oil and sugar, together with bananas, white rice and sweet tea (Table 20). Patients on this diet were offered, on average, 82 g protein and 16.1 MJ per day (P:E ratio 8.5%) including 152 g of oil and 95 g of lactose. The cost of this diet was approximately $1.00 person\(^{-1}\) day\(^{-1}\). During the first few days after admission, the milk component of this diet was diluted to one-third strength with WHO formula ORS. This reduced the total daily average offered to 35 g protein and 10.9 MJ (P:E ratio 5.0%). Initially, the potassium and sodium contents of the two diets were similar. However, during January 1993, bags of the individual salts mineral became available. The author then used cooking scales to measure out appropriate weights to dilute in water to make a concentrated solution. For CuCl\(_2\), the crude scales made this an inaccurate process. From then on, and patients on the LP diet received approximately (per kg body wt \(\times\) d\(^{-1}\)) 1 mmol KCL, 1 mmol tripotassium citrate, 0.4-0.8 mmol MgSo\(_4\), o.31 mmol zinc acetate and 0.003 mmol CuCl\(_2\), raising the amount of potassium they received by 2 mmol kg body wt\(^{-1}\) \(\times\) d\(^{-1}\). For those patients who required rehydration, usually only during the initial phase of treatment, WHO formula ORS was used. It was not feasible to quantify the amount of ORS and, therefore, the additional sodium and potassium consumed over these periods.

On 5 December 1992, the LP diet was first offered to 11 oedematous patients, who had not responded to the HP diet. The positive response in these patients to the change of diet was so dramatic that it was soon considered unethical to use the HP diet in the treatment of oedematous patients. Thus, from 7 December 1992, patients presenting with oedema and those whom the clinician (SC.) considered very ill or moribund, were offered the LP diet during the initial phase of treatment. The HP diet continued to be used from admission for the less severe cases and for many of the patients during the recovery phase of rehabilitation. The onset of this recovery phase was defined clinically in oedematous patients, by a return of appetite and a substantial loss of oedema and / or ascites. As loss of oedema was accompanied by loss of weight, this was accepted
as a sign of a positive response to treatment. (Golden 1993) In marasmic patients, the recovery phase was heralded by a return of appetite and accompanied by steady weight gain for at least three days.

Table 19
The higher-protein diet (HP), containing 16.4% of the energy from protein

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
<th>Protein</th>
<th>Energy</th>
<th>Sodium</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/d</td>
<td>g/d</td>
<td>kJ/d</td>
<td>mmol/d</td>
<td>mmol/d</td>
</tr>
<tr>
<td>Recovery milk</td>
<td>252</td>
<td>55</td>
<td>4276</td>
<td>42</td>
<td>71</td>
</tr>
<tr>
<td>UNIMIX</td>
<td>100</td>
<td>12</td>
<td>1680</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Rice</td>
<td>200</td>
<td>12</td>
<td>2940</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Beans</td>
<td>130</td>
<td>33</td>
<td>1966</td>
<td>1</td>
<td>46</td>
</tr>
<tr>
<td>BP5</td>
<td>275</td>
<td>46</td>
<td>5290</td>
<td>2</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 20
The lower-protein diet (LP), containing 8.5% of the energy from protein

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
<th>Protein</th>
<th>Energy</th>
<th>Sodium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/d</td>
<td>g/d</td>
<td>kJ/d</td>
<td>mmol/d</td>
</tr>
<tr>
<td>DSM</td>
<td>180</td>
<td>65</td>
<td>2646</td>
<td>44</td>
</tr>
<tr>
<td>Oil</td>
<td>150</td>
<td>0</td>
<td>5733</td>
<td>0</td>
</tr>
<tr>
<td>Sugar</td>
<td>160</td>
<td>0</td>
<td>2688</td>
<td>0</td>
</tr>
<tr>
<td>Rice</td>
<td>200</td>
<td>12</td>
<td>2940</td>
<td>0</td>
</tr>
<tr>
<td>Bananas</td>
<td>500</td>
<td>5</td>
<td>2100</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>82</td>
<td>16107</td>
<td>44</td>
</tr>
</tbody>
</table>
7.03(d) **Analysis of mortality.**

Of the 573 patients for which admission data were collected, 16 were admitted primarily on medical grounds, and there was insufficient dietary information for 70 others. These 86 patients were excluded from the analysis of mortality. For analysis, patients were assigned to either the HP group (n = 343) or the LP group (n = 144), according to the diet they received during the initial period of their stay in the centre. Thirteen patients were wrongly allocated to diets by junior staff upon admission. I rectified these mistakes within 3 days and allocated the patients to the correct diet. For the analysis, the diet group of these patients was that of the corrected diet. Twenty-seven patients (all from the marasmic group) were lost to follow up and were excluded from further analysis of mortality associated with the two diets, leaving 377 patients with marasmus or mild oedema and 83 patients with moderate to severe oedematous malnutrition. These data are presented in Table 21. Two by two contingency tables and multiple logistic regression were used to assess the effect of the 2 diets and the mineral supplement on mortality. This allowed us to control for the potential confounding effects of morbidity (oedema, lower respiratory tract infection, dysentery, dehydration, and anaemia) and other variables (age, sex, and time since opening of the centre) upon mortality. The time variable was included in the analysis in order to control for the effect of any time bias in the data, as it was conceivable that patient care, independent of the introduction of the LP diet, improved over time. Variables not independently associated with mortality were excluded from models in a stepwise fashion using estimation techniques.

7.03(e) **Analysis of the effect of HP and LP diets on rates of weight change and the loss of oedema during rehabilitation.**

The rate of weight change (g kg\(^{-1}\)day\(^{-1}\)) for each consecutive 3 day period was calculated for each patient. A matched analysis of the rate of weight change during the first fifteen days of treatment on each diet, (using a paired t-test), was performed on those oedematous patients who changed from HP to LP diets after they had been in the centre for more than 3 days and for whom there were sufficient data (n = 7).
Table 21

Outcome data associated with the use of the higher (HP) and lower (LP) protein diets

<table>
<thead>
<tr>
<th></th>
<th>All patients</th>
<th>Oedematous patients</th>
<th>Marasmic patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Died</td>
<td>Survived</td>
</tr>
<tr>
<td>HP diet</td>
<td>343</td>
<td>78</td>
<td>240</td>
</tr>
<tr>
<td>LP diet</td>
<td>144</td>
<td>25</td>
<td>117</td>
</tr>
<tr>
<td>Total</td>
<td>487</td>
<td>103</td>
<td>357</td>
</tr>
</tbody>
</table>
Section 7.04 Results

7.04(a) General patient data.

The characteristics of the patients who survived and those who dies has been reported in Section 4.05

7.04(b) Effect of diet on mortality.

Mortality was lower in patients with oedematous malnutrition who received the LP diet during the initial phase of treatment (crude OR 0.31, 95% C. I. 0.10, 0.90; Yate’s corrected $\chi^2$ 4.74, $p < 0.05$). This effect remained after adjusting for confounding variables using logistic regression (adjusted OR 0.31, 95% C. I. 0.12, 0.81, likelihood ratio statistic 5.74, $p < 0.05$). This is equivalent to a three-fold reduction in mortality. No such difference was observed in marasmic patients (crude OR 0.52, 95% C. I. 0.24, 1.08; Yates corrected $\chi^2$ 2.97, $p = 0.08$; adjusted OR 0.87, 95% C. I. 0.38, 1.97; likelihood ratio statistic 0.10, $p = 0.74$). Analysis of the effects of the mineral mix in patients receiving the LP diet did not demonstrate any differences in mortality before and after addition of the mineral supplement.

7.04(c) Loss of oedema and gastro-intestinal function.

The appetite of many of the oedematous patients appeared to be very poor on the HP diet. Upon changing to the LP diet, an increase in appetite was reported by many of these patients, including those who had suffered from persistent oedema lasting several weeks on the HP diet. In the 7 patients for whom matched rate of weight change data were available, the rate of loss of oedema, (reflected as weight loss), accelerated after transfer to the LP diet (rate of weight change, $g \, kg^{-1} \, day^{-1}$, mean, S. D.): HP $+6.3$, 12.1; LP $-7.2$, 18.5; difference $= 13.5$, paired $t = 3.18$, $p < 0.05$. Associated with the increased appetite were episodes of watery diarrhoea. This was occasionally very severe, resulting in the rapid appearance of intravascular hypovolaemia. It responded to dilution of the milk element of the diet with WHO formula ORS during the first few days of treatment. The number of days and the degree to which the milk was diluted were tailored for each patient according to the severity of the diarrhoea, clinical signs of intravascular hypovolaemia...
(heart rate, peripheral perfusion, jugular venous pressure, hydration of mucous membranes) and the response to previous dilutions. On occasion, it was necessary to dilute the milk down to one-ninth strength for several days in order to reduce diarrhoea and maintain the appropriate intravascular volume. Once the diarrhoea resolved, the milk concentration was gradually increased to full strength over a week.

7.04(d) Weight change during rehabilitation.

The mean rates of weight change for oedematous and marasmic patients during the initial month of treatment on each diet are shown in Figure 27. During the first 9 days, oedematous patients on the LP diet tended to lose weight as they lost oedema. By contrast, oedematous patients on the HP diet tended to gain weight. After this period the situation reversed and those on the LP diet started to gain weight whilst those receiving the HP diet stayed at the same, or gradually lost, weight. Marasmic adults gained weight similarly on both diets during this initial period. During the recovery phase (days 16 - 60 after starting treatment), mean rates of weight change were similar in both marasmic and formerly oedematous patients (mean, S. D.: marasmic, 6.1, 5.3 g kg\(^{-1}\)day\(^{-1}\); formerly oedematous, 5.1, 4.2 g kg\(^{-1}\)day\(^{-1}\)) and for the HP and LP diets (mean, S. D.: HP, 5.9, 5.6 g kg\(^{-1}\)day\(^{-1}\); LP, 5.6, 4.8 g kg\(^{-1}\)day\(^{-1}\)
Figure 27

Rates of weight change in oedematous (n = 45) and marasmic (n=219) patients receiving the lower-protein (■) and higher-protein (●) diets during the first 33 days of treatment. Note error bars are +/- 1 S. E. of the mean.
Section 7.05 Discussion

7.05(a) The importance of lower protein diets during the initial treatment of severe malnutrition in adults.

In this study, oedematous patients receiving the HP diet suffered a three-fold higher mortality than those receiving the LP diet. Many of these patients also experienced prolonged anorexia and persistence of oedema. The LP diet was associated with lower mortality and accelerated loss of oedema. These differences appear likely to have been due to the different amounts of dietary protein offered during the initial phase of therapy, however problems with the study design and implementation means that such conclusions cannot be categorical.

Other potential explanations must also be examined. The study compared groups of patients differing primarily according to the diet they received. However, patients were not randomly allocated to the diets. The HP diet was started earlier than the lower protein diet and within a week after its introduction, the LP diet was preferential allocated to patients considered by the author to be more severe. It is possible that the differences in outcome that have been ascribed to the differences in diet were, instead, due to differences related to the timing of the diets or to the subjects assigned to each diet. The many factors that changed with time such as improvements in the training of the staff, changes in the general condition of admissions as the famine progressed, and changes in resources for the centre, might have contributed to the differences observed. Although during analysis logistic models, containing a time variable, attempted to allow for these biases, such statistical techniques are poor substitutes for rigorous study design. The non-random allocation of patients to the diets however is likely to have obscured the reported improvements associated with the LP diet. During the first 6 weeks of the study, all patients received the HP diet: during the next 16 weeks, those patients assigned to the LP diet were oedematous or otherwise very ill or moribund were preferentially allocated to the LP diet by the author. On clinical grounds, these patients were expected to have a higher mortality than those assigned to, or already recovering satisfactorily on the HP diet. However, the study has shown that the patients on the LP diet had a three-fold lower mortality and a more rapid loss of oedema than those on the HP diet. Thus, it is possible that, had patient allocation been randomised, the difference in outcome would have been in the same direction but even greater. This is compelling evidence that the difference in outcome was due to the difference in diet.
The diets, however, differed in more than their protein content. Lower energy intake, particularly energy derived from carbohydrate, during the initial treatment with the LP diet, is a possible explanation of the differences in outcome. This might be expected to lower mortality by reducing the incidence of 'refeeding syndrome'. (Weinsier & Krumdieck 1980) Although the aim was to offer diets of similar energy content (see Tables 1 & 2), the LP diet had a greater proportion of its energy derived from fat and was usually given in a more dilute form during the first few days of treatment. This dilution substantially reduced the energy being offered to patients during that time. Although the 'recovery milk' element of the HP diet was also diluted during the first few days of treatment, this dilution caused less of a decrease in the energy content of the HP diet as a whole. These differences are, however, unlikely to explain the higher mortality on the HP diet as, owing to persistent anorexia, most of the oedematous patients receiving the HP diet consumed only a small fraction of the food offered. Their food intakes, though not formally measured, appeared to be very low, making 'refeeding syndrome' unlikely. The marked increase in appetite and thus, presumed increase in food intake, observed in these patients when offered the LP diet, is likely to have more than compensated for the decreased energy content of the diluted diet. Indeed, it is likely that energy intake during the initial phase of treatment on the LP diet was higher than on the HP diet. This would accord with documented experiences in feeding severely malnourished children in Jamaica. (Golden 1982)

Immediately after the change to the LP diet, most of the oedematous patients who had been in the centre for some weeks developed watery diarrhoea. This diarrhoea appeared to be the 'refeeding diarrhoea' frequently described in new arrivals at feeding centres, and generally regarded as the response of a starving and atrophic intestine to the initial reintroduction of food. (Roediger 1986) The absence of 'refeeding diarrhoea' amongst oedematous patients receiving the HP diet and its development when these patients were transferred to the LP diet, supports the observation that the previous intake of the HP diet in these patients was very low.

Alternatively, other differences in the composition of the two diets could have contributed to the difference in mortality. The HP diet had more lactose that might have increased mortality. This is also unlikely as the lower incidence of diarrhoea on the HP diet indicates that lactose intolerance was not a major problem. Although the two diets contained similar amounts of sodium it is also possible that if the critically ill patients ate only the milk elements of the diets sodium intake would have been much on the HP diet. This again is unlikely, as the large quantities of ORS added whilst diluting the LP diet (see 7.03(c) ), would have increased the sodium intake in the patients receiving the LP diet.
In marasmic patients, the diet given during the initial phase of treatment did not affect mortality or initial rate of weight change. This suggests that the dietary differences interacted with metabolic differences between marasmus and oedematous malnutrition. One of the main metabolic differences is in liver function. In this study, few of the marasmic but many of the oedematous patients had clinical signs consistent with liver failure. These included petechial rash and jaundice as well as anorexia, oedema and ascites. Thus, it is possible that there was no difference in outcome associated with diet in marasmic patients because their liver function was better preserved. If correct, this again suggests that it was the protein content of the diet that was of importance.

The study failed to demonstrate any effect of the mineral supplements in patients given the LP diet. This may have been due to the study design whose aim was not to test their effect. However, it is also possible that the mineral intake from the LP diet alone was adequate. This is likely to be true for potassium, whose dietary intake was usually at least 2 mmol kg⁻¹ day⁻¹, but unlikely to be so for the other minerals.

Although recovery from severe adult malnutrition has been systematically studied only rarely, there have been reports of similar poor responses to HP diets wherein oedema was slow to disappear, and sometimes even appeared during treatment (26-28). Ex-inmates of Belsen concentration camp, who experienced degrees of weight loss comparable to patients in Baidoa (mean weight loss 38% corresponding to a BMI of 12 to 14 kg m⁻²) suffered frequently from famine oedema and ascites. (Mollinson 1946) During rehabilitation on a diet containing 64.8 g protein and 3.4 MJ (P:E ratio 32.4%), famine oedema often appeared or increased. (Lipscomb 1945) In these patients, use of casein hydrolysates was associated with increased mortality. (Vaughan & Pitt Rivers 1945) Similar accounts come from the Dutch famine of 1944-5, where the recommended rehabilitation diet contained 300g of protein and 13.4 MJ (P:E ratio 37%). (Burger, Sandstead, & Drummond 1945)

7.05(b) Rates of weight change during the recovery phase of rehabilitation.

The extreme levels of disruption and insecurity present in Baidoa during the time of this study made the operation of the centre very difficult. The mean rates of weight gain, of 5 - 6 g kg⁻¹ day⁻¹ during the recovery phase of rehabilitation, probably represent the lower end of the spectrum of reasonable rates of weight gain in adults recovering from severe malnutrition. Severely malnourished ex-inmates of the Sanbostel concentration camp receiving 31.5 MJ and 297g protein day⁻¹ (P:E ratio 15.8%) gained around 7 g kg⁻¹ d⁻¹ during the recovery phase of their treatment.
In less severely malnourished patients, rates of weight gain appear to be lower. In the Minnesota experiment, 32 volunteers with mild to moderate malnutrition, receiving 10 -14 MJ and 75 -100g protein day\(^{-1}\) (P:E ratios 10.6 - 14.4\%) gained only 1.85 g kg\(^{-1}\) day\(^{-1}\). (Keys 1950b)

7.05(c) **Comparison with children.**

The patterns of presentation and recovery in severely malnourished adults are similar to those seen in children. In children, hypoalbuminaemia is evidence of a poor prognosis. (Vis 1985) Although oedema, in the absence of hypoalbuminaemia, is not necessarily a poor prognostic indicator, (Waterlow 1993) in practice, the frequent coexistence of the two makes oedema a useful prognostic marker. In Baidoa, oedema in adults was associated with a much poorer prognosis (see 4.06(c)). However, it is possible that this finding is not universal. In a Concern TFC in Melanje, Angola during 1993 and 1994, 90% of adults admitted suffered from oedema but this did not appear to be associated with such a poor prognosis (unpublished, Collins 1993). More work is needed on prognostic indicators in severe adult malnutrition.

The maximum rates of weight gain, typically 10 - 20 g kg\(^{-1}\) day\(^{-1}\), recorded in children recovering from severe malnutrition, (Ashworth 1969; Waterlow 1993; Waterlow, Golden, & Patrick 1978) are considerably higher than the rates of weight gain reported here. However, the pattern of recovery is similar. Initially, on a low protein, maintenance energy intake, oedematous children often lose oedema within a week. (Golden 1993) Appetite returns and this, together with loss of oedema, heralds the recovery phase. Amongst our oedematous adult patients, the rates of oedema loss were variable and often much slower. On the LP diet, some patients lost most of their visible oedema and ascites within a few days, the rapid loss generally accompanied by watery diarrhoea. In these patients, care had to be taken to avoid intravascular hypovolaemia. In the absence of guidelines for adults, the author considered a loss of approximately 0.25 to 0.5 litres day\(^{-1}\), equivalent to a 0.25 to 0.5 kg day\(^{-1}\) weight loss. Regulation of the rate of oedema loss was achieved by diluting the high-energy milk with ORS to an extent dictated by the severity of diarrhoea. In other patients, particularly those on the HP diet, the rate of loss of oedema was much slower and pedal oedema or ascites persisted for weeks. Persistent anorexia and debility accompanied this. These patients generally responded rapidly to introduction of the LP diet. The response involved marked increase in appetite and general well being and loss of oedema and ascites. However, minor grades of oedema sometimes persisted for weeks, even after they had recovered much of their original body mass. When oedema increased even on the LP diet the patient usually died.
Section 7.06 Conclusions

Due to the extreme conditions experienced in the TFC operating in a war zone, the subjects in this study were not randomised to the 2 diets, nor were their dietary intakes estimated. During most of the study, those with a worse prognosis on admission received the LP diet. Notwithstanding, on the LP diet, oedematous adults suffered lower rates of mortality and lost oedema more quickly than those receiving a more conventional HP diet. In marasmic adults, there was no difference in mortality between patients on LP and HP diets. During the recovery phase, there were no differences in rates of weight gain between the LP and HP diet groups.

Thus, it appears that, compared with the conventional HP diet, the LP diet was more effective in the treatment of oedematous adults and as effective in the treatment of marasmic adults. The LP diet usually needed to be diluted during the initial phase of treatment. It was cheaper and more easily obtained than the specially manufactured famine-relief foods of the HP diet. This study suggests that such a diet, based on milk, oil, sugar and locally available foods, with a relatively low P:E ratio, should be offered to all severely malnourished adults in both the initial and recovery phases of rehabilitation. By using locally available produce, it may also provide some stimulation of local economy. It should also ease the organisational difficulties involved in the provision of food items during emergency feeding operations. However, more research on treatment protocols for use in severe adult malnutrition is still needed.
Chapter 8 Conclusions

This section pulls together the lessons from this study and presents tentative recommendations for the screening and treatment of adults during famine. The many methodological problems with this research means that it provides no definitive answers to the problems faced by humanitarian workers trying to admit and treat severely malnourished adults during famine. However, it does provide starting points for future research into the assessment and treatment of the condition. For the first time, it provides tentative recommendations for screening severely malnourished admissions into feeding centres, based on data gathered from severely malnourished adults during famine, rather than extrapolated from non-famine populations. This represents an advance from the very limited state of knowledge and screening guidelines that existed when this work began in 1992.

Section 8.01 Screening severely malnourished adults during famine relief programmes

MUAC in combination with clinical signs should be used to screen adult entrance into feeding centres, using the classification shown below. BMI is inappropriate for this purpose, as it is affected by oedema and body shape and is difficult to measure. In any particular situation, workers should only use these suggested criteria as a starting point and adapt them to situation-specific factors.
8.01(a) Admission criteria for TFCs

Admission criteria into adult therapeutic feeding centres should be based upon:

1. MUAC < 160 mm irrespective of clinical signs

or

2. MUAC 161-185 mm plus one of the following:
   ♦ Bilateral pitting oedema (Beattie grade 3 or worse)
   ♦ Inability to stand
   ♦ Apparent dehydration
   ♦ Famine oedema (Beattie grade 3 or worse). This must be assessed by a clinician to exclude other causes of pitting oedema.

