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Height, Weight, and Body Mass Index (BMI) in Childhood

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Introduction

In childhood, height (stature) and weight are the two most frequently used measures of growth and nutritional status. In addition, indices of weight-for-height, especially BMI, are used as a proxy for body fatness or obesity. Since growth is the most sensitive indicator of overall health in childhood, it is essential that accurate measurements be made on a regular basis during routine health supervision of children and adolescents to identify and address significant deviations in a timely manner.

Pediatric health professionals take two basic anthropometric measurements on each child: *recumbent length* (for children *under* two years of age) or *standing height* (for children *over* two years of age) and *weight*. From these two measurements, *body mass index (BMI)* can be derived from a reference chart or calculated by formula. This section will focus on these three measures: height (or length), weight, and BMI. For each measurement the following aspects will be discussed: definition, normal patterns of change, measurement techniques, and interpretation of values using reference growth charts. Since most practicing pediatricians in the U.S., as well as other health professionals who care for children, record their measurements in inches and pounds, these units will be used in the discussion.

Height

Description

Height, or stature, is a linear measure from the base on which the child is standing, to the firm top of the child's head. Height is measured in children over two years of age. It is measured with the child standing with erect posture, and without shoes. From birth to two years of age, the infant or toddler's stature is measured as recumbent length. This is the total length of the child from the bottom of the feet (positioned at a 90-degree angle) to the top of the head. Recumbent length is slightly greater than standing height measured in the same individual.

Normal Patterns of Linear Growth in Childhood

Normal changes in height (or length): during the first year of life, babies increase in recumbent length about 10 inches on average, from about 20 inches long at birth to 30 inches by their first birthday. During the second year of life their length increases by 4 to 5 inches, or about 1/4 inch per month. After age 2 years, height is measured in the standing position. Growth continues at a slower but steady rate of about 2 1/2 inches per year until about the age of 11 in girls and 13 in boys, when the growth spurt associated with puberty and adolescence usually begins. Puberty is characterized by a greater rate of growth, culminating in a peak height velocity (inches grown per year) comparable to the rate of growth during the second year of life. The peak height velocity for girls is about 2 1/2 to 4 1/2 inches/year, and for boys is about 3 to 5 inches/year. For both boys and girls, however, puberty and the pubertal "growth spurt" may occur several years earlier or later than average and still be within a normal range. Normal growth stops when the growing ends of the bones fuse, which usually occurs between 14 and 16 years of age for girls, and between 16 and 18 years of age for boys.

Normal Growth Rates During Childhood and Adolescence

	Growth Rate (per year)	
Age	**Inches (in)**	**Centimeters (cm)**
0–1 year	7–10	18–25
1–2 years	4–5	10–13
2 years to puberty	2–2 1/2	5–6
Girls: pubertal growth spurt	2 1/2–4 1/2	6–11
Boys: pubertal growth spurt	3–5	7–13

Measuring Length

The stature of subjects less than two years of age is measured as recumbent length. This is done most accurately with a measuring "box" or "board" that has an inflexible headpiece against which the top of the head is positioned, and a moveable footboard against which the feet are placed at a 90-degree angle. If possible, the child should be relaxed, the legs should be fully extended, and the head should be positioned so that a line connecting the outer margin of the eyes with the ears is at a 90-degree angle with the bottom of the measuring box. Recumbent length is measured from the top of the head to the bottom of the feet. It should be measured to the nearest quarter inch and recorded in the child's chart. Measurement of recumbent length on an examining table without a "box" should also be from the top of the head to the bottom of the feet, which are positioned at a 90-degree angle. It is recommended that the same examiner measure the child at each visit to minimize inter-examiner variability.

Because recumbent length is slightly greater than standing height, it is recommended that measurements of both length and height be obtained for two visits between two and three years of age. With these simultaneous recumbent length and standing height values, measurement discrepancy can be distinguished from actual change in growth rate.

Measuring Height

The height of subjects older than two years of age is measured, without shoes, with a stadiometer. A stadiometer consists of a measuring tape affixed to a vertical surface, such as a wall or a rigid free-standing measuring device, and a movable block, attached to the vertical surface at a right angle, that can be brought down to the crown of the head. In the absence of a stadiometer, height can be measured on a platform scale, but this is less accurate than the stadiometer. In either case, the subject should stand with heels together and back as straight as possible; the heels, buttocks, shoulders, and head should touch the wall or the vertical surface of the measuring device. The weight of the subject is distributed evenly on both feet and the head is positioned in the horizontal plane. The arms hang freely by the sides with the palms facing the thighs. The subject should be asked to inhale deeply and maintain a fully erect position. The examiner positions the movable block until it touches the head; applying sufficient pressure to compress the hair. The height marker is read while pressing firmly on the headpiece. The number on the height bar immediately behind the indicator line of the height marker is read. The examiner's eyes should look directly at the indicator line at about the same height in order to avoid parallax in reading the measurement. The height is measured to the nearest quarter inch, and then recorded on the child's chart. It is recommended that a second reading be taken to check accuracy.

Height has diurnal variation. Children are tallest in the morning, and shrink as much as a centimeter during the course of a day as the fibrous intervertebral cartilaginous disks are compressed. Diurnal variation in height is completely due to changes in the height of the vertebral column, and full height is regained when the child lies down flat for about 30 minutes.

Interpretation of Height Measurements

Depending on the statural genes that a child inherits from their parents, children tend to gravitate toward a specific percentile or channel of the standard height (or length) charts during the first two to three years of life. Thereafter, most children track close to that percentile or channel, maintaining a stable position relative to their peers.

Children who track consistently along the lowest height percentiles may have *familial short stature* in which the parents are short and the child has simply inherited the same statural genes. Other short children may have *constitutionally delayed growth* characterized by a slower rate of growth in the first two or three years of life, followed by normal growth velocity that tracks along a height percentile or channel lower than expected for the family. These children often have later onset of puberty and its accompanying growth spurt, as well as a parent who followed a similar pattern of growth as a child. Final adult height is generally appropriate for parental height expectations.

Children whose linear growth decelerates and shifts gradually downward to a lower percentile deserve medical evaluation. Poor linear growth may reflect inadequate nutrition, an underlying disease affecting a major organ system, or a genetic abnormality. Children whose linear growth accelerates and shifts upward to a higher percentile also deserve medical evaluation. Increased rate of linear growth may reflect overnutrition, early or precocious onset of puberty, or another endocrine or genetic abnormality.

Reference Charts for Height (and Length)

Growth charts are simple grids which are used to plot out a child's height according to age and sex. Pediatric health professionals should measure and plot height on a growth chart at every visit, at least every six months before school age, and annually thereafter. Growth charts are derived from the heights of large numbers of healthy children of all ages, separating the wide range of normal heights into percentiles by statistical techniques. The spaces between the percentile lines are called channels. Age in years is plotted along the horizontal axis at the bottom of the chart and height in inches (or centimeters) is plotted along the vertical axis on the left of the chart. The 50th percentile, representing the average height for a given age, is drawn as a heavy line. Growth charts are commonly drawn for values between the 5th and 95th or 3rd and 97th percentiles of the population distribution values.

The Center for Disease Control (CDC) has published Growth Charts for boys and girls, for birth to 36 months of age and for ages 2 to 20 years. These include charts for plotting linear growth including Length-for-Age (age 2 years of age and under), Height-for-Age (age 2 years and older), Weight-for-Length, and Weight-for-Height. These charts may be downloaded from the CDC internet website: http://www.cdc.gov/growthcharts.

Weight

Description

Body *weight* is a measure of body mass, which is a composite of each contributing tissue (e.g., fat, muscle, bone, etc). Although weight should ideally be measured without clothing, this is often impractical. Most commonly, weight is measured with the child in underwear only, or in light indoor clothing, without shoes.

Normal Patterns of Weight Gain in Childhood

Newborn infants commonly double their birth weight by six months of age, and triple it by their first birthday. Boys on average increase from 8 pounds at birth to 23 pounds at 1 year; while girls on average increase from slightly less than 8 pounds at birth to about 21 pounds at age 1 year. From 1 to 2 years of age, toddlers who are tracking along the 50th pecentile for weight gain about 5 to 6 pounds, or about 1/2 pound per month, and during the third year of life weight gain averages about 4 pounds. Children tracking along higher percentile zones will gain more, and those tracking on the lower percentiles gain proportionately less.

Measurement Techniques

Weight should be measured in the clinical setting using a standard balance beam scale with moveable weight or with an instrument of equivalent accuracy. It is recommended that the scale be calibrated at least monthly using standard weights. It is preferable to weigh the child without clothing, or in light indoor clothing, but at least the child's shoes and heavy outer clothing should be removed. With older children, heavy belts should be removed and their pockets should be emptied. The beam of the platform scale must be graduated so that it can be read from both sides. The subject stands still over the center of the platform with body weight evenly distributed between both feet. Weight is recorded to the nearest quarter pound.

