

World Health Organization Reference Curves

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Introduction

Childhood overweight and obesity are major public health problems worldwide (1,2). Traditionally, a heavy child meant a healthy child, and the concept “bigger is better” was widely accepted. Today, this perception has drastically changed based on evidence that overweight and obesity in childhood are associated with a wide range of serious health complications and increased risk of premature illness and death later in life (2,3).

Anthropometric references play a central role in identifying children that are overweight or obese, or at risk of becoming so. The assessment of growth based on the appropriate use and interpretation of anthropometric indices is the most widely accepted technique to identify growth problems in individual children and assess the nutritional status of groups of children (4). The correct interpretation of accurate and reliable anthropometric measurements to assess risk, classify children according to variable degrees of overweight and obesity, or evaluate child growth trajectories, is heavily dependent on the use of appropriate growth curves to compare and interpret anthropometric values (5-10).

This chapter presents the growth charts the World Health Organization (WHO) developed for preschool age children (WHO Child Growth Standards) and school-aged children and adolescents (WHO Growth Reference for School-aged Children and Adolescents); it also discusses issues related to their appropriate use for identifying overweight and obese children.

WHO child growth standards (0-60 months)

In April 2006 the World Health Organization released new standards for assessing the growth and development of children from birth to five years of age (11,12). The new standards were developed to replace the National Center for Health Statistics (NCHS)/WHO international growth reference (13), whose limitations have been described in detail elsewhere (4,14).

The origin of the Child Growth Standards dates from the early 1990s when WHO conducted a comprehensive review of anthropometric references. The review showed that the growth pattern of healthy breastfed infants deviated significantly from the NCHS/WHO international reference (15,16). In particular, the reference was inadequate for assessing the growth pattern of healthy breastfed infants (17). An expert group recommended the development of new standards, adopting a novel approach that would describe how children should grow when free of disease and receiving care that followed healthy practices such as breastfeeding and non-smoking (18). This approach would permit the development of a normative standard as opposed to a reference that merely described how children grew in a particular place and time. Although standards and references both serve as a basis for comparison, each enables a different interpretation. Since a standard defines how children should grow, deviations from the pattern it describes are evidence of abnormal growth. A reference, on the other hand, does not provide as sound a basis for making such value judgments, although in practice references often are mistakenly used as standards.

Following the World Health Assembly’s endorsement of these recommendations in 1994, the WHO

Multicentre Growth Reference Study (MGRS) (19) was launched in 1997 to collect primary growth data that would allow the construction of new growth charts consistent with best health practices.

The MGRS, whose goal was to describe the growth of healthy children, was a population-based study conducted in six countries from diverse geographical regions: Brazil, Ghana, India, Norway, Oman, and the USA (19). The study combined a longitudinal follow-up from birth to 24 months with a cross-sectional component of children aged 18–71 months. In the longitudinal component, mothers and newborns were enrolled at birth and visited at home a total of 21 times at weeks 1, 2, 4 and 6; monthly from 2–12 months; and bimonthly in the second year (19).

The study populations lived in socioeconomic conditions favourable to growth. The individual inclusion criteria were: no known health or environmental constraints to growth, mothers willing to follow MGRS feeding recommendations (i.e. exclusive or predominant breastfeeding for at least 4 months, introduction of complementary foods by 6 months of age, and continued breastfeeding to at least 12 months of age), no maternal smoking before and after delivery, single term birth, and absence of significant morbidity. Rigorously standardized methods of data collection and procedures for data management across sites yielded high-quality data (11,12).

The length of children was strikingly similar among the six sites (Figure 1), with only about 3% of variability in length being due to inter-site differences compared to 70% for individuals within sites (20). The similarity in growth during early childhood across human populations means either a recent common origin as some suggest (21) or a strong selective advantage associated with the current pattern of growth and development across human environments. Data from all sites were pooled to construct the standards, following state-of-the-art statistical methodologies (11,22).

