# 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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This section excludes Section 3-5 and Appendix 1-5 and is part of a larger 208 page report.

**IASC GLOBAL NUTRITION CLUSTER**

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# Executive Summary

**Executive summary**

The research reported here was undertaken to assess the relationships between commonly employed anthropometric measures of acute undernutrition in emergencies. It is important to understand these relationships because different indicators classify different children and different numbers of children as malnourished and the choice of indicator will have an impact on decisions to intervene (if these are based upon the results of prevalence surveys), program size, and may also have an effect on mortality rates within programs.

Currently, the majority of agencies use a W/H based index (WHZ) to estimate the prevalence of undernutrition in surveys but use a combination of MUAC and another W/H based index (WHM) for admission into feeding programmes. Historically, most agencies have been using W/H indices calculated using the NCHS reference population but the WHO has recently produced a new reference population. The situation is summarised in *Table XS1.*

**Table XS1 :** Summary of current indicator usage (simplified)

<table>
<tr><th>Function</th><th>Detail</th><th>Location</th><th>Agency</th><th>Indices</th></tr>
<tr><td rowspan="3">Prevalence</td><td>Global</td><td rowspan="3">All</td><td rowspan="2">NGO<br>MoH</td><td rowspan="2">WHZ (NCHS)<br>WHZ (WHO)</td></tr>
<tr><td>Moderate</td></tr>
<tr><td>Severe</td><td>ICRC</td><td>MUAC/H</td></tr>
<tr><td rowspan="6">Admission</td><td rowspan="4">Therapeutic feeding</td><td rowspan="2">Health Facility</td><td>NGO</td><td>WHM (NCHS)<br>WHM (WHO)</td></tr>
<tr><td>MoH</td><td>WHZ (NCHS)<br>WHZ (WHO)<br>Visible Severe Wasting</td></tr>
<tr><td rowspan="2">Community-based</td><td>NGO</td><td>MUAC[†]</td></tr>
<tr><td>MoH</td><td>Confused[‡]</td></tr>
<tr><td rowspan="2">Supplementary feeding</td><td rowspan="2">All</td><td>NGO</td><td>WHM (NCHS)<br>WHM (WHO)<br>Socio-economic criteria<br>Demographic criteria</td></tr>
<tr><td>MoH</td><td>Confused[‡]</td></tr>
</table>

[†] WHM (NCHS) or WHM (WHO) may be used as a secondary criteria
[‡] MUAC, WHM (NCHS), WHO (NCHS), H/A, W/A, and other indicators may be used

The summary presented in *Table XS1* is simplified. MUAC may be used for initial rapid assessment of prevalence. The use of the MUAC indicator for admission into therapeutic feeding programs is complicated by the presence of arcane, contradictory, and inconsistent height and age criteria in national protocols. The use of W/H (WHO) for admission into supplementary and therapeutic feeding programs is complicated by uncertainty with regard to whether WHZ or WHM should be used. Numerous other complications exist when a combination of MUAC and W/H are used for case-detection (screening) purposes.

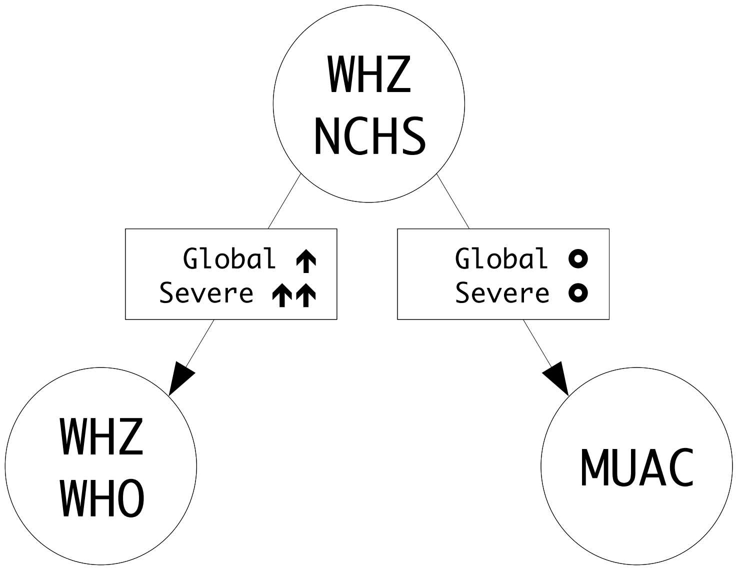
The use of several indices has led to confusion at the field and HQ levels of many agencies about which is the appropriate index to use in which context and how the various indices relate to each other. The research presented in this report aims to shed some light onto these issues.

The database on which this research is based has been compiled from the results of 560 anthropometric surveys of 459,036 children aged between six and fifty-nine months living in 31 countries collected under emergency conditions. To the authors' knowledge it is the largest set of data with the variables of interest available at this time.

**Executive summary : Basic results**

The effects of switching from WHZ (NCHS) to either WHZ (WHO) or MUAC on estimates of prevalence are summarised below:

**Prevalence Estimation (WHZ and MUAC)**




Switching to WHZ (WHO) will lead to surveys reporting **higher** estimates of global prevalence and considerably **higher** estimates of severe prevalence.

Switching to MUAC will lead to little or **no change** in the estimates of global and severe prevalence reported by surveys. This is **not** a general finding. In some populations switching to MUAC will lead to surveys reporting considerably **lower** prevalences. This is because W/H is strongly influenced by body-shape which causes surveys to report upwardly biased estimates of prevalence in populations with short trunks and long limbs.