Weight, like height, has diurnal variation. In contrast to height, however, weight is lowest in the morning after emptying the bladder, and increases gradually through the day, depending on diet and physical activity.

Interpretation of Weight Measurements

Body weight and patterns of weight gain and adiposity in childhood are the result of gene-environment interactions. A child's genotype reflects the genes inherited from his or her parents. The phenotype expressed, however, with respect to body weight and fatness, is also heavily influenced by environmental factors such as diet and physical activity. Most children will gravitate toward a specific percentile curve of the standard weight charts during the first few years of life. However, with the increasing prevalence of childhood obesity in the U.S., it is not uncommon for children's weights to gradually cross upward across percentiles, rather than maintain a consistent percentile position relative to their peers. It is recommended that body weight, height, and calculated BMI values all be monitored carefully during routine health supervision, so that children and adolescents who begin to deviate from normal growth patterns may receive further evaluation and treatment.

Children's weight percentiles may be similar to their height percentiles, or may be somewhat above or below, and still be "normal" or healthy if the BMI is below the 85th percentile for age.

Healthy children who consistently track along the lower weight percentiles throughout childhood are considered normal if their weight is proportionate to their height (close to the same percentile) and consistent with parental heights and weights.

Children whose weight gain decelerates and shifts gradually downward to a lower percentile, or who actually lose weight (with the exception of overweight children on medically supervised diets), should be medically evaluated to determine the cause. Poor weight gain or unexplained weight loss may reflect inadequate nutrition, an eating disorder, an underlying disease affecting a major organ system, or depression or other psychological problems.

Overweight children who are placed on a medically supervised diet to slow down the rate of weight gain or to lose weight should be carefully monitored so adequate intake of essential nutrients is assured through a balanced calorie-controlled diet, and caloric intake is adequate to maintain linear growth throughout treatment.

Reference Charts for Weight

Weight charts are available to plot out a child's weight according to age and gender, similar to height charts. Weight charts are also constructed from the weights of large numbers of healthy children of all ages, separating the wide ranges of weights into percentiles by statistical techniques. As for the height charts, the spaces between percentile lines are called channels. Age in years is plotted along the horizontal axis at the bottom of the chart and weight in pounds (or kilograms) is plotted along the vertical axis on the left of the chart. The 50th percentile, representing the average weight for a given age, is drawn as a heavy line. Weight charts most commonly provide percentile channels between the 5th and 95th percentile, but are also available now for a distribution between the 3rd and 97th percentiles.

The CDC has published Growth Charts for boys and girls for birth to 36 months of age and for ages 2 to 20 years. These include charts for plotting weight, weight-for-age, and weight-for-height. These charts may be downloaded from the CDC website: http://www.cdc.gov/growthcharts.

Body Mass Index (BMI)

Body Mass Index

Body Mass Index, or BMI (wt/ht^2) provides a guideline based on weight and height to determine underweight or overweight status. BMI is not an exact measure of fatness because levels of fatness vary among children at a given BMI. This is true because BMI reflects (1) frame size, (2) leg length, and (3) amount of lean and fat tissue. Although BMI correlates less well with the percent of body weight that is fat than other more direct measures of fat such as triceps skinfold thickness or other body composition techniques, the readily available weight and height data make BMI a more useful tool for assessment of overweight or underweight.

BMI in children and adolescents compares well to laboratory measurements of body fat. Children and adolescents with a BMI-for-age above the 95th percentile are classified as overweight. BMI values above the 95th percentile, applied as a definition of overweight in children and adolescents

1. Reflects adiposity
2. Is consistent across age groups
3. Is predictive of morbidity

The percentage of children and adolescents who are overweight in the U.S. has more than doubled in the past 30 years, and the sharpest increase has occurred in the last 20 years, since the late 1970s. For 6 to 17 year old youth, about 12.5% (or 5.3 million) are overweight (BMI >95th percentile reference value).

The rationale for proposing a pediatric BMI classification is based on studies indicating that BMI is related to health risks. Overweight children are likely to become overweight adults, with risk increasing with severity and duration of the problem. Sixty percent of youth with a BMI-for-age above the 95th percentile have at least one risk factor for cardiovascular disease, while twenty percent have two or more risk factors. High blood pressure, abnormal blood lipid levels (elevated total cholesterol, LDL-cholesterol, and/or triglycerides; low HDL-cholesterol), insulin resistance, and Type II diabetes mellitus are some of the risk factors observed in overweight children and adolescents. Overweight children are also at increased risk for a wide range of other medical and psychological problems.

Normal Patterns of BMI during Childhood and Adolescence

For U.S. children, BMI increases rapidly during the first year of life and then declines to its lowest value on average between four and six years of age. After reaching this nadir, BMI again begins a slow increase throughout the rest of childhood and adolescence. The upward shift of the BMI curve, after reaching the lowest point, has been termed "adiposity rebound." Studies suggest that children who begin their adiposity rebound at younger ages are at greater risk for being overweight as older adolescents and young adults.

Measurement of BMI

BMI, also known as the weight-height index or Quetelet index, is calculated as the quotient of weight divided by height squared:

The *English formula* (in inches and pounds) is as follows:

$$\text{Weight in pounds} \div \text{Height in inches} \div \text{Height in inches} \times 703 = \text{BMI}$$

The *Metric formula* (in meters and kilograms) is as follows:

$$\text{Weight in kilograms} \div \text{Height in meters} \div \text{Height in meters} = \text{BMI}$$

Interpretation of BMI Values

Interpretation of BMI depends on the sex and age of the child, since boys and girls differ in their body fatness as they mature. Therefore BMI is plotted on age and sex-specific charts. Established cutoff points are used to identify children and adolescents who are underweight or overweight. BMI values which should raise clinical concern are the following:

Underweight	BMI-for-Age <5th percentile
"At-Risk" of Overweight	BMI-for-Age 85th–95th percentile
Overweight	BMI-for-Age ≥95th percentile

Reference Charts for Body Mass Index (BMI)

The CDC has published BMI-for-age charts; one chart for boys ages 2 to 20 years, and another chart for girls 2 to 20 years of age. These charts may be downloaded from the CDC internet website: http://www.cdc.gov/nccdphp/dnpa/bmi/bmi-for-age.htm. At the same site, a CDC "Table for Calculated Body Mass Index Values for Selected Heights and Weights for Ages 2 to 20 Years" may also be downloaded. Clinicians can avoid having to calculate BMI values by using this extensive set of tables covering heights from 29 to 78 inches and weights from 18 to 250 pounds.