Additional social factors can be included in the model. The relative weighting of these must be determined locally; for example whether you need one, two or three additional social factors to tip the balance in favour of therapeutic rather than supplementary care. Relevant social factors could include the following:

♦ Access to food (quantity and quality)
♦ Distance from centres
♦ Presence /absence of carers
♦ Shelter
♦ Dependants
♦ Cooking utensils

In any particular situation, workers should take these suggested standards as the starting point and adapt them according to situation-specific factors.

8.01(b) Admission to Supplementary Feeding Programmes

Admission to adult supplementary feeding centres should be based upon the following cut-off:

1. MUAC 161-185 mm and no relevant signs or few relevant social criteria.
Workers should again take these suggested standards as the starting point and adapt them according to situation-specific factors.

Section 8.02 The treatment of severely malnourished adults during famine relief programmes

The findings of this study indicate that a diet with a relatively low protein : energy ratio should be offered to all adults in therapeutic feeding centres. In this study a diet with a protein : energy ratio of 8.5%, diluted with ORS in cases of diarrhoea, proved more effective in treating severely malnourished adults than one with a protein : energy ratio of 16.4%. Since 1992, when the study was undertaken, similar lower protein diets have become commercially available and are now used as standard procedure during relief operations. In particular the Formula 75 (F75) developed for phase 1 feeding for the first few days after admission and formula 100 (F100)(Briend & Golden 1993; Golden 1997) for the rapid growth phase of treatment. F75 has a protein : energy ratio of approximately 5%, an osmolarity of 333 mOsmol/l and a low lactose content. In addition, it is fortified with a mineral mix similar to that used in this study. It therefore appears appropriate for the phase one treatment of severely malnourished adults and I have more recently used it for that purpose with good effect. It is recommended that these diets be used in the treatment of severe adult malnutrition.

Section 8.03 Where do we go from here? future research needs:

8.03(a) Defining functional cut-offs

Longitudinal studies should be undertaken to determine whether individuals falling below specific cut-off points for BMI, and MUAC have elevated morbidity or mortality, poor pregnancy outcome, decreased work ability or physical performance measures. Such studies must be conducted in a variety of situations with varying levels of adult under-nutrition. During emergencies, such studies are problematic. Ideally, studies relating indicators to the risk of mortality in a general population are required to establish functional cut-off points that could be used for the screening of adult admissions to feeding centres. However, famines always involve massive social upheaval and large numbers of afflicted people. These factors, combined with the
armed conflict that has characterised almost all famines during the last ten years, make such broad-based population studies unfeasible. Consequently, no such studies have yet been performed for any nutritional indicator in either adults or children during the height of a famine. Given these difficulties, relating indicators to mortality in a selected feeding centre population may be all that is reasonably possible. The selection bias involved in such studies must be acknowledged and results interpreted with caution.

8.03(b) Patterns and prevalence of adult under-nutrition during famine

Data on the prevalence and patterns of adult under-nutrition during famines may be useful in defining cut-offs. Data on different ethnic groups and settings would be useful.

8.03(c) Practicality of measurements and calculations

The practicality of obtaining various measures should be explored in field situations. Survey organisers should assess the ease of training survey workers in measuring MUAC, weight, and height, as well as assessing inter- and intra-observer variability in these measurements when measuring adults.

8.03(d) Adjusting for differences in body shape

Surveys undertaken in a variety of populations should explore the utility of adjusting indices using weight and height for differences in body shape by using the SH/S Index or other indicators of body shape.

8.03(e) The use of MUAC to monitor recovery from under-nutrition

The changes in MUAC and weight during recovery from under-nutrition should be compared with a view to establishing whether MUAC is useful in this role and if it is, establishing relevant MUAC discharge criteria.
8.03(f) *More data on differentiating between secondary and primary under-nutrition*

Examination of adult failure-to-thrive in centres should include attempts to identify measurements or signs that predict failure-to-thrive in feeding centres.

8.03(g) *The aetiology, significance and treatment of famine oedema and ascites*

More information on the significance and prevalence of famine oedema and ascites is required. It is recommended that surveys assess subjects for these symptoms.

**Section 8.04 Community therapeutic care**

The present focus on therapeutic feeding centres (TFC) as the sole mode of treating severely malnourished people during famine is inappropriate and often counter-productive. The centralised and resource-intensive TFC model of care is maladaptive. A TFC's huge requirement for resources, skilled staff and imported therapeutic products makes it very expensive and highly dependent upon external support. The centralised approach to care and high staff requirements undermine local health infrastructure, disempower communities and promote the congregation of people. Congregation of severely malnourished patients inside the centres promotes centre-acquired infection, a major problem in many TFCs. The congregation of communities around TFCs promotes breakdowns in public health, an important cause of mortality and morbidity during famine. Vitally, during severe famine when severe adult malnutrition is prevalent, the TFC model of care cannot attain adequate coverage of the target population in a timely manner.

During the past three years Ready to Use Therapeutic Foods, nutritional equivalent to the lower protein diet research here, have become available. This opens the possibility of effective outpatient care for the majority of severely malnourished. Workers must research mechanisms of delivering these products to those who require them in an appropriate and cost-effective manner and the possibility of making Ready to Use Therapeutic Foods locally. Drawing upon mother to mother educational and mobilisational techniques, common in development projects might be an appropriate method to promote compliance with therapeutic regimes in the community.
### Chapter 9 Appendices

#### Section 9.01 Appendix 1

**Table 22**

*BMI at admissions in non-oedematous patients who survived stratified by age.*

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>n</th>
<th>Mean BMI kg m$^2$</th>
<th>Median BMI kg m$^2$</th>
<th>Mode BMI kg m$^2$</th>
<th>Variance</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\geq 25$</td>
<td>157</td>
<td>13.3</td>
<td>13.0</td>
<td>11.4</td>
<td>3.24</td>
<td>1.80</td>
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<td>11.9</td>
<td>12.0</td>
<td>2.56</td>
<td>1.60</td>
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</table>

**Table 23**

*BMI at admissions in oedematous patients who survived stratified by age.*

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>n</th>
<th>Mean BMI kg m$^2$</th>
<th>Median BMI kg m$^2$</th>
<th>Mode BMI kg m$^2$</th>
<th>Variance</th>
<th>Standard Deviation</th>
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<tr>
<td>+</td>
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<td>14.6</td>
<td>14.1</td>
<td>14.4</td>
<td>7.7</td>
<td>2.77</td>
</tr>
<tr>
<td>−</td>
<td>16</td>
<td>13.6</td>
<td>13.0</td>
<td>12.7</td>
<td>13.2</td>
<td>3.63</td>
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</table>

**Table 24**

*BMI at admissions of patients who died stratified by age*

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<th>Age (years)</th>
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<th>Mean BMI kg m$^2$</th>
<th>Median BMI kg m$^2$</th>
<th>Mode BMI kg m$^2$</th>
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<td>1.90</td>
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Table 25

Male oedematous patients

<table>
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<th>admission BMI kg m$^2$</th>
<th>died</th>
<th>survived</th>
<th>Total</th>
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<tbody>
<tr>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
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<td>0</td>
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</tr>
<tr>
<td>12</td>
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<td>1</td>
<td>1</td>
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<td><strong>Total</strong></td>
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Table 26
*Female oedematous patients*

<table>
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<th>admission BMI kg m$^2$</th>
<th>died</th>
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<th>Total</th>
</tr>
</thead>
<tbody>
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</tr>
<tr>
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<td>3</td>
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<td>11</td>
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<td>total</td>
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</table>
Figure 28

ROC curves for the prediction of mortality in the centre by the stepped sum clinical model in all admissions (n = 383), BMI in marasmic admissions (n = 218), BMI in marasmic adults (n = 112), BMI in oedematous admissions (n = 55) and BMI in all admissions (n = 383).
Section 9.03 Appendix 3

The mean BMI value in the Sudanese subjects was 3.0 kg m$^2$ lower than in the Angolan and 7.1 kg m$^2$ lower than the weighted mean for the Somali subjects. The difference in weighted mean BMI between the Angolan and Somali subjects was 4.0 kg m$^2$. The pattern in the MUAC data was similar, however the difference in mean MUAC values between the Sudanese and Angolans was less marked (1.3 cm) and that between the Angolan and Somali data greater (4.7 cm).

BMI, MUAC, sample size and analysis of variance of the BMI and MUAC data from 971 non-oedematous adult and adolescent subjects are presented in Table 27 and Table 28.
Table 27

BMI values in the different data set. 1 = S. Sudanese, 2 = non oedematous Angolan, 3 = Concern's Somali workers, 4 = Somali women

<table>
<thead>
<tr>
<th>data set</th>
<th>Obs.</th>
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<th>Mean</th>
<th>Variance</th>
<th>Std. Dev.</th>
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<td></td>
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<td>kg m⁻²</td>
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<td>12757</td>
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Table 28

MUAC values in the different data set. 1 = S. Sudanese, 2 = non oedematous Angolan, 3 = Concern's Somali workers, 4 = Somali women

<table>
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<tr>
<th>data set</th>
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<th>Mean</th>
<th>Variance</th>
<th>Std. Dev.</th>
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<td>cm</td>
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Figure 30

Distribution of MUAC values in all patients included in this work (n = 1940)

Figure 31

Ethnic variation in the relationship between MUAC and BMI. A comparison of the data from South Sudanese women included in this work, with data from populations not suffering from famine, reproduced from the work of James et al. (James et al. 1994)
Figure 32

ROC for MUAC indicators in the identification of BMI thresholds (based upon data in Table 18)

Section 9.04 Appendix 4

9.04(a) The correction of BMI using the Cormic Index (SH/S)

To standardise BMI to take into account changes in SH/S ratio use the equations below to calculate BMI standardised to the actual SH/S ratio for the population under study.

Male subjects - BMI = 0.78(SH/S)-18.43

Female subjects - BMI = 1.19(SH/S)-40.34

Note: SH/S ratios should be expressed as a percentage

The observed BMIs can then be standardised to a SH/S ratio of 0.52 by adding the differences between the observed BMI and BMI standardised for the population SH/S ratio to a BMI standardised to 0.52 using the equation below:

\[ BMIS_{std} = BMIS_{0.52} + (BMISO-BMIS_{0.52}) \]

Where BMISO = standardised BMI,
BMI_{52} = estimated BMI at SH/S of 0.52

BMI_{ob} = actual BMI

BMI_{es} = estimated BMI at actual SH/S

**i. Examples**

A Male population "A" has a mean BMI of 18.5 kg m\(^2\) and a mean SH/S ratio of 50%. The

\[ BMI_{52} = 0.78 \times 52 - 18.43 = 22.13 \]  
\[ BMI_{es} = 0.78 \times 50 - 18.43 = 20.57 \]  
Therefore the \( BMI_{nl} = 22.13 + (18.5 - 20.57) = 20.06 \) kg m\(^2\)

A Female population "A" has a mean BMI of 17.0 kg m\(^2\) and a mean SH/S ratio of 54%. The

\[ BMI_{52} = 1.19 \times 52 - 40.34 = 23.92 \]  
\[ BMI_{es} = 1.19 \times 54 - 40.34 = 21.54 \]  
Therefore the \( BMI_{nl} = 21.54 + (17.0 - 23.92) = 14.62 \) kg m\(^2\)
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Supplementary material


The limit of human adaptation to starvation

Steve Collins

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Severe adult malnutrition is commonly encountered during famine emergency relief programmes. As adult energy requirements are proportionally less than those in children, severe malnutrition and death among adults occurs later than the peak in child mortality. Often, by the time an emergency relief operation is up and running, many of the children have already died, and starving adults constitute a large proportion of the population with nutritional problems. Although there has been much interest in adult malnutrition, simple measurements such as height and weight have rarely been recorded systematically. In studies such as those of Keys and McCance, where height and weight data were recorded, the degree of malnutrition investigated was not severe. There is no classification of severe adult malnutrition. Equivalent classifications in children (weight for height and mid upper arm circumference) are fundamental to the assessment and screening of admissions to child feeding centres, and the lack of such a classification in adults hampers effective patient selection and assessment. This is especially difficult if the volunteers working in famine relief programmes are young, first-time recruits with little or no experience in similar situations. Body mass index (BMI, body weight in kilograms divided by height in metres squared) is a useful indicator of chronic energy deficiency in adults. Potentially it is also useful in the assessment of severe acute adult energy deficiency. This article presents an assessment of BMI during a severe famine.

This study took place in Baidoa, the town at the epicentre of the 1992 famine in Somalia. The famine was caused by the civil war that followed the overthrow of the president, Siad Barre, in 1990. The Bay region of the country was particularly badly affected, and by the autumn of 1992 tens of thousands of people had migrated to Baidoa, the regional capital, in search of food. The death rate among these displaced people was one of the highest ever recorded in a civilian population. It was estimated that by November 1992 up to 75% of the displaced children under the age of 5 had died. The Concern Adult Therapeutic Centre in Baidoa began operating in October 1992, after it became apparent that three-quarters of all deaths occurring in the town were adults or adolescents.

General inpatient data

Of the 573 admissions from whom data were collected, 413 (72%) survived, 122 (21%) died, and 38 (7%) were lost to follow-up. Mean reported age of those that died was 36 years (95% confidence interval (CI) = 33-39), slightly older than the survivors whose mean age was 33 years (95% CI = 31.5-34.5; analysis of variance (ANOVA) = 3.1, P = 0.08). The gender composition of those that died did not differ from survivors (likelihood ratio test = 1.5, P = 0.2). Nineteen percent of deaths occurred within 48 hours after admission, 48% within the first week and 27% during the second week after admission (see Fig. 1). Mean time to discharge was 30.8 days, (34.6 days in oedematous patients and 30.2 days in marasmus (extreme malnutrition with wasting of subcutaneous tissues and muscles) patients).

BMI data

Anthropometric data were recorded on admission to the centre (Table 1). The presence of severe famine oedema increased BMI at admission (Kruskall-Wallis statistic H = 29, P < 0.001). This increase was greater in male than in female patients (partial f statistic = 5.3, P < 0.001). BMI values for those that died were bimodally distributed depending on the presence or absence of oedema. A peak in mortality around a BMI of 11 corresponded to the mortality associated with marasmus, another around 15.5, to mortality associated with oedematous malnutrition. In marasmic patients, the level of BMI at admission was a reasonable predictor of mortality in the centre. This was not the case in patients with famine oedema (see Fig. 2). The association between BMI and risk of mortality in marasmus took different forms in male and female patients. In female patients the risk of mortality increased sharply below a BMI threshold of 11.0 (odds ratio = 9.0, likelihood ratio statistic = 7.9, P = 0.005). In male pa-
tients no such threshold was observed, the risk of mortality gradually increased as BMI declined (odds ratio for each decrease of 1 kg m\(^{-2}\) = 2.3 likelihood statistic 10.8, \(P < 0.005\)).

The lowest BMI compatible with life

The values for BMI at admission of survivors with marasmus or mild famine oedema are presented (Fig. 3). Below a reported age of 25 there was a significant relationship between admission BMI and age (regression coefficient of BMI on age = 0.22, \(\beta\)-coefficient 0.14, \(F\) statistic = 5.0, \(P < 0.05\)). No such relationship existed in patients with a reported age of 25 and above. These data are therefore divided into older adults, aged \(\geq 25\) years, and younger adults, aged 15–24 years. The geometric mean and minimum admission BMI in the older adult group were 13.2 (95% CI = 12.9–13.5) and 10.4. Younger adults had BMI values approximately 1 kg m\(^{-2}\) below those recorded in patients aged \(\geq 25\) years. Geometric mean and minimum BMI values in this group were 12.1 (95% CI = 11.8–12.4) and 9.6. Mean and minimum BMI values were similar for male and female patients, once they were adjusted for the severity of famine oedema. Weight loss, due to loss of oedema during the initial phase of treatment, reduced many patients' BMI values still further. The lowest BMI values recorded in survivors were 10.1 for older, and 8.7 for younger adults. Among these adults, 22% (\(n = 43\)) of survivors aged \(\geq 25\) years and 49% (\(n = 59\)) of survivors aged between 15 and 24 years had BMI values on admission below 10.0, the level previously considered the lowest compatible with life\(^5\). The survival rate among those admitted with BMI values below 11.0, was 65% for older adults (\(n = 23\)) and 82% for younger adults (\(n = 34\)). Mean BMI on discharge was 15.

Famine oedema

Mortality rates were higher in patients presenting with severe famine oedema (Table 1). This was common, seen in 16% of all admissions and 28% of those that subsequently died, and was associated with a poorer prognosis (odds ratio = 2.4, Yates' corrected \(\chi^2 = 11.7, P < 0.001\)). This association was stronger in male than female patients (Wolfs' \(\chi^2 = 4.59, P < 0.05\)). The poor prognosis seen in patients with severe famine oedema was predominantly a result of the increased mortality in patients presenting with pitting oedema, where the oedematous tissue retains for a time an indentation produced by pressure. Pitting oedema was independently associated with mortality (odds ratio for each increase in grade = 1.5, likelihood ratio test = 22.2, \(P < 0.001\)). Male patients had a poorer prognosis at severe grades of pitting oedema than female patients as shown in Fig. 4 (odds ratio (male) = 1.7, likelihood ratio test 23.5, \(P < 0.001\); odds ratio (female) = 1.3, likelihood ratio test = 4.4, \(P < 0.05\)). Minimal pitting oedema was not associated with an increased risk of death in either sex.

Discussion

BMI as an indicator for use in severe famine

BMI was relatively good for indicating the risk of short-term mortality in marasmic patients. The BMI levels used to define differing grades of chronic energy deficiency (CED) were, however, not relevant to severe famine. Most of the displaced adults living in Baidoa during the autumn of 1992 had BMI values below 16 kg m\(^{-2}\), the upper limit defining severe CED\(^4\). Such a cut-off was therefore of little use in differentiating between those who needed therapeutic feeding and those who would survive without it. BMI also had practical limitations that reduced its usefulness in emergency situations. The time required to obtain the necessary height and weight measurements was much greater in adults than in young children. During the early phase of an emergency, when there are large numbers of people seeking treatment, this extra time effectively prevents the use of BMI as a screening tool. In children, assessment of mid upper arm circumference (MUAC), a quick, but sometimes less precise, index of nutritional status\(^5\), is often used during these early phases. There is some research to show that MUAC may be a useful nutritional indicator in adults\(^6\); however, its use for emergency feeding programmes has not yet been evaluated.

The inability of many of the sickest patients to stand up straight to have their height measured also limited the usefulness of BMI. These problems, similar to those met during the assessment of prisoners liberated from Belsen concentration camp\(^6\), resulted in approximately 11% of all admissions and 33% of those who subsequently died not having their BMI assessed on admission. The use of a proxy for height, such as arm span, would improve this. However, the high prevalence of famine oedema with its poor prognosis would still result in underestimating the degree of emaciation based on BMI in many of the most severe cases. The incidence of famine oedema recorded here is not unique. In Belsen, whereas only 6% of patients had moderate or severe famine oedema at admission, many more developed it upon treatment\(^6\). In Melanje, Angola, 90% of 1,100...
The BMI limit in human starvation

These data show that the level of emaciation compatible with life is much lower than previously thought. Conceivably the low BMI values presented here could be in part due to a tall, long-legged phenotype. This phenotype occurs in some east African races, notably Nilotic peoples, such as the Dinka of southern Sudan and the Samburu of northern Kenya. The BMI values in Somalis, a Cushitic people, however, have been recorded as lying within the normal range of 19-21 (ref. 20). Complementary BMI data, collected in the spring of 1993 from 164 of Concern's local Somali workers in Baidoa, and 326 adult Somali women living in the villages surrounding Baidoa, also recorded mean BMI values within the normal range (mean BMI = 20.8, 95% CI = 20.3-21.3 and mean BMI = 19.5, 95% CI = 19.2-19.7, respectively, S.C., unpublished data). Nilotic people can survive at even lower BMI values. In a Concern Adult Therapeutic Centre in Ayod, southern Sudan, BMI values as low as 9.3 were recorded in adults who were still able to walk (S.C., manuscript in preparation).

Survival at these extremely low BMI values would have been aided by the warm climate that existed in Baidoa throughout the period that the centre was operating. Much of the previous data concerning the limits of survival during famine comes from colder climates. Given the inability of severely malnourished people to regulate their body temperature, the limits of survival are likely to be lowest in warm climates.

The gradual nature of the reduction in food intake over a period of two years, as well as previous exposure to CED, may also have facilitated survival at such low BMI values. Habituation to CED has been described in Indian labourers who, with a mean BMI of 16.6, were able to function reasonably normally. By contrast, similar BMI values, rapidly induced in 32 previously well-nourished volunteers, resulted in extremely poor physical and psychological states. The inability of many of the most emaciated patients to stand did not allow for BMI assessment. The mean and minimum BMI values recorded here are therefore higher than the true values at the centre.

Sex difference in adaptation

Sex differences in the extent and prognosis associated with famine oedema were observed. Male patients suffered from more severe grades of oedema and had a worse prognosis at any given grade of severity. This is in keeping with previous observations that famine oedema occurs less frequently in women. These differences in prognosis will need to be taken into account in the creation of guidelines for the assessment and screening of severe adult malnutrition.

Whether the lowest level of BMI compatible with life varies between men and women is less clear. Once the data were adjusted to allow for severity of famine oedema, BMI values appeared similar for male and female patients. However, this should be interpreted with caution. The inpatients at the centre were a selected population, people who had walked, been carried by friends and family, or been transported to the centre by aid workers. The greater numbers of male medical admissions, many of whom could not walk far, is possibly a reflection of an increased tendency to carry male patients to the centre. If there was such a difference, the BMI data would have a sexual bias, greatest at the lower levels of BMI where the inability to walk was more frequent. As a result mean female BMI could have been artificially raised and any sexual differences obscured. Previous anthropometric data are contradictory on this point. Mean weights of people that died during the Madras famine of 1877, were 77 pounds for both men and women (quoted in Aykroyd). On the other hand, Henry, reviewing data largely collected during the Dutch famine of 1945, concluded that the minimum BMI compatible with life is markedly lower in women. More research is needed before realistic anthropometric cut-offs for use in severe adult malnutrition are established.

