Population Nutritional status during famine

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Summary

Background

We predicted that social heterogeneity would lead to changes in the shape of the distribution curve of acute malnutrition when a population is exposed to famine.

Methods

We analysed the body wasting of 6 to 59 month old children from 228 nutritional surveys, that had been conducted in 36 countries, in circumstances of poverty, conflict, drought or famine, by International Humanitarian Organisations. Each survey's descriptive and Kolmorgorov-Smirnov statistics of weight-for-height Z-score were computed. The number and proportion of children classified as malnourished were counted and also calculated from the mean and standard deviation.

Findings

There was no change in the spread of wasting within the population as it became more malnourished. The population distributions did not differ significantly from normal. There was a slight positive skewness and normal kurtosis with extreme malnutrition. Both skewness and kurtosis became marginally positive in overweight populations. Counting and calculating the prevalence of malnutrition gave the same result.

Interpretation

All the individuals within a defined population are equally affected by a famine, despite social inequality. This may be due to social cohesiveness in the sampled populations. Traditional definitions of vulnerability and strategies that aim to target preventive relief may be inappropriately applied in the circumstances of these populations. Calculation from the mean and standard deviation could give a more rapid, efficient and precise estimate of the extent of malnutrition than counting affected individuals.

Introduction

Intuitively, when a population is exposed to famine, children from families with few resources or entitlements quickly become emaciated whereas other families are more able to cope and the wealthy protect their children from starvation. Many studies have sought to identify the most sensitive and specific characteristics of such vulnerability, usually based upon comparisons between families with and without malnourished children. In general, these confirm common experience from all communities. Factors such as a high child to adult ratio, single parent families, lack of parental education, marketable skills, land and other assets, poor housing, water and sanitation, and social disruption are more common in families of the malnourished. In conflict situations, other factors have also to be considered such as displacement, host community attitudes, ethnicity, psychological resilience and "usefulness" to belligerents. International agencies use such determinants of food-security to target, and thereby restrict, relief to the most vulnerable.

As food becomes scarce, a rising proportion of income is spent on food, entitlements are cashed and assets sold. As a society becomes ever more severely stressed, heterogeneity in vulnerability should be translated into an increase in the heterogeneity of actual acute wasting and, consequently, to a widening of the population distribution of wasting. That is, the better off should loose less weight than the worse off and the spread of weights-for-height within the population, as a measure of wasting, should increase. In statistical terms there should be an increase in the population standard deviation of the measures of acute malnutrition. Such "spreading out" may also lead to the population distribution developing long tails; the degree to which this occurs is measured statistically by the moment of kurtosis of the population (with a positive kurtosis the shoulders of the curve move into the tails to give a "Mexican hat" shape, whereas, a negative kurtosis is "pudding" shaped with short tails). Depending upon the relative proportions of highly vulnerable, normal and relatively protected individuals in the population, the distribution may also become asymmetric with one side of the distribution more spread than the other; this is estimated statistically from the moment of skewness. Where most people lose weight, with a few protected, the skew will be positive and where most people cope well but there is small highly vulnerable group the skew will be negative.

As mortality risk rises exponentially with the degree of malnutrition (see Pelletier review), when a substantial proportion of the population is affected, the mortality rate may rise to a level that will affect the population distribution; we would predict a positive skewness when the lower tail of the distribution is lost through death. At a very advanced stage of famine the wide standard deviation may then change to become narrow as the individuals remaining alive in the population bunch towards the lower limits of biological adaptation. The standard deviation, kurtosis and skewness may also be affected if the more able can migrate from the stricken area. Such migration would tend to remove the upper tail of the distribution.

In this study we set out to test whether these predicted changes in the shape of the population distribution of acute malnutrition actually occur as populations are exposed to starvation and famine secondary to complex political emergencies, drought or severe poverty.

Methods.

The raw data from nutritional surveys that had been conducted for the purposes of assessing the prevalence of acute malnutrition in deprived and starving populations were obtained from the non-governmental organisations, Medicine Sans Frontière, Action Contra le Faim and Concern International. 228 surveys were included in the study. They were conducted in 36 different countries in Africa (22), Asia (7), Europe (5) and Latin America (2) from 1987 to 1999. The mean number of subjects per survey was 628 (±300). Table 1 shows the regions, countries and numbers of children that were included in this analysis.

Survey methodology.

Each of the surveys was a two stage cluster survey of children aged from 6 to 59 months of age. In this method 30 clusters are selected at random from a map of the region. In each cluster the first child is selected at random and subsequent children according to the spatial relationship of their house to the last house visited. The number of children for each cluster is calculated according to the expected prevalence of malnutrition in the community. Each survey included, *inter alia*, the children's gender, age, weight and length, for individuals below 85cm, or height for those over 85cm.

The raw data had been entered into Epi-info in the field during the initial survey; they were analysed by the Epi-nut program and used for a contemporary report on the nutritional situation and to mobilise resources, plan relief operations or monitor their effectiveness.

