Lead Review Article

February 2001: 31–36

The New Childhood Growth Charts

Susan B. Roberts, Ph.D., and Gerard E. Dallal, Ph.D.

New childhood growth percentiles have been published recently by the Centers for Disease Control and Prevention, and are designed to replace the widely used 1977 National Center for Heath Statistics percentiles. International definitions for overweight and obesity in childhood, based on the body mass index, also have been published. This review discusses appropriate uses of the new percentile charts and international definitions of overweight.

Introduction

Weight, height, and head circumference are important indicators of development and nutritional adequacy in childhood. These measurements are therefore used by pediatricians to help assess whether the development and feeding of individual patients is adequate and to detect the presence of overweight or undernutrition. Researchers also use information on weight, height, and head circumference to examine the effects of diet and other factors during childhood.

The use of anthropometric measurements during childhood requires recognized reference values against which individuals and groups can be compared. Until recently, the 1977 National Center for Health Statistics (NCHS) percentiles, consisting of 14 age- and gender-specific charts for weight, length/height, weight-for-height, and head circumference percentiles,[1] were recommended for use in the United States. These percentile charts were also adopted by the World Health Organization for worldwide use[2–4] in recognition of the fact that they provided adequate standards for healthy development in a wide range of racial groups.

The 1977 NCHS percentiles[1] were an important advance when they were published because they were the first percentiles developed using national survey data. Additional nonrepresentative data from the Ohio Fels Longitudinal Study[5] were included in the data set used to develop the percentiles owing to the lack of nationally representative data for people 0–2 years of age. However, the percentiles for 2–18-year-olds were derived exclusively from national survey data. The 1977 NCHS percentiles were intended to provide reference values that represent the range of usual pattern of growth within the national population. Thus, they were planned to describe normal rather than recommended growth. Because they were derived from measurements of children growing up in an affluent western country (i.e., the United States), however, they were also widely accepted as a standard indicating the range of desirable, healthy growth.

Drs. Roberts and Dallal are with the Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University, Boston, MA 02111, USA. The work was funded in part with USDA contract 53-3K06-5-10. Contents of this publication do not necessarily reflect the views or policies of the U.S. Department of Agriculture.

The 2000 Centers for Disease Control Percentiles Compared with 1977 National Center for Health Statistics Percentiles

A revision of the 1977 NCHS percentiles was initiated by the U.S. Government in 1985 because percentile charts need to be updated periodically (to reflect secular changes) and because there were known flaws in the 1977 NCHS percentiles that made them imperfect indicators of normal growth.[1] In particular, the use of the nonrepresentative Fels longitudinal data for birth to 3 years[5] was recognized to be problematic. The Fels data were derived from infants living in Ohio between 1929 and 1975, who had different birth weights and different growth rates from current national values. The population was also primarily formula-fed, and it is known that the growth rate of breast-fed and formula-fed infants differs substantially during the first 1–2 years of life.[6] With approximately 1/3 of U.S. infants now breast-fed to 3 months,[7] percentiles based almost exclusively on bottle-fed infants are unsuitable for a large segment of the infant population.

The new updated percentile charts were published by the Centers for Disease Control (CDC) in May 2000 (http://www.cdc.gov/growthcharts)[7] and are recommended for use as an enhanced instrument to evaluate the size and growth of infants and children.[7] In addition to providing a more up-to-date set of reference growth data that have been smoothed using improved statistical techniques, several features of the new percentile charts are noteworthy.

The New Charts Give Additional Percentiles and Extend to 20 Years of Age

The 1977 NCHS percentile charts spanned the 5th to the 95th percentile, and thus approximately 10% of infants and children had values outside the upper and lower percentiles. Because classification of the greatest number of children is desirable, the 2000 CDC charts also give 3rd and 97th percentiles. This effectively reduces the number of infants and children who lay outside the upper and lower limits. In addition, the 2000 CDC percentile charts extend to 20 years of age compared with the previous upper limit of 18 years in the 1977 NCHS percentile charts. The expanded age range again increases the number of children who can be monitored with the charts, and this is particularly valuable in the body mass index charts in view of the rising prevalence of adolescent obesity.[8]