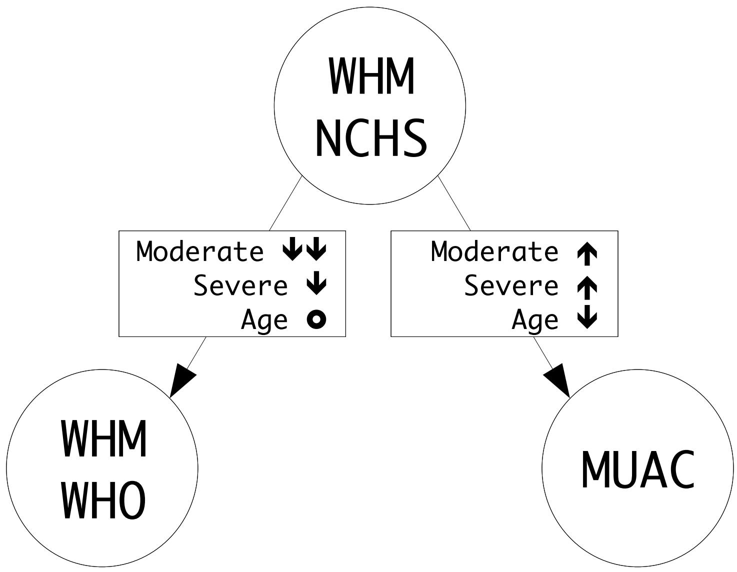
The effects of switching from WHM (NCHS) to either WHM (WHO) or MUAC on estimates of need / program numbers are summarised below:

**Needs Estimation (WHM and MUAC)**

Switching to WHM (WHO) will lead to considerably **lower** estimates of need for programs admitting *moderately* malnourished children and **lower** estimates of need for programs admitting *severely* malnourished children. These differences *may* translate into differences in program size.

Switching to MUAC will result in larger estimates of need for programs admitting either *moderately* or *severely* malnourished children. This is **not** a general finding. This is because W/H is strongly influenced by body-shape which causes surveys to report upwardly biased estimates of prevalence in populations with short trunks and long limbs.

Programs admitting on MUAC will tend to admit more **younger** children than programs admitting on WHM (NCHS) or WHM (WHO).




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.

A more thorough summary can be found in *Section 4* and *Section 5* of this report.

**Executive summary : Recommendations and policy implications**

Nutritional status cannot be directly observed, instead a range of observable indicators (biochemical, clinical and anthropometric) are used but none of these are capable of providing the full picture of an individual's nutritional status. Relatively simple anthropometric measures are used in emergency settings because neither biochemical nor clinical tests are practical. Although no anthropometric measure is a perfect marker of acute malnutrition, in the past, there has been a tendency to view W/H measures as the *gold-standard* anthropometric measure to diagnose acute malnutrition in emergencies. Discrepancies between MUAC and W/H have therefore been explained by MUAC being a poor indicator of nutritional status.

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 (NCHS). The results of two of the analyses presented in this report suggest that 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.

Before the proposed switch over to MUAC, however, certain critical pieces of analysis and / or discussion need to be undertaken and agreed by the technical experts in the field. These are outlined below:

**Mortality risk of excluded children**

The switch to MUAC will result in a reduction in the overall estimates of the prevalence of malnutrition in short-trunked and long-legged populations. For example, there may be a drop in the prevalence of acute malnutrition from c. 20% to c. 7% in the Somali Region of Ethiopia despite the fact that the environment remains the same and the children's nutritional status will not actually have changed. Under the new regime, large numbers of children with < 80% WHM (NCHS) but a normal MUAC will be excluded from feeding programmes. We do not know what the extra risk of mortality is for these children compared to children with a WHM (NCHS) > 80% and a normal MUAC as the longitudinal studies assessing anthropometry and mortality did not study these types of populations. It is likely that some agencies will be uncomfortable switching to MUAC without knowing what the extra risk is for the children who are excluded from programs.

**Recommendation :** Undertake a 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* by the WHO 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.

*Continued ...*

*Continued ...*

**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.

Whilst the work described above is undertaken, the authors of this report recommend that 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.

In the short-term, if agencies do switch over to MUAC there may be a reduced ability to look at trends in the prevalence of acute malnutrition. Often agencies report survey prevalence estimates for a number of years and seasons in order to assess how bad the current situation is, or predict what will probably happen next. If very different prevalences are presented then it may be difficult to interpret the new MUAC data. We recommend that agencies use the location-specific transformations given in this report to estimate the prevalence of malnutrition according to WHZ (NCHS) from the MUAC estimates of new surveys until an historical database of MUAC data becomes available.

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## Section 1

# Background and Research Aims

**Background and research aims**

Mid upper arm circumference (MUAC) has recently been endorsed by the World Health Organisation (WHO) as a suitable tool to diagnose severe acute undernutrition. There are several practical and theoretical advantages of using MUAC rather than weight-for-height (W/H) based measures of undernutrition and many agencies are beginning to move towards using MUAC as a basis for admitting children to feeding programs (either therapeutic or supplementary). Most agencies, however, continue to use a W/H based measure for surveys estimating the prevalence of undernutrition.

The use of different indicators for estimating the prevalence of undernutrition (i.e. W/H) and as case-definitions for admitting children to feeding programs (i.e. MUAC) is confusing. It should be noted, however, that the use of different indicators for these purposes has been common practice for many years. For example, the prevalence of undernutrition in emergencies is commonly measured using W/H z-score (WHZ) based case-definitions and admission decided using case-definitions based upon the W/H percentage of reference median (WHM) and / or MUAC (in developmental / non-emergency contexts there is a tendency to use WHZ based case-definitions in surveys and for admission).

The main source of confusion surrounds the use of MUAC for both estimating prevalence and deciding admission. Recent analyses undertaken by the Government of Ethiopia's Emergency Nutrition Co-ordination Unit (ENCU) suggest that the MUAC and W/H may return different estimates of the prevalence of undernutrition and that the relationship between MUAC and W/H is different in different areas of the country - this may be due to differences in the aetiology of malnutrition or differences in body shape associated with ethnicity (see *Appendix 5*).