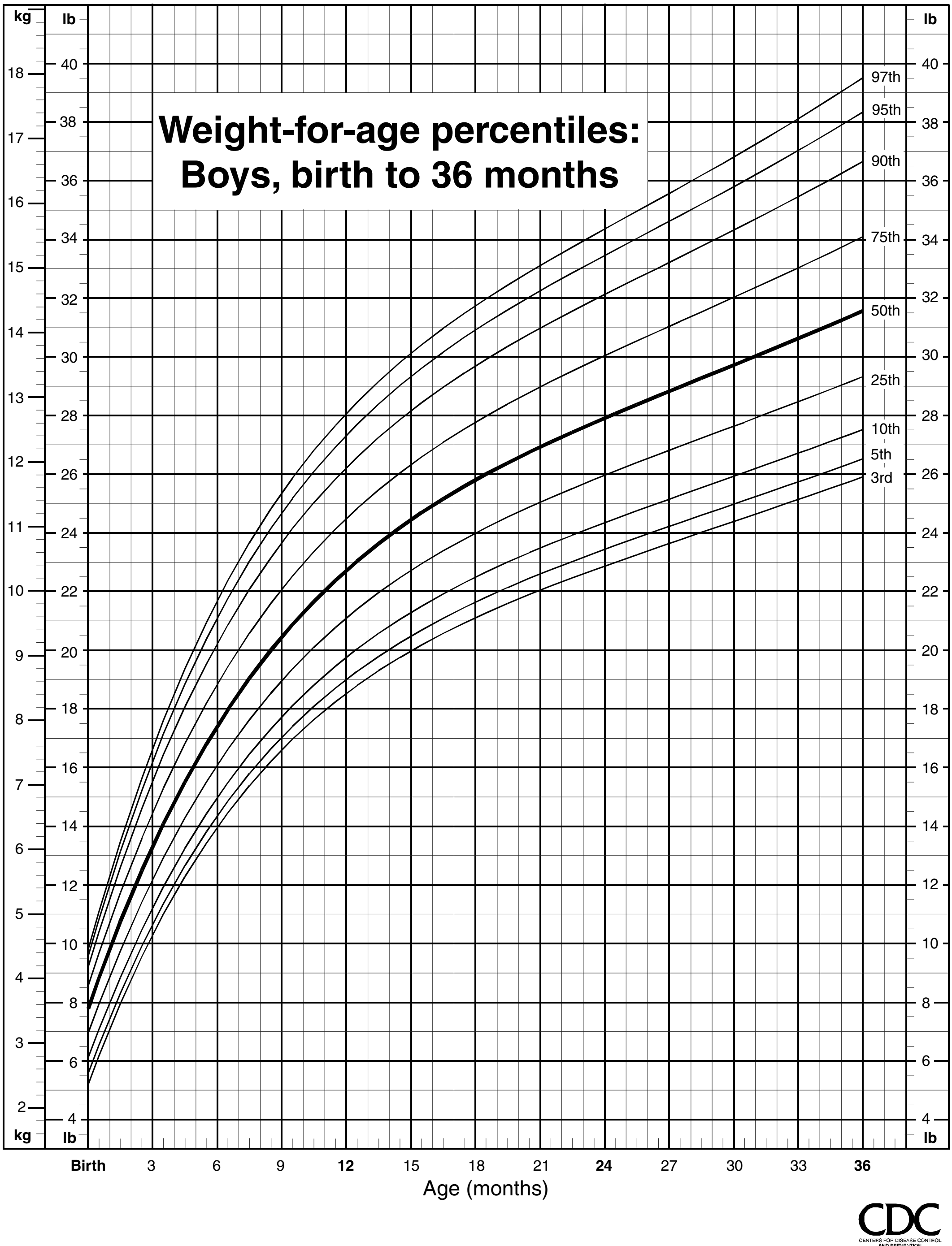

FIGURE 32.1
Weight-for-age percentiles, boys, birth to 36 months, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

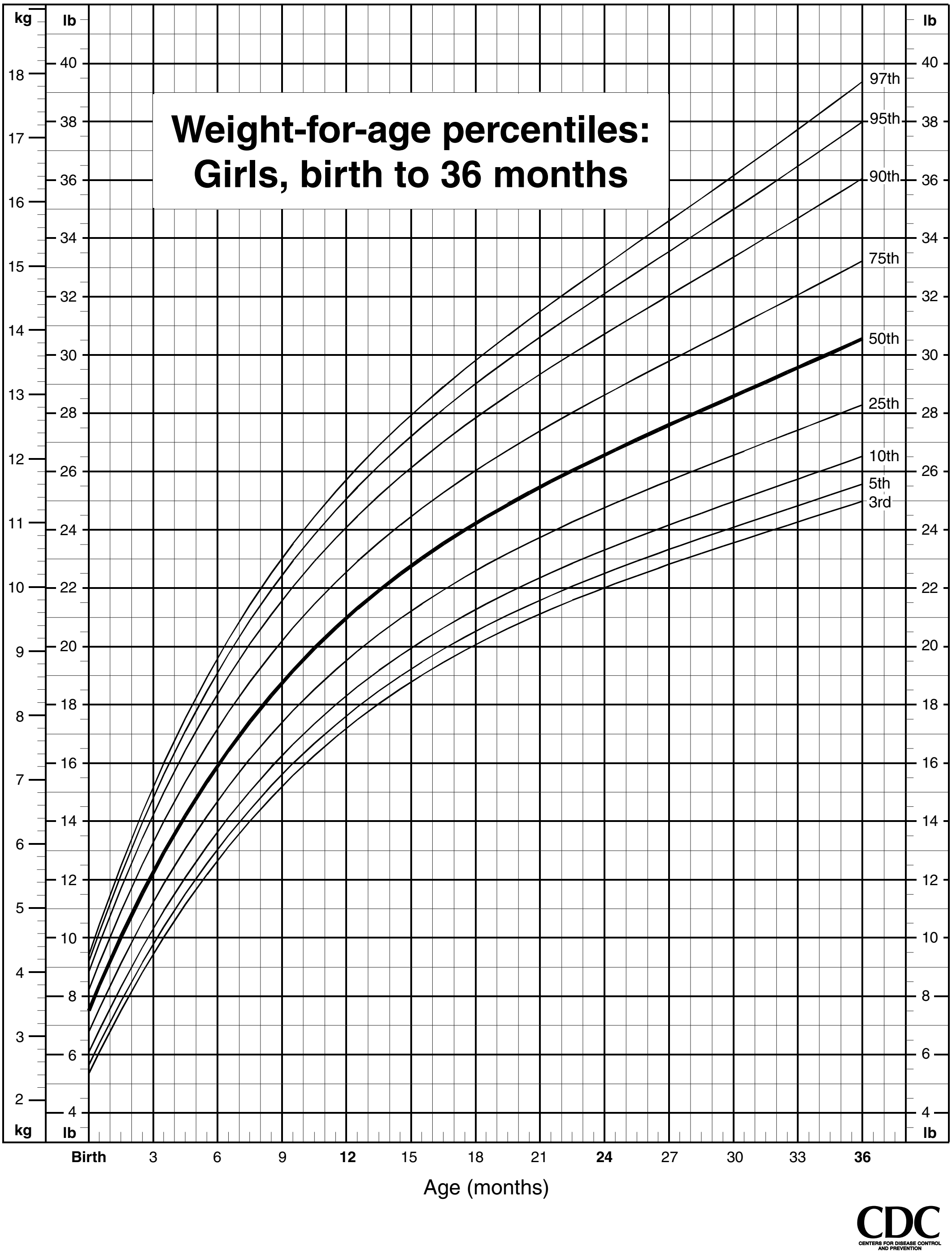

FIGURE 32.2
Weight-for-age percentiles, girls, birth to 36 months, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

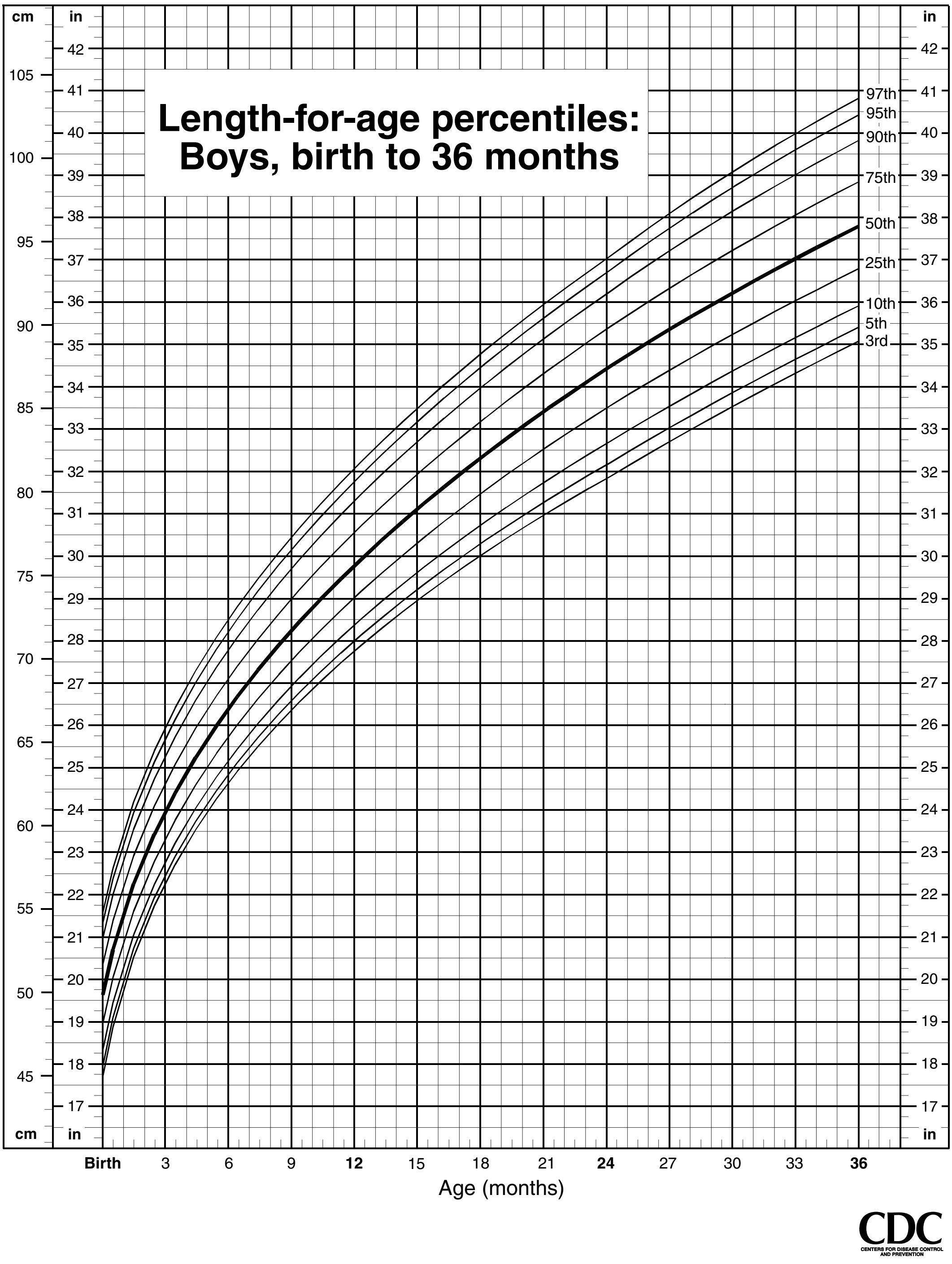

FIGURE 32.3
Length-for-age percentiles, boys, birth to 36 months, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