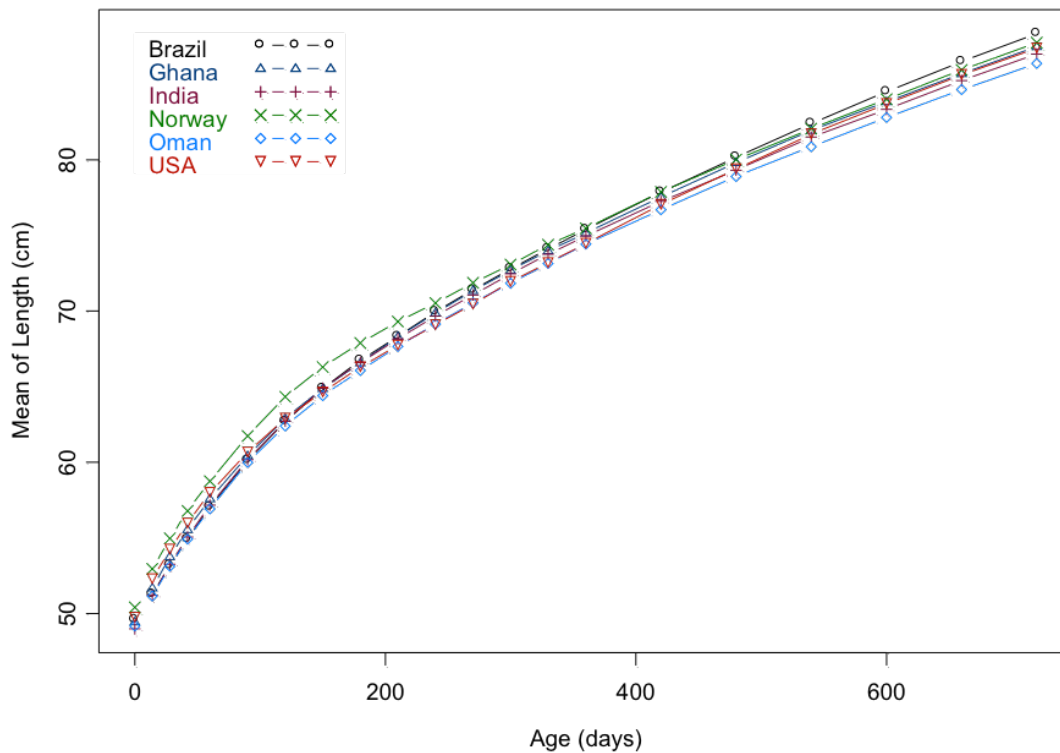


Figure 1. Mean length (cm) from birth to two years for the six WHO Multicentre Growth Reference Study sites

Weight-for-age, length/height-for-age, weight-for-length/height, and body mass index (BMI)-for-age percentile and z-score values were generated for boys and girls aged 0-60 months (11). Standards for head circumference, mid-upper arm circumference, and triceps and subscapular skinfolds were released in 2007 (23); and growth velocity standards for weight, length, and head circumference were issued in 2009 (24). Figure 2 presents a generic growth chart for body mass index-for-age in percentile values for girls aged 0-60 months. The full set of tables and charts is available at the growth standards website (www.who.int/childgrowth/en) together with tools like software, macros, and training materials that facilitate application. The disjunction observed at 24 months in the length/height-based charts represents the change from measuring recumbent length (i.e., lying down) to standing height in children below and above 2 years of age, respectively.