The Revised Percentile Charts are More Firmly Based on Recent Normative Patterns of Childhood Growth

The 2000 CDC percentile charts are derived primarily from data from the National Health Examination Surveys conducted by NCHS from 1963 to 1994 and include data from different racial groups within the United States.[7] The surveys include two cycles of the National Health Examination Survey (NHES II and III) and three cycles of the National Health and Nutrition Examination Surveys (NHANES I, II, and III). In addition, a limited amount of supplementary data was incorporated, primarily at birth, where national survey data are lacking.[7] It should be noted that although racial differences in growth patterns have been reported, they appear to be small and inconsistent,[7] and factors such as nutrition, environment, and family economic situation are recognized as quantitatively more important.[9–13]

One important intended consequence of having more representative data is that there is better continuity between the 0–3-year charts and the ≥2-year charts. Previously, owing to the use of nonrepresentative data for people ages 0–3 and national data for people ages ≥2, there were widely differing weights and some differences in height between the two percentile charts for the overlap period of 2–3 years. As shown in Figures 1 and 2, height values for the same percentiles differed by up to 2 cm and weight differed by up to 1.5 kg. Moreover, because the discrepancies in weight and height occurred at different ages within the 2–3-year overlap period, it was possible for a child to appear overweight on the 0–3-year percentiles but not on the 2–18-year percentiles. By contrast with the 1977 NCHS percentiles, the 2000 CDC percentiles for 0–3 and ≥2 years are closely comparable for both weight and height during the overlap period as shown in Figures 1 and 2. It should be noted that the 2000 CDC percentiles have been adjusted slightly to account for the

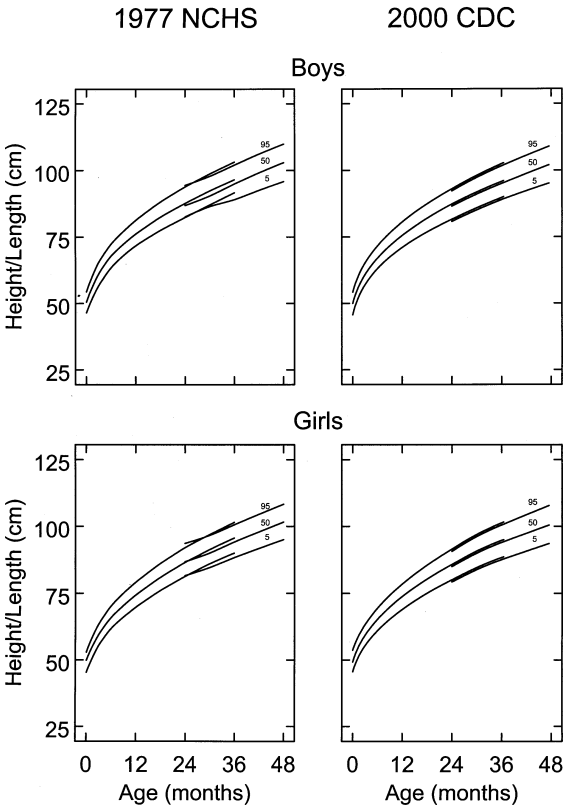

Figure 1. 1977 National Center for Health Statistics (NCHS) and 2000 Centers for Disease Control (CDC) percentiles for height (5th, 50th, 95th) for the age period 0–5 years in boys and girls. Both the 0–3-year and 2–18-year charts are used to illustrate the different overlap period in the NCHS versus the CDC percentiles.

fact that recumbent length (used in the 0–3-year percentiles) should be greater than stature (i.e., height measured vertically during the period 2–18 years) for any individual. In national survey data the mean measured difference is 0.8 cm.[7]

Another significant consequence of updating the data is that the new percentiles better represent current growth patterns. As shown in Figure 3, height percentiles are broadly similar between 1977 NCHS and 2000 CDC charts. Weights are similar between 2 and 13 years, but CDC values tend to be higher than 1977 NCHS for the period 0–2 years and lower for 15 years and older. One potential consequence of the higher weights from 0–2 years is that fewer toddlers will be classified as having high weight-for-length. Because treatment of overweight is not usually recommended before 2 years,[14] however, the relative underclassification of overweight is of limited practical significance.