An additional source of confusion is that the reference population which is used to calculate W/H indices may change from the NCHS reference to the WHO reference. Recent work undertaken at the Institute of Child Health in the United Kingdom suggests that such a change may result in surveys returning different prevalence estimates and different estimates of need (*Table 1.01*).

**Table 1.01 :** Reported effects of changing reference populations

| Indicator | Context | | Effect of change from NCHS to WHO reference |
|---|---|---|---|
| WHZ | Prevalence estimation | Global | Little or no change in prevalence |
| | | Moderate | Reduced prevalence |
| | | Severe | Increased prevalence |
| WHM | Therapeutic feeding | Need | Decreased estimate need |
| | | Discharge | Earlier discharge |

This report presents the results of an analysis of 560 nutritional anthropometry survey datasets and 222 mortality survey datasets with the aims of addressing some aspects of these areas of confusion . The specific research objectives are outlined in Table 1.02.

**Table 1.02 :** Research aims addressed in this report

| Research objectives | Report section(s) |
|---|---|
| 1. To determine the extent to which W/H (NCHS) and W/H (WHO) case-definitions† provide similar estimates of the prevalence of *global* and *severe* acute undernutrition. | 3.1 |
| 2. To determine the extent to which W/H (NCHS) and MUAC case-definitions† provide similar estimates of the prevalence of *global* and *severe* acute undernutrition. | 3.1 |
| 3. To determine the extent to which MUAC and W/H (WHO) case-definitions† provide similar estimates of the prevalence of *global* and *severe* acute undernutrition. | 3.1 |
| 4. To determine the extent to which W/H (NCHS) and W/H (WHO) case-definitions† provide similar estimates of need and program size for programs treating *moderate* and *severe* acute undernutrition. | 3.2, A3, A4 |
| 5. To determine the extent to which W/H (NCHS) and MUAC case-definitions† provide similar estimates of need and program size for programs treating *moderate* and *severe* acute undernutrition | 3.2 |
| 6. To determine the extent to which MUAC and W/H (WHO) case-definitions† provide similar estimates of need and program size for programs treating *moderate* and *severe* acute undernutrition | 3.2 |
| 7. To determine whether differences in the estimates of the prevalence and need of *global/moderate* and *severe* acute undernutrition returned by W/H (NCHS), W/H (WHO) and MUAC case-definitions† vary according to location. | 3.1, 3.2, A2, A5 |
| 8. To describe the relationship between the prevalence of *global* and *severe* acute undernutrition measured using MUAC and W/H case-definitions† and mortality measured by CMR and U5MR in different surveys from different populations. | 3.3 |

† Standard case-definitions are presented in *Tables 2.02, 2.03*

**Section 2**

# Methods

## Methods

### 2.1 The database

This section describes the *database* (i.e. the collection of survey datasets) used in the analysis presented in subsequent section of this report and the data-collection and data-management procedures that were used to create it.

### Collecting the datasets

The nutrition adviser for SC-UK contacted her counterparts at the main agencies working in the field of international nutrition. The aims of the work were outlined and permission to use these agencies' data was sought. Datasets of nutritional anthropometry surveys including age, sex, weight, height, MUAC and oedema were requested. Agencies were also asked to describe where and when the survey took place. Where possible, agencies were also asked to provide mortality data collected at the same time as the anthropometric survey (either the original dataset or the as summary figures) and to report the recall period. Data was received from ACF-F, ACF-US, CONCERN, FSAU, GOAL, MSF-B, MSF-CH, MSF-H, MSF-S, SC-UK and SC-US.

A consultant was employed to collate the surveys that were received from these agencies. The surveys were sorted by geographical area and date. A total of 697 anthropometric and 245 mortality datasets were collected. Given the small number of mortality datasets, the consultant was then employed to check through historical records of mortality data in the Standing Committee on Nutrition's Nutrition Information in Crisis System (SCN/NICS) database and, where possible, to add additional mortality data to the anthropometric datasets. This database was then handed over to the main author.