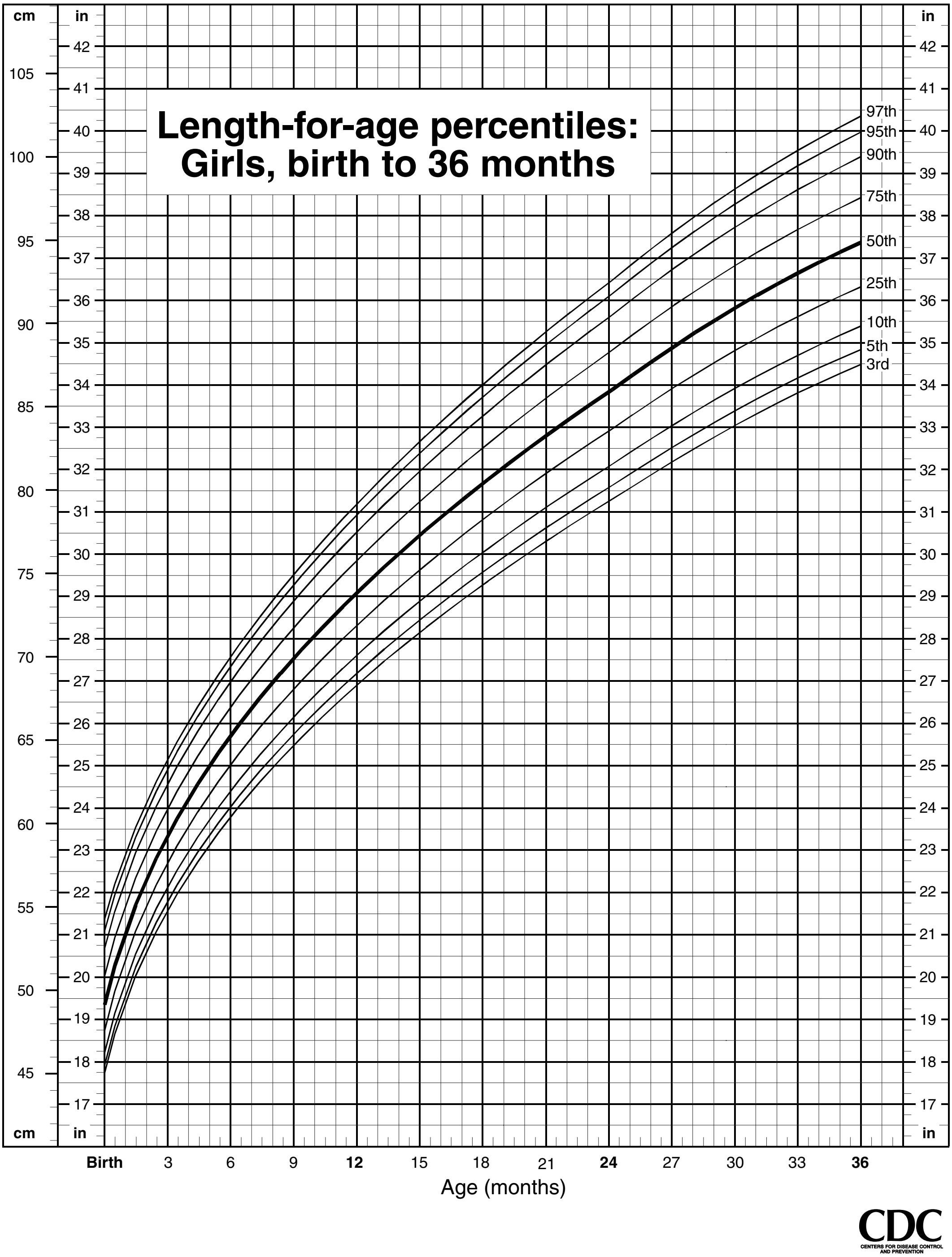

FIGURE 32.4
Length-for-age percentiles, girls, birth to 36 months, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

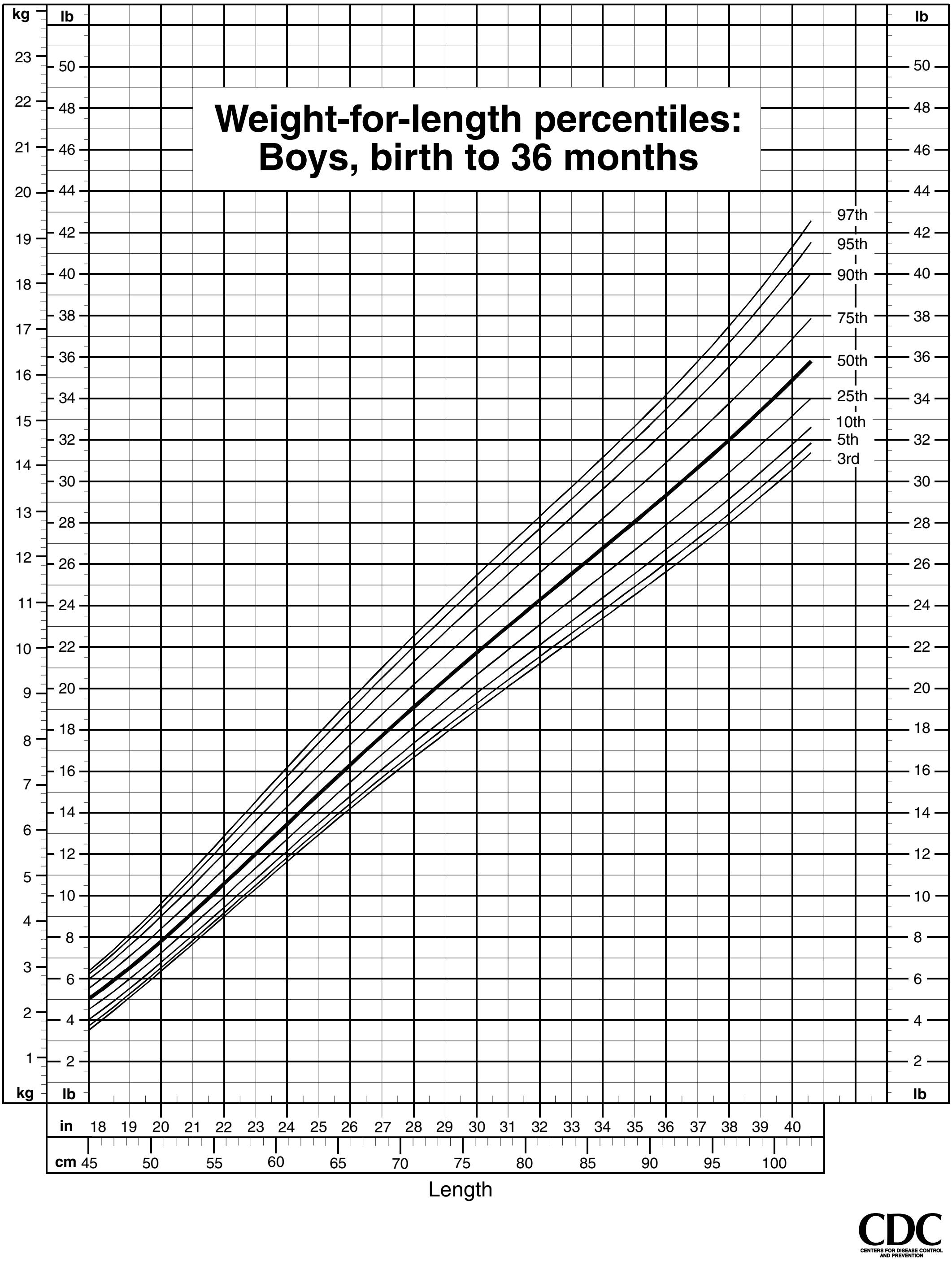

FIGURE 32.5
Weight-for-length percentiles, boys, birth to 36 months, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