The New Charts Now Include Body Mass Index Values for Age 2 and Older

The 1977 NCHS percentile charts did not include body mass index (BMI, kg/m^2) values, but these have been in-

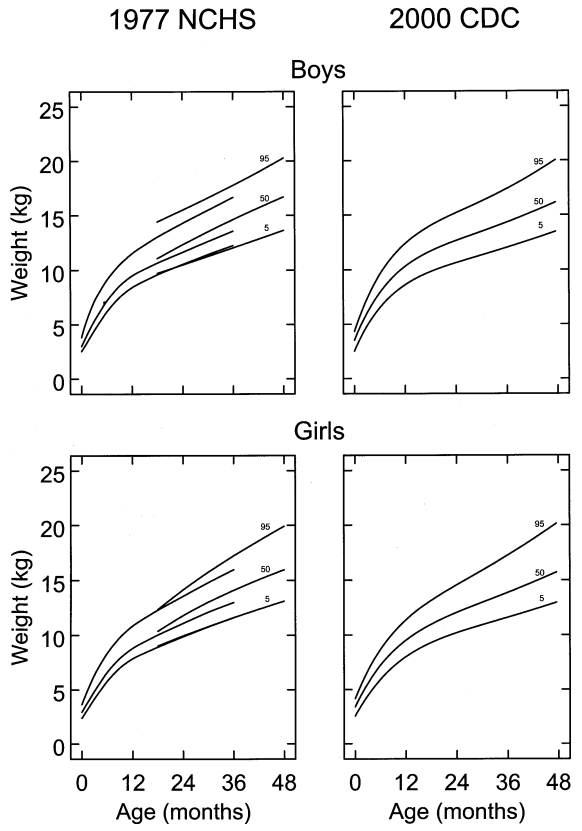

Figure 2. 1977 National Center for Health Statistics (NCHS) and 2000 Centers for Disease Control (CDC) percentiles for weight (5th, 50th, 95th) for the age period 0–5 years in boys and girls. Both the 0–3-year and 2–18-year charts are used to illustrate the different overlap period in the NCHS versus the CDC percentiles.

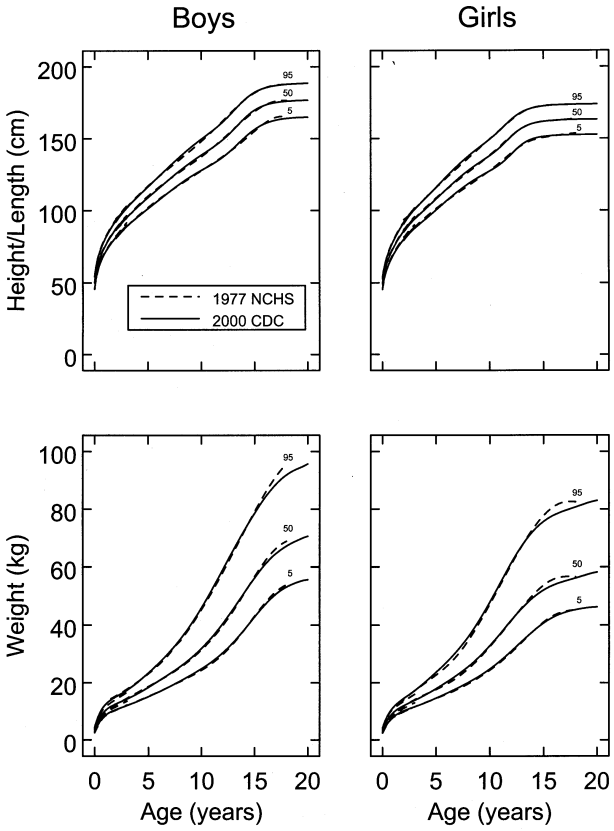

Figure 3. 1977 National Center for Health Statistics (- - - - - -) and 2000 Centers for Disease Control (————) percentiles for weight and height (5th, 50th, 95th) for the age period 0–20 years in boys and girls.