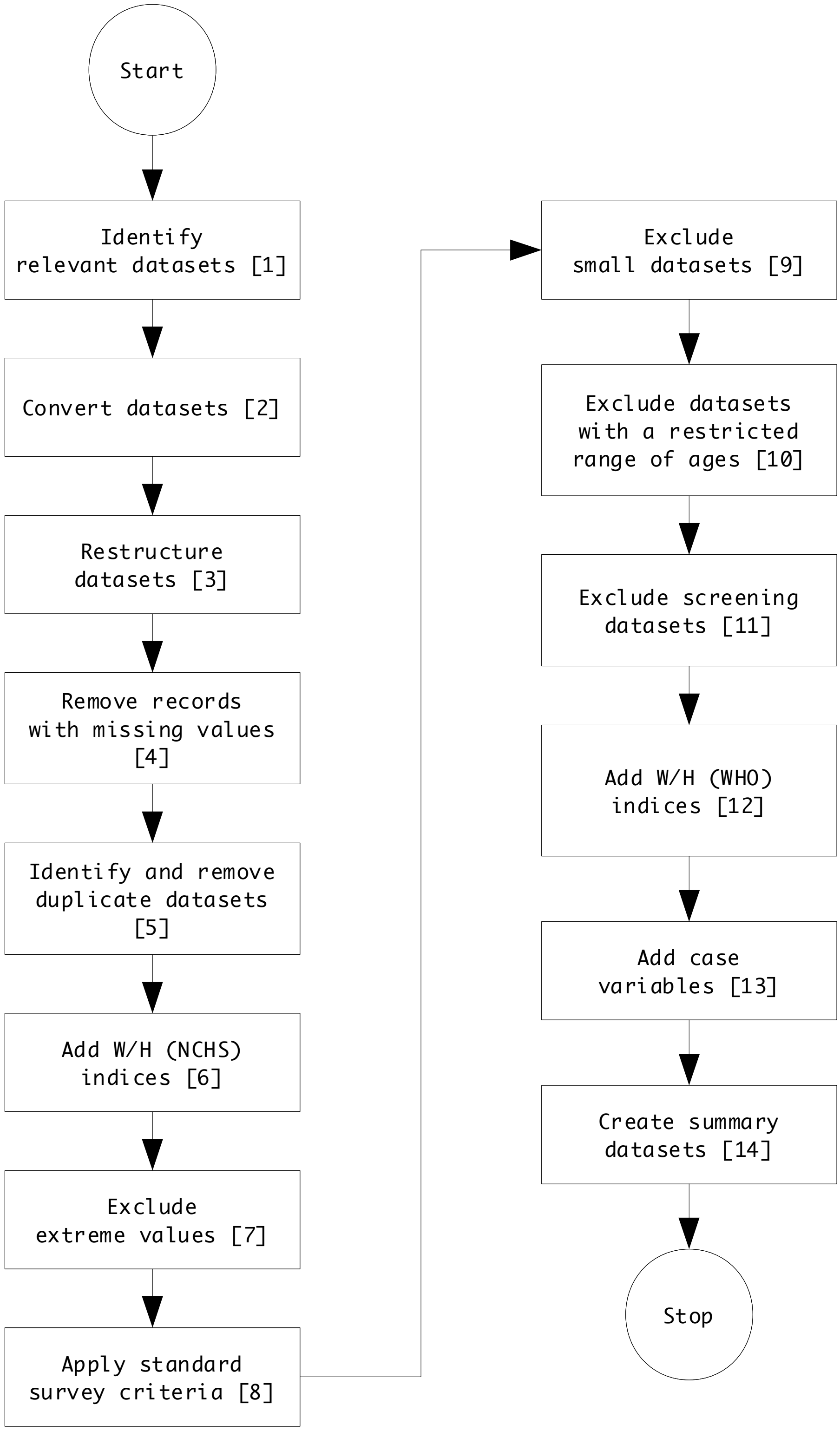
### Data management

The data-management procedures employed are summarised in *Figure 2.01* and presented in more detail below. Each process in *Figure 2.01* has been numbered in order to assist the reader to associate the processes show in *Figure 2.01* with their descriptions in the text.

### [1] : Identify relevant datasets

Some of the collected datasets did **not** contain anthropometry data. These were usually household surveys (e.g. of land ownership, livestock ownership, water utilisation, &c.) or mortality survey datasets. Some datasets did not contain MUAC. Some datasets contained only adult, adolescent, or neonatal anthropometric data. Some "datasets" were actually survey reports rather than survey datasets. All non-relevant datasets and survey reports were identified and deleted.

**Figure 2.01 :** Data-management procedures



**[2] : Convert datasets**

The collected datasets were in a variety of file formats:

***EpiInfo v6.xx*** data files

Microsoft ***Excel*** spreadsheet files

***Lotus-123*** spreadsheet files

***Applix*** tab-delimited spreadsheet files with attached data-dictionaries

***EpiInfo v6.xx*** files were imported into ***R*** using the **read.epiinfo()** function provided by the **foreign** function library and exported as *comma separated value* (CSV) files using the **write.table()** function. Microsoft ***Excel*** and ***Lotus-123*** spreadsheet files were imported into the spreadsheet module of ***OpenOffice*** and exported as CSV files. ***Applix*** tab-delimited spreadsheet files were imported into ***R*** using the **read.table()** function and exported as CSV files using the **write.table()** function.

Corrupted files were, if possible, fixed by hand using ASCII and binary file editors (***kate*** and ***khexedit***) as appropriate.

**[3] : Restructure datasets**

The collected datasets used a variety of variable names in a variety of orders. The datasets that were originally in Microsoft ***Excel*** format files tended not to contain data in a simple “flat-file” format (i.e. records in rows and variables in columns) and required considerable restructuring.

Datasets were restructured by hand using ***OpenOffice*** so that all datasets had the same structure (as shown in *Table 2.01*). The restructured datasets were stored as “flat-file” CSV files with one record per line and variables separated by commas. Decimal numbers were stored with a full-stop character indicating the position of the decimal point. Missing values in the OEDEMA variable were recoded to indicate the absence of bilateral pitting oedema. Files were stored in UNIX™ format (i.e. lines were terminate with LF characters).

**Table 2.01 :** Structure of restructured datasets

| Variable name | Contains ... | Format and coding |
|---|---|---|
| AGE | Age in months | Integer |
| SEX | Sex | 1 = Male / 2 = Female |
| WEIGHT | Weight (kg) | Fixed decimal (1 d.p) |
| HEIGHT | Height (cm) | Fixed decimal (1 d.p) |
| MUAC | Mid-upper-arm-circumference (mm) | Integer |
| OEDEMA | Bilateral pitting oedema | 1 = Present / 2 = Absent |

**[4] : Remove records with missing values**

Records with missing values in any variable were removed from all datasets. This was done in order to ensure that prevalence estimates based on different indicators (i.e. MUAC and W/H) were calculated using the same set of records.

**[5] : Identify and remove duplicate datasets**

Duplicate datasets were identified using the following “case-definitions”:

> Same country of origin AND same mean age
> Same country of origin AND same mean weight
> Same country of origin AND same mean height
> Same country of origin AND same proportion with MUAC < 125 mm
> Same country of origin AND same number of records

Datasets meeting **all** “case-definitions” were considered to be duplicates and one copy retained for further analysis. The remaining datasets were sorted by AGE, SEX, WEIGHT, HEIGHT, MUAC, and OEDEMA. Datasets that were incomplete versions (e.g. partial backups) of other datasets were identified using a combination of the GNU ***head***, ***tail***, and ***diff*** utilities and deleted.