The degree of wasting was calculated as the weight of each child in relation to the weight of a normal child of the same gender and stature using the NCHS standards. The deficit in weight was expressed as multiples of the standard deviation of the NCHS population. This is referred to as the "Z-score" of weight-for-height. When expressed in this way a population that is exactly the same as the standard NCHS population will have a mean Z-score of zero with a standard deviation of one Z-score unit.

In each survey, children with a weight-for-height which was more than 4 z-scores above or below the survey's mean were excluded from the analysis on the basis that their weight or height were incorrectly measured or recorded, or that they did not properly belong to the population being surveyed. Of the original 143,535 children in the 228 surveys, 297 (0.2%) were thus excluded from the analysis leaving a total of 143,238 children.

For each survey the mean, standard deviation and moments of kurtosis (g2) and skewness (g1) of the weight-for-height Z-scores were calculated. In order to examine the degree of deviation from normality the Kolmorgorov-Smirnov statistic was calculated, after standardisation. In this procedure the subjects are sorted and each individual value compared to the value it would have if the population distribution was entirely normal (Gaussian). The Kolmorgorov-Smirnov statistic is the size of the individual observed value that deviates most from the expected value. The units of this "maximum difference" are in standard normal deviates. Systat statistical package was used for computation.

Moderate wasting was defined as a weight-for-height of less than -2 Z score units and severe wasting as a weight-for-height of less than -3 Z score units.

The observed number of children in each survey who were moderately and/or severely wasted were counted. The number of wasted children that would be expected to occur in the sample, if the weights-for-height of the population were normally distributed, was calculated from the normal density function (ZDF_x). The equation $\boldsymbol{ZDF_x\,[(cutoff - mean)/SD]}$ was used, where “cutoff” is <-2Z score for moderate & severe and <-3Z score for severe wasting, and mean and SD are the mean and standard deviations of the weight-for-height Z-score. The expected number of wasted children in the survey was then calculated from the sample size.

The sum of the square of the difference between the observed (O) and expected (E) number of wasted children in each survey, as a function of the expected number, that is $\Sigma(O-E)^2/E$, follows the χ^2 distribution with n-1 degrees of freedom. The statistic will have a probability of $p < 0.05$ if, overall, the observed and expected counts differ significantly; this will occur if the distributions are not normal, in which case the two methods of estimating the true population prevalence from the sample will give different results. Where the expected number of malnourished children is less than 5 inclusion in the sum gives spurious results. Used in this way, the χ^2 statistic specifically examines the lower tail of the distribution at precisely the cutoff points used to define moderate and severe wasting and tests whether knowledge of the sample mean and standard deviation alone can be used to estimate the proportion of moderately and severely wasted children from a population sample.

To examine each survey individually, the same observed and expected numbers were expressed as proportions of the sample population and compared using a procedure for the comparison of two proportions (Armitage 1994). The expected (p_e) as well as the observed proportions (p_o) are both estimates of the true proportion of wasted children in the population; the best estimate of this proportion is thus the pooled proportion (p_p); with variance $(p_o-p_e) = p_p(1-p_p)(2*1/n)$, where n is the sample size. We tested the null hypothesis that both samples measured the same population in each survey by taking

$$Z = (p_o-p_e)/o[p_p(1-p_p)(2 * 1/n)]$$

That is the difference in the two estimates of the proportion of wasted children divided by the square root of the variance. This will be greater than 1.96 if the two methods of obtaining the proportions of malnourished children differ significantly at the 0.05 level (two tailed).

Results.

The means of the weights-for-height from the surveys included in this study ranged from the relatively overweight in the Balkans to some very severely malnourished populations in Africa, where over one third of the population was wasted (table 2).

As populations become more wasted the mean weight-for-height falls. However, as famine supervened there was neither an increase, nor a decrease, in the spread within each population. With extreme malnutrition there was no evidence that the remaining children “bunched” at the lower limits of survival. Linear (and higher degree polynomial) regression of the standard deviation against the survey mean was almost flat (figure 1). The 228 standard deviations were themselves normally distributed with a mean slightly less than the NCHS standard (0.98, 95% CI 0.97-0.99). The spread of the standard deviations of weight-for-height around the NCHS standard population was small; ranging from 0.8 to 1.2 in 95% of the surveys.

Distributions are usually considered to differ little from a normal Gaussian distribution if the moments of kurtosis and skewness are within plus or minus one unit. The moments of kurtosis of the surveys were within these limits in over 90% of the surveys. However, contrary to expectation, the populations where wasting was very common had a normal kurtosis (figure 2) and as the population mean weight-for-height increased the distribution developed a positive kurtosis.

