Weight-for-height and MUAC for estimating the prevalence of acute undernutrition

A review of survey data collected between September 1992 and October 2006

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Down the rabbit hole!
Gold standards and *de facto* standards

Nutritional status can be defined as:

*The internal state of an individual as it relates to the availability and utilisation of nutrients at the cellular level*

This state **cannot** be observed directly so **observable indicators** are used:

- Biochemical
- Clinical
- Anthropometric

None of which, **taken alone or in combination**, are capable of providing a complete picture of an individual's nutritional status.

Two messages:

1. Anthropometric status ≠ Nutritional status ...

   - Anthropometric status ≈ Nutritional status

2. There is **no gold standard** for nutritional status ...

   - The use of WHZ and WHM (NCHS reference) is a *de facto* standard ...

     - It is “what we do” but may not be “what we should be doing”
<table>
<thead>
<tr>
<th>Function</th>
<th>Detail</th>
<th>Location</th>
<th>Agency</th>
<th>Indices</th>
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<tbody>
<tr>
<td><strong>Prevalence estimation</strong></td>
<td>Global</td>
<td>All</td>
<td>NGO</td>
<td>WHZ (NCHS)</td>
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<td>MoH</td>
<td>WHZ (WHO)</td>
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<td>DHS</td>
<td>MUAC (Rapid Assessment)</td>
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<td>Moderate</td>
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<td></td>
<td>ICRC</td>
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<td>MUAC/H</td>
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<td>Severe</td>
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<td><strong>Admission</strong></td>
<td>Therapeutic feeding</td>
<td>Health Facility (DGH and above)</td>
<td>NGO</td>
<td>WHM (NCHS)</td>
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<td>WHM (WHO)</td>
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<td>MoH</td>
<td>WHZ (NCHS)</td>
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<td></td>
<td>WHZ (WHO)</td>
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<td></td>
<td></td>
<td>Visible Severe Wasting</td>
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<td></td>
<td></td>
<td>NGO</td>
<td>MUAC</td>
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<td></td>
<td>Confused (WHM hangover)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>MoH</td>
<td>Confused</td>
</tr>
<tr>
<td><strong>Supplementary feeding</strong></td>
<td></td>
<td>All</td>
<td>NGO</td>
<td>WHM (NCHS)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WHM (WHO)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MUAC (Screening)</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>Socio-economic criteria</td>
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<td></td>
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<td></td>
<td>Demographic criteria</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Clinical criteria</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>MoH</td>
<td>MUAC (EOS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Confused</td>
</tr>
</tbody>
</table>

WHM (NCHS) or WHM (WHO) may be used as a secondary criteria, some confusion regarding age and height criteria for MUAC. MUAC, WHM (NCHS), WHO (NCHS), H/A, W/A, visible wasting, and other indicators may be used.
Adoption of the new WHO reference (AKA standard) for W/H

The WHO reference population is replacing the NCHS reference population ...

- **Piecemeal basis** ...
  - Some MoH programs / national guidelines
  - Any major NGO using it in emergencies?
    - ACF (e.g.) using it in some developmental settings (e.g. H/A in Mongolia)
    - W/A (WHO) adopted for growth monitoring
    - W/A (WHO) to be adopted as basis for target-weight monitoring in HIV/ART programs
  - Others?
  - Some parts of the WHO reference remain to be published ....
    - Not relevant here (e.g. W/A for ages > 59 months due Q4/2007)

- **Planned basis** ...
  - Future adoption by major NGOs / UNOs / MOHs?
    - But ...
      - ICRC (and some others) use MUAC/H (or QUAC)
      - MSF and VALID advocate the *bracelet of life* (banded MUAC strap)
        - Likely to continue to use these regardless of consensus
Some implications of switching from one indicator to another

Switching indicators ...

- An opportunity to ...
  - Standardise case-definitions
  - Institute a major reform ...
    - Switch from W/H to MUAC

This could be characterised by saying:

*We can tinker or we can reform*

But this is likely to be an *oversimplification*:

Switching from NCHS to WHO is likely to have larger implications than just learning a new piece of software using different look-up tables, &c. ... *it may also be a major reform* ...