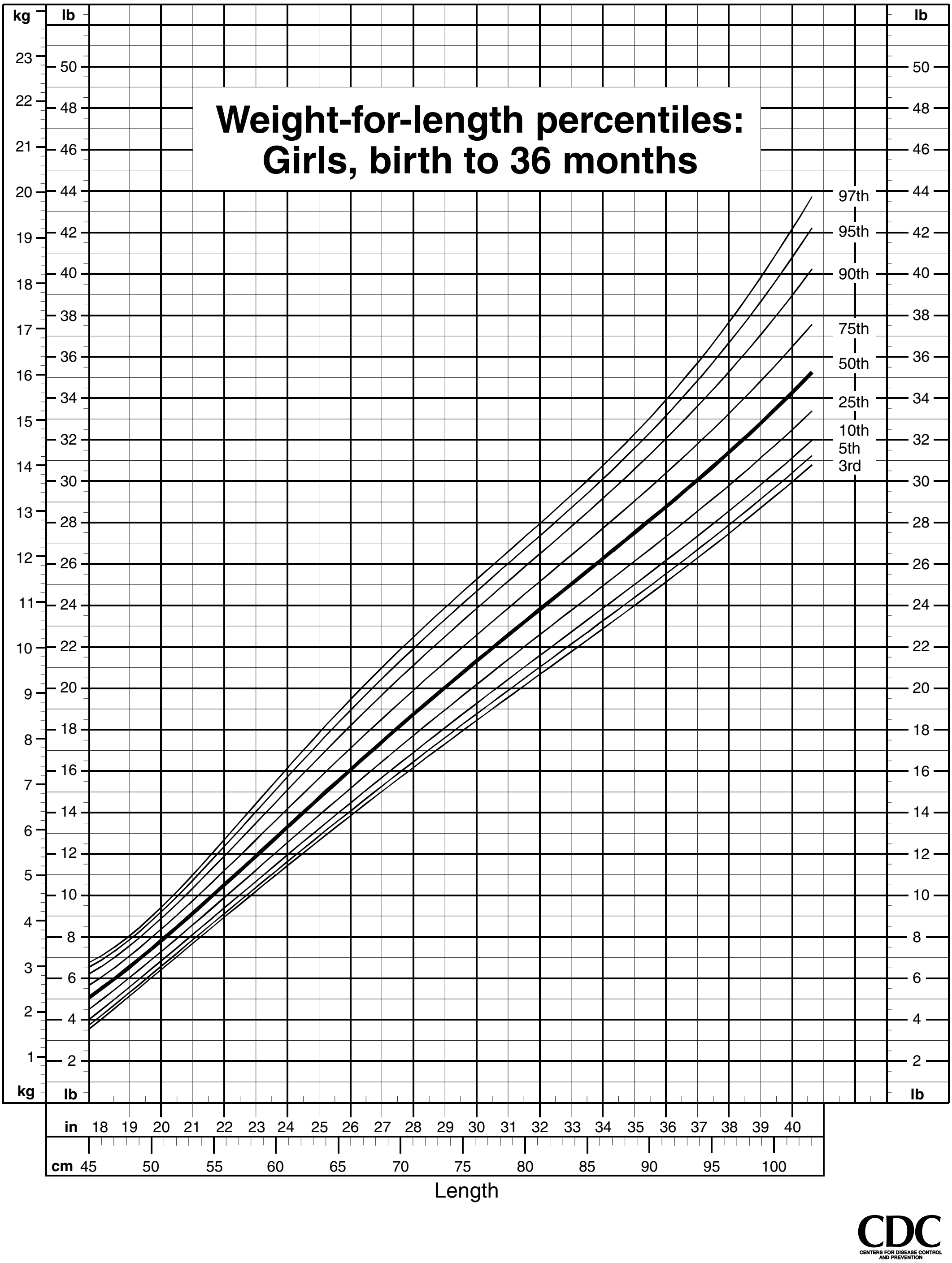

FIGURE 32.6
Weight-for-length percentiles, girls, birth to 36 months, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

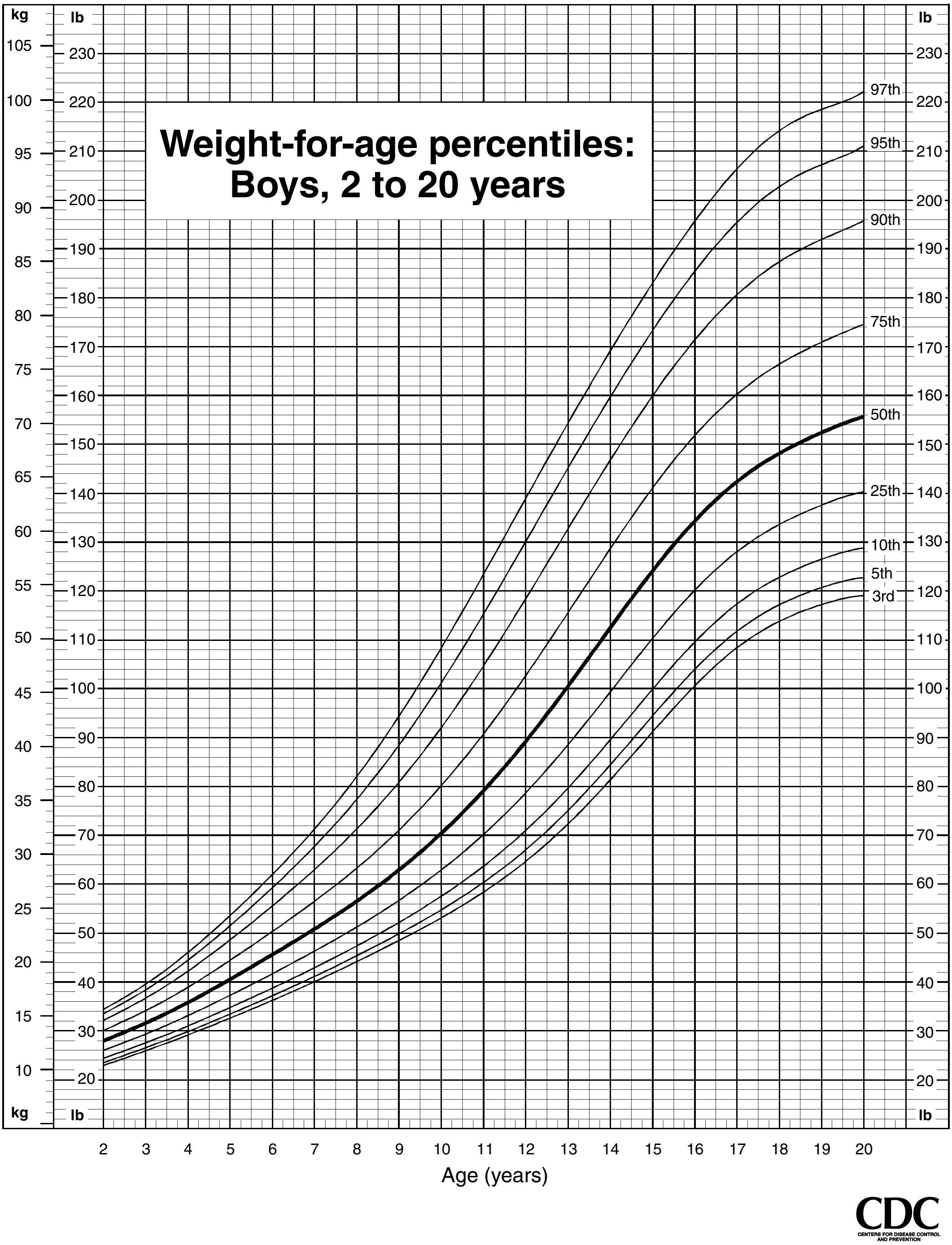

FIGURE 32.7
Weight-for-age percentiles, boys, 2 - to 20 years, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