None of the surveys were sufficiently skewed to deviate significantly from normal and there was not a linear relationship between skewness and weight-for-height ($r=0.12$). However, there was a significant curvilinear correlation between the degree of skewness and the mean weight-for-height of the population. As the populations became either very wasted or overweight a slight positive skewness developed ($r=0.33$, $p<0.001$) (figure 3). Such a skew will occur where either the upper tail is prolonged or the lower tail truncated. It should be emphasised, however, that such degrees of skewness are relatively trivial and are insufficient to cause a difference in the computed and measured proportion of wasting in a survey population.

Our data show that as a population becomes very malnourished, although the distribution develops a positive skew, the kurtosis approximates zero; in this case the asymmetry develops because of losses from the lower end of the distribution. In contrast, as wasting disappears and the population becomes overweight the positive skewness is associated with an increasing kurtosis; here, a higher proportion of the population than expected are obese and found in the upper tail of the distribution.

Of the 228 surveys the Kolmorgorov-Smirnov statistic was not significantly different from Gaussian normality in 225. Three surveys differed statistically from normal (Buchanan, Liberia: 1996, mean WHZ -1.76 ± 0.91, KS-maxdiff = 0.082, $p<0.01$; Labone, South Sudan: 1996, mean WHZ - 1.52 ± 0.99, KS-maxdiff = 0.051, $p<0.05$; Nimule, South Sudan: 1997, mean WHZ - 1.64 ± 0.83, KS-Maxdiff = 0.054, $p=0.01$). Other surveys, which were conducted in the same locations, were included in the database and these did not differ from normal; however, the other surveys were conducted at times when the wasting within the population was not so severe. When the Kolmorgorov-Smirnov maximum-difference was plotted against the survey mean weight-for-height there was a significant curvilinear relationship similar to that illustrated for the moment of skewness ($\text{Maxdiff (KS)} = 0.011\text{whz}^2 + 0.014\text{whz} + 0.036$, $r=0.313$, $P<0.001$). This both confirms that the surveys deviated more from normality as the population became extremely malnourished or overweight and also that this deviation was insufficiently great, within the range of population wasting we have examined, to cause 99% of the curves to differ significantly from normality.

Typical normal probability plots, chosen to illustrate differing degrees of starvation, are shown in figure 4. With this presentation, if the population is normally distributed all the points lie on a straight line. The deviation from this line is what is measured in the Kolmorgorov-Smirnov statistic. For the surveys where the populations were wasted the maximum deviations from the line invariably occurred in the tails of the distribution where values derived from erroneous measurements are more likely to occur. The deviations where the mean weight-for-height was more than zero also appeared to deviate from linearity in the body of the distribution (see Bosnia and Croatia, Figure 4), although this was not significant using the Kolmorgorov-Smirnov test.

The cumulative distribution of the maximum deviations from normality is shown in figure 5. The deviation from normal was less than 0.05 standard-normal-deviates in 90% of the surveys included in this analysis. The surveys whose individual data are shown in figure 4 are marked in fig 5; the surveys illustrated cover the spectrum of the deviations from normal observed.

There were 15 089 moderately or severely wasted children observed in the 228 surveys. The corresponding number calculated from the means and standard deviations was 15 343. Overall, the differences between the observed and expected number of wasted children, in each survey, was not significant (χ^2 =184, df=227, p=0.98).

The observed and expected number of children with severe wasting were 2 132 and 2 153, a discrepancy of 21 children (1.0%). In 115 of the surveys more than 5 severely malnourished children were expected to occur, there was no significant difference in the observed and expected number found in these surveys (χ^2 =133, df=114, p=0.10).

When the difference between the observed and expected proportion of children with wasting were examined for each survey individually only 2 of the 228 surveys were significant for moderate wasting (Ruvuma, Burundi, 1995 $p<0.05$ and Buchanan, Liberia, 1996, $p <0.01$) and two for severe wasting (Kabul, Afghanistan, 1995, $p<0.05$; Nimule, South Sudan, 1997, $P<0.05$). Each survey where the observed and expected proportions were significantly different at one of the cut-off points was not significantly different when the other cut-off point was considered.

Discussion.

We have shown that as a population undergoes starvation there is not an increase in the heterogeneity of wasting within that population. The prior hypothesis was incorrect. Therefore our result calls into question the basic assumption upon which the hypothesis was based; that some members of the population are more vulnerable to wasting and will become quickly emaciated while others are relatively protected. It would appear that, on average, exactly the same absolute quantity of weight is lost by a child in the upper, as in the lower, portions of the distribution. This is counter-intuitive. In is unclear why the results of studies which show clear differences between families of the malnourished and well nourished are not translated into changes at the population level. In general, where these studies have been conducted, the prevalence of wasting has not been high and frequently the cases have been ascertained from health facilities. What characterises a malnourished child’s family under stable circumstances may be different from those of a nutritional emergency or when a large proportion of the population is affected.