**[6] : Add W/H (NCHS) indices**

The datasets were converted from UNIX™ format to MSDOS™ / Windows™ format (i.e. lines terminated with CR and LF characters) using the GNU ***unix2dos*** utility. Each dataset was converted to ***EpiInfo v6.xx*** format using the ***Import*** module of ***EpiInfo v6.xx*** and an appropriately structured and empty data (.REC) file. The weight-for-height z-score (WHZ) and weight-for-height percentage of reference median (WHM) indices were then added using the ***EpiNut*** module of ***EpiInfo v6.xx***.

**[7] : Exclude extreme values**

The resulting data (.REC) files were imported into ***R*** and records with extreme values identified by the ***EpiNut*** module's default flagging criteria (i.e. FLAG ≠ 0) identified and removed. The FLAG variable (added by ***EpiNut***) was then removed from each dataset.

**[8] : Apply standard survey criteria**

Records failing to meet the standard survey criteria:

> (AGE ≥ 6 AND AGE ≤ 59) OR (HEIGHT ≥ 65 AND HEIGHT ≤ 110)

were identified and removed. Remaining records were exported into UNIX™ format CSV files.

**[9] : Exclude small datasets**

All datasets with a sample size of less than 196 were identified and excluded from further analysis. This sample size was chosen as sufficient to estimate a prevalence of 15% with a precision of ± 5% assuming a simple random sample.

*Figure 2.02* shows the distribution of sample sizes in the surveys that comprise the complete study database. The peak just before a sample size of one-thousand (1000) is expected and corresponds to the sample size of approximately nine-hundred (900) that is taken in standard two-stage cluster-sampled nutritional anthropometry surveys (i.e. “30-by-30” surveys) in which is is common practice to sample thirty clusters with about thirty children sampled from each cluster location.

**[10] : Exclude datasets with a restricted range of ages**

Datasets in which:

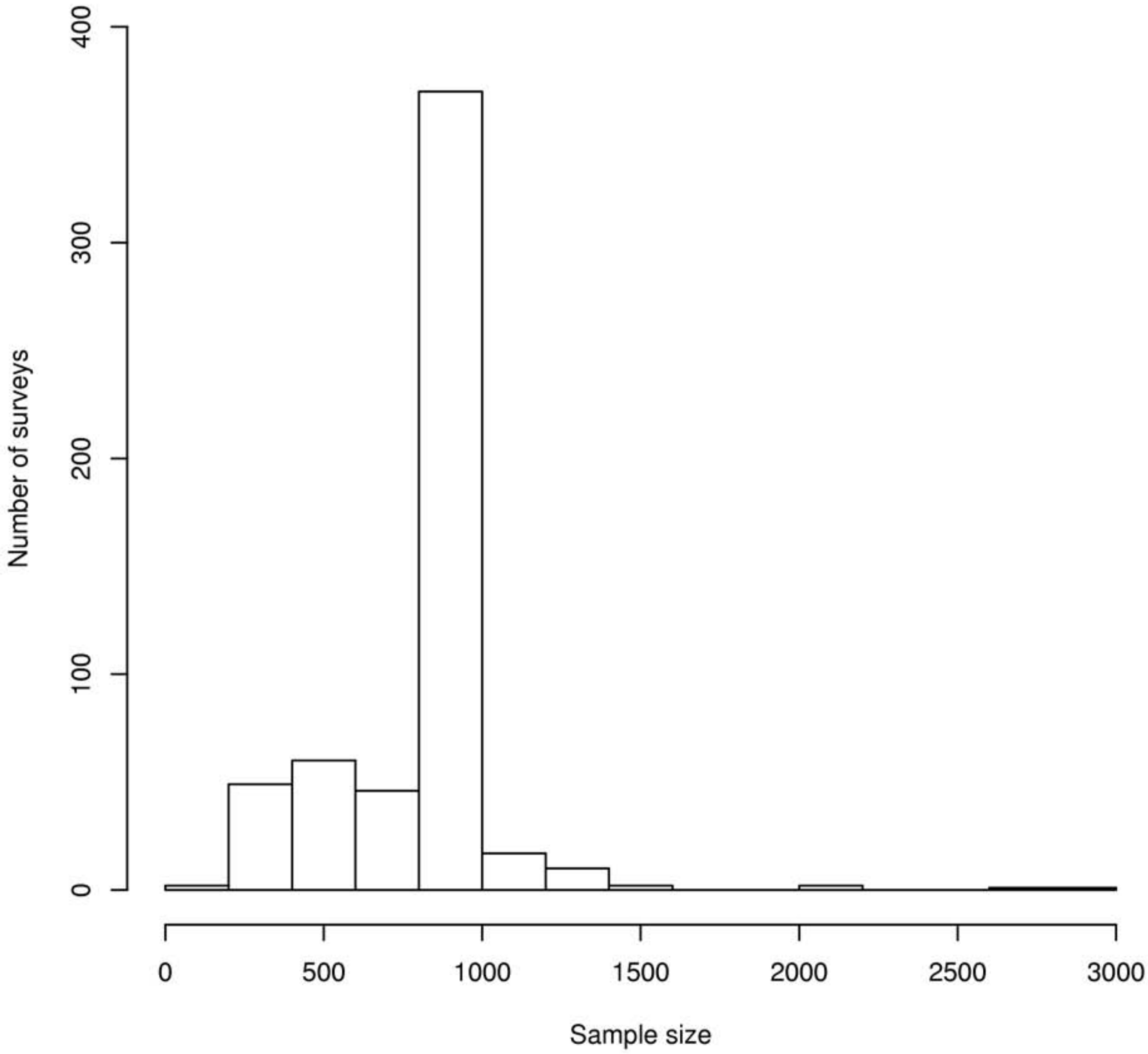
> MUAC was collected only from children with AGE ≥ 12 months
>
> MUAC was collected only from children with HEIGHT ≥ 75 cm
>
> Age was improperly recorded - one dataset was identified with ages entered as AGE = 7 for children below 85.5 cm in height and AGE = 55 for taller children. It was assumed that age data were not collected but added at a later date so as to allow the calculation of W/H indicators using the NCHS reference distribution. The distribution of heights in this dataset was also peculiar with an absence of children with heights between 85.5 cm and 100.0 cm.

were identified and excluded from further analysis.