Adult therapeutic care

The provision of food and medical care in a protected inpatient environment was instrumental in the survival of those admitted. It is likely that very few would have survived outside the centre, forced to queue for food in the general kitchens. However, since the concentration camps were liberated at the end of the Second World War, adult therapeutic centres have not been a feature of emergency relief programmes. The relatively low case fatality rates, even at extreme grades of emaciation, as well as the fast rates of rehabilitation reported here, support the feasibility and utility of adult therapeutic centres. These should constitute a standard part of emergency feeding programmes. There is a need for more research into indicators useful in the screening and assessment of admissions to such centres.

**Fig. 2** The risk of mortality associated with various BMI cut-offs.

**Fig. 3** Body mass index on admission (survivors with marasmus or mild famine oedema).
They were aged between 15 and 80 years (mean 34) and 46% were male. On admission, patients were registered and weighed and had their height measured by trained local enumerators, supervised by a nurse or doctor. A rapid clinical screen, assessing degree of pitting oedema, ascites, anaemia, level of hydration, dysentery, diarrhoea, signs of chest infection and ability to stand was performed by the author or an expatriate nurse. Individual treatment cards were then issued to each patient. The clinical condition and weight of each patient was monitored during rehabilitation, and the outcomes were recorded. The criteria for admission varied depending on the available space in the centre and the existence of other medical facilities in Baidoa. During October and November 1992 there were no alternative medical centres in Baidoa, and therefore, we had to admit a small number of patients whose problems were primarily medical.

From mid-December 1992 on, however, MSF (The Netherlands) operated a medical inpatient unit in Baidoa allowing us to refer such patients. In general only patients with a BMI below 13.5, or those with famine oedema were admitted. Less severely malnourished people were referred to supplementary kitchens.

**Treatment at the centre.** High levels of supervision, with staff patient ratios of 1.8 or less, particularly during the first few days after admission, were maintained. These staff distributed the food and oral rehydration solution (ORS), encouraged patients to eat and drink and helped feed those who were unable to feed themselves.

Patients were orally rehydrated using the WHO formula ORS (sodium chloride 3.5 g l⁻¹, trisodium citrate 2.9 g l⁻¹, potassium chloride 1.5 g l⁻¹ and glucose 20 g l⁻¹). Six to eight meals were offered each day. The diets consisted of high-energy milk (HEM), made from dried skimmed milk, vegetables, oil and sugar), sweet tea, rice, oil, beans, biscuits and local fruits, especially bananas. During the first few days after admission, the HEM component was diluted with ORS. This reduced the incidence and severity of the watery diarrhoea and vomiting that is often associated with the early stages of refeeding severely malnourished people. The degree to which the HEM was diluted was tailored according to the severity of the diarrhoea.

Two therapeutic regimes were used in the centre. A high-protein regime wherein patients were offered 156 g protein and 16.5 MJ (16% of energy from protein, P:E ratio 9.5 g per MJ), and a low-protein regime wherein patients were offered 81 g protein and 16.5 MJ (8.5% of energy from protein, P:E ratio 5 g per MJ). In oedematous patients the high-protein diet was commonly associated with prolonged anorexia, increased or persistent oedema, and occasional instances of sudden death. The introduction of the low-protein diet in December 1992 reduced these complications dramatically. This effect was so marked that subsequently all oedematous patients were given the low-protein diet during the initial phase of their treatment. Data collected at the centre has supported these observations, demonstrating a reduction to one-fourth in mortality amongst the severe oedematous patients who received the low-protein diet (S.C., manuscript in preparation).

Oral antibiotics were needed by the majority of the patients upon admission, with many patients receiving an antibiotic throughout their stay in the centre. Penicillin V or ampicillin were the first-line antibiotics for pulmonary infections; cotrimoxazole and metronidazole for dysenteries and persistent diarrhoeas. Chloramphenicol was the second-line antibiotic.

Discharge criteria were predominantly clinical: freedom from infectious disease, a good appetite, constant weight gain, and the ability to walk and care for themselves were all necessary conditions for discharge. The presence of minimal pedal oedema did not preclude discharge so long as all the above criteria were fulfilled. Upon discharge all patients were issued a 'rehabilitation pack' containing a sheet of plastic, hoes, seeds, a machete, pots and pans, a blanket, water containers and some cloth. Transport to the patients' home village was provided.

**Equipment.** The centre consisted of nine stick shelters with plastic sheeting roofs and mud floors. These provided room for 140 inpatients and 140 family attendants who helped with the day-to-day care of their relatives. Separate shelters were designated for new admissions, those with severe oedematous malnutrition, those with dysentery and those suspected of having pulmonary tuberculosis. A set of standard Hanson spring scales and locally constructed height boards were used to weigh and measure the height of patients. The scales were calibrated in Baidoa and London using known weights. The results were similar at each site: In the useful range of 20–50 kg there was a linear increase in error with the true weight being expressed by the equation, true weight = (1.013987 x scale weight) + 0.707, obtained using linear regression techniques. The correction factors derived from this equation were used to correct each weight measurement.

**Data coding and analysis.** Data were transferred from the inpatient record cards onto specially designed coding forms, entered in duplicate into a PC, and validated for entry error. Pitting oedema was coded using the classification of Beattie et al.⁶ (0 = absent, 1 = minimal oedema on the foot or ankle that was demonstrable but not visible, 2 = visible on foot or ankle, 3 = demonstrable up to knee, 4 = demonstrable up to inguinal ligament, and 5 = anasarca). Pitting oedema, recorded as present but unquantified, was assumed to be moderate (grade 3). Periorbital oedema was coded as 1 (mild), 2 (moderate) and 3 (severe), with 'present but unquantified' again designated as moderate (grade 2).Ascites was similarly coded. Severe oedematous malnutrition was defined as either pitting oedema greater than grade 2, periorbital oedema greater than grade 1, or any ascites. Missing data values were coded as not present. Logistic regression analysis was used to assess the association of clinical features at presentation with mortality. Variables that were not independently associated with mortality were eliminated from the models in a backwards stepwise fashion using estimation techniques. All data entry and analysis were completed using Epi-info v6.02 (ref. 29) and Logistic³⁰.

**Problems.** The frequency with which patients were weighed and the
collection of clinical data varied. This was due to the frequent gun fighting, bandit attacks on expatriate staff houses, attempts at hostage taking, and military occupations that occurred in Baidoa during the study period. The high incidence of expatriate illness and resulting evacuations on medical grounds, contributed to these problems.

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The Need for Adult Therapeutic Care in Emergency Feeding Programs

Lessons From Somalia

Severe adult malnutrition has been neglected by both the medical profession and the agencies providing relief to famine victims. As adults are less vulnerable to the effects of lack of food in the short term, it has been tacitly assumed that their rehabilitation requires nothing more than a basic ration. This assumption continues despite several post–World War II articles relating the importance of appropriate diets and care in the treatment of severely emaciated adults (for example, Lipscomb,1 1945). Thus, while severely malnourished children are provided with specifically designed rehabilitation diets with medical and social care, such measures are not usually taken to help adults or adolescents.

The high adult death rate seen in Baidoa, Somalia, during the autumn of 1992 calls for a reconsideration of the ways in which emergency aid is targeted. Adult deaths accounted for 8900 of the total 15105 deaths recorded by the Somali Red Crescent Society in Baidoa between August 1992 and February 1993. More than 4200 of those adult deaths occurred after September 1992, despite the fact that reasonable quantities of food and resources were available. These figures are from the records of the Somali Red Crescent Society "death truck," which collected unclaimed bodies (those not buried by relatives) for burial. Unfortunately, the workers on the truck were paid according to the numbers of bodies they buried, and in December it was found that their figures were grossly inflated. Whether this distortion was taking place throughout the collection period is unknown. However, as the numbers recorded for the period before November are consistent with those obtained by a team from the Centers for Disease Control and Prevention, it seems more probable that the exaggeration became greater as the actual number of deaths and the earnings of the body collectors decreased.

The majority of the international response to the crisis in Baidoa started in June 1992, but because of fighting and looting, relief was mainly limited to "wet selective feeding" (the distribution of prepared food to targeted populations) until the US Army intervention in mid December. Malnourished children were rehabilitated either in supplementary feeding centers that provided two meals of milk, biscuits, and "unimix" porridge each day, or in 24-hour therapeutic feeding centers that served 6 to 8 meals per day. The supplementary feeding centers were generally medically supervised, providing oral rehydration, basic medical care, and referrals. The therapeutic centers, usually organized by two non-Somali nurses, with the backup of a physician on call, were quasi-medical inpatient departments. In addition to the special diets, these centers provided intense nursing supervision; active oral, nasogastric, or occasionally intravenous rehydration; basic antibiotics, such as ampicillin, co-trimoxazole, and metronidazole; antihelminthics; malaria treatment and prophylaxis; vitamins; and basic nursing care.

In sharp contrast, up until the end of October, the only services for the starving adults were community kitchens. These kitchens had no medical input, and although they were supposed to provide about 8.4 MJ of energy in the form of one plate of rice and beans a day, they were plagued by looting and shortages of supplies. Even when food was available, the lack of supervision and care meant that the sheer physical struggle needed to maintain a place in the queue often resulted in the thinnest going without. This problem was partially addressed at a meeting of the nongovernmental organizations in Baidoa at the end of October and special "vulnerable" kitchens were started. Scouts were appointed to identify the most vulnerable people who were then provided with oral rehydration and basic medical care in addition to the usual meal of rice and beans.

In October 1992, Concern Worldwide, a nongovernmental relief and development agency, opened Bardalli Adult Therapeutic Center, situated in Baidoa town in the Bay region of central Somalia. The center consisted of nine stick shelters with mud floors providing room for 140 severely malnourished adults and adolescents and approximately 140 additional family attendants. All of the first 650 adult and adolescent admissions were seriously ill at presentation, and it is likely that none would have survived given a basic ration of rice and beans alone. Simple measures rehabilitated most very quickly, with an average stay of 25 days.

The majority were treated with only active oral rehydration, basic antibiotics, and a therapeutic diet. The patients were generally from the Bay region of Somalia, an area that until 1990 had been agriculturally rich, providing surplus food for other regions in Somalia. The patients were agriculturalists and pastoralists who had been robbed of their crops, animals, and stocks of food during the previous 2 years of war. Many had walked scores of miles in search of food, and all were chronically malnourished having existed on virtually nothing apart from local roots, leaves, and grasses for months. On admission most of the patients were extremely dehy-
The majority of patients received one of these antibiotics on admission, and many remained on an antibiotic throughout their stay in the center. In addition to these drug regimens, the segregation of the patients with tuberculosis and infective diarrhea from the rest of the patients appeared to reduce the rate of acquired infections. Although data from the center are still being analyzed, the average body mass index (BMI, ie, weight[kg]/height[m^2]) was approximately 13, significantly below the 16 that has been proposed as the indicator of the most severe grade of adult malnutrition. Other adult patients survived with BMIs below 10, refuting the currently accepted view that a BMI below 12 is the absolute lower limit compatible with life.®

Given the number of lives saved (413 of 596 patients for whom outcome is now known) by a comparatively small amount of input, we believe adult therapeutic units should be included more frequently in famine relief programs. Currently, providers sponsored by Concern Worldwide are treating many chronically malnourished adults and adolescents in a therapeutic center in Ayod, South Sudan. At the Ayod center, the average BMI of the first 100 inpatients was below 12, and adults still walking with BMIs as low as 9.2 have been admitted.

The treatment of adult malnutrition is not the same as that of children because of differing nutritional requirements and the practical problems associated with care. For example, anorexia, although common in both children and adults, presented far more of a problem among the adults treated in Baidoa. People were suspicious of nasogastric tubes, which they would generally not allow to remain in place for more than a few hours. Whereas with small children it was practical to introduce a small bore nasogastric tube several times a day even if the patient resisted. The adults would not tolerate multiple insertions.

The precise cause of anorexia in malnutrition is unknown; however, it would appear that a combination of several factors is involved. Infections (eg, amebiasis and shigella); parasitism (eg, giardiasis and small bowel bacterial overgrowth); and deficiencies of specific nutrients, such as zinc and magnesium, with the resulting surfeit of other nutrients that cannot be adequately metabolized or excreted are all likely to play a role.® Depression, a very common presenting complaint, is also almost always a factor.

Other problems seen in these malnourished adults included lower-limb wasting and contractures, caused by months of squatting. These often required extensive physiotherapy, delaying the discharge of otherwise well people.

Nutritional edema was twice as common in adults as in children, present to some degree in 30% of the admissions. This regularly coexisted with ascites (not usually found in children with kwashiorkor) and was associated with a poorer prognosis. In the early stages of recovery these edematous people needed a diet with a relatively low protein to energy ratio of 5 to 1 g/MJ. Interestingly, although the diet used was originally designed for severely malnourished children, the protein content proved to be far more critical in the adults. Whereas the majority of the children with kwashiorkor rapidly improved on the relatively high protein diets generally used in Baidoa, many of the edematous adults given the same diet did not respond well, often increasing their edema and dying unexpectedly. These observations are consistent with records of the refeeding of malnourished adults in Holland during 1944® and from Belsen concentration camp in 1945® where relatively high protein diets were used.

During the last 35 years the lack of attention paid to the problems of severely malnourished adults and adolescents by the medical profession and relief community is astonishing. Despite much early work on adult starvation,® there have been virtually no further descriptions of the forms of adult malnutrition or protocols for treatment since the 1950s. Although weight deficits of 40% are common in famines,® the most recent BMI scale for adult malnutrition defines the category of greatest risk as a BMI below 16, equivalent to a weight deficit of only 20%.® This is substantially higher than the BMI of 14 used as a discharge criterion at Bardalli.® There are no recommended thresholds for screening techniques (such as mid upper-arm circumferences) that can be used for anybody older than age 10 years, and adolescents are ignored in all scales.

This lack of attention led to many deaths in Somalia. A reconsideration of the importance of adult therapeutic care is emergency feeding programs and research into the problem encountered therein is urgently needed. Hopefully the work at Bardalli will rekindle interest in this neglected sphere of human suffering. When data analysis is complete, it should be possible to provide adults anthropometric scales of risk that are applicable to famine situations, together with basic protocols for treating the different forms of adult malnutrition. However, treating severe adult emaciation is a difficult task, and there remains much work to be done.

The famine in Somalia, although extremely severe, was not qualitatively different from other famines, such as Ethiopia in 1984 or the current situation in South Sudan. In all major famines, adults die as well, often leaving orphans requiring long-term care behind them. Many of these people can be saved with some redirection of resources toward adult therapeutic units. In saving adults and adolescents, we are saving those who grow the food, create the wealth, and care for the children.

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London, England

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ASSESSMENT OF NUTRITIONAL STATUS IN EMERGENCY-AFFECTED POPULATIONS

July 2000

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(AED). The opinions expressed herein are those of the authors and do not necessarily reflect the views
of the U.S. Agency for International Development.
This article describes simple techniques suitable for the assessment of the nutritional status of adults aged 20-60 years in emergency-affected populations. The BMI (Body Mass Index), MUAC (Mid-upper Arm Circumference), and clinical models are assessed for their usefulness in determining the prevalence of chronic undernutrition in adults at the population level, and also for screening severely undernourished adults for entrance to feeding clinics.

No consensus on a definitive method to assess adult undernutrition has been reached; more research is required to do this. This article makes only preliminary recommendations.

SURVEYS AND POPULATION LEVEL ASSESSMENTS OF CHRONIC UNDERNUTRITION

The BMI may be used to estimate the prevalence of chronic undernutrition in a population survey, using the classification system shown below.

<table>
<thead>
<tr>
<th>Classification of chronic underweight categories</th>
<th>BMI (kg m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>≥18.5</td>
</tr>
<tr>
<td>Grade I</td>
<td>17.0-18.4</td>
</tr>
<tr>
<td>Grade II</td>
<td>16.0-16.9</td>
</tr>
<tr>
<td>Grade III</td>
<td>≤15.9</td>
</tr>
</tbody>
</table>

The BMI is known to vary with age and body shape. In order to account for changes in body shape the Cormic Index (sitting height/standing height) must be taken into account, and standardised for, when comparing the BMI of different populations.

MUAC may also be used to assess the prevalence of chronic undernutrition at the population level.

SCREENING SEVERELY UNDERNOURISHED ADULTS

No single definition or classification of acute adult undernutrition has been universally accepted, but interim techniques may be recommended until further research clarifies criteria. We suggest that the MUAC in combination with clinical signs should be used to screen adult entrance into feeding centres, using the classification shown below. The BMI is inappropriate for this purpose as it is affected by oedema and body shape and difficult to measure. In any particular situation, workers should only use these suggested criteria as a starting point and adapt them to situation-specific factors.

Admission criteria into adult therapeutic feeding centres should be based upon the following cut-offs:

- MUAC < 160 mm irrespective of clinical signs
- MUAC 161-185 mm plus one of the following:
  - Bilateral pitting oedema (Beattie grade 3 or worse)
  - Inability to stand
  - Apparent dehydration
- Famine oedema (Beattie grade 3 or worse) alone as assessed by a clinician to exclude other causes.

Additional social factors can be included in the model. The relative weighting of these must be determined locally, for example whether you need one, two or three additional social factors to tip the balance in favour of therapeutic rather than supplementary care. Relevant social factors could include the following:

- Access to food (quantity and quality)
- Distance from centres
- Presence / absence of carers
- Shelter
- Dependents
- Cooking utensils

Admission to adult supplementary feeding centres should be based upon the following cut-off:

- MUAC 161-185 mm and no relevant signs or few relevant social criteria.

In any particular situation, workers should take these suggested standards as the starting point and adapt them according to situation-specific factors.
Signalling the need for norms and standards.
The SCN will identify for the attention of technical agencies or other bodies critical areas where norms and standards are missing or out-of-date and holding programmes back. This includes (especially) identifying knowledge gaps and significant areas in dispute or controversy; as well as identifying areas requiring operational research, and facilitating this work.

Extract from the ACC/SCN’s Strategic Plan, April 2000
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INTRODUCTION

This supplement has been produced in response to the increasing number of reports on adult nutrition surveys received by the RNIS and the concomitant interest in the subject shown by the readership. We hope that it will help the readers of the RNIS to interpret the results of the adult nutritional surveys reported.

This article describes simple techniques suitable for the assessment of adult nutritional status in emergency-affected populations. We do not intend it as a comprehensive review of all aspects of assessing adult nutritional status, but as a guide to techniques useful in the field.

During famine-relief operations workers are increasingly recognising and treating severe adult undernutrition. There have, however, been few studies to investigate the problems associated with screening and treating severely undernourished adults during famine and consequently, little guidance is available to field workers. There is at present, no universally accepted definition or classification of acute adult undernutrition and no specific treatment guidelines for the condition. Thus the screening and selection of admissions into therapeutic feeding centres and the dietary treatment of those admitted becomes problematic. Since 1992 however, there have been several advances made in these areas and this article attempts to pull some of these together. We also make some recommendations as to the techniques suitable for the assessment of adult nutritional status under different circumstances.

All of the indicators described in this article attempt to assess adult nutritional status. It is important to realise that, to date, no consensus on a definitive method has been reached; more research is required to achieve this. None of the anthropometric indices described below can be considered to be a gold standard, although body mass index (BMI) has often, mistakenly, been treated as if it were.

This supplement focuses on the nutritional assessment of adults between twenty and sixty years of age. The assessment of older persons is a complex task and is not described in detail here. In addition, the article does not consider the assessment of obesity, micronutrient deficiencies or pregnancy.

Appendix one provides some basic definitions of terms that are employed in the discussion of adult nutritional assessment.

ACUTE AND CHRONIC UNDERNUTRITION

There are two main patterns of undernutrition found in children. These are stunting and wasting. Different processes produce these two patterns and they are assessed using separate anthropometric indices. In children, acute nutritional deficit and/or disease (such as diarrhoea) produce wasting, characterised by a reduction in weight-for-height or arm circumference, or both. Prolonged nutritional deficit and/or disease result in stunting, characterised by a reduction in height-for-age. Wasting and stunting are associated with different functional consequences. Weight-for-height is a powerful predictor of short-term mortality, as is the mid upper arm circumference (MUAC). Height-for-age predicts longer-term mortality.

The nutritional assessment of adults is more problematic. Despite metabolic differences between chronic and acute undernutrition the absence of linear growth removes the power of a height variable to discriminate between the two main patterns of undernutrition. In 1988, the International Dietary Energy Consultative Group proposed a definition of chronic adult undernutrition calling it 'chronic energy deficiency' (CED), clearly differentiating it from 'acute energy deficiency' (AED).

Chronic Energy Deficiency (CED) was defined as:

"A steady state at which a person is in an energy balance although at a cost either in terms of increased risk to health or as an impairment of functions and health."
Acute Energy Deficiency (AED) was defined as:

"A state of negative energy balance, i.e. a progressive loss of body energy"\(^1\)

The differentiation of acute and chronic adult undernutrition is important because the two conditions entail different adaptations and have different functional consequences. For example, habituation to CED has been described in Indian labourers who, with a mean BMI of 16.6 kg m\(^{-2}\), were able to function reasonably normally\(^1\). By contrast, similar BMIs, rapidly induced in 32 previously well-nourished volunteers, resulted in extremely poor physical and psychological states\(^1\). Differentiating between these two types of undernutrition may be difficult with a one-off measurement. They can be distinguished using a series of measurements taken over time, but in practice, this option is often not available. As acute undernutrition wastes peripheral body tissues faster than central tissues, it may be possible to compare two different body measurements in order to differentiate between these two forms of undernutrition. It may also be that adaptation below a certain threshold for each measurement is impossible and hence those falling below that threshold must have acute undernutrition. However, at present there are few data available with which to examine these problems.

We feel that the term "energy deficiency" is unhelpful when applied to undernutrition because it obscures the importance of protein catabolism, deficiencies of vitamins and minerals. For this reason, we prefer the term "undernutrition" rather than "energy deficiency".