It seems as if a person who started with the poverty that sustained a weight-for-height of, say, 0 Z-score, will during the privation have a food availability that sustains a weight-for-height of -1 Zscore, whilst the person who started with this degree of food availability has now fallen to a level that only sustains a weight-for-height of -2 Z-score. Such a simple hypothesis is unlikely. It would necessitate a linear relationship between degrees of privation, food quality or quantity and weight-for-height of the children. The data may be affected by migration with the rich having the resources to move from the survey area, to be quantitatively balanced by the poor who die, leaving a residual population that is normally distributed; again this seems an unlikely explanation. We suggest that there are altruistic or other cohesive social networks whereby members of the community assist each other in times of stress so as to maintain their relative positions as the whole population deteriorates. Certainly people with similar poverty, and with family, ethnic or other ties, tend to live in close geographic proximity. In this case cluster sampling is likely to select 30 groups of children that are each themselves relatively homogeneous. There do not appear to be any quantitative data to address any of these hypotheses, but the real situation is likely to be very complex, and is certainly ill-understood and under-investigated. If we calculate the prevalence of wasting from the mean and standard deviation of each cluster, using the normal density function, we find that the degree of variation between clusters within a survey is much greater than the difference between surveys although each cluster's distribution appears to be Gaussian (M. Golden & Y Grellety, Unpublished). This indicates that there are indeed relatively homogeneous geographical "pockets" within which all the individuals suffer to a similar degree.

Furthermore, the phenomena appear to be reproducible from one country, region and continent to another. The surveys we have examined included such different racial groups as thin, tall pastoralists (Dinka) from Sudan, Bantu groups from central Africa, Tamils from Sri Lanka and people from Central Asia and Europe. We conclude that most communities of the world react in a similar fashion when subject to major nutritional stress.

The normality of the curve and the maintenance of a constant degree of heterogeneity within the population also calls into question the utility of attempting to identify those *individual families* who need special help to *prevent* weight loss. As the whole population has been equally affected by the famine and all individuals have lost comparable amounts of weight, our analysis suggests that preventive relief should be directed at the whole affected community, or pocket areas within the wider community, without targeting individual persons or families that are perceived as particularly vulnerable. Curative programs, on the other hand, are required for the already wasted because of their high mortality risk. However, if resources are only expended upon the wasted then one would not expect to see a substantial change in the prevalence of moderate wasting. This is because, in the dynamic of famine, the treated individuals will be replaced by mildly wasted children deteriorating because "targeting" has denied them relief. In many of the situations where the present surveys were conducted therapeutic and supplementary feeding programs were in operation. They did not appear to affect any of the parameters of the population distribution of wasting. We conclude that it is critical to ensure that the whole population receives an adequate, nutritionally balanced, ration, as the first priority.

It is often assumed that weight-for-height and the prevalence of wasting is a "trailing indicator" in a famine situation. Thus, it is postulated that there is a sequence of events that starts with the population becoming food insecure. The individuals within the population then exercise various coping strategies that ameliorates their condition and prevents anthropometric change; it is only when the coping strategies cannot compensate for the shortfall and fail that anthropometric change starts to occur; as the situation further deteriorates individuals become severely malnourished. This linear sequence may well be the case for individual families, but our results indicate that such a strict temporal sequence, whereby food security indicator deterioration always come well in advance of anthropometric change may not be the case at a population level. As individual families and "pocket areas" go through such a sequence starting at different times and progressing at different rates, from the perspective of the whole population there may be a closely associated steady deterioration in the mean weight-for-height (and consequently the prevalence of those falling below a certain threshold). Longitudinal data with sufficient temporal precision to address this relationship has not been collected.

Our results indicate that with extreme starvation there is some loss from the lower tail of the distribution giving slight skew to the distribution. However, this is much less pronounced than anticipated, and is sufficiently subtle not to render the curves significantly non-normal. The moments of skewness and kurtosis are disproportionately affected by relatively few individuals in the tails of the distributions, where errors of measurement are likely to occur. The pattern in our data only emerges when a sufficiently large number of surveys with a spread of nutritional status are considered; with present survey methodology, the variability is such that it would be unsafe to interpret slight deviations from normality, in individual surveys, in relationship to the particular circumstances of the population.

Surprisingly, the wasted populations approximate normality more closely than the normally nourished populations. Kurtosis reaches zero at -1.5 Z score weight-for-height, when 31% of the population are wasted, and skewness approaches zero most closely at -0.44Z when 6% of the population at wasted. These data differs from the North American population from which the standards are derived. The standard USA population had a positive skew. To circumvent this difficulty different “normal standard deviations” are used as divisors to derive positive and negative Z-score values. Indeed, in overweight populations there is usually a positive skew, particularly in adults but also children. The Croatian survey shown in fig 4 also appeared to be skewed in this way, although its small size made this not significant. It would appear that the effects of abundant energy dense food availability are different from a deprivation of food. Our results, derived from so many different populations, also call into question the validity of deriving standards of weight-for-height from a population that is not normally distributed, particularly an affluent population where bottle feeding and obesity are common. The standards may be more globally applicable if they were assumed to be symmetrically distributed, using the lower portion of the curve and eliminating the obese from the reference. The same divisor would then be used to derive Z-scores above and below the median. Such a change would have a small effect of making more children in affluent countries overweight without altering the prevalence of wasting.

