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CDC Growth Charts: United States

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Abstract

Objectives—This report presents the revised growth charts for the United States. It summarizes the history of the 1977 National Center for Health Statistics (NCHS) growth charts, reasons for the revision, data sources and statistical procedures used, and major features of the revised charts.

Methods—Data from five national health examination surveys collected from 1963 to 1994 and five supplementary data sources were combined to establish an analytic growth chart data set. A variety of statistical procedures were used to produce smoothed percentile curves for infants (from birth to 36 months) and older children (from 2 to 20 years), using a two-stage approach. Initial curve smoothing for selected major percentiles was accomplished with various parametric and nonparametric procedures. In the second stage, a normalization procedure was used to generate z-scores that closely match the smoothed percentile curves.

Results—The 14 NCHS growth charts were revised and new body mass index-for-age (BMI-for-age) charts were created for boys and girls (http://www.cdc.gov/growthcharts). The growth percentile curves for infants and children are based primarily on national survey data. Use of national data ensures a smooth transition from the charts for infants to those for older children. These data better represent the racial/ethnic diversity and the size and growth patterns of combined breast- and formula-fed infants in the United States. New features include addition of the 3rd and 97th percentiles for all charts and extension of all charts for children and adolescents to age 20 years.

Conclusion—Created with improved data and statistical curve smoothing procedures, the United States growth charts represent an enhanced instrument to evaluate the size and growth of infants and children.

Keywords: pediatric growth charts • height • length • weight • body mass index • head circumference • NHANES

Introduction

Growth charts are widely used as a clinical and research tool to assess nutritional status and the general health and well-being of infants, children, and adolescents. Multipurpose growth charts developed in the 1970's by NCHS have been used to evaluate and monitor the growth of infants and children in the United States for more than 20 years. These growth charts were also adapted by the World Health Organization (WHO) for world-wide use.

In 1985 NCHS began a process to revise the 1977 NCHS charts. This revision, presented here, used improved statistical procedures and incorporated additional national survey data from the second National Health and Nutrition Examination Survey (NHANES) and the third NHANES. This report presents the United States growth charts, along with a brief historical background, the rationale for the revision, and the approaches used in the process of revising the 1977 NCHS growth charts.

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Background

Before 1977 the various growth charts in use were based on samples of children that did not represent the U.S. population (1). Consequently, several expert groups recommended that charts be developed using nationally representative survey data (2–4). This charge was met by a NCHS Growth Chart Task Force, and separate growth percentile curves for boys and girls were developed (5,6). These growth references are known as the 1977 NCHS growth charts.

The 1977 NCHS growth charts for older children (ages 2 to 18 years) were constructed with anthropometric data collected during the period 1963–74 in a series of three national health examination surveys consisting of the National Health Examination Survey (NHES) Cycle II for children ages 6–11 years (1963–65), NHES Cycle III for adolescents ages 12–17 years (1966–70), and the first National Health and Nutrition Examination Survey (NHANES) for children ages 1–18 years (1971–74). Due to the limited amount of national survey data for younger ages in the above data sets, an alternative data set was needed to construct the charts for infants (birth to 36 months). The Task Force chose to use data collected in the Fels Longitudinal Study at the Fels Research Institute in Yellow Springs, Ohio (6).

In 1978 the Centers for Disease Control and Prevention (CDC) modified the 1977 NCHS growth curves to develop a set of growth curves approximating normal distributions that would allow the calculation of standard deviation scores (z-scores) for values above and below the median (7). These modified charts were subsequently adopted by WHO and have been widely used internationally (8–10).

When the 1977 NCHS charts were developed, it was recognized that future revisions would be necessary to replace data, modify population estimates, or improve statistical quality (6). Over time, as these charts were used in private pediatric practice, public health clinics, and surveillance programs, some concerns were identified that were considered in the current revision process.