- Switching from one reference (i.e. NCHS) to another (i.e. WHO) may have implications:
  - Different prevalence estimates?
  - Different program sizes?
  - Different children in programs?
This presentation examines the implications of:

- Switching from NCHS to WHO
- Switching from NCHS to MUAC

In terms of:

- Prevalence estimates
- Program sizes
- Ages of children in programs

And concludes with an examination of W/H and MUAC in terms of their value as *gold standards* for assessing the nutritional status of children.
Data Sources

Study database:

- Contains variables for:
  - Demography (age, sex)
  - Anthropometry (weight, height, MUAC)
  - Clinical (oedema)

- 459,036 children collected in 560 anthropometric surveys supplied by:
  - Action Contre La Faim (ACF) / Action Against Hunger (AAH)
  - CONCERN Worldwide
  - Emergency Nutrition Co-ordination Unit (ENCU) Ethiopia
  - Food Security Assessment Unit (FSAU) Somalia
  - GOAL Ireland
  - Médicins Sans Frontières (MSF) Belgium
  - Médicins Sans Frontières (MSF) Holland
  - Médicins Sans Frontières (MSF) Spain
  - Save the Children (SC) United Kingdom (SC-UK) and United States (SC-US)

- 31 countries represented (cross-section of intervention settings)

- Collected between September 1992 and October 2006

Largest set of data with the variables of interest available at the time of analysis.
Prevalence Estimates
Estimates of GLOBAL prevalence – NHCS and WHO

Little Difference
WHO returns higher severe prevalences than NCHS
Estimates of GLOBAL prevalence – NHCS and MUAC

Little Difference
Estimates of SEVERE prevalence – NHCS and MUAC

Little Difference
Another way of looking at this ...

Global
WHO ≈ NCHS
MUAC ≈ NCHS

Severe
WHO > NCHS
MUAC ≈ NCHS

Moderate
WHO < NCHS
MUAC ≈ NCHS
Not quite as simple as that!
Estimates of GLOBAL prevalence – NHCS and WHO
Estimates of SEVERE prevalence – NHCS and WHO
Estimates of GLOBAL prevalence – NHCS and MUAC
Estimates of SEVERE prevalence – NHCS and MUAC
Country specific differences

There are country specific differences:

- Most marked for MUAC vs. NCHS...
  
  - **NCHS**:
    
    - General WHO > NCHS
  
  - **MUAC**:
    
    - Mixed:
      
      - MUAC > NCHS (some places)
      
      - MUAC < NCHS (other places)
      
      - MUAC ≈ NCHS (other places)

Beware prejudgment ... remember:

- W/H is a *de facto* standard not a *gold standard* ...
  
  - W/H *may* be missing something important

We will return to this later
Consequences on intervention decisions

Decisions to intervene informed by the following classification scheme ...

<table>
<thead>
<tr>
<th>Prevalence</th>
<th>Classification</th>
<th>Typical actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5%</td>
<td>Acceptable</td>
<td>No action required</td>
</tr>
<tr>
<td>5% - 9%</td>
<td>Poor</td>
<td>Continue to monitor situation</td>
</tr>
<tr>
<td>10% - 14%</td>
<td>Serious</td>
<td>Intervene</td>
</tr>
<tr>
<td>≥ 15%</td>
<td>Critical</td>
<td>Immediate emergency intervention</td>
</tr>
</tbody>
</table>
Consequences on intervention decisions – NCHS and WHO

Across the entire database ...

