Cut-offs to define outliers in the 2000 CDC Growth Charts

Data quality assessment on anthropometry data:

In the analysis of childhood height and weight data, it is necessary to identify outlier observations, or observations that are considered to be "biologically implausible values (BIVs)". It has become common practice to use z-scores to define which observations are beyond the range of what one would normally expect to find in a population. Typically these outliers are the result of data entry errors or mismeasurement, rather than from true extreme growth.

WHO recommendation on outlier cut-offs (1):

The World Health Organization has defined limits for acceptable data based on the 1977 NCHS/WHO growth charts. Two methods are recommended:

1. Flexible exclusion range: 4 z-score units from the observed mean z-score, with a maximum height-for-age z-score of +3.0.
2. Fixed exclusion range (suitable when the observed mean z-score is above –1.5):

Height-for-age:	<-5.0 and >+3.0
Weight-for-age:	<-5.0 and >+5.0
Weight-for-height:	<-4.0 and >+5.0

These limits have been used in analyses of anthropometric data worldwide. The weight-for-height cutoffs can be applied for BMI-for-age as well.

The 2000 CDC growth charts:

The outlier cutoffs defined for the 1977 NCHS/WHO cutoffs could theoretically be applied to the 2000 CDC growth charts. However, there is an important difference between the two charts that must be accounted for. Whereas the z-scores in the 1977 charts were based on a fixed standard deviation value above and below the median, the 2000 charts allow for a changing standard deviation to account for the skewness of the distributions. Put differently, the 1977 charts were based on an additive model, but the 2000 charts are based on a multiplicative model (using the LMS methodology).

While the LMS model captures the distribution of height, weight and head circumference fairly accurately for measurements that actually occur in the data, its projection into the extreme tails of the distribution can be problematic. For highly skewed indices, such as the weight of older children, there comes a point at which high z-scores become undefined. The problem is simply that the consequence of using a box-cox transformation to account for skewness has the unintended effect of mapping all high values to essentially the same (plausible) z-score.

For example, consider trying to establish an upper limit for the weight of 17-year old girls. The LMS parameters of weight-for-age in this group are: L= -1.838091576, M= 55.18216811, and S= 0.161752634. To set the cutpoints for outliers, we would want to exclude measurements beyond +5.0 z-scores. Using the equation:

$$C = M (1 + LSZ)^{**}(1/L)$$

we would compute the quantity 1 + LSZ = 1+ (-1.8381 * 0.1618 * 5.0) = -0.4870. Since this is a negative value, it is impossible to raise it to the power of 1/L. Thus, the weight corresponding to a +5.0 z-score cannot be computed. In fact, the +4.0 z-score is similarly not calculable.

Alternatively, one can observe the problem in calculating the z-score for a specific measurement. Consider a 17-year-old girl who weighs 150 kilograms (clearly overweight, but not an unreasonable weight). Her z-score would be calculated as +2.83. But suppose that her data were inadvertently entered in the computer as 1500 kilos (a clearly impossible value). Her z-score would not be remarkably different (+3.36) and we would not identify this value as an outlier using the WHO cut-offs.

Recommended solution:

To define outlier measurements, we recommend calculating "flags" for each anthropometric indicator that operate more like the z-scores in the 1977 charts. These flags are created on a linear scale so that their performance at extreme values can still be mathematically calculated. If we calculate these flags using a methodology similar to the 1977 NCHS/WHO growth charts (2), we can avoid the mathematical problems described above.

In this method, we first calculate a standard deviation above and below the median. These are calculated by taking half of the difference between 2 z-scores and 0 z-score points. Using these "fixed" standard deviations, we can then calculate any "flag" or "modified z-score" that we need. For example, we would consider an observation with a weight-for-height "flag" greater than +5.0 to be an outlier.

Calculations:

```
SDlow  = (M-M*(1-2LS)^(1/L))/2
SDhigh = (M*(1+2LS)^(1/L)-M)/2

if Anth < M then Flag = (Anth-M)/SDlow
             else Flag = (Anth-M)/SDhigh
```

where
Anth is the passed in anthropometric measurement for the child.

SDlow or *SDhigh* is the standard deviation calculated in a fashion similar to the NCHS/WHO normalized curves (i.e. using the difference between the 2 z-score point and the mean.)

and

Flag is the z-score as it would have been computed in the WHO methodology, such that the WHO limits can be used.

Using weight-for-age as an example,

```
if  Flag < -5 then BIVwt=1; (too low)
  else if Flag >5 then BIVwt=2; (too high)
  else BIVwt=0; (normal range)
```

These calculations are included in the SAS code for the 2000 CDC growth charts available online and will be incorporated into the next release of Epi-Info.

Reference:

1. World Health Organization. Physical Status: The Use and Interpretation of Anthropometry. WHO technical report series: 854. Geneva, Switzerland: World Health Organization; 1995.
2. Dibley MJ, Goldsby JB, Staehling NW, Trowbridge FL. Development of normalized curves for the international growth reference: historical and technical considerations. Am J Clin Nutr. 1987;46:736-748.
3. Dibley MJ, Staehling NW, Nieburg P, Trowbridge FL. Interpretation of Z-score anthropometric indicators derived from the international growth reference. Am J Clin Nutr. 1987;46:749-762.