Most of these concerns centered on the infant charts and were largely associated with characteristics of the Fels data. The Fels data collected from 1929–75 came from a single longitudinal study of primarily formula-fed, white middle-class infants in a limited geographic area of southwestern Ohio. In addition to not being a nationally representative sample, the Fels data were of concern because (a) observations were recorded at 3-month intervals from 3 through 12 months, intervals that are inadequate to present reference data at 1-month intervals used in the growth charts; (b) birth weights from 1929 to 1975 do not match recent national birth weight distributions; (c) differences between recumbent length and stature may have been too large, suggesting limitations in the recumbent length data; and (d) size and growth patterns of formula-fed infants do not represent growth patterns of combined breast- and formula-fed infants in the population (6,9,11–13). In addition, use of recumbent length measurements for infants from the Fels data and the stature measurements from the NCHS data sets resulted in inconsistent percentile estimates from the 1977 charts when the transition is made from recumbent length to stature between 24 and 36 months of age. Other concerns, not restricted to the infant charts, included the limited ability to assess size and growth at extremes beyond the 5th and 95th percentiles, the absence of weight-for-stature references for most adolescents, and the inability to assess growth beyond 17 years of age (14). In part because of these concerns, with the planning of NHANES III in 1985, NCHS initiated the revision of the 1977 growth curves.

This publication presents the United States growth charts, consisting of smoothed major percentile curves for 16 growth charts (eight for boys and eight for girls), as shown in table 1. This revision provides more accurate size and growth references using more representative data sets and more advanced statistical methods than were used previously. A brief description of the methods used to revise the charts, including the statistical smoothing procedures and a limited comparison of the 1977 NCHS and the revised percentile curves are included in this report. In addition, future related products are listed and briefly described. The revised growth charts for the United States were developed by the Growth Chart Working Group, consisting of the authors of this publication.

Methods

Revision process

The initial step in planning the revision process came with the design of the Third National Health and Nutrition Examination Survey (NHANES III). With the availability of improved statistical smoothing procedures and additional national survey data from the NHANES II (1976–80) beginning at age 6 months, and NHANES III (1988–94) beginning at 2 months, revising the NCHS growth charts was both timely and possible. In fact the NHANES III was specifically designed to over-sample infants and children ages 2 months–5 years to enrich the collective data base for infants and preschoolers.

To identify major concerns that could be addressed in the revision process and to obtain expert opinions on how best to resolve a variety of issues, NCHS sponsored a series of five workshops from 1992 to 1997. These workshops included leading authorities from many Federal agencies and academic institutions with expertise in child growth and growth charts, biostatistics, pediatric practice, and applied public health nutrition.

- The first workshop addressed general problems and potential solutions, gave structure to the overall revision process, and identified outstanding issues that would require further in-depth discussion by subject matter experts (14).
- The second workshop was dedicated to designing and exploring the feasibility of conducting a multi-center infant growth study to provide supplementary data in the period from birth to early infancy where national survey data were lacking.

- The third workshop explored existing data on the growth of low-birth weight (LBW) infants and addressed the question of whether LBW and very low-birth weight (VLBW) infants should be included in the revised charts (15).
- The fourth workshop considered changes in body weight over time. Increases in the prevalence of overweight among preschoolers (16) and older children (17) were observed between NHANES III and earlier national surveys. At this workshop participants discussed the options and implications associated with excluding the NHANES III weight data. Also discussed were statistical issues associated with pooling multiple national data sets (18).
- The fifth workshop explored options and needs at the Federal, State, and local levels regarding formatting, dissemination, and training issues relevant to the revised growth charts.

Data sets

The revised growth charts were developed to describe the size and growth of children in the United States. They are based primarily on physical measurements taken as part of a series of national health examination surveys conducted by NCHS from 1963 to 1994. These surveys included Cycles II and III of the National Health Examination Survey (NHES II and III) and three National Health and Nutrition Examination Surveys (NHANES I, NHANES II, and NHANES III). In each of these cross-sectional surveys, a national probability sample of the civilian, noninstitutionalized population of the United States was examined. The anthropometric data for the revised growth charts were obtained using standard pediatric measurement procedures (19, 20). A limited amount of supplementary data was incorporated, primarily at birth, where national survey data were lacking. The sources of data for each chart are shown in table 1 and all of the data sets are listed in table 2 for each anthropometric variable.

The growth charts were generated from observed data for selected anthropometric variables. To construct the revised charts, the national survey data were pooled with supplemental data to create a combined growth chart data set. Pooling data sets was required in part to obtain the necessary precision for calculating percentile distributions (21). In the growth chart data set, age is truncated to the nearest full month, for example, 1 month (1.0–1.9 mo), 11 months (11.0–11.9 mo), 23 months (23.0–23.9 mo), and so forth.