<table>
<thead>
<tr>
<th>Prevalence class by W/H (WHO)</th>
<th>&lt; 5%</th>
<th>5% - 9%</th>
<th>10% - 14%</th>
<th>≥ 15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5%</td>
<td>82</td>
<td>12</td>
<td></td>
<td>94</td>
</tr>
<tr>
<td>5% - 9%</td>
<td>6</td>
<td>160</td>
<td>17</td>
<td>183</td>
</tr>
<tr>
<td>10% - 14%</td>
<td>3</td>
<td>81</td>
<td>17</td>
<td>101</td>
</tr>
<tr>
<td>≥ 15%</td>
<td>1</td>
<td>181</td>
<td>182</td>
<td>560</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prevalence class by W/H (NCHS)</th>
<th>&lt; 5%</th>
<th>5% - 9%</th>
<th>10% - 14%</th>
<th>≥ 15%</th>
</tr>
</thead>
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<td>1</td>
<td>181</td>
<td>182</td>
<td>560</td>
</tr>
</tbody>
</table>

Legend for colour-coding employed in the table above

<table>
<thead>
<tr>
<th>W/H (WHO) indicator is lower by ...</th>
<th>W/H (WHO) indicator higher by ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 classes</td>
<td>1 class</td>
</tr>
<tr>
<td>2 classes</td>
<td>No difference</td>
</tr>
<tr>
<td>1 class</td>
<td>1 class</td>
</tr>
<tr>
<td></td>
<td>2 classes</td>
</tr>
<tr>
<td></td>
<td>3 classes</td>
</tr>
</tbody>
</table>

Small increase in critical classifications
Small increase in intervene decisions
A simple thing we can do now
Consequences on intervention decisions – NCHS and MUAC

Across the entire database ...

<table>
<thead>
<tr>
<th>Prevalence class by W/H (NCHS)</th>
<th>Prevalence class by MUAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 5%</td>
<td>&lt; 5%</td>
</tr>
<tr>
<td>36</td>
<td>94</td>
</tr>
<tr>
<td>5% - 9%</td>
<td>12</td>
</tr>
<tr>
<td>81</td>
<td>183</td>
</tr>
<tr>
<td>10% - 14%</td>
<td>5</td>
</tr>
<tr>
<td>28</td>
<td>101</td>
</tr>
<tr>
<td>≥ 15%</td>
<td>6</td>
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<tr>
<td>32</td>
<td>182</td>
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<tr>
<td>59</td>
<td>59</td>
</tr>
<tr>
<td>186</td>
<td>560</td>
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<tr>
<td>156</td>
<td></td>
</tr>
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<td>159</td>
<td></td>
</tr>
</tbody>
</table>

Legend for colour-coding employed in the table above

<table>
<thead>
<tr>
<th>MUAC indicator is lower by ...</th>
<th>MUAC indicator higher by ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 classes</td>
<td>3 classes</td>
</tr>
<tr>
<td>2 classes</td>
<td>2 classes</td>
</tr>
<tr>
<td>1 class</td>
<td>1 class</td>
</tr>
<tr>
<td>No difference</td>
<td>No difference</td>
</tr>
</tbody>
</table>

Increase in serious classification
Decrease in critical classifications
Increase in intervene decisions
Consequences on intervention decisions

Switching from NCHS to WHO or MUAC will have consequences:

- **W/H (WHO):**
  - General (i.e. regardless of location) slight increases

- **MUAC:**
  - Increases in some locations
  - Decreases in other locations:
    - Somali populations, Sudan, Chad, Indian sub-continent
  - No change in other locations
Program Sizes
Prevalence estimates and their limitations when estimating need

Estimates of need from surveys:

\[
\text{Estimated need} = \text{Estimated prevalence} \times \text{Population} \quad \text{aged 6–59 months}
\]

- Problems:
  - Surveys are cross-sectional “snapshots”:
    - Estimate is quickly out-of-date:
      - We really need incidence as well as prevalence data
  - Need to correct for achievable coverage:
    \[
    \text{Program numbers} = \text{Estimated prevalence} \times \text{Population} \times \text{Coverage} \quad \text{aged 6–59 months}
    \]
    - Coverage not independent of indicator:
      - Evidence from CTC and EOS:
        - Programs using MUAC tend to have higher coverage than those using W/H
        - Many reasons ...