**[11] : Exclude screening datasets**

Datasets in which WEIGHT and HEIGHT were recorded only for children below a MUAC cut-off (typically ≤ 135 mm) were identified and excluded from further analysis.

**Figure 2.02 :** Distribution of sample sizes in the surveys that comprise the complete study database



**[12] : Add W/H (WHO) indices**

Weight-for-height z-score (WHZ) and weight-for-height percentage of reference median (WHM) indices were calculated using the WHO reference population data and added to each dataset using a purpose-written ***R*** script and reference datasets downloaded from the WHO website.

WHZ was calculated using the formula:

$$WHZ = \frac{\left[\frac{y}{M(t)}\right]^{L(t)} - 1}{S(t)L(t)}$$

and WHM was calculated using the formula:

$$WHM = \frac{y}{M(t)} \times 100$$

Where:

| | | |
|---|---|---|
| $y$ | = | WEIGHT |
| $t$ | = | HEIGHT |
| $L(t)$ | = | Reference *L* for SEX and HEIGHT |
| $M(t)$ | = | Reference *M* for SEX and HEIGHT |
| $S(t)$ | = | Reference *S* for SEX and HEIGHT |

Corrections for departure from normality in the extreme tails of the WHZ distribution (i.e. greater than ± 3 standard deviations) were **<u>not</u>** applied since this had no relevance to the application reported here.

The weight-for-**<u>length</u>** reference was used for children with HEIGHT < 85 and the weight-for-**<u>height</u>** reference was used for children with HEIGHT ≥ 85. This height threshold (i.e. 85 cm) was used because it reflects the standard practice of measuring the supine length of children with heights below 85 cm and the standing height of children with heights of 85 cm or greater.

**[13] : Add case variables**

Variables indicating case / non-case status meeting the case-definitions shown in *Table 2.02* (*prevalence* indicators) and *Table 2.03* (*need* indicators) were added to each dataset. In this context “need” is defined as meeting the admission criteria for supplementary or therapeutic feeding programs run by international NGOs. These programs generally use WHM in admission criteria as it is easier to calculate at the “program gate” than WHZ and because WHM results in smaller and more easily managed programs.

The case-definitions shown in *Table 2.02* and *Table 2.03* are used in the analyses presented in *Section 3*, *Section 4*, and *Section 5* of this report. *Appendix 3* and *Appendix 4* present analyses using different cases-definitions (see *Table A3.01* and *Table A4.01* for details of the case-definitions used in these appendices).

**Table 2.02 :** Indicators and case-definitions (*prevalence*)

| | Case-definition | |
|---|---|---|
| **Indicator** | **Global acute undernutrition** | **Severe acute undernutrition** |
| **W/H (NCHS)** | WHZ < -2.00 OR OEDEMA | WHZ < -3.00 OR OEDEMA |
| **W/H (WHO)** | WHZ < -2.00 OR OEDEMA | WHZ < -3.00 OR OEDEMA |
| **MUAC** | MUAC < 125 mm OR OEDEMA | MUAC < 110 mm OR OEDEMA |

**Table 2.03 :** Indicators and case-definitions (*need*)

| | Case-definition[†] | |
|---|---|---|
| **Indicator** | **Moderate acute undernutrition** | **Severe acute undernutrition** |
| **W/H (NCHS)** | WHM < 80% AND WHM ≥ 70% WITHOUT OEDEMA | WHM < 70% OR OEDEMA |
| **W/H (WHO)** | WHM < 80% AND WHM ≥ 70% WITHOUT OEDEMA | WHM < 70% OR OEDEMA |
| **MUAC** | MUAC < 125 mm WITHOUT OEDEMA | MUAC < 110 mm OR OEDEMA |

[†] These are program admission criteria for supplementary and therapeutic feeding programs (see text)

**[14] : Create summary datasets**

Summary datasets were created containing *prevalence* and *need* estimates and the median age of cases found using each case-definition in each dataset.

## Summary of excluded datasets

*Table 2.04* shows the number of datasets excluded during data-management and the reasons for their exclusion.

**Table 2.04 :** Excluded datasets

| Reason for exclusion | Number excluded |
|---|---|
| Duplicates | 26 † |
| Small dataset | 10 |
| Screening dataset | 4 |
| Restricted range of ages | 53 |
| Improper age recording | 1 |
| All reasons | 94 |

† 26 of 52 duplicates retained

A record of non-relevant excluded datasets was not maintained.

## Mortality data

Mortality data were collected from original survey reports and the SCN / NICS database and a summary data file created.

## Data analysis

The analyses presented in this report was performed using the summary datasets using purpose-written ***R*** functions and scripts. See **Analyical methods** (below) for more details.

**The study database**

The database used in the analysis presented here is available for use by other researchers provided appropriate permissions are obtained from the original owners of the data. A description of the study database is given below.

**The study database – Individual datasets**

Individual survey datasets are stored in individual MSDOS™ / Windows™ format CSV files structured as "flat-files" with one record per line and variables separated by commas. Decimal numbers are stored with a full-stop character indicating the position of the decimal point. *Table 2.05* describes the structure of the individual survey datasets.