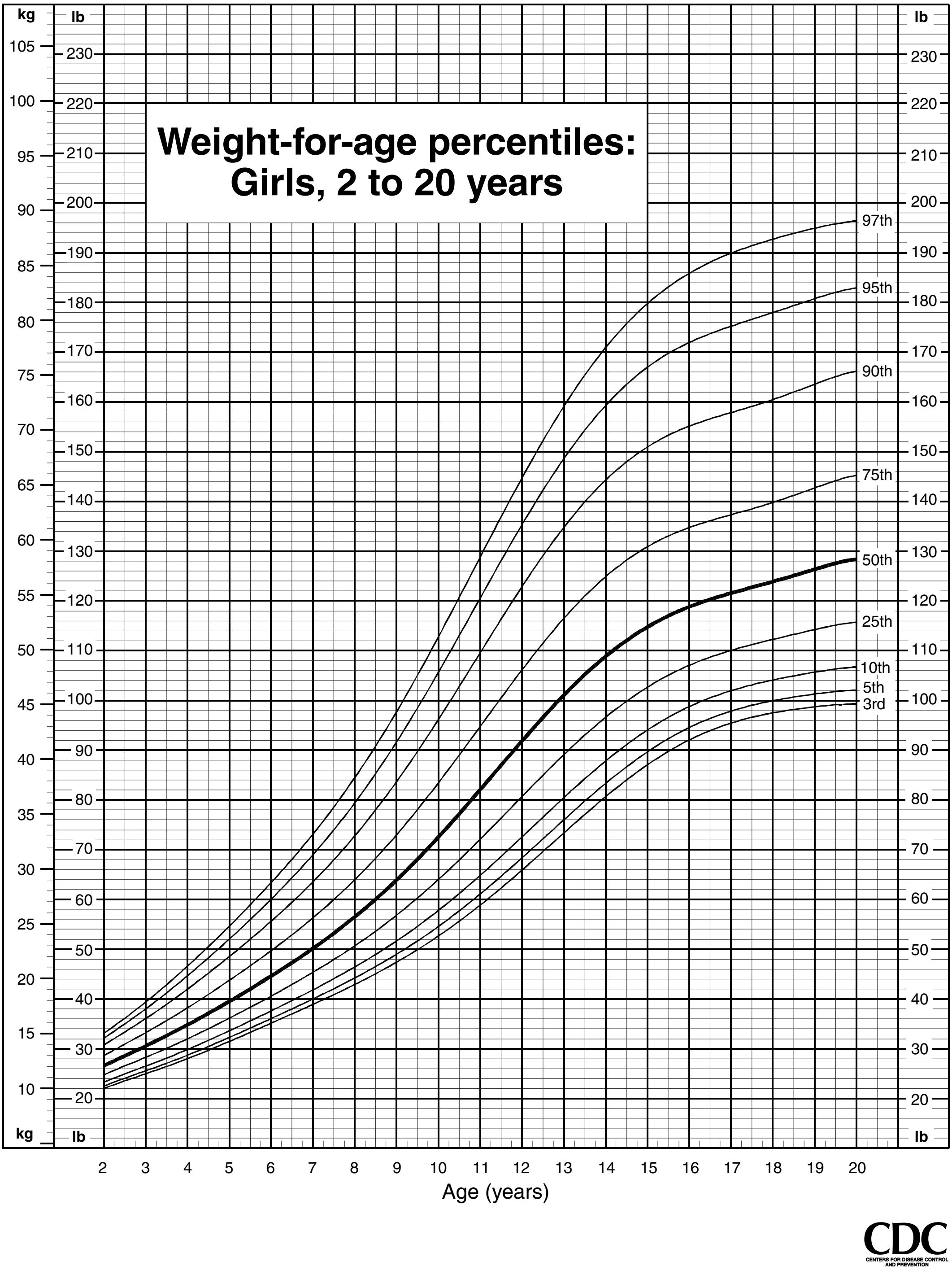

FIGURE 32.8
Weight-for-age percentiles, girls, 2 to 20 years, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

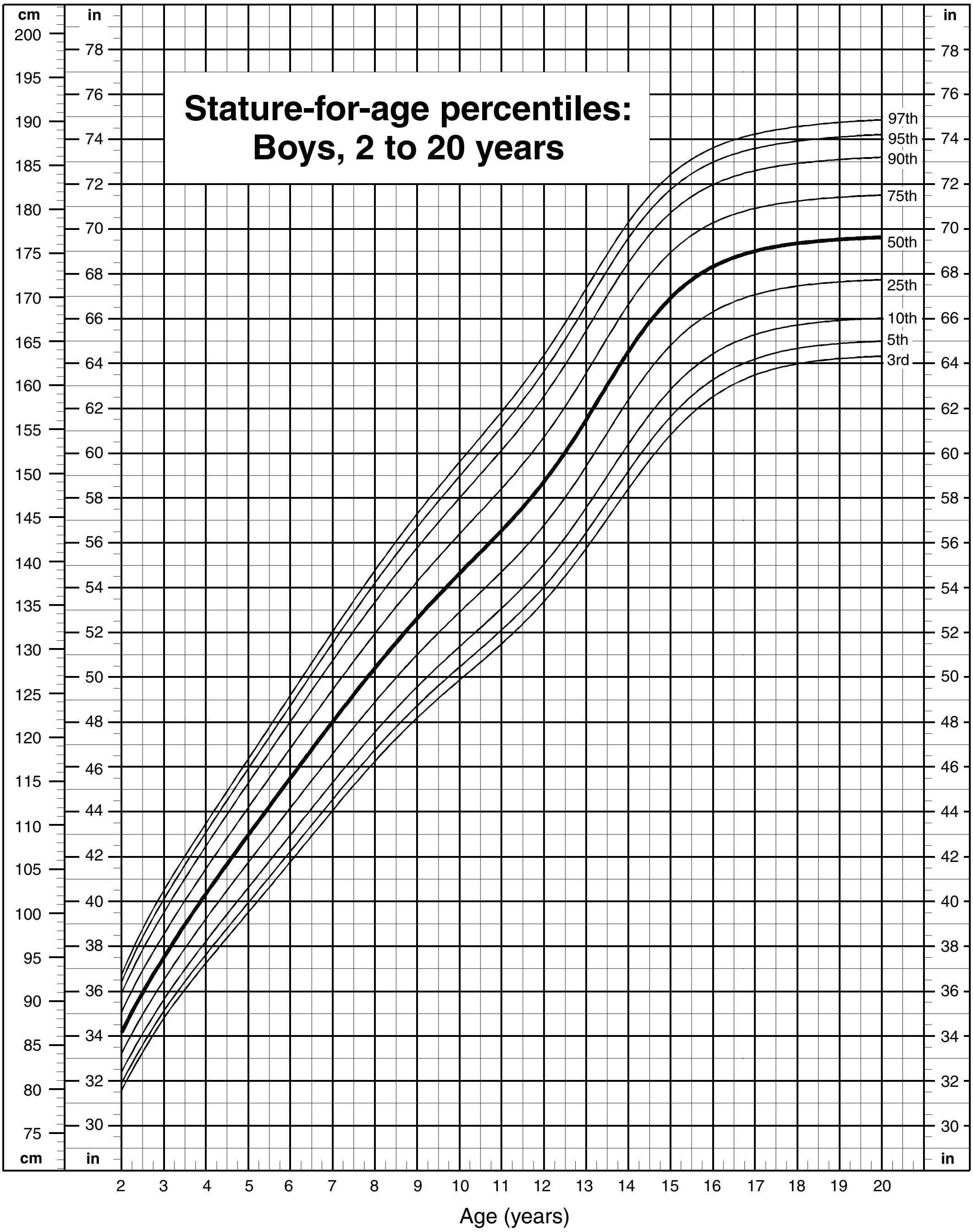

FIGURE 32.9
Stature-for-age percentiles, boys, 2 to 20 years, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