cluded in the 2000 CDC percentile charts (Figure 4) because BMI is a better indicator of relative weight than weight-for-height.[15] BMI percentiles are given for 2 years and older, and are provided primarily to aid diagnosis of overweight and underweight. Current U.S. recommendations for diagnosis of overweight suggest that the 95th percentile be used to diagnose overweight and the 85th percentile to identify children at risk of overweight.[15] For this reason, the 2000 CDC BMI percentiles include both 85th and 95th values. BMI changes with age, and thus the definition of overweight BMI varies over time from a low of 17.5–18.5 (in boys and girls at 4.25 and 4 years, respectively) to 30.5–31.7 (in boys and girls at 20 years, respectively).

NHANES III data for ages 6 and over were not included in the data set used to calculate the BMI percentiles because of the marked increase in weight of children 6 years and older in NHANES III compared with previous surveys. The inclusion of NHANES III data would have shifted the percentiles up and resulted in a relative underclassification of the prevalence of overweight. Because the 85th percentile of BMI is used to classify risk of overweight and the 95th percentile is used to classify over-

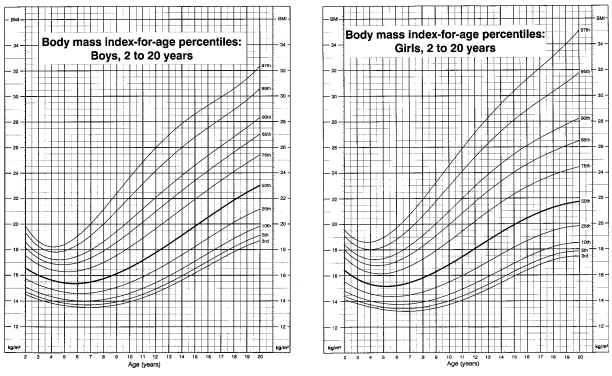

Figure 4. The Centers for Disease Control growth charts: United States. Body mass index (BMI, kg/m^2) percentiles for boys and girls ages 2–20 years. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

weight,[15] the data used effectively define overweight as a fixed percentage relative to population surveys prior to NHANES III. Thus, the BMI charts can be considered more as recommendations for the healthy range of BMI rather than current population values because they are designed primarily to provide a reference for the diagno-

sis of overweight. They potentially can be used to diagnose underweight as well (e.g., at the 10th or 5th percentiles) but accepted definitions for underweight are needed.

It is important to note that BMI is not a perfect indicator of body fatness and thus may falsely classify some children of normal fatness as overweight and some overweight children as not overweight.[16] Some component of the variability in the relationship between BMI and body fatness may be due to error in the measurement of body fatness. Factors such as enhanced muscular development, large head size, and a high torso-to-leg ratio, however, may all falsely elevate BMI into an overweight range in some nonoverweight children. The potential for false classification of children is especially a concern before age 5, when the high BMI percentiles are very close together. For example, differences in head circumference between a 3-year-old child on the 10th head circumference percentile and one on the 90th percentile translate into a body weight difference of approximately 0.75 kg (assuming the head weighs 1.7 g/cm^3 and is a sphere). A 3-year-old child's BMI would therefore vary by approximately 0.85 units depending on whether head circumference was on the 10th or 90th percentile. This could mean the difference between the 75th and 85–95th percentile for BMI, or in other words the difference between no weight concern and a diagnosis of risk of overweight. The effect of the relative length of torso and legs can also be predicted using theoretical calculations. Assuming that the percentage of standing height attributed to torso varies from 35% to 38% and that, for a given contribution to height, torso weight is twice as heavy but of similar fatness to that of legs or neck,[17] BMI would vary by approximately 0.4 units. These calculations highlight the potential for misclassification of individuals, especially those between the 85th and 95th percentiles. Until improved methods for determining body fatness are routinely available, some individual judgment is needed in applying BMI standards for risk of overweight to individual children.