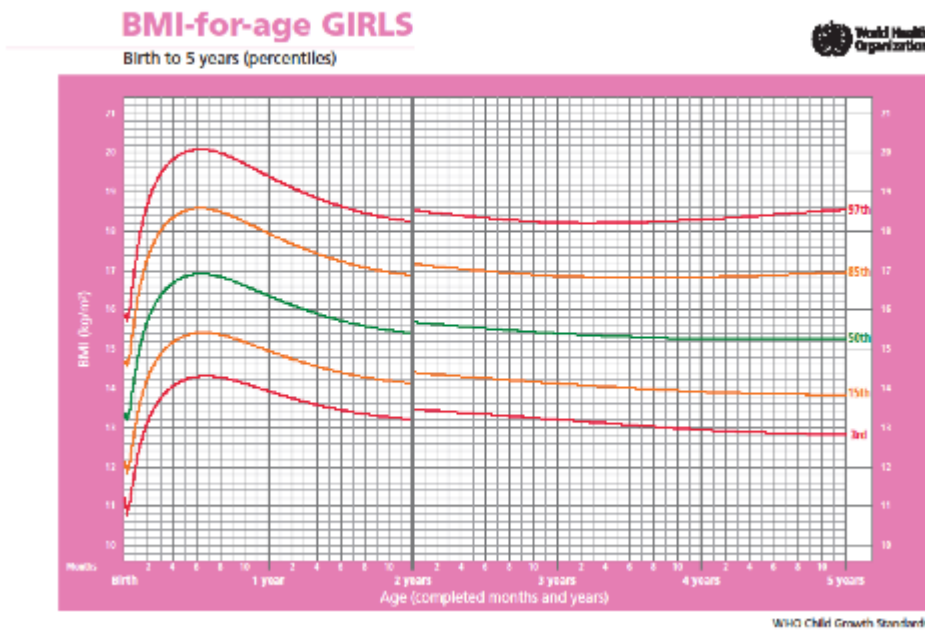


Figure 2. Body mass index-for-age in percentile values for girls aged 0 to 60 months

Detailed evaluation of the WHO standards as part of their introduction has provided an opportunity to assess their impact on child health programmes. Since their release in 2006, the standards have been widely implemented globally, with over 130 countries thus far having adopted them (25). Reasons for adoption include: 1) providing a more reliable tool for assessing growth that is consistent with the Global Strategy for Infant and Young Child Feeding; 2) protecting and promoting breastfeeding; 3) enabling monitoring of malnutrition’s double burden, stunting and overweight; 4) promoting healthy growth and protecting the right of children to reach their full genetic potential; and 5) harmonizing national growth assessment systems. In adopting the WHO growth standards, countries have harmonized best practices in child growth assessment and established the breastfed infant as the norm against which to assess compliance with the right of children to achieve their full genetic growth potential.

The WHO standards provide an improved tool for monitoring the rapidly changing rate of growth in early infancy (9,26). They also demonstrate that healthy children from around the world who are raised in healthy environments and follow recommended feeding practices have strikingly similar patterns of growth. The ancestries of the children included in the WHO standards were widely diverse. They included people from Europe, Africa, the Middle East, Asia and Latin America. In this regard they are similar to growing numbers of populations with increasingly diverse ethnicities. These results indicate that we should expect the same potential for child growth in any country. They also imply that deviations from this pattern must be assumed to reflect adverse conditions that require correction, e.g. inadequate or lack of breastfeeding, nutrient-poor or energy-excessive complementary foods, unsanitary environments, deficient health services and/or poverty.

Technical and scientific research has validated the robustness of the WHO standards and improved

understanding of the broad benefits of their use:

- The WHO standards identify more children as severely wasted (27). Besides being more accurate for predicting mortality risk (28-30), using these standards results in shorter duration of treatment, higher rates of recovery, fewer deaths, and reduced loss to follow-up or need for inpatient care (31).
- The WHO standards confirm the dissimilar growth patterns for breastfed and formula-fed infants, and they provide an improved tool for correctly assessing the adequacy of growth in breastfed infants (7-9). They thereby reduce considerably the risk of unnecessary supplementation or breastfeeding cessation, which are major sources of morbidity and mortality in poor-hygiene settings.
- In addition to confirming the importance of the first two years of life as a window of opportunity for promoting growth, the WHO standards demonstrate that intrauterine retardation in linear growth is more prevalent than previously thought (5,9), thereby making a strong case for starting interventions early in pregnancy and even before.
- Another important feature of the WHO standards is that they demonstrate that undernutrition during the first six months of life is a considerably more serious problem than previously thought (5,10), thereby reconciling the rates of undernutrition observed in young infants and the prevalence of low birth weight and early abandonment of exclusive breastfeeding.
- Using the WHO standards results in a greater prevalence of overweight that varies by age and the nutritional status of the index population (5)(Figure 3). The WHO standards also improve early detection of excess weight gain among infants and young children (6,32), showing that obesity often begins in early childhood, as indeed should measures to tackle this global public health menace.
- Lastly, the WHO standards are an important means for ensuring the right to health of all children and achieving their full growth potential. They provide sound scientific evidence that, on average, young children everywhere experience similar growth patterns when their health and nutrition needs are met. For this reason the WHO standards can be used to assess compliance with the UN Convention on the Rights of the Child, which recognizes the duties and obligations to children that cannot be met without attention to normal human development.