Statistical sample weights have been calculated for each national survey. These sample weights take into account unequal probabilities of selection resulting from the complex sampling cluster design, planned over sampling of selected subgroups, nonresponse, and noncoverage. These survey-specific sample weights were applied to the national survey sample data to make them representative of the U.S. population at the time the surveys were conducted. Statistical sampling weights were not necessary for the supplemental data.

Data exclusions

To avoid the influence of an increase in body weight and BMI that occurred between NHANES III and previous national surveys (17,22), data for NHANES III subjects ages ≥ 6 years were excluded from the revised weight and BMI growth charts. This was done to avoid an upward shift of the weight and BMI curves. Without this exclusion, the 85th and 95th percentile curves would have been higher and fewer children and adolescents would have been classified at risk of overweight or overweight. The decision to exclude NHANES III data was based on expert opinion solicited from a variety of sources. However, it was recognized that exclusion of selected data resulted in a modified growth reference. This, in turn, resulted in an exception to the Working Group's intent to produce charts that could be characterized strictly as growth references that represented national data for all variables.

The growth patterns of preterm, VLBW infants are known to be considerably different from those of higher birth weight term infants (23). This knowledge, in combination with the availability of specialized growth charts to track the growth of VLBW infants (24–26), led to the decision to exclude data for VLBW (< 1500 gm) infants from the revised infant growth charts.

Statistical smoothing procedures

Data were grouped by single month of age from 1 through 11 months, by 3-month intervals from 12 through 23 months, and by 6-month intervals from 24 months through 19 years. Data for weight-for-length and weight-for-stature were grouped by 2 cm intervals. The weighted empirical percentile estimates were obtained by applying the survey-specific sample weights. Then, weighted empirical percentile data points were calculated and plotted at the midpoint of each age group (or the midpoint of each 2-cm interval for length or stature).

When the observed percentile points are plotted on a graph and connected, the resulting lines are jagged or irregular, in part because of sampling variability. Because of these irregularities, statistical smoothing procedures were applied to the observed data to generate smoothed curves for selected percentiles and to generate parameters that can be used to produce additional percentiles. The smoothing procedures are described in more detail below.

The smoothed percentile curves were developed in two stages. In the first stage selected percentiles were smoothed with a variety of parametric and nonparametric procedures. In the second stage the smoothed curves were approximated using a modified LMS estimation procedure, as described below, to provide associated z-scores that closely match the empirically smoothed percentile curves.

In the first stage of smoothing, smoothed percentile curves were created from the empirical data points. The method of smoothing empirical percentiles for infant weight, length, and head circumference was based upon a family of three-parameter linear models (27–30). The method of smoothing the empirical percentiles for older children differed among the growth variables. For the smoothing of weight-for-age

percentiles, a locally weighted regression procedure was first applied to better discern the patterns of change over time in the empirical percentile curves. This procedure applies a weight function to data in the neighborhood of the value to be estimated, so that ages at measurements that are close to that of the value to be estimated receive larger weights than those further away from the specific age. Locally weighted regression generated intermediate results. The intermediate results were further smoothed using a family of parametric models. The smoothed weight-for-age percentiles for infants and the smoothed percentiles for older children were combined in a manner that resulted in a continuous transition between these two sets of percentile curves.

Smoothing of the empirical percentiles for stature-for-age was based upon a nonlinear model that ensured a monotonic increase in stature during the growth period; this captures early childhood growth, pubertal growth, and post-pubertal growth patterns.

Weight-for-length empirical data were adjusted and merged with the weight-for-stature data. These combined data were smoothed with a polynomial regression model.

Empirical percentile curves for BMI-for-age were considerably more irregular than those for stature-for-age and weight-for-age. Similar to weight-for-age, locally weighted regression was applied to the BMI empirical percentile curves to discern the shape of the curve. The intermediate smoothed percentile curves were then fit by a polynomial regression to achieve reasonably smoothed curves and to summarize the BMI-for-age percentile curves in polynomial equations.

For each set of percentile curves, the initial smoothing methods were applied to the nine empirical percentiles (3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th) for each age group. In addition, the 85th percentile was included in the BMI-for-age charts because the 85th percentile of BMI has been recommended as a cutoff threshold to identify children and adolescents at risk for overweight (31,32). The initial smoothing procedures are summarized in table 3. A detailed description of these procedures will be presented in future reports.