Nutritional surveys are critical tools to assess and monitor an emergency situation. They, with mortality surveys, are the principle data used to persuade donors, International Agencies and non-governmental organisations to commit effort and funds for relief. Such surveys are also used to determine the magnitude and the type of response that has to be planned and implemented. The accuracy of the methods and the confidence of donors and planners are therefore critical. When the original survey methodology was being devised, appropriately, no assumptions was made about the nature of the distribution of wasting within the population. Therefore, sufficient children had to be sampled to allow the proportion who were malnourished to be directly counted. Even with a sample of 900, if the true prevalence of moderate malnutrition is 10% and severe malnutrition 1%, then, on average, only 9 severely wasted children will found in the survey. Because of the relatively small number of individuals observed, the confidence interval around this number is large. If the affected population has 35,000 children then relatively expensive therapeutic facilities will need to be provided for up to 350 severely malnourished children, a number that would overwhelm the normal health facilities, and there will be about 3150 moderately malnourished children who will need supplementary feeding. This effort requires considerable human and material resources to be mobilised, planning, logistic support and time to implement. Any error in the survey could have a considerable impact on whether the response is appropriate.

For this reason relatively large amounts of time, effort and funds are committed to nutritional surveys. They are frequently conducted under hazardous conditions where the staff collecting the data are in personal danger. To avoid a long delay before the results are available many teams of field workers are recruited, trained and then all staff are committed to intensive data collection for the duration of the survey, to the exclusion of their other pressing duties. Surveys are not repeated frequently enough to assess how the nutritional status of a population is changing over short periods of time. There are few experienced staff available in such situations to go with each of the teams and the training is often rushed. The quality of the data collected may then be questioned by donors and others. This leads to equivocation before committing the massive sums of money involved in relief – a delay which often costs many lives.

Both statistical methods of comparison of the estimates of the true population of malnutrition (counts and proportions) show that the estimation of the population prevalence of wasted and severely wasted children by calculation from the mean and standard deviation gives the same result as that obtained when the wasted children are individually found and counted. Indeed, the deviations from normality that we observed in a few of the surveys are more likely to be due to methodological errors when teams of observers are quickly recruited, trained and urgently sent into hazardous situations to collect the data, than true deviations.

If the actual weight-for-height information from every child in the population sampled is used, instead of only the dichotomous position of the child with respect to the cut off point, then far fewer children are required to make an estimate of the prevalence of moderate and severe malnutrition. Indeed, there need not be any severely malnourished children included in a survey for an accurate estimate of prevalence to be made. Errors of measurement or recording, that invariably occur, are most likely to be found in the tail of the distribution and will have a much greater effect upon the estimate of the population prevalence by direct counting than by calculation from the mean and standard deviation. It is likely therefor that calculating prevalence gives a more accurate estimate of the true population prevalence than that obtained from counting.

If the same degree of precision is obtained with far fewer subjects there will be major advantages. The data could be obtained and analysed more quickly, and the staff put at less physical risk collecting data. Fewer staff would be diverted from other pressing relief work. The data could be collected by one team which would become highly trained and experienced and produce data with less error. With the same expenditure, the survey team could be employed permanently during the crisis to repeat surveys at frequent intervals and give a clearer view of the evolution of the famine and the adequacy of the humanitarian response.

In none of the surveys that we examined were there sub-populations that differed markedly in nutritional state. If a survey is observed to differ significantly from normality or have a large standard deviation, then we suggest that either two distinctly different populations may have been included in the sample or there is methodological error. All surveys should be checked for normality and any difference investigated; for example, such differences could occur with discrimination against minorities or between displaced and resident populations.

We would emphasise that we have not considered oedematous malnutrition, another form of acute malnutrition that occurs in famine and must be sought. There is a danger that if sample size is reduced this problem may be overlooked entirely. We have also only examined wasting which can change relatively rapidly with disease and the availability and quality of food; stunting in height, which is caused by longstanding malnutrition may show a different pattern.