Primary undernutrition develops when nutrient intake is insufficient to provide for normal physiological needs. In adults, primary undernutrition is invariably due to a lack of food. Secondary undernutrition occurs when an underlying disease process (for example, HIV/AIDS, TB and cancer) increases metabolic demands and/or decreases food intake or utilisation. The treatment of primary and secondary undernutrition may be quite different.

MEASURING NUTRITIONAL STATUS IN ADULTS

An ideal index of nutritional status, for any age group, should meet the following requirements:

- It must be correlated with body fat and protein stores.
- It must be correlated with health or functional outcomes.
- It must be simple to obtain and interpret in the field. It must also be accurate (close to the true value), valid (represent what it is thought to represent) and precise (repeatable).

In addition to these requirements, as adult height is largely determined by an individual's genotype and childhood nutritional experience\(^1\), it follows that if an index is to reflect current nutritional status in adults it must be independent of height.

WEIGHT

The use of weight alone to assess nutritional status should be limited to monitoring purposes because it is confounded by height. Weight is appropriate for monitoring the progress of patients suffering from long-term morbidity, recovering from disease or surgery, or during nutritional rehabilitation within a therapeutic feeding centre.

BODY MASS INDEX

The body mass index (BMI) is calculated from weight and height measurements using the formula BMI = weight (in kg) divided by height (in m\(^2\)). The BMI was first introduced by Quetlet in order to eliminate the confounding effects of height on weight. In normal adults, the ratio of the weight to the square of height is roughly constant, and a person with a low BMI is underweight for their height\(^1\). BMI reflects protein and fat reserves, which in turn reflect functional reserves including the ability to survive nutritional deficit and some diseases.

BMI may be appropriate for population-level assessments of chronic undernutrition. In 1988, researchers proposed the use of BMI to define and diagnose chronic undernutrition\(^1\). This
classification provides a useful framework for the analysis of height and weight data from chronically undernourished adult populations.

Table 1 The classification of categories of chronic undernutrition

<table>
<thead>
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<th>Classification of underweight categories</th>
<th>BMI (kg m⁻²)</th>
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</tr>
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</table>

(adapted from Ferro-Luzzi et al, 1992)

There is an increasing body of evidence that low BMI is related to both increases in morbidity and mortality in fertile-age women, to the chances of having low birth weight babies. In addition, BMI is known to be highly correlated with both fat and fat-free mass, although these associations may vary with age, sex and ethnicity.

However, there are several difficulties associated with the use of BMI as an anthropometric index. These difficulties can broadly be separated into theoretical and practical problems.

THEORETICAL PROBLEMS WITH BMI

Body shape – Many factors other than nutritional status determine BMI. Most important of these is body shape, in particular the ratio of leg-length to trunk-length, sometimes called the sitting-height to standing height ratio (SH/S) or Cormic index. This index varies both between populations and within populations. These differences result in world-wide (i.e. between populations) variation in the SH/S ratio from 0.48 in Australian aborigines up to 0.55 in the Japanese. This has a considerable influence on BMI, equivalent at the extremes of the range of SH/S ratio, to a variation of over 6 kg m⁻².

Figure 1 The effect of varying sitting height: stature ratio (SH/S) on BMI for a 70 kg, initially 1.75 metre male (from Morgan 1994)
There is also considerable within-population variation in the Cormic Index. In one aboriginal population, the within-population range for the Cormic Index was 0.41 - 0.54. This is greater than the world-wide variation in Cormic Index and equivalent to more than 10 kg m\(^{-2}\) variation in BMI, dependant upon shape alone.

Sitting height can be measured by sitting the person on a straight-backed chair with a height board strapped to the back. This measurement is then used to correct BMI by applying a correction factor based on a linear regression model (see box 1).

Comparisons of BMI between different populations can be made using a correction factor based upon the mean Cormic Index for each population. Such corrections should always be made when BMI is used to compare the nutritional status of different populations.

Follow-up surveys for the comparison of within-population data (for example, before and after an intervention, surveillance by repeated surveys etc) do not require the Cormic Index correction.

If BMI is being used to assess an individual for undernutrition the estimation of the individual's Cormic Index should be used as a correction factor. Without this correction the sensitivity and specificity of BMI as a screening indicator may be low. During emergencies, especially at the height of a famine relief program, when there are large numbers of people competing for relatively scarce resources, there is almost never sufficient time or staff to perform this standardisation. We therefore feel that BMI is inappropriate for this role.

**Age** — Adult body size, shape and composition vary with age. Adults tend to loose fat free mass (FFM) and increase fat mass (FM) with age. These changes may alter the functional significance of BMI at different ages. Some NGOs use different cut-off points for older adults when admitting individuals to a feeding programme. For example, for adults aged 50y+ Action Contre La Faim (ACF) admits adults to therapeutic feeding centres and supplementary feeding centres using the cut-offs of 15kg m\(^{-2}\) and 16 kgm\(^{-2}\) respectively, but admits those aged less than 50 at 16kg m\(^{-2}\) and 17kg m\(^{-2}\).

**Box 1**

### THE CORRECTION OF BMI USING THE CORMIC INDEX (SH/S)

In order to standardise BMI to take into account changes in SH/S ratio we recommending using the equations below to calculate BMI standardised to the actual SH/S ratio for the population under study.

**Male subjects** - \( BMI = 0.78(SH/S) - 18.43 \)

**Female subjects** - \( BMI = 1.19(SH/S) - 40.34 \)

Note: SH/S ratios should be expressed as a percentage

The observed BMIs can then be standardised to a SH/S ratio of 0.52 by adding the differences between the observed BMI and BMI standardised for the population SH/S ratio to a BMI standardised to 0.52 using the equation below:

\[
BMI_{std} = BMI_{obs} + (BMI_{ob} - BMI_{es}),
\]

Where
- \( BMI_{std} \) = standardised BMI
- \( BMI_{obs} \) = observed BMI
- \( BMI_{ob} \) = estimated BMI at SH/S of 0.52
- \( BMI_{es} \) = estimated BMI at actual SH/S

**Examples**

1. A Male population "A" has a mean BMI of 18.5 kg m\(^{-2}\) and a mean SH/S ratio of 50%. The \( BMI_{ob,52} = 0.78*52-18.43 \approx 22.13 \). The \( BMI_{es} = 22.13 + (18.5 - 20.57) = 20.06 \) kg m\(^{-2}\).

2. A Female population "A" has a mean BMI of 17.0 kg m\(^{-2}\) and a mean SH/S ratio of 54%. The \( BMI_{ob,52} = 1.19*52-40.34 \approx 23.92 \). The \( BMI_{es} = 21.54 + (17.0 - 23.92) = 14.62 \) kg m\(^{-2}\).

These are ad-hoc modifications to the standard cut-off points for the use of BMI to assess undernutrition. As yet there are no published data that support the use of distinct cut-off points for different age groups. Many adults in the developing world do not know their exact age and it may, therefore, be difficult to differentiate the diagnosis of nutritional status according to age in an emergency situation. It may be useful, however, to...
separate age groups when presenting the results of an adult nutritional survey using BMI in a non-emergency setting, where age can be ascertained using instruments such as local event diaries which would seldom be available in an emergency situation.

The increasing prevalence of kyphosis and scoliosis with age further necessitates the use of proxies for height when assessing the nutritional status of older adults.

Chronic and acute undernutrition – A great deal of research has focused on use of BMI for the assessment of chronic undernutrition in stable populations. This role is primarily that of prevalence estimation, providing information useful in planning at a population level. This is a different role to that of screening individuals who may be suffering from acute undernutrition in order to regulate admissions to feeding centres. The common assumption in contemporary NGO field manuals and recent academic articles that BMI is also an appropriate indicator for screening during famine, has not been tested.

BMI cut-off points for screening adult admissions to feeding centres, extrapolated directly from CED, may be inappropriate. The cut-off point of 16 kg m\(^{-2}\), that indicates severe chronic undernutrition does not necessarily reflect the degree of acute undernutrition that requires specialised treatment. During a famine, there is intense competition for entry into feeding centres and it is important that screening indicators are specific, only selecting those who would die if not given specialised treatment.

As adults are usually the primary caregivers and income earners in a household, it is also important not to admit those who do not need therapeutic treatment into a centre as this may have a negative affect on the rest of the household.

In 1996, Ferro-Luzzi and James adjusted their theoretical estimation of the lowest BMI compatible with life down from 12 kg m\(^{-2}\) in order to account for the extremely low BMIs being observed in Somalia during the famine there in 1992. They created two new BMI cut-offs of <13 kg m\(^{-2}\) and <10 kg m\(^{-2}\), denoting severe wasting and extreme wasting respectively. These values did not take into account the Somali long-legged phenotype, an important factor explaining the very low BMIs observed. Thus the cut-off values they propose are probably too low. In our experience a BMI of 10 kg m\(^{-2}\) after standardisation to a SH/S ratio of 0.52 is probably not compatible with life. One of 13 kg m\(^{-2}\), probably represents a degree of emaciation where peripheral stores have already been exhausted with a corresponding increase in central catabolism. This level is therefore probably inappropriately low to be used as a cut-off for admission into an adult therapeutic centre.

**Practical Problems with BMI**

**Difficulties in obtaining the component measures of BMI during famine** – The height and weight measurements required to assess BMI are often difficult to obtain during famine. Chair or bed-scales are usually unavailable and thus patients must be able to stand in order to be weighed. Usually, many of the most severely undernourished adults requiring admission to therapeutic feeding centres cannot stand at all and BMI cannot be estimated. In addition, many studies have reported that gross weakness, flexor contractions, or scoliosis are common. These prevent many patients standing straight enough for accurate height estimation. As height is a squared term, these errors are magnified in BMI calculation.

If BMI is to be used during an emergency there is a need to obtain robust, reliable and precise scales that can withstand repeated measurements under dry, dusty and hot conditions. These may be expensive.

**Difficulties in the calculation of BMI** – Even in non-famine situations the calculation of BMI and Cormic Index may be unfamiliar to field workers and therefore difficult. ACF have developed tables of weight-for-height that show BMI ranges (like those used for children) that may reduce this difficulty.

**Difficulties in obtaining the component measures of BMI in elderly and handicapped people** – As adults become older, spinal disease (predominantly osteoarthritis and osteoporosis) affects an increasing proportion of people. These conditions affect the ability to stand straight and make the accurate measurement of height
impossible. BMI, based on height cannot therefore be used in older adults. Recognition of this problem has prompted research into the use of proxy measures of height. Researchers have shown a good relationship between arm-span, demi-span, femur length, knee height and height. These proxies are converted to estimates of height using correction factors derived from regression equations. As the relationship between proxies and height has been shown to vary between ethnic groups and by age, different correction factors should be applied to different populations. Suitable population-specific correction factors to apply to proxy measures of height are usually unavailable in emergencies.

In elderly individuals, there are no viable alternatives to estimating height from arm span or demi-span. It should be recognised, however, that at the individual level, there is significant error involved in the estimation of height using correction factors based on population means. For example, the standard error of the estimate of height from arm span is reported to be between 2.5 and 3.8 cm. The squaring of the height element in calculating BMI magnifies these differences.

_Famine oedema_ - Adult nutritional oedema is common during famine and its presence increases weight, producing an upward bias in BMI. In adults the frequent co-existence of pitting oedema and ascites means that oedema fluid can often account for over 10% of body weight. Famine oedema is also associated with poor prognosis (see Figure 2). Consequently, patients with severe famine oedema often have a poorer prognosis the higher their admission BMI, the opposite of the situation in marasmic patients (see Figure 3). BMI is therefore, not an appropriate indicator for people suffering from famine oedema. This may be corrected by using a modified screening criteria (i.e. BMI below a cut-off point OR the presence of oedema). However, as the presence of oedema, particularly in older adults, may not always be indicative of undernutrition, it will be necessary to train field workers to differentiate between the causes of oedema in adults. Alternatively, adults presenting with oedema will have to be referred to a clinician who is able to differentiate between the types of oedema.

As the prevalence of famine oedema is frequently high during emergencies (see Table 2), the inability of BMI to assess oedematous adults limits the usefulness of BMI as a screening tool to assess acute adult undernutrition.

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Year</th>
<th>Prevalence of famine oedema</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collins</td>
<td>Somalia</td>
<td>1992</td>
<td>24%</td>
</tr>
<tr>
<td>Collins</td>
<td>Angola</td>
<td>1993</td>
<td>90%</td>
</tr>
<tr>
<td>Collins</td>
<td>Sudan</td>
<td>1993</td>
<td>0%</td>
</tr>
<tr>
<td>Zimmer et al.</td>
<td>France</td>
<td>1942</td>
<td>50%</td>
</tr>
<tr>
<td>Mollinson</td>
<td>Germany</td>
<td>1945</td>
<td>typical finding</td>
</tr>
<tr>
<td>McCance et al.</td>
<td>Germany</td>
<td>1946</td>
<td>common</td>
</tr>
<tr>
<td>Debarry</td>
<td>France</td>
<td>1945</td>
<td>100%</td>
</tr>
<tr>
<td>Keys et al.*</td>
<td>U.S.A.</td>
<td>1945</td>
<td>87%</td>
</tr>
</tbody>
</table>

* In a selected population of previously well-nourished American volunteers starved under experimental conditions
Figure 2: Pitting oedema and the odds of mortality, based upon the grading system described in Table 4 (adapted from Collins 1995).  

![Graph showing odds of mortality vs grade of oedema](image)

Figure 3: The odds of mortality below different thresholds of admission BMI for oedematous (N=75) and marasmic (N=218) patients admitted to a therapeutic centre in Baidoa, Somalia during 1992/3 (adapted from Collins 1995).  

![Graph showing odds of mortality vs body mass index](image)
SUMMARY – THE USE OF BMI

In our opinion, the many problems with the use of BMI for screening acutely undernourished adults admissions to feeding programmes during famine relief programmes make the indicator inappropriate for this role.

BMI combined with an assessment of the prevalence of famine oedema is an appropriate indicator for population-level assessment of chronic undernutrition. These data can be categorised according to the classification given in Table 1 above. Such surveys should also assess MUAC.

If BMI survey data are used to compare BMIs between populations, estimates should be corrected by standardisation to a SH/S ratio of 0.52 using the mean SH/S ratio for the specific populations being studied.

Inside feeding centres it is useful to assess a standardised BMI on each patient admitted (standardised using individualised SH/S ratios).

MID-UPPER ARM

CIRCUMFERENCE (MUAC)

MUAC is the circumference of the left upper arm, measured at the mid-point between the tip of the shoulder and the tip of the elbow (olecranon process and the acromion). In children, MUAC is useful for the assessment of nutritional status 51, 52, 53, 54, 55, 56. It is good at predicting mortality and in some studies, MUAC alone 57, 58, 69 or MUAC for age 10, predicted death in children better than any other anthropometric indicator. This advantage of MUAC was greatest when the period of follow-up was short 60.

The MUAC measurement requires little equipment and is easy to perform even on the most debilitated individuals. Although it is important to give workers training in how to take the measurement in order to reduce inter- and intra-observer error, the technique can be readily taught to minimally trained health workers 61. It is thus potentially suited to screening admissions to feeding centres during emergencies. The use of MUAC in emergencies is, however, still controversial, and disagreement over the preferential selection of younger children, the levels of cut-off points used, the efficiency of a two-phase screening process and poor reproducibility in the measurement continue 62, 63, 64, 65, 66. Consequently, some humanitarian relief agencies remain sceptical about the use of MUAC in emergencies 67.

At present during emergencies, MUAC is only recommended for use with children between one and five years of age 66, 37, 38. It is, however, increasingly being used to assess adult undernutrition during famine 69, 70, 71. Measurements of adult MUAC have long been known to reflect changes in adult body weight 72, and the major determinants of MUAC, arm muscle and sub-cutaneous fat, are both important determinants of survival in starvation 73, 74, 42. As MUAC is less affected than BMI by the localised accumulation of excess fluid (pedal oedema, periorbital oedema, ascites) common in famine, it is likely to prove to be a more sensitive index of tissue atrophy than low body weight. It is also relatively independent of height 70.

The use of MUAC has not been evaluated as a prognostic indicator. However, estimates of arm muscle area (AMA) or corrected arm muscle area (CAMA), corrected for humerus cross-sectional area, have been incorporated into diagnostic schemes for adult undernutrition in hospitals 75 and used as prognostic indicators in the elderly and in cancer patients 76, 77. However, it is unlikely that CAMA or AMA will be of use in emergency assessments as both require accurate measures of skin-fold thickness that would be hard to obtain given the rush and pressure of an emergency operation.

Ferro-Luzzi and James 36 have proposed MUAC cut-off points for use in screening acute adult undernutrition. They base these on extrapolation from more normally nourished populations in developing countries, without reference to data from acutely undernourished adults during famine. Although there is some evidence that the undernourished category may be associated with increased morbidity in chronically undernourished populations 19, we doubt whether the criteria proposed are appropriate for screening acutely undernourished adults.

Data from famines suggest that the relationship between MUAC and BMI is not constant during
Acute undernutrition and that an accelerated loss of peripheral tissue during acute undernutrition has a relatively greater depressing effect on MUAC than upon BMI. These data also suggest that during acute undernutrition the differences in MUAC between men and women become less pronounced, a finding supported by previous observations in more normally nourished populations.

It is likely, therefore, that in populations suffering from famine, MUAC cut-off points denoting moderate to severe undernutrition should be adjusted. Values of 185 mm denoting moderate undernutrition and 160 mm denoting severe undernutrition in both sexes have been proposed and used in famines. Given that there are different cross-sectional humerus bone areas in men versus women, it is unclear whether common cut-off points for both sexes will prove appropriate.

Theoretical Problems with MUAC

Lack of data upon which to decide useful cut-off points - There are insufficient data available correlating MUAC with mortality and other functional measures in adults. Cut-off points based on risk of mortality cannot, therefore, be presented with any degree of certainty. There exists a need for more field studies during emergency famine-relief operations to evaluate the power of MUAC to predict adult mortality in different famine-affected populations.

Age - The use of MUAC in adults may be affected by the redistribution of subcutaneous fat towards central areas of the body during ageing. In older children and adolescents, the rapidly changing patterns of skeletal muscle and subcutaneous fat are also likely to be a problem. Age-specific MUAC cut-off points may be required for older children, adolescents, and the elderly.

Ethnicity - Ethnic differences in MUAC have not been sufficiently studied to determine whether a single cut-off point for MUAC could be used for all ethnic groups.

Practical Problems with MUAC

Measurement error - In children, the use of MUAC is associated with two problems: the preferential selection of younger children as undernourished and a lack of reproducibility in MUAC measurements. Problems with the reproducibility of MUAC measurements are potentially a more serious obstacle to the use of MUAC in adults. As in children, both inter- and intra-observer errors in MUAC measurements may occur. The importance of these errors needs to be investigated, but it is likely that the larger dimension of the adult arm will reduce the relative importance of such errors. The development of colour-banded numeric MUAC bands reflecting threshold values of MUAC with a change of colour would further reduce these problems by removing numerical errors. Given the ease with which MUAC measurements can be performed it would be feasible to refer any patients found to have a MUAC within a few millimetres on either side of the threshold (designated on the band as a different coloured zone) to a more experienced worker for verification or for further (e.g. clinical) assessment as part of a two-stage screening process. The width of this zone should be based upon a more detailed examination of errors in the evaluation of adult MUAC by minimally trained workers. Colour-banded MUAC measurement straps are already in use with children.

The assessment of adult nutritional status using MUAC requires no equipment apart from a tape measure. As the index is the actual measurement itself, mathematical manipulation of the measurement obtained is not necessary. The ease with which MUAC can be assessed makes it suitable for nutritional screening during the height of an emergency where time and skilled personnel are at a premium.

Summary - The Use of MUAC

In our opinion, MUAC is an appropriate indicator for the assessment of acute adult undernutrition. The indicator is useful for both screening acute adult undernutrition and for estimating prevalence of undernutrition at a population level. We suggest, that until more data are available, the following cut-off points are used for both sexes for screening adult admissions to feeding centres.
At present there is insufficient data to assess the usefulness of MUAC as a tool with which to monitor treatment in adult feeding centres. More data is required to assess this role.

COMBINATION MEASURES

Some authors have proposed the combined use of BMI and MUAC, suggesting that such a classification might prove better able to discriminate between at-risk individuals and those who are thin but not at risk. Given the relative strengths of the two indicators, it is probable that this combination will only be appropriate for the population assessment of CED. However, we see little advantage of a combination measure over the use of BMI alone.

CLINICAL SIGNS FOR SCREENING ACUTE UNDERNUTRITION

For many years, it has been recognised that undernutrition increases both susceptibility to, and the severity of, infection. Vitamin, mineral and other dietary deficiencies, depressed cell mediated and humeral immunity, gastric acidity, mucosal integrity and altered flora are all known to increase susceptibility to infection and the ability of an individual to utilise their energy and protein reserves. The situation in an emergency is usually made worse by the breakdown in public health infrastructure and the congregation of displaced people in crowded and unhygienic conditions. This combination of poor public health environment and immunosuppression means that in famine it is usually infection combined with metabolic dysfunction rather than absolute loss of fat or fat-free mass that kills people. This is different from the situation in industrialised countries where exhaustion of fat or fat-free mass is more often the terminal event.

Therefore, the clinical signs of infection or metabolic dysfunction are likely to be useful prognostic indicators. This possibility has been investigated in children but rarely in adults. Although reported as effective in identifying children at a high risk of mortality, these models have been criticised because the interactions between the features used, such as oedema and hypoprotinaemia, were not taken into account.

FAMINE OEDEMA

In both children and adults, famine oedema has long been recognised as an important sign relating to the severity of undernutrition (see above). In adults, famine oedema is common and usually (but not always) related to a poor prognosis. For this reason the presence of famine oedema is usually used as an indicator of severe undernutrition. It is important to note, however, that the prognostic significance of adult famine oedema varies according to the context and in some occasions, the sign is of less use as an indicator of severity.