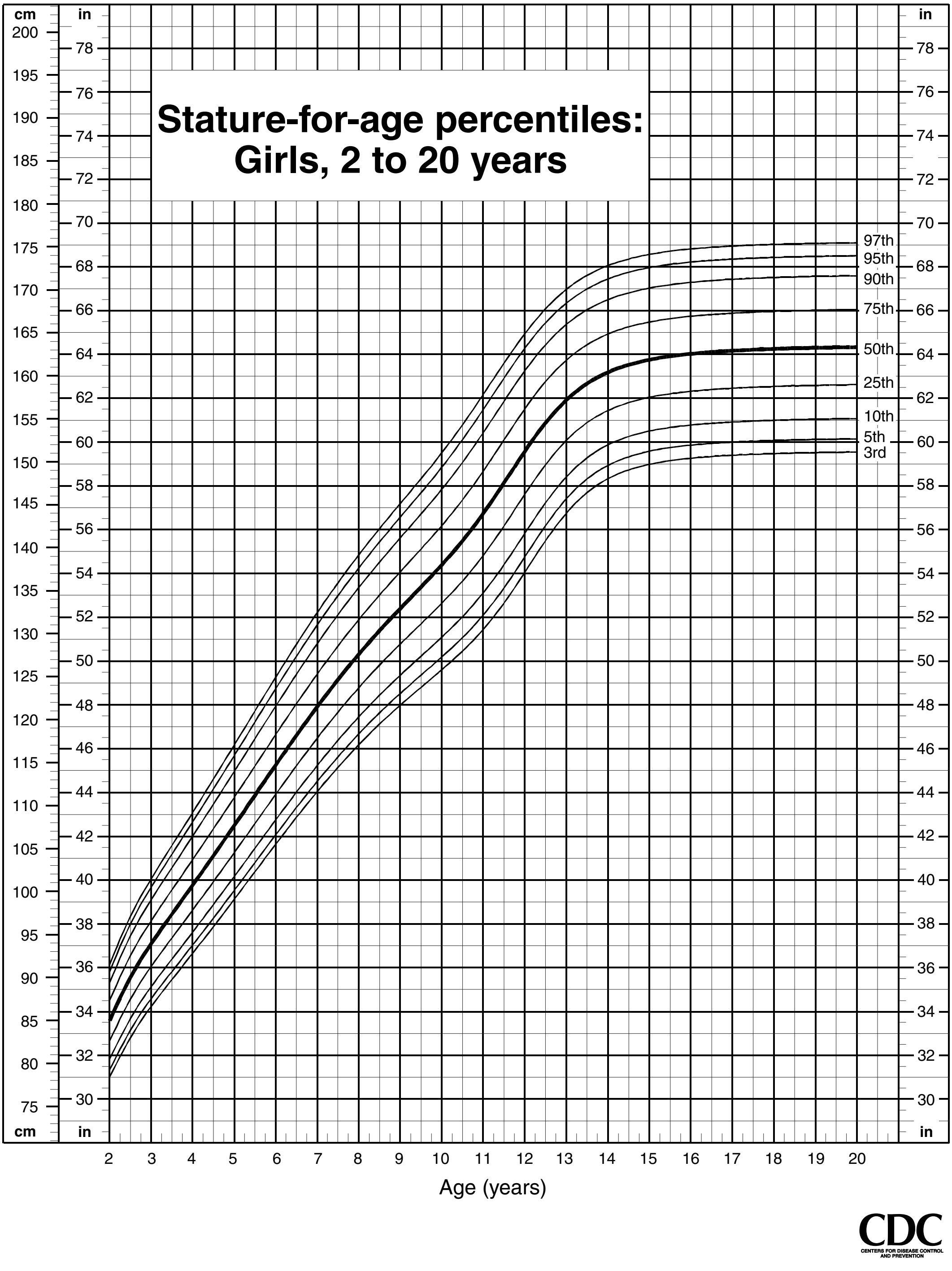

FIGURE 32.10
Stature-for-age percentiles, girls, 2 to 20 years, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

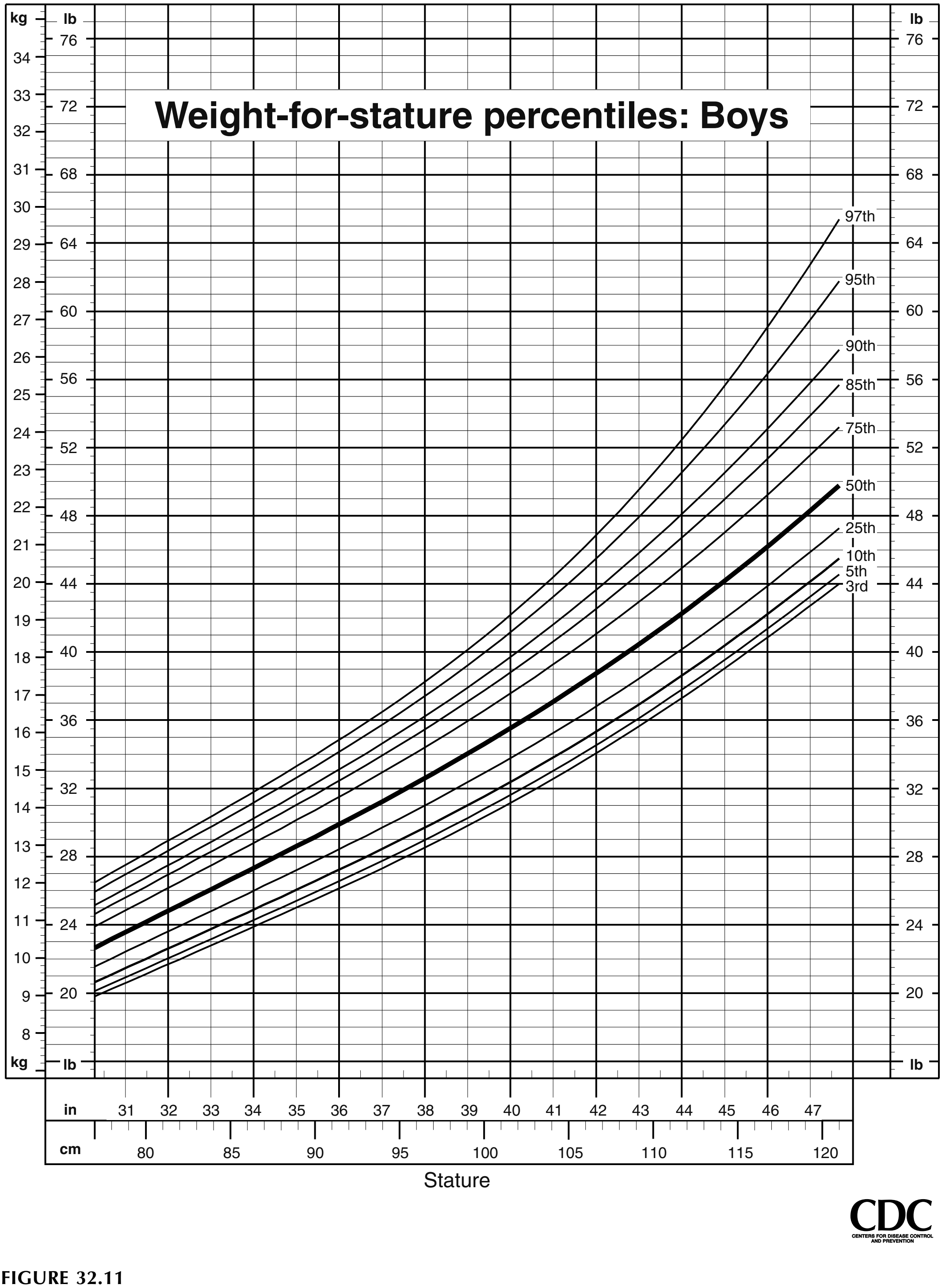

FIGURE 32.11
Weight-for-stature percentiles, boys, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

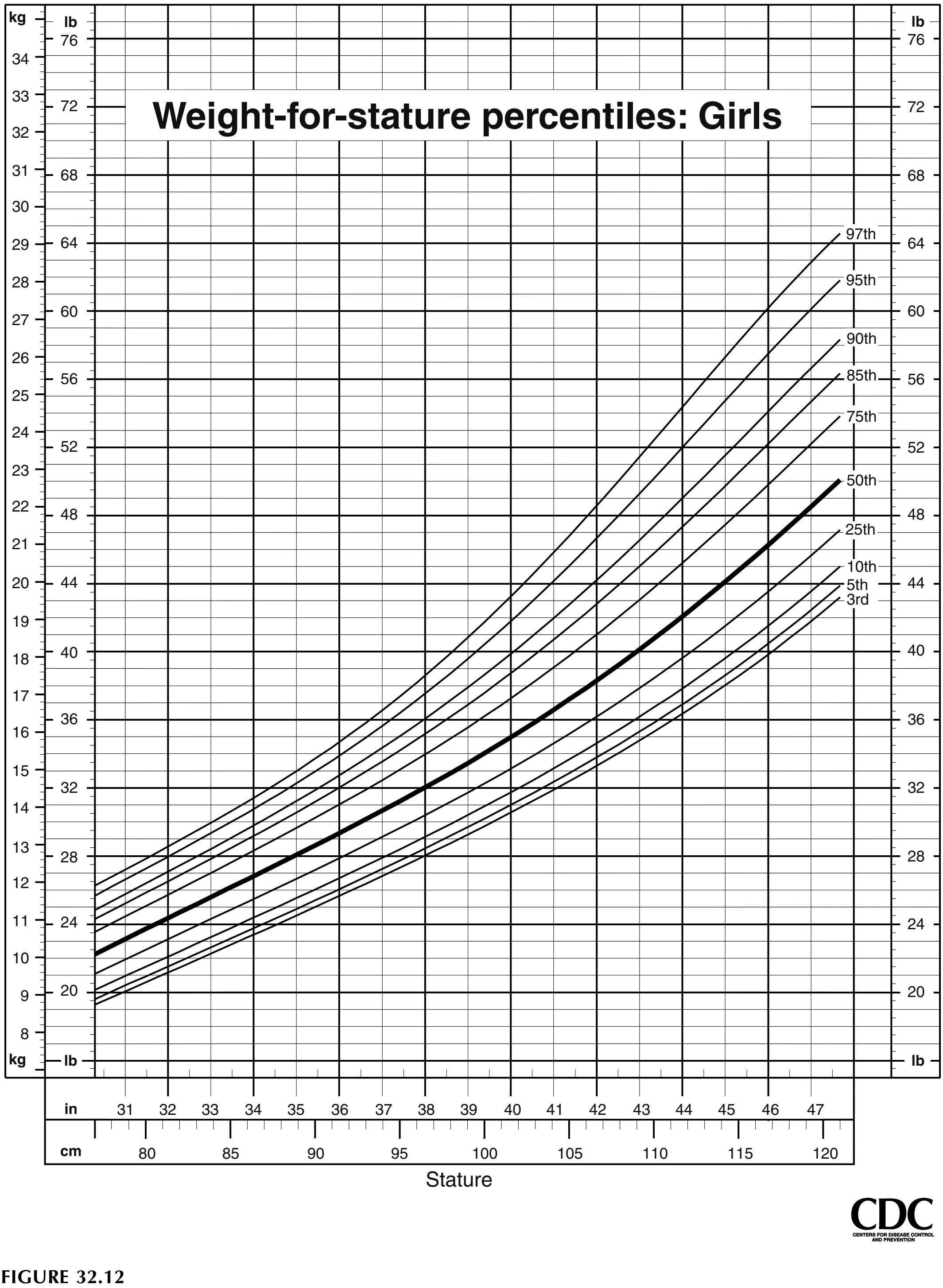

FIGURE 32.12
Weight-for-stature percentiles, girls, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