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Table 1. Surveys analysed

Region	**Country**	**surveys**	**total children**
Africa: Central	Burundi	9	5 095
	Central African Republic	1	443
	Congo	5	3 817
	Kenya	2	570
	Rwanda	13	7 168
	Tanzania	10	7 021
	Uganda	9	5 363
Africa: Sahel	Ethiopia	2	1 583
	Somalia	13	6 274
	Sudan	15	10 187
	Tchad	9	7 042
Africa: Southern	Angola	5	2 938
	Madagasgar	3	1 942
	Malawi	24	9 375
	Mozambique	7	1 861
	Zambia	1	504
	Zimbabwe	3	1 361
Africa: West	Cote d'Ivoire	2	1 377
	Liberia	26	23 229
	Mauritania	2	2 182
	Sierra Leone	19	14 685
Latin America	Haiti	8	5 829
	Nicaragua	3	1 544
Asia	Armenia	1	263
	Afghanistan	4	4 094
	Bangladesh	2	935
	Mongolia	2	1 138
	Philippines	1	630
	Sri Lanka	2	1 822
	Tajikistan	4	3 592
Europe	Albania	1	904
	Bosnia	10	3 196
	Croatia	8	3 458
	Kosova	1	920
	Macedonia	1	896
	total	228	143 238

Table 2 Summary of distributional parameters derived from 228 nutritional surveys.

Statistic		**Mean**	**± sd**	**2.5 & 97.5 centile**		**Normality**[*]
mean	Z score	-0.63	± 0.48	-1.56	+0.36	NS
standard deviation	Z score	0.98	± 0.08	0.83	1.15	NS
Maximum	Z score	2.7	± 0.6	+1.2	+4.1	NS
Minimum	Z score	-3.7	± 0.5	-4.7	-2.4	<0.01
Moment of kurtosis		0.31	± 0.39	-0.36	+1.18	NS
Moment of skewness		0.09	± 0.20	-0.27	+0.52	NS
Kolmorgov-Smirnov statistic	SND**	0.034	± 0.013	0.018	0.059	<0.005
moderate and severe wasting	%	10.1	± 9.0	0.8	33.5	<0.001
moderate wasting (<-2 Z WH)	%	8.6	± 7.2	0.7	28.6	<0.001
severe wasting (<-3 Z WH)	%	1.5	± 0.2	0.0	6.9	<0.001

* The normality of distribution of the parameters was assessed with the Kolmorgov-Smirnov test. NS = not significantly different from a normal distribution.

** SND = Standard Normal Deviates.

WH = weight-for-height

Legends to Figures

Figure 1. The relationship between the sample mean and standard deviation of weight-for-height Z-score for children aged 6 to 59 months in 228 nutritional surveys. The relationship is not significant ($r=0.02$).

Figure 2. The change in moment of Kurtosis of weight-for-height distributions in surveys of children aged 6-59 months as the population becomes progressively more wasted.
Kurtosis = 0.33whz + 0.05; $r=0.41$, $p<0.001$.

Figure 3. The change in the moment of Skewness in weight-for-height distributions in 228 surveys of children aged 6-59 months as the population becomes progressively more wasted.
Skewness = 0.17whz2 + 0.15whz + 0.08; $r=0.33$ $p < 0.001$

Figure 4. Normal probability plots of weight-for-height z-scores of individual subjects from illustrative surveys with different degrees of wasting within the population.
In order from most to least wasted - Mozambique 1992, n=168 maxdiff 0.051; Kenya 1992, n=428, maxdiff 0.024; Ethiopia 1995, n=793, maxdiff = 0.030; Rwanda 1994, n=887, maxdiff = 0.024; Uganda 1998, n = 951, maxdiff = 0.020; Nicaragua 1997, n=528, maxdiff = 0.035; Bosnia 1993, n=452, maxdiff = 0.046; Croatia 1990, n=445, maxdiff = 0.055.
maxdiff = maximum difference from normality with the Kolmorgorov-Smirnov procedure.

Figure 5. The maximum deviation of individual data points from a normal (Gaussian) distribution, determined by the Kolmorgorov-Smirnov procedure, in 228 nutritional surveys carried out in emergency situations. SND = Standard Normal Deviate. The 8 surveys illustrated in figure 4 are marked with a larger square symbol.

CONTRIBUTIONS,

Michael Golden formulated the hypotheses, analysed the data and wrote the paper. Yvonne Grellety was responsible for organising and conducting the majority the surveys and helped interpret the data.

Fig 1

Figure 1. The relationship between the sample mean and standard deviation of weight-for-height Z-score for children aged 6 to 59 months in 228 nutritional surveys. The relationship is not significant (r=0.02).