Famine oedema in adults should be diagnosed in a similar way to that in children, using firm pressure applied over a bony prominence for approximately 3 seconds and assessing whether an indentation remains after the pressure is removed. The severity of oedema should be graded using the system devised by Beattie during the Second World War. In our experience pitting oedema of grade 3 and above are often associated with a markedly worse prognosis particularly if they occur in male patients. Lesser grades of oedema rarely appear to be clinically relevant.

It is important to note that oedema in adults may be induced by reasons other than undernutrition including cardiac, vascular, renal and hepatic disease. Differentiating between nutritional oedema and oedema secondary to other causes can be difficult and usually requires clinical expertise.
Table 4 Classification of famine oedema based on the Beattie classification

<table>
<thead>
<tr>
<th>Grade</th>
<th>Extent of oedema</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>absent</td>
</tr>
<tr>
<td>1</td>
<td>minimal oedema on the foot or ankle that was demonstrable but not obvious</td>
</tr>
<tr>
<td>2</td>
<td>obvious oedema on foot or ankle</td>
</tr>
<tr>
<td>3</td>
<td>oedema demonstrable up to knee</td>
</tr>
<tr>
<td>4</td>
<td>oedema demonstrable up to inguinal ligament</td>
</tr>
<tr>
<td>5</td>
<td>total body oedema (anasarca)</td>
</tr>
</tbody>
</table>

Features of famine oedema not included in the Beattie classification

- Ascites: in isolation probably not a useful indicator of the severity of primary undernutrition. Prognosis relates to extent of accompanying oedema. Often occurs in secondary to disease (especially TB).
- Peri-orbital: in isolation does not appear to reflect a poor prognosis.
- Scrotal: probably the result of ascitic fluid tracking downwards under the influence of gravity, in isolation does not appear to reflect a poor prognosis.
- Hydroarthrosis: significance unknown.

CLINICAL MODELS

In adults, until recently the use of clinical models to assess nutritional status appears to have been restricted to the nutritional assessment of surgical patients. Since 1992, similar assessments have been made amongst severely undernourished adult inpatients in several therapeutic feeding centre during different famines. A model using three clinical signs: apparent dehydration, oedema and inability to stand has proved useful in predicting prognosis among adult patients. These three clinical signs were far better at predicting mortality than BMI, were easy to elicit and the model only involves counting.

To be useful in screening admissions to therapeutic feeding centres during famine rather than predicting prognosis in those already admitted, an indicator of nutritional status must be added to this basic clinical model. This allows the model to differentiate between those with clinical illness but no undernutrition, better treated in medical units, from those with both illness and undernutrition, best treated in specialisation feeding centres. A combination model, “The Concern Health and Nutrition Evaluation Score” (CHANCES) has been used in Ajiep in South Sudan during 1998 (see Table 5). In addition to the basic signs demonstrated in Table 5, additional relevant criteria, in particularly social criteria such as presence of a carer or distance away from feeding centres can also be added to the model.

Preliminary indications are that this model performed well.

Table 5 The CHANCES screening model for acute adult undernutrition during famine

<table>
<thead>
<tr>
<th>Category</th>
<th>Action</th>
<th>MUAC (mm)</th>
<th>Relevant clinical signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Do not admit</td>
<td>&gt; 185</td>
<td>+/-</td>
</tr>
<tr>
<td>Moderate undernutrition</td>
<td>Supplementary feeding</td>
<td>160 - 185</td>
<td>-</td>
</tr>
<tr>
<td>Severe undernutrition</td>
<td>Therapeutic feeding</td>
<td>160 - 185</td>
<td>+</td>
</tr>
<tr>
<td>Severe undernutrition</td>
<td>Therapeutic feeding</td>
<td>&lt; 160</td>
<td>+/-</td>
</tr>
</tbody>
</table>

*An adult presenting with bilateral oedema (Beattie grade 3 or more), but not low MUAC, should be referred to a clinician in order to assess whether s/he has nutritional oedema. If the oedema is nutritional s/he should be admitted to the Therapeutic Feeding Centre.
ACTIVITIES OF DAILY LIVING

Some workers have suggested that measuring functional ability rather than anthropometry may provide a useful screening tool. Functional ability is usually measured using scores derived from the answers to a set of several related questions. Such an instrument should be able to differentiate between those who can and cannot care for themselves. Valid and reliable sets of questions can, however, be time consuming to develop and test. Currently available instruments (e.g. those used for needs assessment in the elderly) may be appropriate in emergency situations but still require field testing during famine and identification of valid and reliable cut-off points. The CHANCES model creates a composite function/clinical score, with function being assessed solely by ability of an individual to stand. As in the CHANCES model, an indicator of nutritional status would need to be included to allow the instrument to differentiate between those with clinical illness but no undernutrition, best treated in medical units, and those with undernutrition, best treated in specialist feeding centres.

SUMMARY — THE USE OF CLINICAL MODELS

In our opinion, the combination of MUAC and clinical signs, based upon the CHANCES clinical model, is the method of choice for screening acutely undernourished adult admissions into feeding centres.

Admission criteria into adult therapeutic feeding centres should be based upon the following cut-offs:

- MUAC < 160 mm irrespective of clinical signs
- MUAC < 161-185 mm plus one of the following:
  - Bilateral pitting oedema (Beattie grade 3 or worse)
  - Inability to stand
  - Apparent dehydration
- Famine oedema (Beattie grade 3 or worse) alone as assessed by a clinician to exclude other causes.

Admission to adult supplementary feeding centres should be based upon the following cut-off:

- MUAC < 161-185 mm and no relevant signs or few relevant social criteria.

In any particular situation, workers should take these suggested standards as the starting point and adapt them according to situation-specific factors.

It is important to note that the CHANCES model presented here screens adults in urgent need of nutritional support. If in a particular situation, the needs are such that workers have to make the CHANCES model more stringent in order to avoid being overwhelmed by admissions it is essential that they call for assistance and additional resources. In such situations vigorous advocacy is essential to publicise the extent of the crisis and call for help.

PRIMARY AND SECONDARY UNDERNUTRITION

An important problem in assessing adult undernutrition during famine is the inability to differentiate between primary and secondary undernutrition. At present, there are no one-off measurements that can do this. In practice admission into selective feeding programmes should be based on the CHANCES criteria, irrespective of whether the adult is suffering from primary or secondary undernutrition. Those with malnutrition secondary to infection (for example,
TB or HIV) will fail to respond adequately to treatment. Adult selective feeding programmes must therefore be designed in a way that allows for these people to be referred to other more appropriate support or treatment programmes. The design of these is beyond the scope of this article.

In future, as catabolic hormones produced in response to infection have a greater influence on peripheral energy and protein stores it might be that in secondary undernutrition resulting from infection the MUAC is more depressed than BMI. This might lead to the possibility of using a combination of the two indicators to differentiate between primary and secondary undernutrition. To date, no work has been undertaken to investigate this possibility.

**General summary – suggested indicators for assessing adult undernutrition in the field**

Earlier in this report we defined the criteria of an ideal index of nutritional status. Table 6 shows how BMI, MUAC, and CHANCES meet these criteria.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>BMI</th>
<th>MUAC</th>
<th>CHANCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent of height</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Correlated with body energy stores</td>
<td>Yes</td>
<td>Upwardly biased by oedema</td>
<td>Yes</td>
</tr>
<tr>
<td>Correlated with health / functional outcomes</td>
<td>Yes in chronic</td>
<td>?</td>
<td>Yes</td>
</tr>
<tr>
<td>Simple to obtain and interpret</td>
<td>No</td>
<td>Yes</td>
<td>Proposes clinical signs are easy to elicit.</td>
</tr>
<tr>
<td>Measurements difficult in patients unable to stand and those with musculo-skeletal problems.</td>
<td>No</td>
<td>Yes</td>
<td>Proposes clinical signs are easy to elicit.</td>
</tr>
<tr>
<td>Accurate</td>
<td>?</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Needs correction for body shape using extra measurement of SH/S and further arithmetic.</td>
<td>?</td>
<td>Yes</td>
<td>See MUAC.</td>
</tr>
<tr>
<td>Valid</td>
<td>?</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Not in the presence of oedema.</td>
<td></td>
<td></td>
<td>See MUAC.</td>
</tr>
<tr>
<td>Precise</td>
<td>Yes</td>
<td>?</td>
<td>See MUAC.</td>
</tr>
<tr>
<td>measurement errors in children. Insufficient data in adults.</td>
<td></td>
<td></td>
<td>See MUAC.</td>
</tr>
</tbody>
</table>
In table 7 we present some interim recommendations for techniques that may be used, under different circumstances for the assessment of adult nutritional status. These recommendations are preliminary and there is a need for further research to clarify the criteria. It must also be noted that, in emergency relief programmes, the appropriate indicator cut-off point (screening level) is that which selects the number of individuals that can be treated with the resources at hand. In reality, such cut-off point values often cannot be determined universally but must be tailored to suit the resources available in each particular situation. The choice of underlying body measurement may also be determined by available equipment (e.g. scales may not be available to measure weight).

Patterns and prevalence of adult undernutrition during famine - Data on the prevalence and patterns of adult undernutrition during famines may be useful in defining cut-offs. Data on different ethnic groups and settings would be useful.

Table 7 The applicability of BMI, MUAC, Weight, and CHANCES in different situations

<table>
<thead>
<tr>
<th>Situation</th>
<th>BMI</th>
<th>MUAC</th>
<th>Weight</th>
<th>CHANCES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic undernutrition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute undernutrition</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monitoring nutritional rehabilitation</td>
<td></td>
<td></td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>(&amp; progressive illness / post operative recovery)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

WHERE DO WE GO FROM HERE? FUTURE RESEARCH NEEDS:

Defining functional cut-offs - Longitudinal studies should be undertaken to determine whether individuals falling below specific cut-off points for BMI, and MUAC have elevated morbidity or mortality, poor pregnancy outcome, decreased work ability or physical performance measures. Such studies must be conducted in a variety of situations with different levels of undernutrition among adults. During emergencies, such studies are problematic. Ideally studies relating indicators to the risk of mortality in a general population are required to establish functional cut-off points that could be used for the screening of adult admissions to feeding centres. However, famines always involve massive social upheaval and large numbers of afflicted people. These factors, combined with the armed conflict that has characterised almost all famines during the last ten years, make such broad-based population studies unfeasible. Consequently, no such studies have yet been performed for any nutritional indicator in either adults or children during the height of a famine. Given these difficulties, relating indicators to mortality in a selected feeding centre population may be all that is reasonably possible. The selection bias involved in such studies must be acknowledged and results interpreted with caution.

Practicality of measurements and calculations - The practicality of obtaining various measures should be explored in field situations. Survey organisers should assess the ease of training survey workers in measuring MUAC, weight, and height, as well as assessing inter- and intra-observer variability in these measurements when measuring adults.

Adjusting for differences in body shape - Surveys undertaken in a variety of populations should explore the utility of adjusting indices using weight and height for differences in body shape by using the SH/S Index or other indicators of body shape.

The use of MUAC to monitor recovery from undernutrition. The changes in MUAC and weight during recovery from undernutrition should be compared with a view to establishing...
whether MUAC is useful in this role and if it is, establishing relevant MUAC discharge criteria.

More data on differentiating between secondary and primary undernutrition - Examination of adult failure-to-thrive in centres should include attempts to identify measurements or signs that predict failure-to-thrive in feeding centres.

The aetiology, significance and treatment of famine oedema and ascites - More information on the significance and prevalence of famine oedema and ascites is required. It is recommended that surveys assess subjects for these symptoms.
REFERENCES

Anthropometric Assessment of the Nutrition Status of Adults in Emergency-Affected Populations


95. Last JM. *A dictionary of epidemiology*. 2ed. OUP; Oxford.

APPENDIX 1: BASIC DEFINITIONS

WASTING
Low weight-for-height, usually defined as less than −2SDs of the NCHS/WHO reference median value, or sometimes 80% of the NCHS/WHO reference median of weight-for-height. At present, no clear definition of wasting in adults is available.

STUNTING
Low height-for-age, usually defined as less than −2SDs of the NCHS/WHO reference median value, or sometimes 80% of the NCHS/WHO reference median of height-for-age.

BMI
Body mass index (weight/height^2). An index of protein and fat stores.

FAMINE OEDEMA
Bilateral dependant pitting oedema resulting from undernutrition. In both adults and children this is an important sign of severe undernutrition, carrying a high mortality risk.

MUAC
The mid upper arm circumference, measured on a straight left arm (in right handed people) mid way between the tip of the shoulder (acromium) and the tip of the elbow (olecranon). An index of peripheral protein and fat stores. This is an accepted measure of acute undernutrition.

ASCITES
The accumulation of serous fluid in the peritoneal cavity.

CORMIC INDEX
The ratio of leg-length to trunk-length, sometimes called the sitting height to standing height ratio (SH/S).

INCIDENCE
The number of new cases of undernutrition in a defined population within a specified period of time.

PREVALENCE
The total number of undernourished individuals in a given population at any one time.

INDICATOR
An indicator is a variable taking one of two possible values, one indicating the presence of a condition, the other indicating absence of the condition. In the context of assessing nutritional status this will usually mean whether or not an individual is above or below a pre-defined value of a particular body measurement or combination of measurements (e.g. MUAC, weight, BMI). A clear idea of the purpose of the assessment being undertaken should inform the choice of body measurement used and the cut-off points that are applied to it.

SENSITIVITY
Sensitivity is the number of people correctly identified by an indicator as being undernourished divided by the total number of undernourished people measured. A sensitive indicator will identify a large proportion of the undernourished people measured.

SPECIFICITY
Specificity is the number of people correctly identified by an indicator as non-undernourished divided by the total number of non-undernourished people measured. A specific indicator will correctly identify a large proportion of the non-undernourished people measured.
SURVEILLANCE

Ongoing scrutiny, generally using methods distinguished by their practicability, uniformity, and frequently their rapidity, rather than by complete accuracy. Its main purpose is to detect changes in trend or distribution in order to initiate investigative or control measures. The appropriateness of a nutritional indicator for surveillance lies in its ability to reflect the true incidence of undernutrition in a population. The principal objective of a surveillance system is to provide information in order to aid decision making at a community level and there may be no immediate benefits for the individuals surveyed. Surveillance normally estimates incidence rather than prevalence.

NUTRITIONAL SURVEY

A survey which examines the presence or absence of undernutrition in each member of a representative sample of a population at one particular time. A survey estimates prevalence rather than incidence.

SCREENING

In the context of nutrition, the purpose of screening is to select individuals at increased risk of morbidity and mortality who are likely to respond to treatment and to treat them. The numbers selected by the indicator used are those that need treatment. In emergency relief programmes, the appropriate indicator cut-off point (screening level) is that which selects the number of individuals that can be treated with the resources at hand. Such cut-off point values cannot therefore be determined universally but must be tailored to suit the resources available in each particular situation. The choice of underlying body measurement will often be determined by available equipment (e.g. scales may not be available to measure weight).

CLINICAL MONITORING

The performance and analysis of routine measurement aimed at detecting changes in the nutritional status of an individual.
Our long-run vision is of a world in which malnutrition is no longer a human development constraint. This is possible, but to achieve it will require decisive action at country level, supported by a coherent and co-ordinated international strategy, founded on human rights and providing a framework for action throughout the UN and international development finance system, implemented in close partnership with NGOs, bilaterals and governments. Nutrition needs to be made a key development priority, recognized as vital to the achievement of other social and economic goals. Good nutrition under normal conditions contributes to the prevention and mitigation of death and malnutrition in emergency situations. Good nutrition facilitates the prompt return to conditions favouring development following disasters.

The mandate of the ACC/SCN is to raise awareness of nutrition problems and mobilize commitment to solve them -- at global, regional and national levels; to refine the direction, increase the scale and strengthen the coherence and impact of actions against malnutrition world wide; and to promote cooperation amongst UN agencies and partner organizations in support of national efforts to end malnutrition in this generation.

Three main areas for action have been identified: (i) Promote of harmonized approaches among the UN agencies, and between the UN agencies and governmental and non-governmental partners, for greater overall impact on malnutrition. (ii) Review the UN system response to malnutrition overall, monitor resource allocation and collate information on trends and achievements reported to specific UN bodies. (iii) Advocate and mobilize to raise awareness of nutrition issues at global, regional and country levels and mobilize accelerated action against malnutrition. These three functions are all vital and of equal importance and can be seen as a triangle, one dependent on the other.

The UN members of the ACC/SCN are the FAO, IAEA, IFAD, ILO, UN, UNAIDS, UNDP, UNEP, UNESCO, UNFPA, UNHCHR, UNHCR, UNICEF, UNRISD, UNU, WFP, WHO and the World Bank. The ADB and IFPRI are also part of this group. From the outset, representatives of bilateral donor agencies and NGOs have participated actively in SCN activities. The Secretariat is hosted by WHO in Geneva.

The SCN undertakes a range of activities to meet its mandate. Annual meetings have representation from those mentioned above as well as academia -- a one-day Symposium is held during the annual meeting, focusing on a subject of current importance for policy. The SCN convenes working groups on specialized areas of nutrition; currently there are nine working groups in areas ranging from foetal and infant malnutrition, nutrition of the school aged child, and household food security to capacity building.

The SCN’s reports on the world nutrition situation, published every two to three years, are authoritative sources of information to guide the international community in its nutrition work. Nutrition Policy Papers and the SCN News summarise current knowledge on selected topics. Quarterly bulletins on the nutritional status of refugees and displaced persons are also published in collaboration with a large network of NGOs.
GENERAL SUMMARY – SUGGESTED INDICATORS FOR ASSESSING ADULT UNDERNUTRITION IN THE FIELD

SURVEYS AND POPULATION LEVEL ASSESSMENTS OF CHRONIC UNDERNUTRITION

1. BMI
2. MUAC

If the survey results are used to compare BMI between populations then BMI must be standardised for the average population Cerrmic Index (sitting height/standing height)

SCREENING SEVERELY UNDERNOURISHED ADULTS

THERAPEUTIC FEEDING CENTRES

CHANCES model:

1. MUAC < 160 mm alone
2. MUAC < 161-185 mm plus one of the following:
   - Oedema
   - Inability to stand
   - Apparent dehydration
3. Famine oedema (Beattie grade 3 or worse) alone as assessed by a clinician to exclude other causes

Additional social factors can be included in the model. The relative weighting of these, for example whether you need one, two or three additional social factors to tip the balance in favour of therapeutic rather than supplementary care must be determined locally. Relevant social factors could include the following:
   - Access to food (quality and quantity)
   - Distance from centres
   - Presence/absence of carers
   - Shelter
   - Dependents
   - Cooking utensils

SUPPLEMENTARY FEEDING CENTRES

MUAC < 161-185mm and no relevant clinic signs or few relevant social criteria

In any particular situation, workers should take these suggested standards as the starting point and adapt them according to situation-specific factors.
Using Middle Upper Arm Circumference to Assess Severe Adult Malnutrition During Famine

Steve Collins, MB, BS

Objectives.—To examine the use of middle upper arm circumference measurement (MUAC [cm]) and body mass index measurement (BMI [kg/m²]) in the screening of severely malnourished adults during famine.

Design.—Nonrandomized cohort study, correlating measurements of MUAC and BMI.

Setting.—The Concern Worldwide adult feeding center in the village of Ayod in south Sudan. The area had experienced several years of war, leading to severe famine during early 1993.

Participants.—A total of 98 adult inpatients belonging to the Nuer tribe. Criteria for entry into the study were prior admission to the feeding center and the ability to stand and have a BMI measured.

Main Outcome Measures.—A comparison of the ease of use of MUAC and BMI assessments, and a correlation of MUAC and BMI measurements.

Results.—An MUAC measurement was easier to perform on severely malnourished adults than BMI assessment. For MUAC, the patient could be standing, sitting, or, in extreme cases, lying. For BMI, patients were required to stand. Measuring BMI requires a height board, weighing scales, and mathematical calculations; to measure MUAC, only a tape measure is required. A correlation between measurements of MUAC and BMI was demonstrated (r=0.88; 95% confidence interval, 0.82-0.92; P<.001). The proportions of the population and the actual individuals identified as malnourished by the 2 indicators were similar.

Conclusions.—The MUAC measurement reflects adult nutritional status as defined by BMI. During famine, MUAC may be better suited to screening admissions to adult feeding centers than BMI. Studies to assess the capacity of MUAC cutoffs to predict mortality in severe adult malnutrition are needed.

JAMA. 1996;276:391-395

SEVERE ACUTE adult malnutrition is common during famine. Without specialized treatment, it is associated with a high mortality. Delivering assistance to these malnourished adults is therefore one of the major tasks facing emergency relief programs. During the height of a famine when large numbers of people are competing for scarce resources, accurate targeting of emergency food supplies is vital. Screening admissions to feeding centers to separate those who would not survive without special treatment from the majority who would is central to effective targeting. In children, this is carried out using anthropometric indicators based on measurements of weight, height, and middle upper arm circumference (MUAC).

For adults, anthropometric indicators of acute energy deficiency with cutoff values appropriate to severe famine do not exist. During the initial phases of famine relief operations, there may be many hundreds of adults crowding for admission to an adult therapeutic center. In a Concern Worldwide adult feeding center in Angola during 1993, more than 300 people were screened per day by a single expatriate worker and his team of local staff. The lack of an appropriate screening tool to differentiate quickly those who will not live without specialized assistance from those who will poses difficulties for famine relief workers.

This is especially true if the volunteers working in famine relief programs are young, first-time recruits with little or no experience in similar situations. These problems can lead to turning away adults who require specialized therapy or admitting those not requiring such attention. This results in unnecessary adult mortality, inefficient operation of adult feeding centers, and suboptimal allocation of resources.

Body mass index (BMI [kg/m²]) is an accepted indicator of chronic energy deficiency (CED) in adults that has been shown to reflect risk of mortality in nonfamine situations. In the absence of data from acutely malnourished adults, it has been assumed that BMI is also an ap-
The potential usefulness of MUAC in the assessment of adult severe malnutrition. The cutoff values applicable to adult CED are too high to be appropriate in famine situations, when the majority of adults can have BMIs below 16 kg/m², the upper limit defined as severe CED.** Such a cutoff is therefore of little use in differentiating between those who need therapeutic feeding and those who would survive without it.