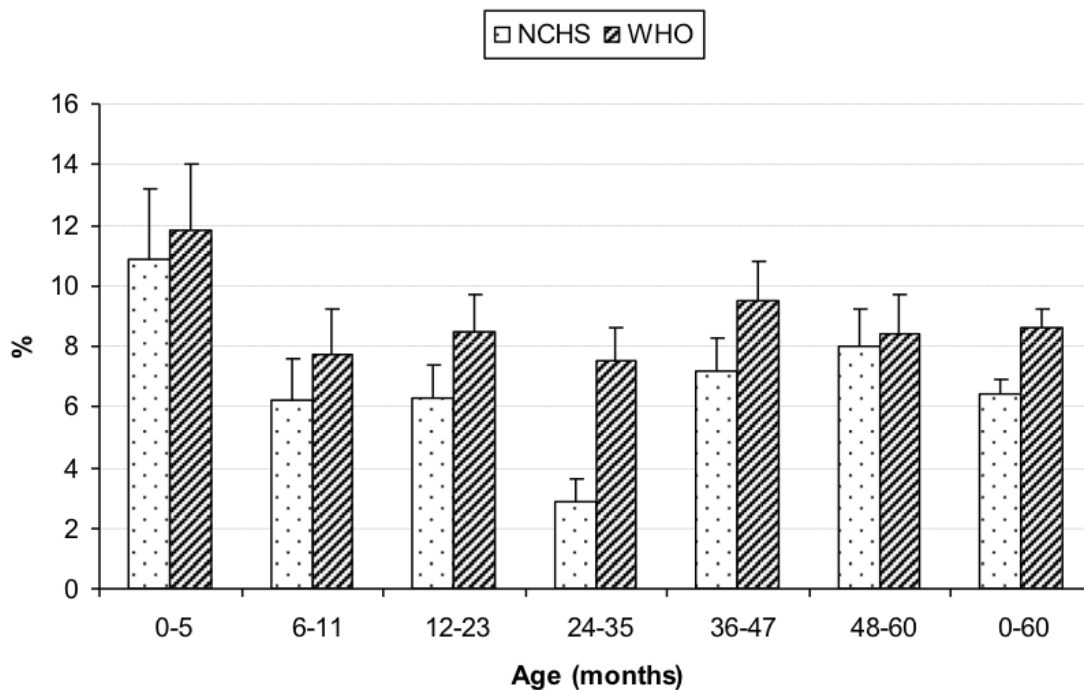


Figure 3. Prevalence of overweight (above +2 SD weight-for-length/height) by age based on the WHO standards and the NCHS reference in the Dominican Republic.

WHO growth reference for school-aged children and adolescents (61 months-19 years)

Much less is known about the growth and nutritional status of school-age children and adolescents. Reasons for this lack of knowledge include the rapid changes in somatic growth, problems of dealing with variations in maturation, and difficulties in separating normal variations from those associated with health risks.

The release of the WHO standards for preschool children and increasing public health concern over childhood obesity stirred interest in developing appropriate growth curves for school-age children and adolescents. As countries proceeded to implement WHO growth standards for preschool children, the gap across all centiles between these standards and existing growth references for older children became a matter of concern. The 1977 NCHS reference (13) and more recent examples such as the CDC 2000 reference (33,34), the IOTF cut-off points (35) and other contemporary references (36-38) all suffer from a biological drawback characterised by weight-based curves, such as the BMI, that are markedly skewed to the right, thereby redefining overweight and obesity as ‘normal’ (39,40). The upward skewness of these references results in an underestimation of overweight and obesity and an overestimation of undernutrition (e.g., prevalence of thinness or children below the 3rd percentile) (41,42). The latter is worrisome as it might prompt the overfeeding of healthy, constitutionally small children.