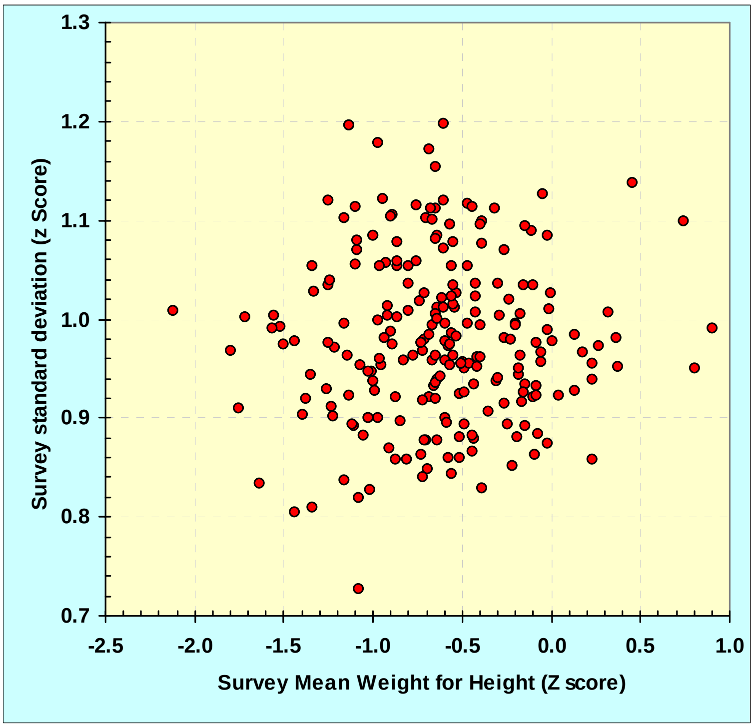

Fig 2

Figure 2. The change in moment of Kurtosis of weight-for-height distributions in surveys of children aged 6-59 months as the population becomes progressively more wasted.
Kurtosis = 0.33whz + 0.05; r=0.41, p<0.001.

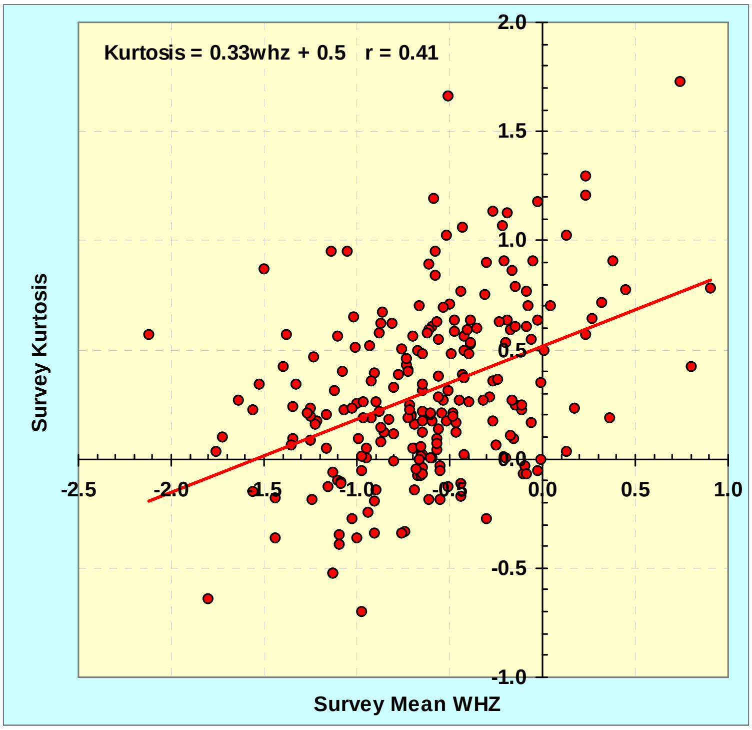

Fig 3

Figure 3. The change in the moment of Skewness in weight-for-height distributions in 228 surveys of children aged 6-59 months as the population becomes progressively more wasted. Skewness = 0.17whz2 + 0.15whz + 0.08; r=0.33 p < 0.001

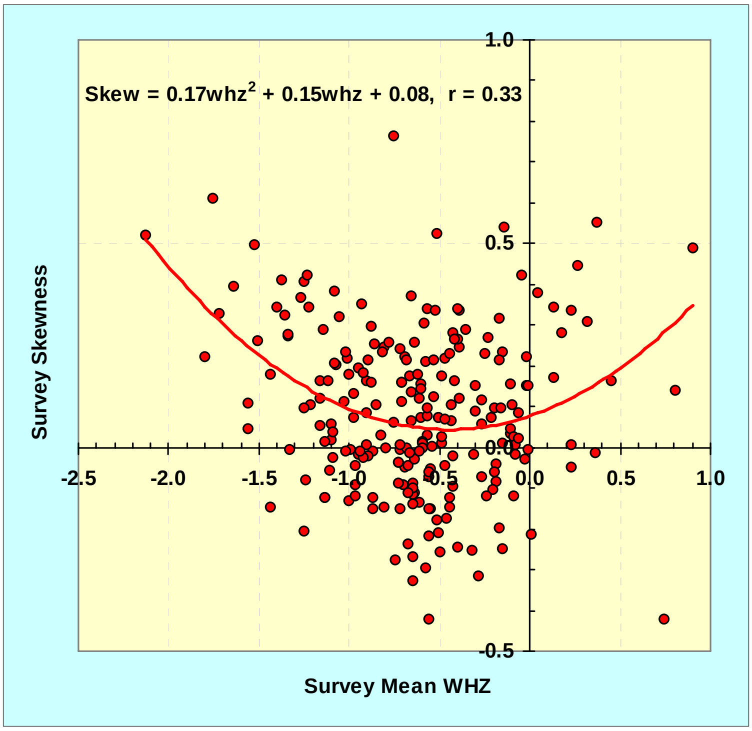

Fig 4

Figure 4. Normal probability plots of weight-for-height z-scores of individual subjects from illustrative surveys with different degrees of wasting within the population.