Limitations in the Use of the 2000 CDC Percentiles

Although an important advance over the 1977 NCHS percentiles, the 2000 CDC percentiles are not necessarily ideal for use in all infants and children. In particular, they may misdiagnose the normalcy of growth in young, exclusively breast-fed infants. This is because there are recognized differences in the growth patterns of infants depending on whether they are breast-fed or bottle-fed in the first months of life. Breast-fed infants typically gain more weight than expected based on the 1977 NCHS percentiles (themselves derived primarily from formula-fed infants) between birth and 6–7 months; breast-fed infants then gain less weight until at least 12 months.[18] The 2000 CDC percentile charts were derived from both breast-fed and formula-fed infants and, although they better reflect the average growth pattern of infants who received mixed feedings, they may still falsely indicate high weight gain in breast-fed infants up to 7 months. No finalized charts are currently available for exclusively breast-fed infants, but preliminary percentile charts have been published by the World Health Organization,[6] and data are currently being collected from seven international sites to develop new international standards for growth in exclusively breast-fed infants.[7]

In addition, the 2000 CDC growth percentiles (similar to other national percentile charts) show average growth patterns that do not reflect the individual pattern of growth during the adolescent growth spurt. This is because the adolescent growth spurt in an individual child typically lasts 2–3 years, but the timing varies substantially between individuals so that some children enter their growth spurt period by 10 years or earlier and others do not complete it until age 16 or 17.[19] Percentile charts based on cross-sectional data (such as the 1977 NCHS and 2000 CDC charts) effectively average growth across the prepubertal period, the adolescent growth spurt, and the postpubertal period of different children, giving an apparently similar rate of growth throughout middle and late childhood when in fact individual rates of growth vary substantially and predictably in a very different pattern. Moreover, weight and height velocities do not exactly coincide.[19] For these reasons, care must be taken to avoid false-positive diagnosis of overweight during the pubertal period. Percentile charts for weight and height based on longitudinal growth measurements[20] might in theory usefully supplement existing growth charts for the pubertal period, but currently available charts are derived from small nonrepresentative samples measured more than 35 years ago.

Comparison of the 2000 CDC Charts with International BMI Charts

At the same time that the 2000 CDC percentiles were published, Cole et al.[21] reported internationally derived, age-specific BMI values for children equivalent to BMI definitions of overweight (BMI = 25) and obesity (BMI = 30) in adults. To do this, Cole et al.[21] obtained national survey data from six countries (Brazil, Britain, Hong Kong, the Netherlands, Singapore, and the United States). For each country, the percentiles equivalent to BMI values of 25 and 30 at age 18 years were determined, and then BMI values at different childhood ages were obtained for the same percentiles. As shown in Figure 5, there was substantial agreement in childhood BMI values between the six countries, and thus mean values for different ages were computed to give age-specific BMI cut-offs equivalent to adult BMIs of 25 and 30. The theoretical advantage of this approach, which was recommended by an International

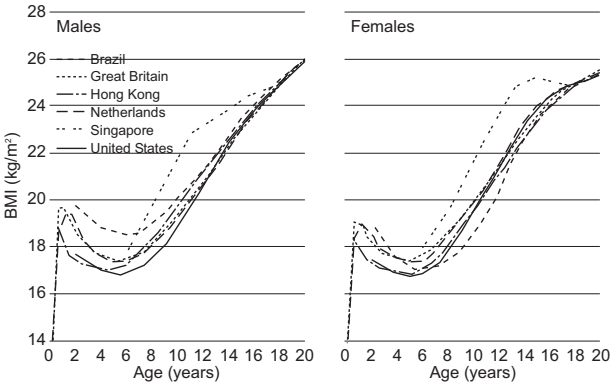

Figure 5. Percentiles for overweight in six countries for boys and girls ages 2–20 years passing through body mass index (BMI, kg/m^2) of 25 and 30 at age 18 years. Reprinted with permission from Cole et al.[21]