**Table 2.05 :** Structure of individual survey datasets

| Variable name | Contains ... | Format and coding |
|---|---|---|
| AGE | Age in months | Integer |
| SEX | Sex | 1 = Male / 2 = Female |
| WEIGHT | Weight (kg) | Fixed decimal (1 d.p) |
| HEIGHT | Height (cm) | Fixed decimal (1 d.p) |
| MUAC | Mid-upper-arm-circumference (mm) | Integer |
| OEDEMA | Bilateral pitting oedema | 1 = Present / 2 = Absent |
| EPI.WHZ† | W/H z-score (NCHS) | Fixed decimal (2 d.p) |
| EPI.WHM† | W/H percentage of median (NCHS) | Fixed decimal (2 d.p) |
| WHO.WHZ | W/H z-score (WHO) | Fixed decimal (2 d.p) |
| WHO.WHM | W/H percentage of median (WHO) | Fixed decimal (2 d.p) |

† The "EPI" prefix indicates "added by the ***EpiNut*** module of ***EpiInfo v6.xx***)"

Each survey dataset file is named according to the following convention:

***aaaaNN*.csv**

Where:

***aaaa*** = Four letter code indicating country and region of origin

***NN*** = Two digit serial number

***.csv*** = Suffix identifying the file as a CSV file

*Table 2.06* shows the four letter codes used to indicate country and region of origin in the names of the individual survey dataset files. *Table 2.06* also shows the number of individual datasets by county and region of origin and the number of associated mortality estimates available in a summary dataset (see below).

**Table 2.06 :** Codes used to indicate country and region of origin in the names of the individual dataset files and the number of datasets and mortality estimates from each country

| Code | Country / Region | *N* (Anthropometry) | *N* (CMR) | *N* (U5MR) |
|---|---|---|---|---|
| **afgh** | Afghanistan | 35 | 16 | 17 |
| **alba** | Albania | 1 | 0 | 0 |
| **ango** | Angola | 17 | 0 | 0 |
| **burm** | Burma | 8 | 1 | 1 |
| **buru** | Burundi | 15 | 4 | 6 |
| **cafr** | Central African Republic | 2 | 1 | 1 |
| **cdiv** | Cote d'Ivoire | 3 | 0 | 0 |
| **chad** | Chad | 32 | 4 | 8 |
| **drcz** | Democratic Republic of Congo / Zaire | 33 | 11 | 4 |
| **erit** | Eritrea | 2 | 0 | 0 |
| **ethi** | Ethiopia (NOS) | 45 | 42 | 41 |
| **eths** | Ethiopia (**S**omali) | 8 | 7 | 7 |
| **guin** | Guinea | 2 | 0 | 1 |
| **hait** | Haiti | 30 | 18 | 18 |
| **indo** | Indonesia | 1 | 0 | 0 |
| **keny** | Kenya | 7 | 1 | 0 |
| **libe** | Liberia | 31 | 10 | 10 |
| **mace** | Macedonia | 1 | 0 | 0 |
| **mala** | Malawi | 9 | 0 | 0 |
| **moza** | Mozambique | 9 | 0 | 0 |
| **nica** | Nicaragua | 2 | 0 | 0 |
| **nige** | Niger | 4 | 3 | 3 |
| **paki** | Pakistan | 9 | 1 | 4 |
| **rwan** | Rwanda | 13 | 2 | 2 |
| **sier** | Sierra Leone | 38 | 10 | 10 |
| **soma** | Somalia | 17 | 2 | 3 |
| **sril** | Sri-Lanka | 3 | 0 | 0 |
| **sudd** | Sudan (**D**arfur) | 28 | 20 | 20 |
| **sudn** | Sudan (**N**orth) | 47 | 8 | 22 |
| **suds** | Sudan (**S**outh) | 66 | 22 | 13 |
| **taji** | Tajikistan | 5 | 0 | 0 |
| **tanz** | Tanzania | 6 | 2 | 2 |
| **ugan** | Uganda | 30 | 4 | 4 |
| **zamb** | Zambia | 1 | 0 | 0 |

### The study database – Summary datasets

Two summary datasets are included in the study database:

**mortality.data.csv**

This file contains the summary mortality data. Variables are:

| | |
|---|---|
| **id** | Identifier (corresponds with the name of the associated anthropometry survey dataset file |
| **cmr** | Crude mortality rate (deaths / 10,000 / day) |
| **u5mr** | Under five-years mortality rate (deaths / 10,000 / day) |

**DataSources.csv**

This file contains supplementary information regarding the anthropometry survey datasets. Variables are:

| | |
|---|---|
| **id** | Identifier (corresponds with the name of the associated anthropometry survey dataset file |
| **country** | Country of origin |
| **region** | Region (within country) of origin |
| **date** | Month and year (MM/YYYY) of data collection |
| **agency** | Original owner of the data |

The anthropometry and median age of cases summary datasets are **not** included in the study database.

### The study database – Numbers

The study database contains 560 anthropometry survey datasets with a total of 459,036 children aged 6-59 months. The mortality summary dataset contains 222 records providing 189 estimates of the crude mortality rate (CMR) and 197 estimates of the under five-years mortality rate (U5MR). The analysis presented in this report is based on the study database described above.

**Analytical methods**

The analyses presented in this report show the relationships between the estimated prevalences of undernutrition defined using the different case definitions described in *Table 2.02* and *Table 2.03.* A variety of statistical plots and tests are presented.

*Figure 2.03* provides a description of the most commonly used statistical plots in the report. These include histograms, scatter-plots, quantile-quantile (QQ) plots and smoothed density plots. The QQ plots in the bottom-left panel of these figures are constructed by plotting the *ordered* values of the prevalence estimates obtained by one case-definition against the *ordered* values of the prevalence estimates obtained by another case-definition. *Box 2.01* provides further explanation of the scatter and quantile-quantile (QQ) plots.

Further analyses present difference vs. mean plots and proportional difference plots. These are described in *Box 2.02* and *Box 2.03*.

*Appendix 1* shows a worked example of how the figures in this report may be interpreted.

**Figure 2.03 :** Description of comparison plots

Histogram of the distribution of prevalence estimates found using the first named indicator.

Histogram of the distribution of prevalence estimates found using the second named indicator.