The analysis presented here ignores all of this and presents only prevalence of children at the time of the survey meeting program admission criteria ... prevalence of eligibility
WHO returns lower estimates of need for supplementary feeding programs than NCHS
WHO returns slightly lower estimates of need for therapeutic feeding programs than NCHS

NOTE: Community-based / PHC-based therapeutic feeding programs should use MUAC
Estimates of MODERATE prevalence – NHCS and MUAC

MUAC returns higher estimates of need for supplementary feeding programs than NCHS

NOTE: MUAC case-definition is MUAC < 125 mm and this could be lowered to MUAC < 120 mm (EOS)
MUAC case-defining thresholds (as defined by mortality risk)

NOTE: W/H case-definitions are “statistical” rather than “functional”
MUAC returns higher estimates of need for therapeutic feeding programs than NCHS

NOTE: Very large evidence base for the 110 mm threshold (see previous slide)
Another way of looking at this ...

Moderate
WHO < NCHS
MUAC > NCHS

Severe
WHO < NCHS
MUAC > NCHS
Not as quite as simple as that!

Country specific differences:

- **W/H (WHO):**
  - General (i.e. regardless of location) decreases

MUAC ... follows the same pattern as prevalence:

- Increases in some locations
- Decreases in other locations:
  - Somali populations, Sudan, Chad, Indian sub-continent
- No change in other locations
Age differences – MODERATE CASES

MUAC selects younger children than NCHS

WHO ???
Age differences – SEVERE CASES

MUAC selects younger children than NCHS

WHO selects children of similar ages to NCHS
Early analysis of the country specific differences (prevalence by NCHS and MUAC) suggested that these may be due, in part, to differences in body shape.

NOTE: Data from Ethiopia (NOS), Ethiopia (SOMALI REGION), Kenya (WAJIR – ETHIC SOMALI)
The study database contained insufficient data to test this hypothesis:

- Body shape:
  - Sitting to standing height ratio (SSR):
    - Sitting height (we don't have this)
    - Standing height (we have this)

Following finding of “MUAC differences” (MUAC < W/H particularly in older children):

- Somalia (SC-UK, 10/2005 (showed SSR differences in small sample); FSAU, repeated finding)
- Work to determine thresholds for MUAC case-definitions for the Ethiopian EOS program (ENCU, 3/2006)

ENCU (funded by UNICEF) with the assistance of CONCERN Worldwide and SC-UK undertook a study (5/2006) investigating the relationships between:

- Weight-for-height z-scores (WHZ) and body-shape (SSR)
- Mid-upper-arm-circumference (MUAC) and body-shape (SSR)

The study sampled three widely separated populations from Ethiopia.

The sampled populations were classified as either pastoralists or agrarians.
Study Findings

In children aged 24 months or older or 85 cm or taller, the study found:

- WHZ and MUAC return similar prevalences in agrarians.
- WHZ returns higher prevalences than MUAC in pastoralists.
- Pastoralists and agrarians tend to have different body shapes.
- WHZ is effected by body-shape to such an extent that the use of WHZ may produce biased estimates of prevalence in both pastoralists and agrarians.
- The bias produced by the use of WHZ is very large in pastoralists (c. 850%).
- The bias produced by the use of WHZ is small in agrarians.
- MUAC is effected by body-shape but not to the extent that it produces biased estimates of prevalence.

These findings were not altered significantly by the choice of reference population or growth standard (i.e. NCHS or WHO) used to calculate WHZ.
Study conclusions

The study results lead to the following recommendations:

- MUAC should be used for prevalence estimation by survey.
- WHZ should **not** be used for prevalence estimation by survey.
- Further research should concentrate on improvements to survey methods made possible by the use of MUAC for the purposes of prevalence estimation.
Physical models (BEWARE: Speculative hand-waving argument follows)

Simple physical model of walking:

- Maximum walking and running speeds:
  \[ v \propto \sqrt{gL} \]

- Walking speed with minimum expenditure of energy (natural walking speed):
  \[ v \propto \frac{\alpha}{\pi} \sqrt{\frac{3}{2}} gL \]