A potential approach to overcoming this flaw would be to use lower cut-offs to screen for overweight and obesity (40). However, better still would be to use growth curves based on samples that have achieved expected linear growth while not being affected by excessive weight gain relative to linear growth (43). The case made for using a national reference has traditionally been that it is more representative of a given country's children than any other reference could possibly be. But given the child obesity epidemic, this is no longer valid for weight or BMI. No sooner is a new reference produced than it is out of date.

The need to harmonise growth assessment tools, conceptually and pragmatically, prompted evaluation of the feasibility of developing a single international growth reference for school-aged children and adolescents (41). Recognising the limitations of existing reference curves (e.g. the NCHS/WHO growth reference, the CDC 2000 growth charts, and the IOTF cut-offs) for assessing childhood obesity, the expert group recommended that appropriate growth curves for these age groups be developed for clinical and public health applications. It also agreed that a multicentre study, similar to that leading to the development of the WHO Child Growth Standards from birth to 5 years of age, would not be feasible for older children because it would be impossible to control the dynamics of their environment. It was thus decided that a growth reference should be constructed for this age group using available historical data (43).

Following the expert group recommendations, WHO proceeded to reconstruct the 1977 NCHS/WHO growth reference for the period 5-19 years. It used the original sample (a non-obese sample with expected heights), supplemented with data from the WHO Child Growth Standards (to facilitate a smooth transition at 5 years), and applied state-of-the-art statistical methods (44). The new curves are closely aligned with the WHO Child Growth Standards at 5 years, and the recommended adult cut-offs for overweight and obesity at 19 years (BMI of 25 and 30, respectively)(Figure 4). The full set of tables and charts for height, weight and BMI can be found at: www.who.int/growthref/en, including application tools such as software for clinicians and public health specialists (45).

Figure 4. WHO BMI-for-age cut-offs for defining obesity, overweight, thinness and severe thinness in school-age and adolescent boys.

The WHO reference for school-age children and adolescents provides a suitable reference for the 5 to 19 years age group to be used in conjunction with the WHO Child Growth Standards from 0 to 5 years. Since its release in 2007 many countries have switched to using these charts including developed countries, for example Canada (Figure 5), Switzerland (46) and several others in Europe (47).

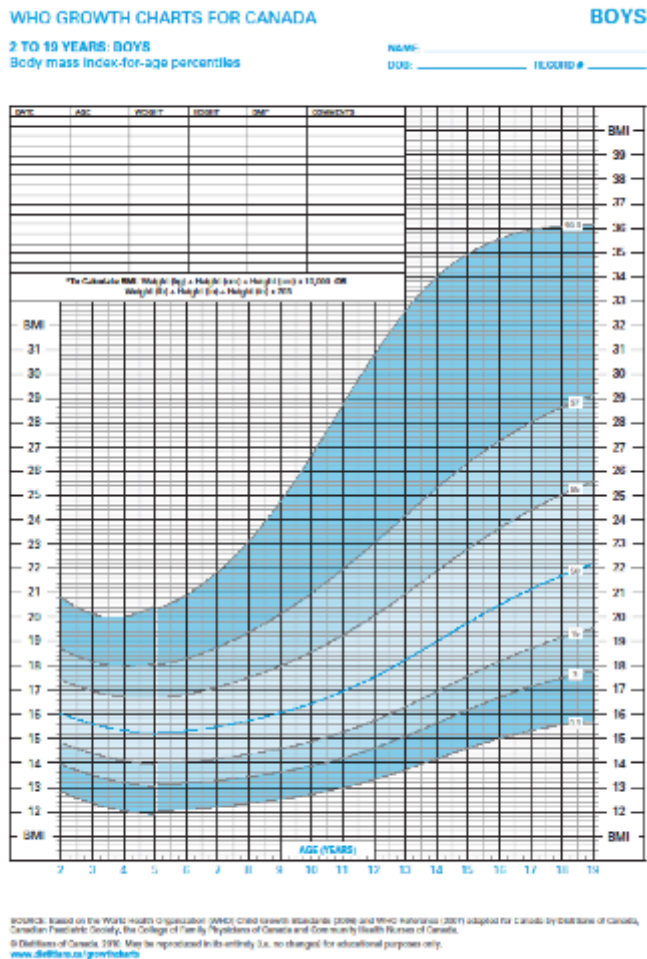


Figure 5. WHO Growth Charts for Canada. Body mass index-for-age percentiles, 2 to 19 years: boys