In the second stage, a modified LMS statistical smoothing procedure was applied to the smoothed curves generated in the first stage of the process. For ease of interpolation between percentiles, a normal transformation of the curves is useful. A normal transformation makes it possible to estimate any percentile and allows the calculation of standard deviation units (SDU) and z-scores.

With the exception of stature, which tends to be normally distributed, for most other anthropometric measures neither the empirical nor the smoothed data strictly follow a normal distribution. Rather, the distribution contains some degree of skewness. To remove skewness, a power transformation can be used so that one tail of the distribution is stretched while the other tail is shrunk. One means of doing this is to apply a Box-Cox transformation to transform the data to a nearly normal distribution. When applied to percentile curves, this is known as the LMS technique (33). The assumption is that after the appropriate power transformation, the data are closely approximated by a normal distribution (34). The transformation does not adjust for kurtosis, but kurtosis is a less important contributor than skewness to nonnormality (35).

In the LMS technique, three parameters are estimated: the median (M), the standard deviation (S), and the power in the Box-Cox transformation (L). The equation for the LMS is:

$$Centile = M\,(1 + LSZ)^{1/L}$$

where Z is the z-score that corresponds to the percentile. The usual practice is to use a penalized likelihood estimation procedure applied to the empirical data to generate age-specific estimates of L, M, and S. These age-specific estimates of L, M, and S are then smoothed. A smoothed percentile curve or an individual standardized score can be obtained from the smoothed values of L, M, and S (33,34). However, a smoothed percentile curve based on this type of LMS estimation procedure can be somewhat different from the curve that is obtained by smoothing empirical data points.

A modified estimation procedure was used to increase the agreement between the empirically smoothed curves and the LMS smoothed curves. In the modified LMS approach used for the present analyses, observed percentile curves were initially smoothed, as described above. Then, the Box-Cox power transformation (36) was used to specify an equation at each of the previously smoothed major percentiles. A simultaneous solution for the three parameters was generated using the SAS procedure NLIN (37). The set of L, M, and S parameters that best matched the set of smoothed percentiles was obtained as a solution to a system of equations rather than as likelihood-based estimates from empirical data. These parameters allowed final curves to be produced that are extremely close to the curves smoothed for each major percentile from the first stage of curve smoothing. The advantage is that the final curves retain a nearly identical appearance to the initially smoothed percentiles, and the z-scores can be obtained in a continuous manner. The final set of percentile curves presented in this report was produced using the modified LMS estimation procedure.

Evaluation

After the smoothing process, an extensive evaluation was carried out for the revised percentile curves. Each of the major percentiles was compared with the corresponding empirical percentile data using graphic comparisons, evaluation of the empirical percent below the smoothed percentiles, and chi-square tests. The objective of these procedures was to look for any anomalous features of the smoothed percentiles, such as large or systematic differences between the smoothed percentiles and the empirical data. The smoothed percentiles were also compared with the 1977 NCHS percentile curves, and any large differences were investigated. The revised charts were checked for disjunctions between the charts for

infants and those for older children to ensure smooth transitions between related charts such as length-for-age and stature-for-age, and also weight-for-length and weight-for-stature. It should be noted that the fit of the LMS parameters to percentiles other than the major percentiles was not evaluated.

Results

The final smoothed percentile curves that constitute the 16 revised U.S. growth charts are shown in figures 1–16, depicting the 3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th percentiles. In addition, the 85th percentile for weight-for-stature and BMI-for-age are shown in figures 13–16. The 3rd, 5th, 95th, and 97th percentiles are shown on a single chart in this report. The final charts, tabular data points of the smoothed percentiles, and LMS values by age and sex are available on the Internet (http://www.cdc.gov/growthcharts).

Differences between the 1977 NCHS and the revised U.S. growth charts

A comparison of the 1977 NCHS and the revised U.S. growth charts is provided in table 4 by variable and age. When the 1977 NCHS and the United States growth charts are compared, there are some minor differences in the percentile lines. These differences vary by chart and by percentile within a given chart. As expected, more differences occur between the two versions among the charts for infants than among the charts for older children and adolescents. Since BMI-for-age represents a new chart, comparisons cannot be made with an earlier version.

Below age 24 months, the revised weight-for-age curves are generally higher than in the 1977 charts. This will result in more frequently classifying infants as underweight. Similarly, this shift would be expected to result in lower comparative estimates of overweight when the revised charts are used.

