

8. CONCLUSION

The goal of the MGRS was to describe the growth of healthy children. Well-defined criteria were applied in the study design to achieve this aim (de Onis et al., 2004b). The sample used for the construction of the growth standards for the head and arm circumferences and the skinfold thicknesses was the same one used for the construction of the standards based on length or height, weight and age (WHO Multicentre Growth Reference Study Group, 2006d, 2006g).

The construction of the child growth curves followed a careful, methodical process. Rigorous methods of data collection, standardized across sites, were followed during the entire study. Sound procedures for data management and cleaning were applied (Onyango et al., 2004). As a result, the anthropometric data available for analysis were of the highest possible quality. The selection of the best statistical approach to construct the standards followed a broad consultative process that included a thorough review of 30 available methods. State-of-the-art statistical methodologies were then employed to generate the standards (Borghini et al., 2006).

The Box-Cox-power-exponential (BCPE) method (Rigby and Stasinopoulos, 2004), with curve smoothing by cubic splines, was selected as the approach for constructing the growth curves. The BCPE accommodates various kinds of distributions, from normal to skewed or kurtotic, as necessary. There was wide variability in the degrees of freedom required for the cubic splines to achieve the best models. Except for head circumference-for-age, which followed a normal distribution, all other standards required the modelling of skewness but not kurtosis. A set of diagnostic tools was used to detect possible biases in estimated percentile or z-score curves. These included examining patterns of differences between empirical and fitted centiles, and comparing observed and expected proportions of children with measurements below selected percentile curves. Percentile and z-score curves for boys and girls were generated for head circumference-for-age (0–60 months), arm circumference-for-age (3–60 months), triceps skinfold-for-age and subscapular skinfold-for-age (3–60 months). Appendix A summarizes the specifications of the BCPE models for each of the standards.

Overall, concordance between smoothed curves and empirical centiles was free of bias in both the median range and the tails, indicating that the resulting curves are an adequate description of the true growth of healthy children. The average absolute difference between smoothed and empirical centiles was 0.091 cm for boys' and girls' head circumference-for-age (Figures 5-8 and 15-18); 0.102 cm and 0.098 cm for boys' and girls' arm circumference-for-age, respectively (Figures 27-30 and 38-41); 0.152 mm and 0.146 mm for boys' and girls' triceps skinfold-for-age, respectively (Figures 50-53 and 61-64); and 0.101 mm and 0.136 mm for boys' and girls' subscapular skinfold-for-age, respectively (Figures 73-76 and 85-88). Taking the sign into account, the average differences are close to zero: 0.031 cm and 0.022 cm for boys' and girls' head circumference-for-age, respectively; 0.004 cm and -0.003 cm for boys' and girls' arm circumference-for-age, respectively; 0.024 mm and 0.028 mm for boys' and girls' triceps skinfold-for-age, respectively; and 0.018 mm and 0.024 mm for boys' and girls' subscapular skinfold-for-age, respectively. These results indicate lack of bias in the fit between smoothed and empirical percentiles.

As was done for the construction of the first set of standards (WHO Multicentre Growth Reference Study Group, 2006d), a restricted application of the LMS method was used for the construction of the indicators arm circumference-for-age and skinfold thicknesses, limiting the Box-Cox normal distribution to the interval corresponding to z-scores where empirical data were available (i.e. between -3 SD and 3 SD). Beyond these limits, the standard deviation was fixed to the distance between ± 2 SD and ± 3 SD, respectively. This approach avoids making assumptions about the distribution of the data beyond the limits of the actual data (e.g. the 3 SD corresponds to the 99.9th percentile).

All four indicators presented in this report are a new addition to the previously available set of indicators in the NCHS/WHO reference. Head circumference-for-age is often used in clinical settings as part of health screening for potential developmental or neurological disabilities in infants and young children (WHO, 1995). Very small and very large circumferences are both indicative of health or developmental risk. Arm circumference-for-age is used as an alternative indicator of nutritional status when the collection of length/height and weight measurements is difficult, as happens in emergency humanitarian situations due to famine or refugee crises (WHO, 1995). Triceps and subscapular skinfold measurements assess the thickness of subcutaneous tissue and reflect fatness primarily. The skinfold indicators are thus a useful addition to the battery of growth standards for assessing childhood obesity.

The WHO Child Growth Standards provide a technically robust set of tool for assessing the well-being of infants and young children. They were derived from children who were raised in environments that minimized constraints to growth such as poor diets and infection. In addition, their mothers followed healthy practices such as breastfeeding their children and not smoking during and after pregnancy. The standards depict normal early childhood growth under optimal environmental conditions and can be used to assess children everywhere, regardless of ethnicity, socioeconomic status and type of feeding. Together, three new elements — a *prescriptive* approach that moves beyond the development of growth references towards a standard, inclusion of children from around the world, and links between physical growth and motor development — provide a solid instrument for helping to assess the health and nutritional needs of the world's children.