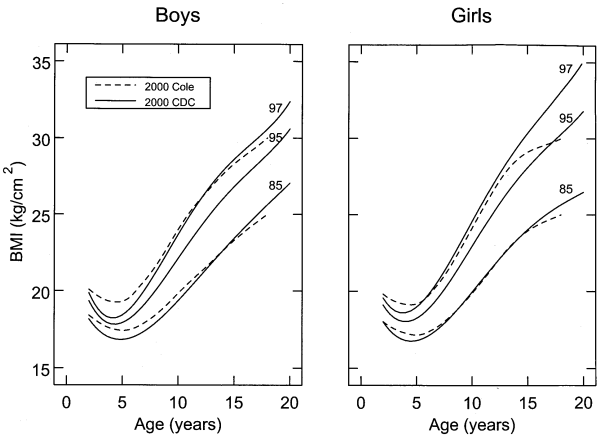

Figure 6. Comparison of Cole et al.[21] body mass index (BMI, kg/m^2) definitions of overweight and obesity during childhood (- - - - -) with 2000 Centers for Disease Control (CDC) 85th and 95th percentiles (defined as risk of overweight and overweight, respectively) and the 2000 CDC 97th percentile (——).

Obesity Task Force,[22,23] is that it attempts to create absolute BMI cut-offs during childhood that equate definitions of overweight and obesity between children and adults. Adult BMI definitions of 25 for overweight and 30 for obesity were originally developed based on increased health risks[24] and it is not currently known whether equivalent percentiles in childhood confer similar risks. Nevertheless, the publication of these childhood BMI cut-offs derived from international data raise the question of the extent to which international and national definitions of overweight are comparable, and if they are not, which standard should be used to define overweight in the United States and elsewhere?

Figure 6 shows a comparison of the CDC 85th and 95th percentiles with the overweight and obesity cut-offs for BMI of Cole et al.[21] As shown for both boys and girls the 2000 CDC definition of overweight (95th percentile) is markedly higher than the Cole et al.[21] definition of overweight except for the period between 4 and 5 years. In other words, by the current U.S. definition, many fewer children in the United States and worldwide are overweight. In fact, the 2000 CDC definition of risk of overweight (85th percentile) most closely approximates the Cole et al.[21] definition of overweight, with the Cole et al.[21] values tending to be slightly higher for ages 2–10 years, and slightly lower for age 17 years and above. (The differences between these two curves are never substantial, but are greatest for the period 3 to 7 years, when the Cole et al.[21] values are approximately 0.5 BMI units greater.) In addition, the CDC BMI definition of overweight is not similar to the Cole et al.[21] definition of either overweight or obesity, but the CDC 97th BMI percentile is similar to the Cole et al.[21] definition of obesity for the period 7–14 years. These comparisons raise the important issue that greater agreement is needed between national and international agencies with regard to definitions of what age-specific BMI values constitute "risk of overweight," "overweight," and "obesity."

Recommended Uses of the New Percentile Charts

The 2000 CDC percentiles for weight, height, and head circumference are recommended to replace the 1977 NCHS percentiles for both assessments of individual patterns of growth and in research studies. Because the 2000 CDC percentiles are based on more up-to-date data, including representative populations in the 0–3-year age group, they are clearly an important advance over the 1977 NCHS percentiles and will help reduce misdiagnosis of abnormal growth.

Both the 2000 CDC percentiles and the BMI cut-offs of Cole et al.[21] can potentially be used to assess different degrees of overweight in children. Current CDC recommendations to use the CDC 85th percentile for risk of overweight and the 95th percentile for overweight make them appropriate for assessment of individual children and research in the United States. The BMI cut-offs from Cole et al.[21] also will be valuable for obesity research in different countries, including international comparisons, and may in the future become more accepted for general use in the United States if they are proven to predict morbidity and mortality in either childhood or adulthood. Although BMI percentile charts will not by themselves reduce the prevalence of growth disorders such as obesity, their increased use will help identify those children who are overweight and therefore in need of help. What is needed now is proven and accepted methods of overweight prevention and treatment in children that will help provide the necessary follow-up to improved diagnosis.

Acknowledgements: We thank Drs. R.J. Kuczmarski and W.H. Dietz for valuable advice during the preparation of this manuscript.