Quantile-quantile (QQ) plot comparing the distributions of prevalence estimates found using the two named indicators. The QQ plot shows the *ordered* values of the prevalence estimates obtained by one case-definition plotted against the *ordered* values of the prevalence estimates obtained by the other case-definition. Deviations from the 45° line show areas of dissimilarity between the two distributions. The plotted points do not necessarily represent paired estimates from the same survey dataset as would be the case with a traditional scatter-plot.

Smoothed density plot showing the shape of the two distributions. The solid line shows the shape of the distribution of prevalence estimates found using the first named indicator. The dashed line shows the shape of the distribution of prevalence estimates found using the second named indicator.

**Box 2.01 :** Scatter-plots and quantile-quantile (QQ) plots

$x$ is a vector of prevalence estimates found by the first case-definition:

$x_1$ = prevalence found in the first survey

$x_2$ = prevalence found in the second survey

...

$x_n$ = prevalence found in the $n^{th}$ survey

$y$ is a vector of prevalence estimates found by the second case-definition:

$y_1$ = prevalence found in the first survey

$y_2$ = prevalence found in the second survey

...

$y_n$ = prevalence found in the $n^{th}$ survey

A traditional **scatter-plot** is a plot of $x$ against $y$. The plotted points represent pairs of prevalence estimates from the same survey:

$x_1$, $y_1$

$x_2$, $y_2$

...

$x_n$, $y_n$

A **quantile-quantile (QQ) plot** is a plot of $x$ sorted in ascending order against $y$ sorted in ascending order. The plotted point are **<u>not</u>** constrained to represent pairs of prevalence estimates from the same survey. If the distributions of $x$ and $y$ are identical then the plotted points in a QQ plot will follow a straight line with a slope of one. Deviations from this line indicate areas of dissimilarity between the two distributions. QQ plots, therefore, provide a simple visual means of comparing two distributions.

**Box 2.02 :** Difference vs. mean plots

$x$ is a vector of prevalence estimates found by the first case-definition:

$x_1$ = prevalence found in the first survey

$x_2$ = prevalence found in the second survey

...

$x_n$ = prevalence found in the $n^{th}$ survey

$y$ is a vector of prevalence estimates found by the second case-definition:

$y_1$ = prevalence found in the first survey

$y_2$ = prevalence found in the second survey

...

$y_n$ = prevalence found in the $n^{th}$ survey

Scatter-plots are one way of representing the relationship between $x$ and $y$ (see *Box 3.01*). This relationship may also be examined using a **difference vs. mean plot** which plots the mean of each pair of prevalence estimates:

$$\frac{x_i + y_i}{2}$$

on the horizontal axis and the difference between paired prevalence estimates:

$$x_i - y_i$$

on the vertical axis.

**Difference vs. mean plots** also show the mean difference between the paired prevalence estimates and 95% confidence limits for the mean difference. Approximately 95% of the differences should fall between these confidence limits provided the differences are symmetrically and normally distributed.

If the two case-definitions tend to return similar prevalence estimates then the plotted points will describe a symmetrical “funnel” or “cloud” around a mean difference of zero.

A “funnel” or “cloud” of points that is symmetrical about a mean difference other than zero is indicative of one case-definition tending to return higher (or lower) prevalence estimates than the other case-definition.

A “funnel” or “cloud” or points that is **not** symmetrical about the mean difference is indicative of one case-definition tending to return higher (or lower) prevalence estimates than the other case-definition with the magnitude of the difference being dependent upon prevalence.

**Box 2.03 :** Proportional Difference plots

An alternative approach to scatter-plots (see *Box 2.01*) and difference vs. mean plots (see *Box 2.02*) is to specify one variable as a *standard* against which the other variable is compared by plotting the *standard* on the horizontal axis and the **proportional difference** between the *standard* and the *comparison* variables:

$$percentage\ difference = \frac{comparison - standard}{standard} \times 100$$

on the vertical axis.

When proportional differences are expressed as percentages, a value of 100% corresponds to a doubling of prevalence, 200% to a tripling of prevalence, and so-on.

Small absolute differences in case numbers will translate into large proportional differences at low levels of prevalence but not at higher levels of prevalence. For example:

| | | One Survey | Another survey |
|---|---|---|---|
| **Sample size** | | 900 | 900 |
| ***Standard* case-definition** | **Cases** | 1 | 109 |
| | **Prevalence** | $\frac{1}{900} \times 100 = 0.11\%$ | $\frac{109}{900} \times 100 = 12.11\%$ |
| ***Comparison* case-definition** | **Cases** | 3 | 111 |
| | **Prevalence** | $\frac{3}{900} \times 100 = 0.33\%$ | $\frac{111}{900} \times 100 = 12.33\%$ |
| **Proportional difference** | | $\frac{0.33 - 0.11}{0.11} \times 100 = 200\%$ | $\frac{12.33 - 12.11}{12.11} \times 100 = 2\%$ |

Proportional difference plots will, therefore, tend to display an “L-shaped” or “funnel-shaped” pattern of points.

If there is agreement between the prevalence estimates returned by the *standard* and *comparison* case-definitions then the plotted points will approach and cluster around a proportional difference of zero as prevalence increases.

If the plotted points tend to cluster above or below a proportional difference of zero then one case-definition tends to return higher (or lower) prevalence estimates than the other case-definition.

**The WHO classification of the severity of the prevalence of malnutrition**

When deciding the need for intervention, prevalence estimates are often checked for membership of a class or category of prevalence. The WHO proposes the use of the following classification scheme for *global* prevalence estimates using the W/H (NCHS) case-definition (*Table 2.07*):

**Table 2.07 :** Severity-defining prevalence classes

| Prevalence | Classification | Typical actions |
|---|---|---|
| < 5% | Acceptable | No action required |
| 5% - 9% | Poor | Continue to monitor situation |
| 10% - 14% | Serious | Intervene |
| ≥ 15% | Critical | Immediate emergency intervention |

These prevalence classes presented in *Table 2.07* are used throughout this report.