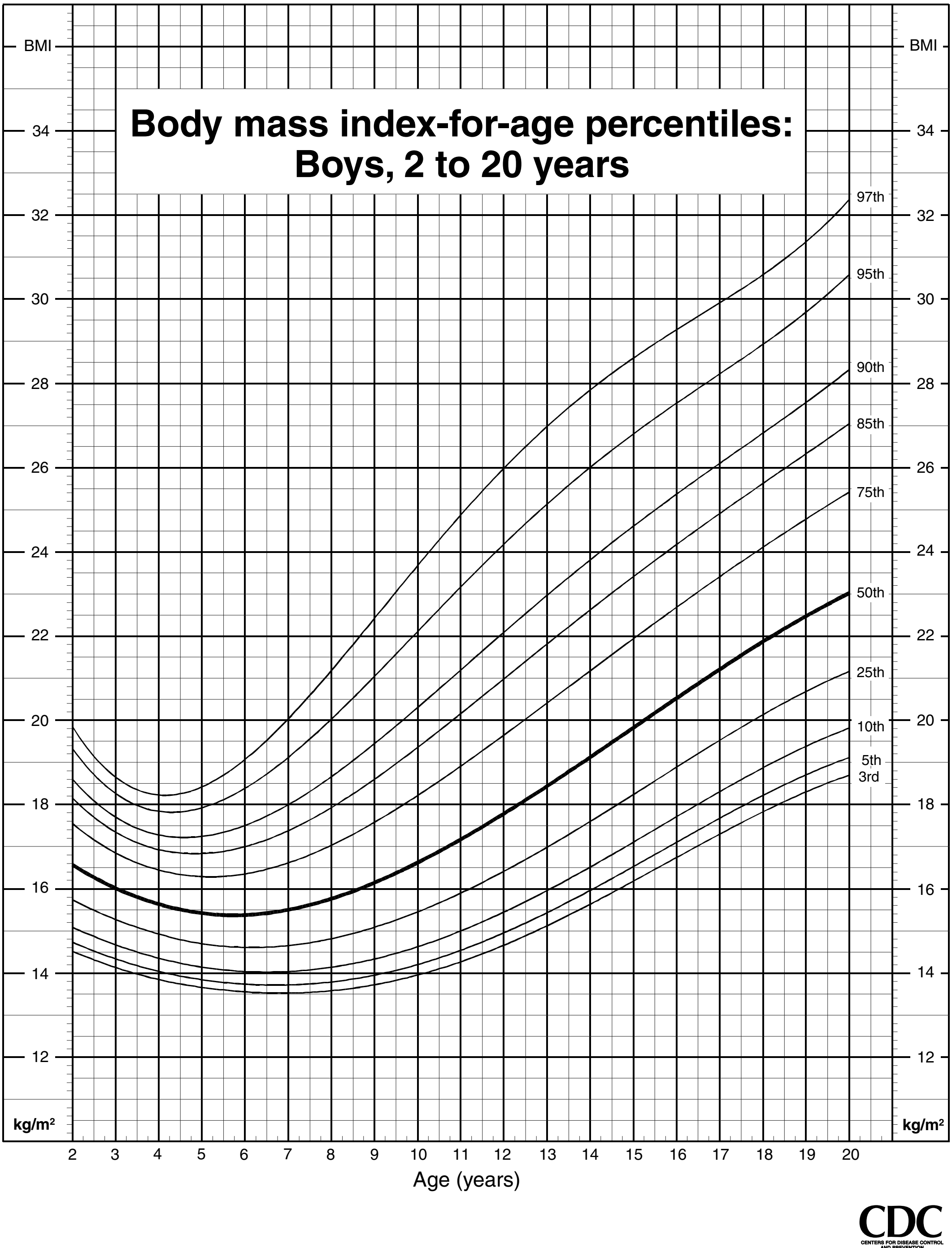

FIGURE 32.13
Body mass index-for-age percentiles, boys, 2 to 20 years, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

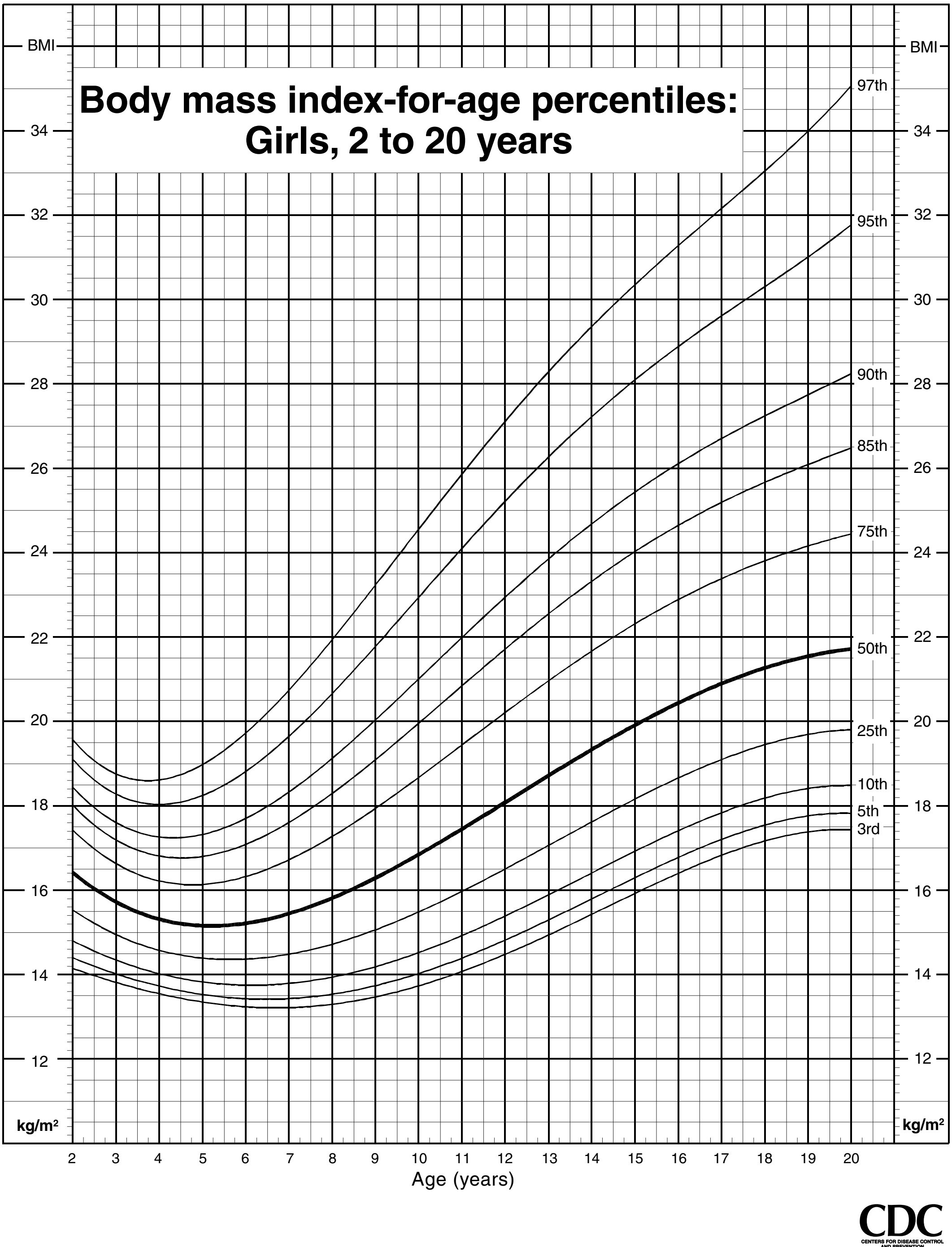

FIGURE 32.14
Body mass index-for-age percentiles, girls, 2 to 20 years, CDC growth charts: United States. Source: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Sources of Further Information

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