- Longer limbs mean:
  - Faster maximum walking (and running) speeds
  - Faster natural walking speeds ....
    - Faster speeds (or larger ranges) with lower (or similar) energy expenditures
  - Lower SSR which means ...
    - Lower WHZ

Pastoralism requires:

- Ability to walk long distances efficiently (i.e. with low energy expenditures)
Gold standards and *de facto* standards (REPEATED)

Nutritional status can be defined as :

> *The internal state of an individual as it relates to the availability and utilisation of nutrients at the cellular level*

This state **cannot** be observed directly so **observable indicators** are used :

- Biochemical
- Clinical
- Anthropometric

None of which, taken alone or in combination, are capable of providing a full picture of an individual's nutritional status.

Two messages :

1. Anthropometric status ≠ Nutritional status ...
   
   - Anthropometric status ≈ Nutritional status

2. There is **no** gold standard for nutritional status
   
   - The use of WHZ and WHM (NCHS reference) is a *de facto* standard ...
     
     - It is “what we do” but may not be “what we should be doing”
Gold standards and *de facto* standards

Nutritional status can be defined at the **individual** level as:

*The ratio of nutrient reserves to the nutrient requirements of organs*

It is generally recognised that:

- Muscle plays a special role as a nutrient reserve during infection and that infection is a major etiological factor in acute undernutrition (**NOTE**: Preferential catabolism of peripheral tissue (mostly muscle) associated with infection)

- Muscle mass is critical to survival, normal absorption, and normal metabolism (**NOTE**: Low muscle mass associated with metabolic “derangements” such as kwashiorkor ... MUAC detects kwashiorkor!)

We can review anthropometric indices with references to this definition:

- **Weight-for-height (W/H)**:
  - Expresses the relationship between weight and height:
    - In children, about 4% of weight is nutrient reserve in muscle ...
      - About 96% of weight is **unrelated** to important nutrient reserves (80% water)
    - Height is almost completely **unrelated** to the nutrient requirements of organs

- **Mid-Upper-Arm-Circumference (MUAC)**:
  - Directly related to muscle mass ... 
    - A **direct** measure of important nutrient reserves
Gold standards and *de facto* standards

The best anthropometric indicator of nutritional status (compared to *body composition* analysis by DXA) ...

- **Lean-Mass-Ratio (LMR) ...**
  - Ratio of estimated mass of limbs to the estimated mass of the trunk

But ...

- LMR is difficult to measure ...
  - Too difficult to measure in the field

So ...

- **Which practicable anthropometric indictor is most strongly associated with LMR?**

  Two very clear answers :

  - ✔ MUAC (uncorrected for height or age) is most strongly associated with LMR
  - ✗ W/H is *not* associated with LMR
Gold standards and *de facto* standards

<table>
<thead>
<tr>
<th>Index</th>
<th>Measure</th>
<th>R</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>MUAC</td>
<td>Uncorrected</td>
<td>0.591</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Weight-for-age</td>
<td>z-score</td>
<td>0.325</td>
<td>0.0149</td>
</tr>
<tr>
<td></td>
<td>% median</td>
<td>0.311</td>
<td>0.0200</td>
</tr>
<tr>
<td>Height-for-age</td>
<td>z-score</td>
<td>0.438</td>
<td>0.0007</td>
</tr>
<tr>
<td></td>
<td>% median</td>
<td>0.426</td>
<td>0.0010</td>
</tr>
<tr>
<td>MUAC-for-age</td>
<td>z-score</td>
<td>0.382</td>
<td>0.0037</td>
</tr>
<tr>
<td></td>
<td>% median</td>
<td>0.277</td>
<td>0.0402</td>
</tr>
<tr>
<td>MUAC-for-height</td>
<td>z-score</td>
<td>0.348</td>
<td>0.0088</td>
</tr>
<tr>
<td></td>
<td>% median</td>
<td>0.323</td>
<td>0.0156</td>
</tr>
<tr>
<td>Weight-for-height</td>
<td>z-score</td>
<td>0.075</td>
<td>0.5885</td>
</tr>
<tr>
<td></td>
<td>% median</td>
<td>0.114</td>
<td>0.4074</td>
</tr>
</tbody>
</table>

Adapted from Brambilla et al, 2000
Gold standards and *de facto* standards

This is all a bit abstract ... a bit theoretical ... let's change our perspective ...