1. Hamill PVV, Drizd TA, Johnson CL, et al. Physical growth: National Center for Health Statistics percentiles. Am J Clin Nutr 1979;32:607–29
2. World Health Organization. A growth chart for international use in maternal and child health care: guidelines for primary health care personnel. Geneva: World Health Organization, 1978
3. De Onis M, Yip R. The WHO growth chart: historical considerations and current scientific issues. Bibl Nutr Dieta 1996;53:74–89
4. Dibley MJ, Staehling N, Bieburg P, Trowbridge FL. Interpretation of Z-score anthropometric indicators derived from the international growth reference. Am J Clin Nutr 1987;46:749–62
5. Fomon SJ. Nutrition of normal infants. St. Louis, MO: Mosby, 1993
6. WHO Working Group on Infant Growth. An evaluation of infant growth. A summary of analyses performed in preparation for the WHO expert committee on physical status: the use and interpretation of anthropometry. Geneva: World Health Organization, Nutrition Unit, 1994
7. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. Advance data from vital and health statistics. Hyattsville, MD: National Center for Health Statistics, 2000;314(314):1–28 Available at: http://www.cdc.goc/growthcharts
8. Troiano RP, Flegal KM. Overweight prevalence among youth in the United States: why so many different numbers? Int J Obes Relat Metab Disord 1999;23:S22–7
9. Habicht J-P, Martorell R, Yarbrough CEA. Height and weight standards for preschool children: how relevant are ethnic differences in growth potential? Lancet 1974;i:611–5
10. Graitcer PL, Gentry EM. Measuring children: one reference for all. Lancet 1981;ii:297–9
11. Jones DY, Nesheim MC, Habicht J-P. Influences in child growth associated with poverty in the 1970s: an examination of HANES I and HANES II, cross-sectional U.S. national surveys. Am J Clin Nutr 1985;42:714–24
12. Martorell R, Mendoza F, Castillo R. Poverty and stature in children. In: Waterlow JC, ed. Linear growth retardation in less developed countries. Vol 14. Nestle Nutrition Workshop Series. New York, NY: Raven Press, 1988;57–73
13. Yip R, Scanlon K, Trowbridge F. Improving growth status of Asian refugee children in the United States. JAMA 1992;267:937–40
14. Roberts SB, Heyman MB, Tracy L. Feeding your child for lifelong health. New York, NY: Bantam, 1999
15. Himes JH, Dietz WH. Guidelines for overweight in adolescent preventive services: recommendations from an expert committee. Am J Clin Nutr 1994;59:307–16
16. Dietz WH, Bellizzi M. Introduction: the use of body mass index to assess obesity in children. Am J Clin Nutr 1999;70:123S–5S
17. Trowbridge FL, Marks JS, de Romana GL, et al. Body composition of Peruvian children with short stature and high weight-for-height. II Implications for the interpretation for weight-for-height as an indicator of nutritional status. Am J Clin Nutr 1987;46:411–8
18. Dewey KG, Heinig MJ, Nommsen LA, et al. Growth of breast-fed and formula-fed from 0–18 months: the DARLING study. Pediatrics 1992;89:1035–41
19. Tanner JM, Whitehouse RH, Takaishi M. Standards from birth to maturity for height, weight, height velocity and weight velocity: British children, 1965, part 1. Arch Dis Child 1966;41:454–71
20. Tanner JM, Whitehouse RH. Clinical longitudinal standards for height, weight, height velocity, weight velocity, and stages of puberty. Arch Dis Child 1976;51:170–9
21. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 2000;320:1240–3
22. Dietz WH, Robinson TN. Use of the body mass index (BMI) as a measure of overweight in children and adolescents. J Pediatr 1988;132:191–3
23. Bellizzi MC, Dietz WH. Workshop on childhood obesity: summary of the discussion. Am J Clin Nutr 1999;70:173S–5S
24. World Health Organization. Obesity: preventing and managing the global epidemic. Report of a WHO consultation, Geneva, 3–5 June 1997. Geneva: World Health Organization, 1998