The height and weight measurements required to calculate BMI are time-consuming and difficult to obtain from the most severely emaciated people who often cannot sit up unaided. In practice, this results in BMI assessment frequently being omitted. Famine edema, seen in up to 90% of adults suffering from severe acute malnutrition, and also confounds estimations of BMI. Famine edema is a poor prognostic sign in adult malnutrition and is associated with a markedly increased relative risk of mortality. It is not reflective of body weight. As a consequence, in those patients with severe famine edema, the relative risk of mortality increases as BMI increases, the opposite of that seen among marasmic patients. This increase nullifies the ability of BMI to reflect severity of malnutrition or risk of mortality in patients with severe famine edema.

Thus, BMI may be an inappropriate measure for the majority of a famine-afflicted population.

In children, MUAC has been shown to be useful in the assessment of nutritional status. The measurement is easy to perform even on the most debilitated children, is efficient at predicting mortality, and can be readily taught to minimally trained health workers. It is well suited to screening admissions of children to feeding centers during the initial phase of an emergency aid operation. At present during famines, MUAC is only recommended for use in children between 1 year and 5 years of age and is not used in the assessment of adult malnutrition. However, measurements of arm circumference in adults have long been known to reflect changes in body weight. More recently, such measurements have been used in the diagnosis of adult malnutrition in hospitals and as a prognostic indicator in the elderly or in those with cancer. A reasonably close relationship between adult MUAC and BMI has been demonstrated in normal adult populations from a number of developing countries, but to date no such comparisons have been made during severe famine.

The aim of this study was to examine the potential usefulness of MUAC in the assessment of severely malnourished adults during the height of a famine and the relationship between MUAC and BMI. This was to be achieved by comparing estimations of MUAC with those of BMI and relating each to short-term outcomes such as mortality and length of stay. Ideally, a study relating MUAC to the risk of mortality in the general population is required to establish functional MUAC cutoff points that could be used for the screening of adult admissions to feeding centers. However, famine always involve massive social upheaval and large numbers of afflicted individuals. These factors, combined with the armed conflict that has characterized almost all famines during the last 10 years, make such broad-based population studies unfeasible. As a consequence, no such studies have yet been performed for any nutritional indicator in either adults or children during the height of a famine.

Given these difficulties, relating MUAC to mortality in a selected feeding- center population may be a reasonable alternative, better than an absence of information on the use and suitability of adult nutritional indicators in famine. Data obtained from such selective studies are useful in providing a general idea of the suitability of different admissions into feeding centers during famine. In addition, they provide information about anthropometric thresholds requiring various levels of intervention once a person is admitted to a feeding center and hence provide information against which the performance of differing curative regimens can be judged.

The Ayod, south Sudan, study population was chosen for this study based on an observation of a high prevalence of severe malnutrition and very low prevalence of famine edema. A low prevalence of famine edema was considered desirable as edema is a potential confounder of the relationship between BMI and MUAC.

In this study, it was not possible to evaluate short-term outcomes and their relation to the nutritional indicators. The reason for this failure was that during the second week of April the village of Ayod, including the Concern Worldwide adult center where the study was taking place, was attacked. The villagers were forced to flee, and all Concern staff were evacuated. Tragically, when Concern workers were able to return to Ayod, the center had been destroyed, and the occupants had either fled or been murdered.

METHOD

Body mass index and MUAC were assessed in 98 severely malnourished adult inpatients from the Nuer tribe at the Concern Worldwide feeding center in Ayod during April 1993. Patients were suffering from acute nonedematous malnutrition, complicated by a variety of infections commonly seen during famine, of which dysentery, respiratory infection, helminthiasis, and malaria were the most common. An epidemic of visceral leishmaniasis (kala-azar) was reportedly also present in the area. (oral communication, A. Davis, MSc, Médecins Sans Frontières, Holland, 1995).

During the first week after their admission, all patients who could stand were measured, weighed, and had their MUAC assessed. The MUAC was assessed on the left arm midway between the olecranon and the tip of the acromion process of the scapula, using a standard, nonstretachable tailor's tape measure, read to the nearest 5 mm. The weight of the patients in minimal clothing was assessed to the nearest 100 g using Soehnle digital electronic scales, previously calibrated against known weights in the United Kingdom. The height was assessed using Microtoise stadiometers to the nearest 5 mm. Height measurements were made with the patients standing with their heels together and their legs and back as straight as possible. All patients were lost to follow-up.

To allow for comparisons with previous studies, the relationship between MUAC and BMI is presented using the regression line $\text{MUAC} = \text{BMI} + c$ with $c$ = intercept and $c$ = regression coefficient. The reason for which the 2 indices identified the same individuals, however, was analyzed in terms of the sensitivity and specificity of MUAC in identifying those individuals below specified BMI cutoffs. In this analysis, BMI was the dependent variable, and the regression line $\text{BMI} = \text{MUAC} - c$ was used. Integer values of BMI between 16 and 10 were assigned as cutoff points, and the corresponding MUAC values predicted from the regression line. Body mass index was taken as the reference indicator because it is the more accepted indicator of adult nutritional status. However, since BMI has not yet been shown to be a criterion standard for the assessment of acute malnutrition in adults, this choice was somewhat arbitrary. Data were analyzed using Epi Info and Microsoft Excel.

RESULTS

The MUAC and BMI values recorded in the center are presented in Table 1. Mean BMI values (kg/m²) were higher for male than female patients (mean, male 13.3 kg/m², female 12.6 kg/m²; analysis of variance (ANOVA) $F = 2.86, \text{df} = 1.96, \text{P} = .07$). This result is of borderline significance. Mean MUAC values...
The sensitivity-specificity analysis indicated that the individuals identified by the regression line of MUAC on BMI remained high for all the cutoff values and an analysis of the sensitivity, specificity, and predictive power of MUAC with respect to BMI as presented in Table 2. The proportions defined by the 2 indicators were similar, although at the lower end of the BMI range, MUAC tended to define a slightly smaller proportion of the population than the comparable BMI cutoffs. The sensitivity-specificity analysis indicated that the individuals identified by the 2 indices were also similar, particularly within the BMI range of 16 kg/m² to 13 kg/m². The positive predictive value for the prediction of BMI by MUAC remained high for all the cutoff values. Below a MUAC of 18.5 cm (BMI of 13 kg/m²), the relative proportion of the population defined by MUAC, and the sensitivity of MUAC in predicting BMI fell. This cutoff point corresponded to a position on the relative operating characteristic (ROC) curve for the prediction of BMI by MUAC, where sensitivity was maximized without an appreciable loss in specificity (Figure 2).

**COMMENT**

The patients in this study presented with extremely severe emaciation. Thirty-five percent (34/98) of the patients had a BMI below 12 kg/m², the level previously considered to be the lowest limit compatible with recovery. These extremely low BMI measurements, although in part due to the tall, long-legged, Nilotic phenotype of the Nuer people, are similar to recent observations from Somalia. New Guinea, India, China, Senegal, Zimbabwe, Mali, and Ethiopia, which contain significant racial variation. In some of the data sets that contribute to the common regression lines, such as those for Ethiopian, Somali, and Chinese women, the relationship between BMI and MUAC is much more similar to that seen in this study. Several other reasons may explain why the relationship between MUAC and BMI are closely related in both male and female patients. Differences between the male and female regression lines were not significant. The regression line of MUAC compared with BMI in the Ayod study population differed from that recorded in the better-nourished populations. At the most severe levels of emaciation (ie, MUAC <16 cm and BMI <11 kg/m²), this difference is of practical significance, equivalent to a change of 1 to 2.5 cm in MUAC.

**Table 1.** BMI and MUAC Data (n=98)

<table>
<thead>
<tr>
<th>Sex</th>
<th>No.</th>
<th>Median BMI</th>
<th>Median MUAC</th>
<th>Lower Quartile BMI</th>
<th>Lower Quartile MUAC</th>
<th>Upper Quartile BMI</th>
<th>Upper Quartile MUAC</th>
<th>Normal Values, Mean±SD†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>44</td>
<td>13.4 10.2 11.8 14.4 20.0±2.19 19 12.5 17.8 20</td>
<td>Male, Regression MUAC on BMI Slope 0.86, Intercept 7.36</td>
<td>Female, Regression MUAC on BMI Slope 1.16, Intercept 3.28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>54</td>
<td>12.5 9.3 11.3 13.9 20.4±2.65 17.5 15 16 19.5 24.8±2.59</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*BMI indicates body mass index; and MUAC, middle upper arm circumference.
†Normal values based on a sample of 5669 adults from developing countries.

**Figure 1.** Scattergram illustrating the relationship between middle upper arm circumference (MUAC) and body mass index (BMI) measurements in the Ayod study population, taken at the height of a severe famine (n=98), and a comparison between these data and other data from more normally nourished populations in developing countries. There was a close correlation between MUAC and BMI in the Ayod population. The regression line of MUAC on BMI in this population differed from that recorded in the better-nourished populations. At the most severe levels of emaciation (ie, MUAC <16 cm and BMI <11 kg/m²), this difference is of practical significance, equivalent to a change of 1 to 2.5 cm in MUAC.
and BMI might differ between a famine-affected population and other better-nourished populations. For example during starvation, tissue with a low metabolic rate, such as subcutaneous fat and skeletal muscle, is preferentially catabolized. This would tend to decrease the rate of decrease in MUAC compared with BMI and revert the MUAC on BMI regression line back toward that seen in better-nourished populations. The drop in the sensitivity of MUAC when compared with BMI that occurred below an MUAC of 18.5 cm (Table 2) might be a reflection of such a change. The requirement to be able to stand as a criterion for entry into this study would have resulted in a selection bias within the sample population partially obscuring this effect. Only those with sufficient peripheral muscle mass remaining to enable them to stand would have been selected. Although fewer than 10 patients were excluded from the study because they could not stand, many of them would have been those who had exhausted their peripheral stores. The drop in the sensitivity of MUAC at extreme grades of emaciation would most likely have been greater had the whole population of the center been measured. At present the relative importance of these effects is unknown, and more work is required before more precise MUAC cutoffs can be derived.

Assessment of adult nutritional status using MUAC requires no equipment apart from a tape measure. As the index is the actual measurement itself, there is also no need for mathematical manipulation of the measurements obtained. In contrast, assessment of BMI requires a height board and weighing scales that often need recalibration in the hot dusty environments in which famines usually occur. In addition, the 2 measurements obtained must be mathematically transformed before being useful. All these processes are prone to error, especially during the highly pressurized circumstances characteristic of the early phases of famine relief programs. At the height of a famine, there are always many people in need of treatment and few facilities or staff with which to treat them. The ease with which MUAC can be assessed, therefore, suit it for nutritional screening during the height of an emergency where time and skilled personnel are at a premium.

In children, MUAC is associated with 2 problems: the preferential selection of younger children as malnourished and a lack of reproducibility in MUAC measurements. The preferential selection of younger children as malnourished results from the gradual increase in the normal MUAC between the ages of 1 year and 5 years. In older children and adolescents, the rapidly changing patterns of skeletal muscle and subcutaneous fat are likely to exaggerate this problem, and it is unlikely that MUAC will be of much use in these groups. In adults, the use of MUAC is not subject to such errors caused by growth, but can be affected by the redistribution of subcutaneous fat toward central areas of the body with aging. Potentially more serious obstacles to the use of MUAC in adults are the problems with the reproducibility of MUAC measurements. As when MUAC is measured in children, interobserver and intraobserver errors in MUAC measurements may occur. However, the larger dimension of the adult arm is likely to reduce the relative importance of these errors. The development of colored, nonnumeric MUAC bands reflecting threshold values of MUAC with a change of color would further reduce these problems by eliminating numerical errors. Given the ease with which MUAC measurements can be performed, it would be feasible to refer any patients found to have an MUAC within 0.5 cm either side of the threshold, a zone marked by a different color, to a more experienced worker for verification. These problems are currently being investigated using data from several Concern Worldwide adult therapeutic centers.

The results of this study indicate that MUAC is potentially useful for differentiating adults who require emergency feeding from those who are likely to survive without it. The destruction of the Ayod center and the death and dis-
persion of its inpatients prevented any analysis of the relationship between MUAC and mortality. This is a major limitation to this study, and in the absence of these data, functional MUAC cutoff values based on risk of mortality cannot be presented. However, the drop in sensitivity of MUAC below a level of 16.5 cm is likely to reflect the change from central to peripheral protein stores at a point when peripheral energy and protein stores have become exhausted. This level of MUAC may represent a functional threshold below which there is an increase in the catabolism of visceral protein from vital organs such as the heart. At this degree of emaciation, patients are unlikely to survive given only a general ration, and specialized nutritional and medical support is required (S.C., M. Myatt, B.E. Golden, MD, unpublished data, 1995).

CONCLUSION
During famine, a practical indicator with which to assess adult malnutrition is needed, especially during the initial phases of emergency relief operations. This study indicates that MUAC is well suited to such a role, and its use has several advantages over the use of BMI. Insufficient data are currently available to stipulate the functional MUAC cutoff value that differentiates malnourished adults that require specialized therapeutic care from those who can survive without it. To that end, additional research is required to evaluate the power of adult MUAC to predict mortality in different famine-affected populations.

I would like to thank Anila Ennis, Fr. Jack Fincance, and Roberta Gordon, without whose help this work would not be possible, and Mark Myatt, Hannah Scaife, MSc, and Andrew Tomkins, FRCP, for their advice and encouragement.
Short-term Prognosis in Severe Adult and Adolescent Malnutrition During Famine
Use of a Simple Prognostic Model Based on Counting Clinical Signs

Steve Collins, MBBS
Mark Myatt, BA

For many years, it has been recognized that malnutrition increases both susceptibility to and severity of infection. Vitamin, mineral, and other dietary deficiencies, depressed cell-mediated and humoral immunity, gastric acidity, mucosal integrity, and altered flora are all known to increase susceptibility to infection. The situation in famine is usually worsened by a breakdown in public health infrastructure and congregation of displaced people in crowded and unhygienic conditions. In situations of malnutrition in developed countries, exhaustion of fat or fat-free mass is most often the terminal event, but the combination of poor public health environment and immunosuppression in famine means that it is infection, rather than absolute loss of fat or fat-free mass, that kills people.

The strong association between infection and mortality indicates that clinical signs are likely to be useful prognostic indicators. Clinical models for prediction of mortality, useful in the screening of admission to child feeding centers, have been proposed. Although reported to be effective in identifying children at high risk of mortality, these models have been criticized because interactions between the features used, such as edema and hypoproteinemia, were not taken into account. In adults, the use of clinical models to assess nutritional status appears to have been restricted to well-nourished surgical patients. To date, similar assessments have not been made in severely malnourished adults or during famines.

Extreme conditions often characterize famine relief programs. Levels of need are high and trained staff, equipment, and buildings are scarce. Some-
times, crowds of several thousand people may gather, attempting to gain admission to centers. Such centers may become overcrowded, disorganized, and dysfunctional if patient selection and prioritization is not efficient. Tools to assess patients must be quick, simple, and reliable, even when used by minimally trained staff, who may be barely literate. This study investigates the effectiveness of assessment tools, body mass index (BMI) and models using ordinarily clinical signs, during the height of a major famine.

**METHODS**

**Subjects**

This retrospective cohort study involved clinical record data of 393 patients admitted to the Concern Worldwide Adult Therapeutic Center, Baidoa, Somalia, between November 4, 1992, and March 15, 1993. Criteria for inclusion in this retrospective analysis were BMI at admission of 13.5 kg/m² or less or any signs of edematous malnutrition, a reported age of 15 years or older, the presence of an inpatient treatment and clinical data card, and no record that the patient was admitted because of medical criteria alone. Of these 393 patients, 10 were excluded owing to the absence of outcome data. The mean reported age of the remaining 383 subjects was 33.0 years, with no significant age difference between sexes (t = 1.32; P = .19). Of those admitted, 48.4% were men (Table 1). Mean (SD) BMI at admission was 12.7 (2.0) kg/m²; mean (SD) weight was 34 (7.2) kg. Mean admission BMI of survivors was 12.6 kg/m² vs 12.9 kg/m² for nonsurvivors.

<table>
<thead>
<tr>
<th>Variables</th>
<th>All Patients</th>
<th>Survivors (n = 292)</th>
<th>Nonsurvivors (n = 91)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-reported age, mean (SD) [range], y</td>
<td>33.0 (16.0) [15.0-89.0]</td>
<td>32.7 (14.8) [15.0-89.0]</td>
<td>33.8 (16.5) [15.0-80.0]</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male, No. (%)</td>
<td>382</td>
<td>296</td>
<td>86</td>
</tr>
<tr>
<td>Female, No. (%)</td>
<td>197 (51.6)</td>
<td>140 (47.9)</td>
<td>45 (50.0)</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>No. 341</td>
<td>244</td>
<td>97</td>
</tr>
<tr>
<td>Male, No. (%)</td>
<td>185 (48.4)</td>
<td>140 (47.9)</td>
<td>45 (50.0)</td>
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<td>Female, No. (%)</td>
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<td>152 (52.1)</td>
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<td>Mean (SD) [range]</td>
<td>12.7 (2.0) [9.0-24.0]</td>
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<td>12.9 (1.9) [9.3-17.6]</td>
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### Center, Staff, and Equipment

The therapeutic feeding center consisted of 9 stick shelters with plastic sheeting roofs and mud floors. Separate shelters were designated for new admissions, those with edematous malnutrition, those with dysentery, and those suspected of having pulmonary tuberculosis. Beds were not available and all patients had to lie on plastic sheets on compacted mud floors.

The center was staffed by 1 expatriate physician, 1 to 2 expatriate nurses, 3 local nurses, and approximately 30 other helpers and cooks. High levels of supervision were maintained, with staff-patient ratios of 1:8 or less, particularly during the first few days after admission. These staff members distributed food and oral rehydration solution (ORS), encouraged patients to eat and drink, and helped feed those who were unable to feed themselves.

A set of standard Hanson spring scales and a locally constructed height board were used to weigh and measure patients. The scales were calibrated in London, England, and Baidoa using known weights. Results were similar at both sites. In the useful range of 20 to 50 kg, there was a linear increase in error (r = 0.99). A correction factor derived using ordinary least squares linear regression was used to correct each weight measurement.

### Medical Treatment

Oral antibiotics were needed by the majority of patients on admission, with many patients continuing to receive an antibiotic throughout their stay in the center. Penicillin V and ampicillin were the first-line antibiotics for pulmonary infection, as were trimethoprim-sulfamethoxazole and metronidazole for dysentery and persistent diarrhea. Chloramphenicol was the only second-line antibiotic used.

Discharge criteria were predominantly clinical. Freedom from infectious disease, absence of diarrhea, a good appetite, constant weight gain, and ability to walk and care for oneself were all necessary conditions for discharge. The presence of minimal pedal edema did not preclude discharge as long as these criteria were met. On discharge, transport to patients' home villages was provided.

### Dietary Treatment

Patients were orally rehydrated using the World Health Organization formula for ORS (sodium chloride, 3.5 g/L; trisodium citrate, 2.9 g/L; potassium chloride, 1.5 g/L; and glucose, 20 g/L). The degree to which the high-energy milk component was diluted was tailored according to severity of diarrhea. The amount of high-energy milk was diluted to achieve the correct energy density of the formula. The high-energy milk was diluted to achieve the correct energy density of the formula.

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</table>
protein diet was associated with pro-
longed anorexia, increased or persis-
tent edema, and occasional instances of
sudden death. Introduction of the lower-
protein diet in December 1992 reduced
the center have supported these obser-
vations, demonstrating a 4-fold reduc-
tion in mortality among patients with
severe edema who received the low-
protein diet.10

Data Collection and Coding
On admission, patients were regis-
tered and weighed and had their height
measured by trained local enumera-
tors, supervised by a specially trained
nurse or the clinician responsible for
collecting clinical data (S.C.). Body
mass index was calculated from weight
measurements taken within 2 days of
admission; 97.6% (n = 289) of BMIs
were calculated on the day of admis-
sion. A rapid clinical screen, assessing
degree of pitting edema, ascites, hydra-
tion, dysentery, diarrhea, anemia, signs
of chest infection, and ability to stand,
was performed by either the supervis-
ing clinician or a nurse. Weight and/or
clinical condition of each patient was
monitored daily. Outcome (death in the
center, discharge alive, or lost to follow-
up) was recorded on individual pa-
tient cards and in the center’s register.

Data were transferred from inpatient
record cards onto specially designed cod-
ing forms, double-entered into a per-
sonal computer, and validated for entry
error. Pitting edema was coded using the
classification of Beattie et al11 (0 = ab-
sent; 1 = minimal edema on foot or ankle
that is demonstrable but not visible;
2 = visible on foot or ankle; 3 = demon-
strable up to knee; 4 = demonstrable up
to inguinal ligament; 5 = anasarca). Pit-
ing edema that was recorded as present
but unquantified was assumed to be mod-
erate (grade 3). Periorbital edema was
coded as 1 (mild), 2 (moderate), or 3 (se-
vere), with present but unquantified
edema again assumed to be moderate
(grade 2). Ascites was similarly coded.
Severe edematous malnutrition was
defined as either pitting edema greater
than grade 2, periorbital edema greater
than grade 1, or an ascites. Apparent
dehydration was defined as sunken eyes,
decreased urine output, or dry mucous
membranes. Diarrhea (profuse, fre-
quent, watery stool) and dysentery (pro-
fuse, frequent, watery stool with blood
and or without pus) were coded as
present or absent. Missing data values
were coded as not present.

The level of supervision of data col-
lection was variable. Occasionally, ex-
patriate access to the center by the su-
ervising clinician and nurses was
restricted for part of a day because of
gun fighting, bandit attacks, attempts
at hostage taking, and military occu-
pations that occurred in Baidoa dur-
ing the study period.