In order from most to least wasted - Mozambique 1992, n=168 maxdiff 0.051; Kenya 1992, n=428, maxdiff 0.024; Ethiopia 1995, n=793, maxdiff = 0.030; Rwanda 1994, n=887, maxdiff = 0.024; Uganda 1998, n = 951, maxdiff = 0.020; Nicaragua 1997, n=528, maxdiff = 0.035; Bosnia 1993, n=452, maxdiff = 0.046; Croatia 1990, n=445, maxdiff = 0.055. maxdiff = maximum difference from normality with the Kolmorgorov-Smirnov procedure.

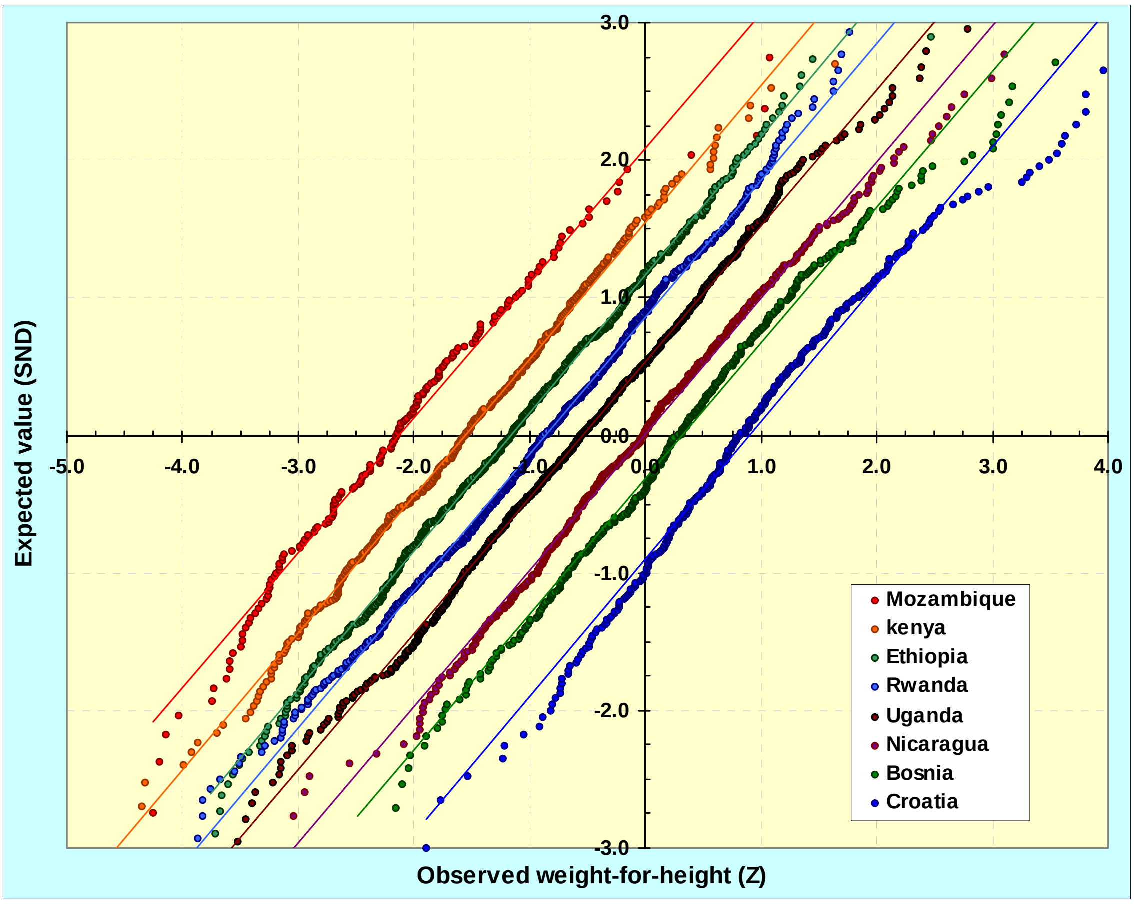

Fig 5

Figure 5. The maximum deviation of individual data points from a normal (Gaussian) distribution, determined by the Kolmorgorov-Smirnov procedure, in 228 nutritional surveys carried out in emergency situations. SND = Standard Normal Deviate. The 8 surveys illustrated in figure 4 are marked with a larger square symbol.