- **What are we measuring?**
  - *Thinness* (an observable indicator of nutritional status)
  - Mortality risk (an observable indicator of nutritional status *and* nutrition-related mortality risk)

If we aim to **prevent mortality** then a case-definition should:

- Identify individuals who are at **high risk of dying** if they remain untreated but would be likely to **survive if treated** in an appropriate nutritional support program

The utility of a case-definition is defined by the ability to **reflect mortality risk** as well as the ability to reflect nutritional status

So ...

**Which practicable anthropometric indicator is most strongly predictive of mortality?**

- ✔ MUAC ... consistent across locations ... large multi-centred evidence base ... and ...
  - ✔ Wasting ascertained by MUAC is treatable

**Which practicable anthropometric indicator is least strongly predictive of mortality?**

- ✗ W/H ... levels of risk not consistent across locations ... large multi-centred evidence base
Gold standards and *de facto* standards

The point of this review ...

- W/H is **not** a gold standard ...
  - It is a *de facto* standard (just “what we do” not “what we should do”)
- If we are looking for a gold standard ...
  - **MUAC is the strongest practicable candidate**
Food for thought ...

- Switching from W/H (NCHS) to W/H (WHO) is not straightforward. The likely effect of such a switch is that we will intervene more frequently in order to treat fewer children.

- There is now a large body of evidence from the field that MUAC is the most appropriate indicator for use in admission into emergency feeding programmes in terms of achieving SPHERE minimum standards for coverage. There is also a large body of evidence indicating that MUAC is a better predictor of mortality than W/H. W/H is influenced by body shape and should not be used in some populations.

- Taken together, this body of evidence strongly suggests that MUAC is a better indicator of acute malnutrition than W/H and that, in the future, agencies should uniformly use MUAC and / or oedema to estimate the prevalence of acute malnutrition and to admit children into feeding programmes.
Some issues ...

Mortality risk of “excluded” children:

- In short-trunked and long-legged populations ...
  - Prevalence drops from (e.g.) 20% to 7% (Ethiopia, Somali Region)
  - Large number of children > 80% WHM with normal MUAC no longer eligible but ...
    - Environment remains the same and children’s nutritional status will not have changed
  - Is this legitimate?

  Recommendation: Longitudinal study to assess the risk of morbidity and/or mortality in children classified as normal MUAC but low W/H in different ethnic groups.

Classification of the prevalence of malnutrition:

- Many emergencies previously classified as critical or serious using the WHM (NCHS) case-definition would be re-classified as poor or acceptable. This may result in a reduction in the number of feeding programs undertaken in emergencies or the use of different strategies to reach children.

  Recommendation: Review the WHO classification of the severity of prevalence of malnutrition in a population using data from surveys with information on MUAC and mortality.

Confusion between MoH and NGO definitions of acute malnutrition:

- The WHO has just produced its new international standards for acute malnutrition based on W/H which it is encouraging national Governments to adopt. Confusion will arise between MoH clinics using W/H measurements and NGOs using MUAC measurements to diagnose acute malnutrition.

  Recommendation: Negotiate with the WHO to replace W/H with MUAC to measure acute malnutrition in its roll-out of the new growth standards (this is already happening in IMCI and paediatric HIV/ART programs).
A simple thing we can do now

Whilst the work described above is undertaken ...

- All agencies collect MUAC in their surveys and the SCN / NICS, CREN, UNICEF, WHO and any other agencies systematically record, report and compile data on MUAC so that trend data on MUAC can be compiled for different populations ...
  - Need to collect MUAC for estimating need in community-based programs already
"That's all folks!"