Data Analysis
Bivariate and multivariate logistic regres-
sion analyses were used to assess the
association of clinical features at presen-
tation with mortality in the center.
Variables that were not independently as-
associated with mortality were elimi-
nated from the logistic models in a back-
ward-stepwise fashion using estimation
techniques. Odds ratios (ORs) of the 3
signs independently associated with
death were used to construct a predic-
tive model. If a patient exhibited none
of these signs, the score was 0. If they
exhibited 1 sign, their score was the OR
associated with that sign. If more than 1
clinical sign was present, their score was
the sum of the ORs associated with each
sign. The sensitivity and specificity of
predicted mortality at score intervals of
0.5 were calculated and receiver operat-
ing characteristic (ROC) curves were
plotted. Receiver operating characteris-
tic curves plot sensitivity against
specificity and are a useful means of
assessing the ability of an indicator to
discriminate between healthy and dis-
 eased persons or, in this case, between
patients with differing outcomes (sur-
vival or death). A simpler model using
a count of clinical signs was also con-
structed. In this model, the score for each
patient was the number of 3 relevant
clinical signs exhibited.

The association between BMI and
survival was explored in a systematic
manner. A series of indicator variables
was created using successively higher
BMI cut-points at intervals of 0.5 kg/m²
(ie, variables were created to indicate
whether an individual BMI was <10.0,
10.5, 11.0, 11.5, 12.0, 12.5, etc). Each
indicator was tabulated against sur-
vival. The indicator with the most sig-
nificant positive association (BMI <11.0
kg/m²; OR, 2.44; 95% confidence inter-
val, 1.11-5.32; Yates-corrected χ² = 5.22; P<.05) was then included in
the predictive model.

A simulation exercise was under-
taken to validate the methods used to
construct the models. Each run of the
simulation involved splitting the data set
into 2 parts by randomly selecting (us-
ing a pseudorandom number genera-
tor) approximately half of the available
records as a training data set and using
the other half of the data as a validation
data set. The ORs and uncorrected χ² for
each association between predictor vari-
ables and death were calculated using the
training data set. Sums of ORs and sign-
count models were then constructed us-
ing variables with significant positive as-
sociations with death, defined as any
variable having an OR of greater than
unity and an uncorrected χ² of greater
than 3.84 (ie, P≤.05 for tables with 1 df).
Models constructed using these vari-
bles were then tested on the valida-
tion data set. The simulation was run
1000 times. All data entry and analyses
were performed using Epi Info, Logis-
tic,13 and Microsoft Excel.14

RESULTS

Ninety-one (23.8%) of the 383 pa-
tients died before discharge. Median
time to death was 8 days (range, 1-53
days). Table 2 shows the clinical sign
variables that were independently asso-
ciated with survival and the ORs asso-
ciated with these variables. Ascites
was not associated with survival. Se-
vere edema, inability to stand, and ap-
parent dehydration were indepen-
dently associated with mortality.

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Table 3 presents the sensitivity and specificity for prediction of death in all 383 patients for all combinations of clinical models created using edema, inability to stand, and apparent dehydration. The most discriminatory model (ie, the model with the greatest sum of sensitivity and specificity) was that based on the presence of any 1 of these 3 signs. This model predicted 77% of deaths at a specificity of 59%.

Figure 1 shows the ROC curves for the prediction of short-term mortality using the sum-of-ORs clinical model and BMI. The prediction of death by the sum of the ORs of severe edema, inability to stand, and apparent dehydration performed at the highest level of sensitivity and specificity. Prediction of death using BMI alone in these patient yielded worse-than-random results. When BMI was used in a subpopulation selected to include only marasmic patients who could stand (n=218), performance was similar to the clinical model, predicting 46% of deaths at a specificity of 85%. When use of BMI was further restricted to include only marasmic women who could stand (n=108), BMI performed better than the clinical model, predicting 56% of deaths at a specificity of 87%.

The ROC curve for the model constructed by counting clinical signs was identical to that produced using the sum-of-ORs clinical model. Addition of a BMI marginally improved these models. ROC curves for these models are presented in Figure 2.

Nine hundred ninety-three runs (99.3%) of the simulation of the sum-of-ORs clinical model yielded a predictive model better than random. The mean area under the ROC curves for these 1000 simulations was 63.25% (SD, 4.23%). Nine hundred ninety-seven runs (99.7%) of the sign-count clinical model predicted deaths in a near identical fashion (Figure 2). Use of this sign-count model required only a count of relevant clinical signs, not calculation of ORs, which would be difficult in the field. Eliciting the 3 clinical signs used in the model was quick and easy in all patients and required no equipment. Consequently, the sign-count model can be readily taught to local workers and is suitable for use as a prognostic model in the field, even during the early phases of a famine relief program.

Table 3. Prediction of Mortality by 3 Clinical Signs (N = 383)*

<table>
<thead>
<tr>
<th>Signs</th>
<th>No. of Nonsurvivors Predicted to Die</th>
<th>No. of Survivors Predicted to Die</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>Accuracy, %</th>
<th>PPV, %</th>
<th>NPV, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dehydration</td>
<td>39</td>
<td>63</td>
<td>43</td>
<td>76</td>
<td>70</td>
<td>38</td>
<td>81</td>
</tr>
<tr>
<td>Edema</td>
<td>33</td>
<td>55</td>
<td>36</td>
<td>81</td>
<td>70</td>
<td>38</td>
<td>80</td>
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<tr>
<td>Inability to stand</td>
<td>17</td>
<td>21</td>
<td>19</td>
<td>93</td>
<td>75</td>
<td>45</td>
<td>79</td>
</tr>
<tr>
<td>Combined using &quot;and&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edema and inability to stand</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>99</td>
<td>76</td>
<td>50</td>
<td>77</td>
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<td>Dehydration and inability to stand</td>
<td>8</td>
<td>9</td>
<td>9</td>
<td>99</td>
<td>77</td>
<td>67</td>
<td>78</td>
</tr>
<tr>
<td>Dehydration and edema</td>
<td>9</td>
<td>12</td>
<td>10</td>
<td>98</td>
<td>75</td>
<td>45</td>
<td>77</td>
</tr>
<tr>
<td>All 3 signs</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>76</td>
<td>50</td>
<td>76</td>
</tr>
<tr>
<td>Combined using &quot;or&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edema or inability to stand</td>
<td>47</td>
<td>73</td>
<td>52</td>
<td>75</td>
<td>69</td>
<td>39</td>
<td>83</td>
</tr>
<tr>
<td>Dehydration or inability to stand</td>
<td>48</td>
<td>80</td>
<td>53</td>
<td>73</td>
<td>68</td>
<td>38</td>
<td>83</td>
</tr>
<tr>
<td>Dehydration or edema</td>
<td>63</td>
<td>106</td>
<td>69</td>
<td>64</td>
<td>65</td>
<td>37</td>
<td>87</td>
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<tr>
<td>Any 1 sign</td>
<td>70</td>
<td>121</td>
<td>77</td>
<td>59</td>
<td>63</td>
<td>37</td>
<td>69</td>
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<tr>
<td>Any 2 signs</td>
<td>18</td>
<td>17</td>
<td>20</td>
<td>94</td>
<td>77</td>
<td>51</td>
<td>79</td>
</tr>
</tbody>
</table>

*PPV indicates positive predictive value; NPV, negative predictive value.

COMMENT

The risks of mortality associated with apparent dehydration, inability to stand, and severe edema were independent of each other. A patient presenting with more than 1 of these signs therefore had a risk of mortality equivalent to the sum of the risks of all the signs that were present. A scoring system based on the sum of the ORs predicted 77% of deaths at a specificity of 59%. A simplified model, using only the presence or absence of 3 clinical signs—severe edema, inability to stand, and apparent dehydration—predicted deaths in a near identical fashion (Figure 2). Use of this sign-count model required only a count of relevant clinical signs, not calculation of ORs, which would be difficult in the field. Eliciting the 3 clinical signs used in the model was quick and easy in all patients and required no equipment. Consequently, the sign-count model can be readily taught to local workers and is suitable for use as a prognostic model in the field, even during the early phases of a famine relief program.

The capacity of BMI to predict death was limited. Only among female marasmic patients who could stand did BMI perform better than the clinical...
models. When nonmarasmic patients and those unable to stand were included (ie, the entire patient cohort), the prediction of mortality using BMI was worse than random (Figure 1). Assessment of BMI was also difficult and time-consuming. Dehydration present among patients admitted to the center reduced admission BMIs. Because apparent dehydration was also a sign of poor prognosis, its presence tended to make BMI a better predictor of death in the center. The inability of most severely dehydrated people to stand meant that they could not have their BMI estimated within 2 days of admission and were therefore not included in the BMI prognostic models. It is therefore likely that the reduction of admission BMIs due to dehydration was not a major effect.

Presence of severe edema was associated with a poor prognosis and increased admission BMI. This confounding meant that the ability of BMI to predict death among patients with edema was worse than random. Because severe edema was common, BMI was not useful as a prognostic indicator when applied to the entire center population (Figure 1).

These results indicate that at the extremes of emaciation observed in adult therapeutic feeding centers, clinical illness is a better indicator of prognosis than degree of wasting as defined by BMI. A model using the presence of readily discernible clinical signs is useful in identifying patients at high risk of death. The high-risk patients identified by this prognostic model can then be moved to specialized feeding centers or areas within existing feeding centers with the most motivated staff, a higher level of medical supervision, and, if necessary, higher caregiver-patient ratios. This is a different role than that of screening admissions for entry into feeding centers, a research priority in severe adult/adolescent malnutrition. Rather than identifying inpatients with a poor prognosis, a screening indicator must identify persons in the general population who are likely to respond to treatment if admitted to a feeding center but who will die if not admitted. The specificity and sensitivity requirements for screening are different than those required for prognostic indicators. To be useful in famine relief programs, where there are often large crowds of people attempting to gain entry into feeding centers, a screening indicator must have a high specificity. This is not the prime requirement for a prognostic indicator. We have demonstrated that the sign-count model is sensitive for predicting death within a therapeutic feeding center. We have not assessed its potential for use as a screening tool to exclude individuals from admission to feeding centers.

This potential use for screening admissions to therapeutic feeding centers needs to be investigated further. Although the model is somewhat nonspecific for identification of patients who would die despite having been given treatment in the center, it is likely that in the absence of treatment, many more of the individuals identified would have died. The model might therefore be more specific if used for screening. To increase the model's specificity for identifying malnourished individuals at greater risk of dying, an indicator of nutritional status would need to be added to the model. Middle upper arm circumference (MUAC), recently shown to be a potentially useful indicator of acute adult malnutrition, might be suitable. Addition of MUAC would differentiate between those with clinical illness but no malnutrition, who would be better treated in medical units, from those with both illness and malnutrition, who would be best treated in specialized feeding centers. By weighting the model appropriately, having an MUAC below a certain threshold could be made a necessary prerequisite for selection. This would ensure a high prevalence of malnutrition in the population assessed by the sign-count part of the model.

Within this selected population, the specificity of the clinical signs for identifying death among persons who did not receive treatment would be high, fulfilling the requirement for screening. Use of this single model would be equivalent to application of a 2-stage screening procedure. Such a 2-stage system is similar to that used by 1 of us (S.C.) when confronted with large crowds of malnourished adults. In such situations, a rapid visual inspection and a very brief clinical examination are undertaken to assess fat in the upper arms out-
Short-term Prognosis in Malnutrition During Famine

side of the center, followed by more involved anthropometric and clinical inspection inside the center. In this ad-hoc system, the initial screen outside of the center increases the prevalence of severe malnutrition requiring urgent assistance among persons who are allowed through the gates to be assessed by a more time-consuming clinical examination. In this selected population, the higher prevalence of life-threatening malnutrition makes the relatively low specificity of the clinical screen less important. The sign-count model proposed here, combined with an MUAC cutoff, would formalize this method, making it more useful to workers with less experience. The threshold of both MUAC and the clinical score chosen as a screening cutoff would depend on the context and the relative balance of resources and needs.  

Emergency relief programs must ensure that the majority of a population has access to the minimum requirement to maintain life. This requires prioritizing lower-input interventions with a large coverage of the vulnerable population above high-input services treating relatively few. Access to a life-sustaining general ration, providing at least 8786 kJ from grains, legumes, and vegetable oil; adequate water; sanitation; basic care; and dry supplementary feeding, must, therefore, form the basis of any relief program. 14 Therapeutic feeding centers are efficient and effective only if these basic prerequisites are in place. This hierarchy of interventions constitutes a form of triage. During the initial stages of famine, need will usually outstrip the available resources and the focus should be on ensuring that the general ration is adequate before targeted feeding centers are established. At this stage, those too malnourished to survive with this basic support will die. As resources increase, it will become possible to undertake therapeutic feeding, although, initially, clinical triage may be necessary.  

For example, in the town of Wau in southern Sudan during June through August 1998, more than 100 therapeutic centers would have been required to treat the estimated 16000 children and adults requiring therapeutic feeding. 15 At that time, there was only a single 24-hour therapeutic feeding center with a maximum capacity of 400 patients. In this context, given the limited means available, selecting only those patients with a good chance of survival would have optimized the efficient use of resources. In this study, the combination of 2 relevant clinical signs predicted death at sensitivities of greater than 95%. In Wau, the combination of these 2 signs would have been a useful triage tool to determine the low end of the spectrum of malnutrition severity among patients whom the center would admit.  

Relief programs are rarely totally overwhelmed, and it is important that the existence of a triage tool does not undermine international will to provide sufficient humanitarian assistance during emergencies. Screening and prognostic indicators are also different than markers of improvement during treatment. In this study, maintenance of fluid balance and hydration, disappearance of edema, and a steady increase in weight in the absence of increasing edema were all markers of improvement. This has been reported previously. 16,20  

Ideally, a study evaluating the relationship between clinical signs and risk of mortality in a general population experiencing famine is required to establish relevant clinical screening criteria. However, conducting such broad-based population studies is probably not feasible during famine and none have yet been undertaken in such conditions. Given these difficulties, evaluating prognostic models in selected feeding center populations is a feasible alternative. It is certainly better than the current absence of information on prognostic indicators in famine.  

In conclusion, counting simple clinical signs is a useful method of assessing prognosis in severe adult and adolescent malnutrition during famine. The addition of an anthropometric indicator is likely to make these models useful for screening admissions of adults to feeding centers. The poor association of BMI with prognosis and difficulties in obtaining BMI estimations during extreme conditions, such as the famine in Somalia, make BMI inappropriate for such a role. Middle upper arm circumference might prove to be more useful in this context. More work on identifying relevant clinical signs and combining them with MUAC in such models for use in screening is required.  

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References

Dietary treatment of severe malnutrition in adults

Steve Collins, Mark Myatt, and Barbara Golden

ABSTRACT The aim of this study was to compare the effects of two diets, differing primarily in protein content, on the nutritional rehabilitation of severely malnourished adults. The study took place in the Concern Worldwide Adult Therapeutic Feeding Centre in Baidoa, the town at the epicenter of the 1992 famine in Somalia. The response to treatment in 573 patients admitted to the center between November 1992 and March 1993 was studied. Mortality, appetite, rates of edema loss, and weight gain in 2 groups of patients receiving either a higher-protein (16.4% of energy from protein) or lower-protein (8.5% of energy from protein) diet were compared. Among edematous patients, the use of the lower-protein diet during the initial phase of treatment was associated with a threefold decrease in mortality (P < 0.05) and accelerated resolution of edema (P < 0.05). Among marasmic patients, no differences in mortality or rate of weight gain were observed. The large reduction in mortality associated with the use of the lower-protein diet in edematous patients appeared to be due to the lower amount of dietary protein. However, differences in the 2 diets other than or in addition to the protein content may have contributed. Notwithstanding, the data obtained suggest strongly that severely malnourished adults, particularly those with edema, recover more successfully with a diet of lower protein content than usually recommended. The lower-protein diet used in this study was much cheaper and more easily obtained than the conventional higher-protein diets in Baidoa.

KEY WORDS Malnutrition, refeeding, protein-energy malnutrition, PEM, edematous malnutrition, dietary protein, Somalia, marasmus, famine

INTRODUCTION Severely malnourished adults are encountered frequently during emergency famine relief programs (1). Because adult energy requirements are proportionately less than those of children, the peak incidence of severe malnutrition and death in adults generally occurs later than in children (2). Often, by the time an emergency relief operation is up and running, many of the children have already died (3) and malnourished adults constitute a large proportion of the nutritional problem (4, 5). The difficulties of feeding severely malnourished adults, especially those with edematous malnutrition, have long been recognized (6). During the first half of this century, these problems received considerable attention from the scientific community and, generally, diets containing relatively high amounts of protein were recommended (7–12). In the early 1950s, scientific attention shifted toward malnourished children, in whom the quantity and quality of dietary protein required for successful rehabilitation became the focus of much research (13, 14). In particular, the importance of liver pathology in kwashiorkor was recognized (15). Recently, it was shown in children with kwashiorkor that mortality was minimal when diets containing only maintenance levels of protein (< 1 g·kg⁻¹·d⁻¹) were given (16, 17). Up to the time of the Somali famine in 1992, however, these diets had been tested only in specialized hospital units and no field research had been performed during an emergency relief program.

The difficult circumstances that exist during famines generally prevent the execution of classical, scientifically rigorous research. This has resulted in an absence of field research since the late 1940s when the concentration camps in Europe and the Far East were liberated. In the absence of field research, results from studies performed in less severely malnourished subjects, usually in hospital settings, have been extrapolated to the very different circumstances found during war and famine. Thus, it was shown that adult subjects with body mass indexes (BMIs, in kg/m²) of 17–18 respond well to diets with protein-to-energy ratios (P:Es) > 19% (18). As a result, such high-protein diets have continued to be recommended for the management of severe adult malnutrition. Such diets were used in all Concern Worldwide therapeutic feeding centers (TFCs) during the Somali relief operation in 1992–1993. However, the adults admitted to these TFCs generally had BMIs of 10–13, far less than those that had been studied. They also often had edema (19). It was observed that many of these patients, particularly those with edema, were refusing the high-protein diets. Thus, the hypothesis was advanced that the high-protein diets were deleterious during the initial phase of rehabilitation. Therefore, the aim of this study was to compare the immediate and short-term effects of a lower-protein diet with a diet containing more protein, to determine if the lower-protein diet was associated with a better outcome.

The large reduction in mortality observed with the use of the low-protein diet during the initial phase of rehabilitation was associated with a threefold decrease in mortality (P < 0.05) and accelerated resolution of edema (P < 0.05). Among marasmic patients, no differences in mortality or rate of weight gain were observed. The large reduction in mortality associated with the use of the lower-protein diet in edematous patients appeared to be due to the lower amount of dietary protein. However, differences in the 2 diets other than or in addition to protein content may have contributed. Notwithstanding, the data obtained suggest strongly that severely malnourished adults, particularly those with edema, recover more successfully with a diet of lower protein content than usually recommended. The lower-protein diet used in this study was much cheaper and more easily obtained than the conventional higher-protein diets in Baidoa.

See corresponding editorial on page 10.

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tein diet with those of the conventional higher-protein diet during nutritional rehabilitation of severely malnourished adults admitted to a TFC during the emergency relief program in Baidoa.

SUBJECTS AND METHODS

All adults admitted to the Concern Worldwide Adult Therapeutic Feeding Centre in Baidoa between 25 October 1992 and 30 March 1993 were studied. The center was established according to internationally accepted guidelines and operated according to the principles of best clinical practice given the prevailing circumstances. The setting and the conditions, that is, an emergency feeding center in a war zone, did not allow us to carry out a formally designed study and the number of observations made and the degree of control possible were constrained by the circumstances. The criteria for admission varied depending on the space available in the center and the existence of other medical facilities in Baidoa. In general, only patients with a BMI <13.5, those assessed as very severely malnourished by the clinician (SC), those too ill to be weighed and measured on admission, or those with edematous malnutrition were admitted to the center. Less severely malnourished persons were referred to supplementary kitchens. During October and November 1992, there were no alternative medical centers in Baidoa and 16 patients with BMIs >13.5 and medical rather than nutritional problems were admitted. This practice stopped in mid-December 1992 when a medical inpatient unit was opened in Baidoa.

Five hundred seventy-three patients were admitted to the center. They were aged between 15 and 80 y (median: 30 y) and 46% were male. The age distributions of male and female patients were similar. On admission, patients were registered, weighed, and had their height measured by trained local assistants, supervised by a specially trained nurse or the clinician (SC). A rapid clinical screen, assessing degree of pitting edema, ascites, hydration, dysentery, diarrhea, anemia, signs of chest infection, and ability to stand was performed by either the clinician (SC) or the nurse. The weight or clinical condition or both of each patient were monitored daily during rehabilitation and outcome was recorded. Lack of trained staff and an extremely high patient load prevented detailed recording of individual food intake. Pitting edema was graded by using the classification of Beatitie et al (12) as grade 0 (absent), 1 (minimal edema on the foot or ankle, demonstrable but not visible), 2 (visible on foot or ankle), 3 (demonstrable up to knee), 4 (demonstrable up to inguinal ligament), and 5 (anasarca). Pitting edema that was recorded as present but unquantified was assumed to be moderate (grade 3); unquantified edema was recorded in 4.3% of patients. Periorbital edema was separately graded as 0 (absent), 1 (mild), 2 (moderate), and 3 (severe), with present but unquantified edema assumed to be grade 2. Ascites was similarly graded. Edematous malnutrition was defined as either pitting edema greater than grade 2, periorbital edema greater than grade 1, or any ascites. Missing data values were coded as absent and excluded from further analysis. Data were analyzed by using EPI INFO (20), LOGISTIC (21), and Microsoft EXCEL (22).

The center consisted of nine stick shelters with roofs made of plastic sheeting and mud floors. Separate shelters were designated for new admissions, those with edematous malnutrition, those with dysentery, and those suspected of having pulmonary tuberculosis. The center was staffed by 1-3 expatriate staff members, 3 local nursing staff members, and 30 other helpers and cooks. These staff members distributed the food and oral rehydration solution (ORS), encouraged patients to eat and drink, and helped feed those who were unable to feed themselves. High levels of supervision, with one staff member for less than 9 patients, were maintained during the daytime, particularly during the first few days after admission. At night, frequent gun battles and attempts at hostage-taking meant that supervision by expatriate workers was impossible.