Defining childhood overweight and obesity in individuals and populations

The classification of overweight and obesity is based not only on the use of an appropriate reference population with which to compare the individual child or community; it is also grounded in the selection of a suitable anthropometric indicator together with appropriate cut-off points to classify children according to severity levels which best identify risk of overweight/obesity-related morbidity and mortality.

The body mass index, a measure of body mass relative to height, has emerged as the most practical, universally applicable, inexpensive and non-invasive anthropometric indicator for classifying overweight and obesity (4). Although there is some reluctance to describe children as obese on the basis of BMI alone, i.e. without taking into account a more direct measure of body fat (48), recognition of the difficulties inherent in obtaining more proximate measures of body fat and lack of references to interpret them has resulted in BMI-for-age alone being used to define overweight and obesity. In its favour, increased BMI-for-age in childhood and adolescence is associated with higher percentages of body fat (49-51) and known risk factors for cardiovascular disease (52). It is important to note that, in preschool-age children, weight-for-length (below two years of age) and height (above two years of age) are also valid indicators for classifying young children as overweight and obese, and can be used instead of BMI-for-age as they yield very similar results (1).

The cut-off points WHO recommends for classifying overweight and obesity in preschool-age children (0-5 years) are detailed in the training course on child growth assessment (53). Children above +1SD are described as being “at risk of overweight”, above +2SD as overweight, and above +3SD as obese. WHO has opted for a cautious approach because young children are still growing in terms of height and there are few data on the functional significance of the upper end of the BMI-for-age distribution cut-offs at such young ages in healthy populations like the WHO standards (54). Caution is all the more important given the risks for very young children, in light of their nutrient requirements for growth and development, of being placed on restrictive diets.

For older children, the WHO adolescence BMI-for-age curves at 19 years closely coincide with the definitions for adult overweight (BMI 25) at +1 SD and adult obesity (BMI 30) at +2 SD, which were derived based on associations with mortality (4). As there were no similar associations with functional outcomes in the school age and adolescent periods, the BMI cut-offs at 19 years were tracked back along the +1SD and +2SD lines to age 5 years (44)(Figure 4). Recent research shows that obese and overweight school-age children and adolescents as defined by these BMI-for-age cut-offs are at substantially increased risk for adverse levels of several cardiovascular disease risk factors such as hypertension, high insulin, high HOMA, high triglycerides, low HDL-Cho, high LDL-Cho, and high uric acid (55). These results provide evidence that the WHO cut-offs for childhood overweight and obesity are well-suited to identifying children with metabolic and vascular risk.

Table 1 summarizes the WHO classification of nutrition conditions in children and adolescents based on anthropometry.

Table 1: WHO Classification of nutrition conditions in children and adolescents based on anthropometry

Classification	Condition	Age: Birth to 60 months ^{1,3} Indicator and cut-off	Age: 61 months to 19 years ^{2,3} Indicator and cut-off
Based on body mass index (BMI)	Possible risk of overweight	BMI-for-age (or weight-for-height) >1SD to 2SD	
	Overweight	BMI-for-age (or weight-for-height) >2SD to 3SD	BMI-for-age >1SD (equivalent to BMI 25 kg/m ² at 19 y)
	Obese	BMI-for-age (or weight-for-height) >3SD	BMI-for-age >2SD (equivalent to BMI 30 kg/m ² at 19 y)
	Thin		BMI-for-age < -2 to -3 SD
	Severely thin		BMI-for-age < -3 SD
Based on weight and height	Stunted	Height-for-age < -2SD to -3SD	Height-for-age < -2SD to -3SD
	Severely stunted	Height-for-age < -3SD	Height-for-age < -3SD
	Underweight	Weight-for-age < -2SD to -3SD	Weight-for-age (up to 10y) < -2SD to -3SD
	Severely underweight	Weight-for-age < -3SD	Weight-for-age (up to 10 y) < -3SD
	Wasted	Weight-for-height < -2SD to -3SD	
	Severely wasted	Weight-for-height < -3SD	