A set of standard spring scales and a locally constructed height board were used to weigh and measure patients. The scales were calibrated in London and Baidoa with known weights. The results were similar at both sites. In the useful range of 20–50 kg, there was a linear increase in error ($r = 0.99$) with the true weight being expressed by the following equation: true weight = ($1.013987 \times$ scale weight) + 0.707. The correction factor derived from this equation was used to correct each weight measurement.

Medical treatment in the center

Oral antibiotics were given to most patients at admission, with many continuing to receive an antibiotic throughout their stay. Penicillin V, ampicillin, cotrimoxazole, and metronidazole were first-line antibiotics and chloramphenicol was the second-line antibiotic. Discharge criteria were predominantly clinical. Absence of clinical evidence of infection, a good appetite, constant weight gain for a minimum of 3 d, and the ability to walk and care for oneself were all necessary conditions for discharge. The presence of minimal pedal edema did not preclude discharge.

Diet

During their stay in the center, patients received 6–8 meals each day. For the first month of operation, the standard higher-protein diet (HP diet) used in all of the other TFCs in Baidoa was the only diet available. This diet consisted of recovery milk [King’s Food (Ermelo, Holland), a blend of dried skim milk, vegetable oil, vitamins, and minerals], UNIMIX (a blend of soya flour, oil, and sugar), rice, beans, and BP5 biscuits (Compact, Bergen, Norway) (Table 1). The recovery milk and BP5 biscuits were premixed fortified foods, designed especially for famine relief and marketed in Europe; the UNIMIX was a premixed, fortified food made up for UNICEF in various factories in Africa. Patients receiving this diet were offered, on average, 158 g protein/d and 16.2 MJ/d (P:E, 16.4%), including 70 g oil and 137 g lactose. The cost of this diet was $US1.90 per person daily.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
<th>Protein</th>
<th>Energy</th>
<th>Sodium</th>
<th>Potassium</th>
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<td>4276</td>
<td>42</td>
<td>71</td>
</tr>
<tr>
<td>UNIMIX</td>
<td>100</td>
<td>12</td>
<td>1680</td>
<td>0</td>
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</tr>
<tr>
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<td>12</td>
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<td>8</td>
</tr>
<tr>
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<td>130</td>
<td>33</td>
<td>1966</td>
<td>1</td>
<td>46</td>
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<tr>
<td>BP5 biscuits</td>
<td>275</td>
<td>46</td>
<td>5300</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>—</strong></td>
<td><strong>158</strong></td>
<td><strong>16151</strong></td>
<td><strong>45</strong></td>
<td><strong>156</strong></td>
</tr>
</tbody>
</table>

1 The higher-protein diet contained 16.4% of energy from protein. UNIMIX was made up for UNICEF in various factories in Africa. BP5 biscuits were manufactured by Compact (Bergen, Norway).
DIETARY TREATMENT OF SEVERE MALNUTRITION

During the first few days after admission, the milk component of this diet was diluted to half strength with the World Health Organization (WHO) formula ORS (WHO, Geneva), containing 3.5 g NaCl/L, 2.9 g trisodium citrate/L, 1.5 g KC1/L, and 20 g glucose/L. This reduced the total daily average offered to 129 g protein and 14 MJ (P:E, 8.5% ), including 152 g oil and 95 g lactose. The cost of this diet was US$1.00 per person daily. During the first few days after admission, the milk component of this diet was diluted to one-third strength with the WHO formula ORS. This reduced the total daily average offered to 35 g protein and 10.9 MJ (P:E, 5.0%). Initially, the potassium and sodium contents of the two diets were similar. However, during January 1993 mineral supplements became available and patients receiving the LP diet received (per kg body weight) 1 mmol KCl, 1 mmol tripotassium citrate, 0.4–0.8 mmol MgSO4, 0.031 mmol zinc acetate, and 0.003 mmol CuCl2, raising the amount of potassium they received by 2 mmol kg body weight d−1 d−1. For those patients who required rehydration, usually only during the initial phase of treatment, the WHO formula ORS was used. It was not feasible to quantify the amount of ORS and, therefore, the additional sodium and potassium consumed during these periods.

On 5 December 1992, the LP diet was first offered to 11 edematous patients who had not responded to the HP diet. The positive response in these patients to the change of diet was so dramatic that it was soon considered unethical to use the HP diet in the treatment of edematous patients. Thus, from 7 December 1992 on, patients with edema and those whom the clinician (SC) considered very ill or moribund were offered the LP diet during the initial phase of treatment. The HP diet continued to be used from admission in the less severe cases and for many patients during the recovery phase of rehabilitation. The onset of this recovery phase was defined clinically in edematous patients by a return of appetite and a substantial loss of edema or ascites or both. Because loss of edema was accompanied by loss of weight, weight loss was accepted as a sign of a positive response to treatment (16). In marasmic patients, the recovery phase was defined by good appetite and steady weight gain for ≥3 d.

Analysis of mortality

Of the 573 patients for whom admission data were collected, 16 were admitted primarily on medical grounds and we did not have sufficient dietary information for 70. These 86 patients were excluded from the analysis of mortality. For analysis, patients were assigned to either the HP group (n = 343) or the LP group (n = 144) according to the diet they received during their initial period of stay in the center. Thirteen patients were wrongly allocated to diets by junior staff on admission. These mistakes were rectified within 3 d by the clinician (SC) and the patients were assigned to the correct diet. For the analysis, the diet group of these patients was that of the corrected diet. Twenty-seven patients (all from the marasmic group) were lost to follow-up and were excluded from further analysis of mortality associated with the two diets, leaving 377 patients with marasmus or mild edema and 83 patients with moderate to severe edematous malnutrition. These data are presented in Table 3.

Two-by-two contingency tables and multiple logistic regression were used to assess the effect of the 2 diets and the mineral supplement on mortality. This allowed us to control for the potential confounding effects of morbidity (edema, lower respiratory tract infection, dysentery, dehydration, and anemia) and other variables (age, sex, and time since opening of the center) on mortality. The time variable was included in the analysis to control for the effect of any time bias in the data, as it was conceivable that patient care, independent of the introduction of the LP diet, improved over time. Variables not independently associated with mortality were excluded from models in a stepwise fashion using estimation techniques.

Analysis of effects of HP and LP diets on rates of weight change and loss of edema during rehabilitation

The rate of weight change (g kg−1 d−1) for each consecutive 3-d period was calculated for each patient. In those edematous patients who changed from the HP to the LP diet after they had been in the center for >3 d and for whom there were sufficient data (n = 7), a matched analysis using a paired t test of the rate of weight change during the first 15 d of treatment on each diet was performed.

RESULTS

General patient data

The degree of emaciation and clinical condition of the 573 patients at the center were reported elsewhere (19). Mean BMI on admission

TABLE 2
The lower-protein diet

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
<th>Protein (g/d)</th>
<th>Energy (kJ/d)</th>
<th>Sodium (mmol/d)</th>
<th>Potassium (mmol/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dried skim milk</td>
<td>180</td>
<td>65</td>
<td>2646</td>
<td>44</td>
<td>73</td>
</tr>
<tr>
<td>Oil</td>
<td>150</td>
<td>0</td>
<td>5733</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sugar</td>
<td>160</td>
<td>0</td>
<td>2688</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rice</td>
<td>200</td>
<td>12</td>
<td>2940</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Bananas</td>
<td>500</td>
<td>5</td>
<td>2100</td>
<td>0</td>
<td>51</td>
</tr>
<tr>
<td>Total</td>
<td>—</td>
<td>82</td>
<td>16107</td>
<td>44</td>
<td>132</td>
</tr>
</tbody>
</table>

1 The lower-protein diet contained 8.5% of energy from protein.

TABLE 3
Outcome data associated with use of higher-protein (HP) and lower-protein (LP) diets

<table>
<thead>
<tr>
<th></th>
<th>All patients</th>
<th>Edematous patients</th>
<th>Marasmic patients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Died</td>
<td>Survived</td>
</tr>
<tr>
<td>HP diet</td>
<td>343</td>
<td>78</td>
<td>240</td>
</tr>
<tr>
<td>LP diet</td>
<td>144</td>
<td>25</td>
<td>117</td>
</tr>
<tr>
<td>Total</td>
<td>487</td>
<td>103</td>
<td>357</td>
</tr>
</tbody>
</table>
was 13.1 (95% CI: 12.9, 13.3); mean body weight was 35 kg. Four hundred thirteen (72%) of these patients survived, 122 (21%) died, and 38 (7%) were lost to follow-up. Edematous malnutrition was common and was associated with increased mortality. It was present in 16% of all admissions and 28% of those who subsequently died. Case fatality rates were 37% for edematous malnutrition and 20% for marasmus or mild edema \[\text{OR: 2.4; 95% CI: 1.4, 3.9; Yates's corrected chi-square: 11.7, } P < 0.001\]. The prognosis in edematous malnutrition was worse for male than for female patients \(\text{OR: 4.1, 95% CI: 1.9, 8.7; female OR: 1.4, 95% CI: 0.6, 2.9; Woolf's test for the heterogeneity of odds ratios: 4.59, } P < 0.05\). Nineteen percent of deaths occurred within 48 h of admission, 48% within the first week, and 27% during the second week after admission. Median time to discharge for all patients was 28 d (35 d in edematous patients, 27 d in marasmic patients). Mean BMI at the time of discharge was 15.0.

**Effect of HP and LP diets on mortality**

Mortality was lower in patients with edematous malnutrition who received the LP diet during the initial phase of treatment \(\text{crude OR: 0.31; 95% CI: 0.10, 0.90; Yates's corrected chi-square: 4.74, } P < 0.05\) than in those who received the HP diet. This effect remained after confounding variables were adjusted for by logistic regression \(\text{adjusted OR: 0.31; 95% CI: 0.12, 0.81; likelihood ratio statistic: 5.74, } P < 0.05\). This is equivalent to a threefold reduction in mortality. No such difference was observed in marasmic patients \(\text{crude OR: 0.52; 95% CI: 0.24, 1.08; Yates's corrected chi-square: 2.97, } P = 0.08\), and adjusted OR: 0.87; 95% CI: 0.38, 1.97; likelihood ratio statistic: 0.10, \(P = 0.74\). Analysis of the effects of the mineral mix in patients receiving the LP diet did not uncover any significant differences in mortality before and after addition of the mineral supplement.

**Effect of HP and LP diets on loss of edema and gastrointestinal function**

In the 7 patients for whom matched data for rate of weight change were available, the rate of loss of edema, reflected as weight loss, accelerated after transfer to the LP diet \[\text{mean (± SD) rate of weight change: 6.3 ± 12.1 and } -7.2 ± 18.5 \text{ g·kg}^{-1}·\text{d}^{-1} \text{ with the HP and LP diets, respectively; difference } = 13.5; \text{ paired } t = 3.18, P < 0.05\]. The appetite of many of the edematous patients appeared to be poor with the HP diet. When these patients were switched to the LP diet, an increase in appetite was observed in many, including those who had suffered from persistent edema lasting several weeks while they received the HP diet. Associated with the increased appetite were episodes of watery diarrhea. These were occasionally severe, resulting in the rapid appearance of intravascular hypovolemia. Patients with watery diarrhea responded to dilution of the milk element of the diet with the WHO formula ORS during the first few days of treatment. The number of days and the degree to which the milk was diluted were tailored for each patient according to the severity of the diarrhea, clinical signs of intravascular hypovolemia (heart rate, peripheral perfusion, jugular venous pressure, and hydration of mucous membranes), and the response to previous dilutions. On occasion, it was necessary to dilute the milk to one-ninth strength for several days to reduce diarrhea and maintain the appropriate intravascular volume. Once the diarrhea resolved, the milk concentration was gradually increased to full strength over 1 wk.

**Weight change during rehabilitation**

The mean rates of weight change for edematous and marasmic patients during the initial month of treatment on each diet are shown in Figure 1. During the first 9 d, edematous patients receiving the LP diet tended to lose weight as they lost edema. By contrast, edematous patients receiving the HP diet tended to gain weight. After this period the situation reversed and those receiving the LP diet started to gain weight whereas those receiving the HP diet stayed at the same weight or gradually lost weight. Marasmic adults gained weight similarly with both diets during this initial period.

During the recovery phase (16–60 d after the start of treat-
marasmic and formerly edematous patients (rate of weight change: 6.1 ± 5.2 and 5.1 ± 4.2 g·kg\(^{-1}·d^{-1}\), respectively) and for the HP and LP diets (rate of weight change: 5.9 ± 5.6 and 5.6 ± 4.8 g·kg\(^{-1}·d^{-1}\), respectively).

**DISCUSSION**

**Importance of lower-protein diets during the initial treatment of severe malnutrition in adults**

In this study, mortality was threefold higher in edematous patients receiving the HP diet than in those receiving the LP diet. Many of these patients also experienced prolonged anorexia and persistent edema. The LP diet was associated with lower mortality and accelerated loss of edema. These differences appear likely to have been due to the different amounts of dietary protein offered during the initial phase of therapy.

Other potential explanations, however, must also be examined. The study compared groups of patients differing primarily according to the diet they received. However, allocation of patients to the diets could not be randomized and it is possible that the differences in outcome ascribed to differences in diet were instead due to differences in time since the center opened or to differences in the subject groups assigned to each diet. In the analysis of mortality, the use of multiple logistic regression allowed us to control for differences in time. With respect to subject differences, during the first 6 wk of the study, all patients received the HP diet; during the next 16 wk, those patients assigned to the HP diet were edematous or otherwise very ill or moribund. On clinical grounds, these patients were expected to have a higher mortality than those assigned to or already recovering satisfactorily on the HP diet. However, the study showed that patients receiving the LP diet had a threefold lower rate of mortality and a more rapid loss of edema than patients receiving the HP diet. Thus, it is possible that had we randomly assigned patients the difference in outcome would have been in the same direction but even greater. This is compelling evidence that the difference in outcome was due to the difference in diet.

The diets, however, differed in more than their protein contents and it is also probable that intake of the two diets differed. Lower energy intake, particularly energy derived from carbohydrates, during the initial treatment with the LP diet is a possible explanation of the differences in outcome. Lower energy intake might be expected to lower mortality by reducing the incidence of refeeding syndrome (23). Although the aim was to offer diets of similar energy contents (Tables 1 and 2), the LP diet had a greater proportion of its energy derived from fat and was usually given in a more dilute form during the first few days of treatment. This dilution substantially reduced the energy being offered to patients during that time. Although the recovery milk element of the HP diet was also diluted during the first few days of treatment, this dilution caused less of a decrease in the energy content of the HP diet as a whole. These differences, however, are unlikely to explain the higher mortality associated with the HP diet because as a result of persistent anorexia most of the edematous patients receiving the HP diet consumed only a small fraction of the food offered. Their food intakes, although not formally measured, appeared to be very low, making refeeding syndrome unlikely. The marked increase in appetite, and thus presumed increase in food intake, observed in these patients when they were offered the LP diet is likely to have more than compensated for the decreased energy content of the diluted diet. Indeed, it is likely that energy intake during the initial phase of treatment with the LP diet was higher than with the HP diet. This agrees with documented experiences in feeding severely malnourished children in Jamaica (24).

Immediately after the change to the LP diet, most of the edematous patients who had been in the center for some weeks developed watery diarrhea. This diarrhea appeared to be the refeeding diarrhea frequently described in new arrivals at feeding centers and generally regarded as the response of a starving and atrophic intestine to the initial reintroduction of food (25). The absence of refeeding diarrhea among the edematous patients receiving the HP diet and its development when these patients were transferred to the LP diet supports the observation that intake of the HP diet in these patients was low. Other differences in composition of the two diets could also have contributed to the difference in mortality. The HP diet had more lactose, which could possibly have increased mortality. This is also unlikely, though, because the lower incidence of diarrhea among patients receiving the HP diet indicates that lactose intolerance was not a major problem.

In marasmic patients, the diet given during the initial phase of treatment did not affect mortality or initial rate of weight change. This suggests that the dietary differences interacted with metabolic differences between marasmus and edematous malnutrition. One of the main metabolic differences is in liver function. In this study, few of the marasmic but many of the edematous patients had clinical signs consistent with liver failure. These included petechial rash and jaundice as well as anorexia, edema, and ascites. Thus, it is possible that there was no difference in outcome associated with diet in marasmic patients because their liver function was better preserved. If correct, this again suggests that it was the protein content of the diet that was of importance.

The study failed to show any effect of the mineral supplements in patients given the LP diet. This may have been due to the study design, the aim of which was not to test the effect of these supplements. However, it is also possible that the mineral intake from the LP diet alone was adequate. This is likely to be true for potassium, dietary intake of which was usually ≥2 mmol·kg\(^{-1}·d^{-1}\), but unlikely to be so for the other minerals.

Although recovery from severe adult malnutrition has been systematically studied only rarely, there have been reports of similar poor responses to HP diets wherein edema was slow to disappear and sometimes even appeared during treatment (26–28). Ex-inmates of Belsen concentration camp, who experienced degrees of weight loss comparable with those in patients in Baidoa (mean weight loss of 35%, corresponding to a BMI of 12–14) frequently suffered from famine edema and ascites (9). During rehabilitation with a diet containing 64.8 g protein and 3.4 MJ (P:E, 32.4%), famine edema often appeared or increased (10). In these patients, use of casein hydrolysates was associated with increased mortality (29). Similar accounts were reported from the Dutch famine of 1945, for which the recommended rehabilitation diet contained 300 g protein and 13.4 MJ (P:E, 37%) (8).

**Rates of weight change during the recovery phase of rehabilitation**

The extreme levels of disruption and insecurity present in Baidoa during the time of this study made the operation of the center difficult. As a result, the mean rates of weight gain...
(5–6 g·kg\(^{-1}·d^{-1}\)) during the recovery phase of rehabilitation probably represent the lower end of the spectrum of reasonable rates of weight gain in adults recovering from severe malnutrition. Severely malnourished ex-inmates of the Sanbostel concentration camp receiving 31.5 MJ and 297 g protein/d (P:E, 15.8%) gained >7 g·kg\(^{-1}·d^{-1}\) during the recovery phase of their treatment (30). In less severely malnourished patients, rates of weight gain appear to be lower. In the Minnesota experiment, 32 volunteers with mild to moderate malnutrition who received 10–14 MJ and 75–100 g protein/d (P:E, 10.6–14.4%) gained only 1.85 g·kg\(^{-1}·d^{-1}\) (31).

**Comparison with children**

The patterns of presentation and recovery in severely malnourished adults are similar to those in children. In children, hypoaalbuminemia is evidence of a poor prognosis (32). Although edema, in the absence of hypoaalbuminemia, is not necessarily an indicator of a poor prognosis (14), in practice, the frequent coexistence of the two makes edema a useful prognostic marker. In Baidoa, edema in adults was associated with a much poorer prognosis (19). However, it is possible that this finding is not universal. In a Concern Worldwide TFC in Melange, Angola, during 1993 and 1994, 90% of adults admitted suffered from edema but this was not associated with such a poor prognosis (S Collins, unpublished observations, 1993). More work is needed on prognostic indicators in severe adult malnutrition.

The maximum rates of weight gain, typically 10–20 g·kg\(^{-1}·d^{-1}\), recorded in children recovering from severe malnutrition (14, 33, 34) are considerably higher than the rates of weight gain reported here. However, the pattern of recovery is similar. Initially, with a low-protein, maintenance energy intake, edematous children often lose edema within 1 wk (16). Appetite returns and this, together with loss of edema, heralds the recovery phase. Among our edematous adult patients, the rates of edema loss were variable and often much slower. With the LP diet, some patients lost most of their visible edema and ascites within a few days, the rapid loss generally being accompanied by watery diarrhea. In these patients, care had to be taken to avoid intravascular hypovolemia. In the absence of guidelines for adults, we aimed at a loss of ≈0.25–0.5 L/d, equivalent to a weight loss of 0.25–0.5 kg/d. Regulation of the rate of edema loss was achieved by diluting the high-energy milk with ORS to an extent dictated by the severity of diarrhea. In other patients, particularly those receiving the HP diet, the rate of loss of edema was much slower and pedal edema or ascites persisted for weeks. This was accompanied by persistent anorexia and debility. These patients generally responded rapidly to introduction of the LP diet. The response involved marked increase in appetite and general well-being and loss of edema and ascites. However, minor grades of edema sometimes persisted for weeks, even after the patients had recovered much of their original body mass. When edema increased even with the LP diet, the patient usually died.

**Conclusions**

Because of the extreme conditions in this TFC, which was operating in a war zone, the subjects in this study were not randomly assigned to the 2 diets, nor were their dietary intakes estimated. During most of the study, those with a worse prognosis on admission received the LP diet. Notwithstanding, with the LP diet, edematous adults suffered lower rates of mortality and lost edema more quickly than did those receiving a more conventional HP diet. In marasmic adults, there was no difference in mortality between patients receiving LP and HP diets. During the recovery phase, there were no differences in rates of weight gain between the LP and HP diet groups.

Thus, it appears that, compared with the conventional HP diet, the LP diet was more effective in the treatment of edematous adults and as effective in the treatment of marasmic adults. The LP diet usually needed to be diluted during the initial phase of treatment. It was cheaper and more easily obtained than the specially manufactured famine relief foods of the HP diet. We suggest that such a diet, based on milk, oil, sugar, and locally available foods, with a relatively low P:E, should be offered to all severely malnourished adults in both the initial and recovery phases of rehabilitation. By using locally available produce, use of such diets may stimulate the local economy. Their use should also ease the organizational difficulties involved in the provision of food items during emergency feeding operations. More research on treatment protocols for use in severe adult malnutrition is needed.

We thank the Concern Worldwide staff and the patients in Baidoa, who made this study possible; Ben Rigby, for his help with data coding and entry; and Michael Golden, Hannah Scrase, Jeremy Sheham, Keith Sullivan, and Andrew Tomkins, for their advice and encouragement.

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