1. **WHO Child Growth Standards:** <http://www.who.int/childgrowth/en/index.html>
2. **WHO Growth Reference for school-aged children and adolescents:** <http://www.who.int/growthref/en/>
3. Z-score and percentile equivalence:

- 3 = 0.1
- 2 = 2.3
- 1 = 15.9
- +1 = 84.1
- +2 = 97.7
- +3 = 99.9

In assessing levels of severity for overweight and obesity in children under age 5 years, it is important to consider the actual value in kg of “excess” weight at different cut-offs for a still-growing 5-year-old in contrast to an adolescent who has reached adult height. For example, the “excess weight” carried by a boy of median height-for-age with a BMI-for-age of 2 SD at 19 years is 23.3 kg, while the equivalent “excess” for a boy at age 5 is 3.7 kg. Assuming that there is “excess weight” in both cases, its implications are likely greater for the former, who has reached his adult height, than for the latter, who could still grow (in terms of height) into his weight (56). When evaluating young children, clinicians might even prefer to avoid classifying a child at this age (0-5 years), and focus instead on the individual growth trajectory and the clinical assessment. Clinicians can also assess more proximate measures of body fat in individual children such as the triceps and subscapular skinfolds for which WHO standards are also available (24,26).

Conclusion

Growth curves are an essential tool in paediatric practice. Their value resides in helping to determine the degree to which physiological needs for growth and development are being met during the important childhood period. However, their usefulness goes far beyond assessing children's nutritional status. Many governmental and international intergovernmental and nongovernmental agencies rely on growth charts for assessing the general well-being of populations, formulating health and related policies, and planning interventions and monitoring their effectiveness.

Accurate interpretation of child growth depends on prescriptive standards or, if unavailable, on reference data that accurately estimate the prevalence of overweight and obesity. Using the right growth curves is crucial since the accurate evaluation of growth trajectories and the appropriate choice of interventions to improve child health are determined on this basis.

There is broad international consensus concerning the utility of the WHO Child Growth Standards for assessing the growth of children 0 to 5 years of age. The standards are derived from children who were raised in environments that minimised constraints to growth such as poor diets and infection. In addition, their mothers followed healthy practices such as breastfeeding and not smoking during and after pregnancy. The standards depict normal human growth under optimal environmental conditions and can be used to assess children everywhere, regardless of ethnicity, socioeconomic status and type of feeding. They also demonstrate that healthy children from around the world who are raised in healthy environments and follow recommended feeding practices have strikingly similar patterns of growth.

The International Pediatric Association (57) and several other national and international professional associations have endorsed the use of the WHO growth standards. The European Society for Paediatric Gastroenterology, Hepatology and Nutrition (ESPGHAN) (42,58) has also recommended their use in Europe. According to ESPGHAN, infants who are breastfed for the first 12 months of life show a slower growth pattern during infancy, which is likely to be associated with less obesity and improved health later in life. Another justification for their recommendation is that use of the standards has the potential to encourage prolonged breastfeeding and increase awareness about early obesity (42).

To complement the growth standards for under-five children, WHO developed a growth reference for school-aged children and adolescents. The reference's curves are closely aligned with the WHO Child Growth Standards at 5 years, and the recommended adult cut-offs for overweight and obesity at 19 years. They fill the growth-curve gap and provide an appropriate reference for the 5 to 19 years age group. Obesity and overweight defined using the WHO BMI-for-age cut-offs identify children with higher metabolic and vascular risk, while emphasising the importance of preventing overweight and obesity in childhood to reduce cardiovascular risk.

As a final note, it is essential that the same reference data be used in assessing both individuals (clinical use) and populations (health planning use) to ensure coherence between what paediatricians see in their daily practice and the population-based data health planners use in

designing treatment and preventive services.

Note: WHO holds the copyright for the WHO Child Growth Standards and the WHO Growth Reference for School-aged Children and Adolescents.

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