After approximately age 6 months, across the major percentiles for both boys and girls, the revised length-for-age curves tend to be lower than those for the 1977 curves. The magnitude of this change appears to be slightly larger for girls than for boys. This shift would be expected to result in less frequent classification of low length-for-age when using the revised charts.

At small lengths (approximately 50–70 cm), the revised weight-for-length percentiles are somewhat higher than the 1977 percentiles. The accentuated dip that occurred in the 50–70 cm range for the 5th and 10th percentiles in the 1977 charts is no longer apparent in the revised charts. Short infants will more frequently be classified as underweight, that is, a low weight-for-length, when the revised charts are used in place of the 1977 charts.

The revised head circumference-for-age percentiles are generally higher than the 1977 percentiles from birth to approximately 4–6 months. This is more evident at the upper percentiles. At 4–6 months there is a crossover effect. After this age the revised percentiles are consistently lower than the 1977 percentiles.

Compared with the 1977 charts, use of the revised weight-for-stature curves will result in more boys and girls ages 2 to 5 years classified as underweight when either the 5th or 10th percentile cutoff criteria are applied. This is attributable to the finding that the revised curves are higher for these percentiles in comparison with the 1977 version. The 1977 10th percentile is now equivalent to the revised 5th percentile for both boys and girls. In contrast to the 1977 charts, shorter boys and girls will more often be classified as overweight and taller children will less often be classified as overweight when the revised charts are used. This is attributable to a downward shift in the revised weight values at lower statures and an upward shift in weight at the higher statures. The upward shift of the revised curves is more apparent for girls than for boys. Beginning at statures ≥ 110 cm, the revised percentile curve is ≥ 2 lb higher than the 1977 curves.

Overall, from age 2 to approximately 14 years, the revised weight-for-age percentiles are quite similar to the 1977 percentiles for boys and girls. From 14 to 17 years, the shapes of the 1977 curves are more erratic than those of the revised curves. This may be attributable to limitations of the smoothing procedures used in the development of the 1977 charts in combination with the availability of only limited data beyond age 17 years that reduced the stability of the end points of the percentile curves. This suggests that the revised charts are an improvement in that regard.

The revised stature-for-age percentiles and the 1977 percentiles for boys and girls are remarkably similar. As with the weight-for-age charts for older children, the revised percentiles beyond 17 years are smoother than the 1977 percentiles mainly because more data were available. The differences between the 1977 and the revised charts are attributable to a combination of factors including data sets used, exclusion criteria applied, and statistical curve smoothing procedures selected.

Discussion

Revision of the 1977 NCHS growth charts would not have been possible without additional national survey data collected in the NHANES II and NHANES III surveys. Beginning in 1992, a series of workshops sponsored by NCHS called upon the expertise of many individuals to provide guidance on a variety of technical issues that had to be addressed. Appropriate sample sizes and characteristics along with the review of available statistical smoothing procedures were explored. The smoothed percentile curves were generated and underwent a systematic evaluation process, refinements were made as necessary, and the charts were re-evaluated. The final smoothed percentile curves presented in this report result from the contributions of many people over a period of years.

Major features of the revised charts

The most salient features of the revised U.S. growth charts include the following: (a) development of BMI-for-age charts; (b) development of 3rd and 97th smoothed percentiles for all charts

and the 85th percentile for the weight-for-stature and BMI-for-age charts; (c) development of smoothed z-score and percentile curves that are completely compatible; (d) incorporation of data from five national surveys, collected from 1963–94; (e) data from the Fels Longitudinal Study (1929–75) that were used in the 1977 NCHS growth charts were replaced with national survey data; (f) elimination of disjunctions between curves for infants and older children; and (g) extending all charts for children and adolescents to 20 years.

The major underlying difference between the revised U.S. growth charts for infants and the 1977 NCHS infant charts is that weight and length data from the Fels Longitudinal Study were replaced with nationally representative data from U.S. health examination surveys and supplemented with data at birth from Wisconsin and Missouri (1989–94). The revised head circumference-for-age charts were also constructed from national survey data, except for the point at birth. The head circumference data used at birth were from the Fels Longitudinal Study collected from 1960–94, corresponding to the years of birth for subjects from the national survey data. The national survey data better represent the combined size and growth patterns of breast- and formula-fed infants in the general U.S. population (1971–94) and replace data for primarily formula-fed infants from the Fels Longitudinal Study (1929–75).

In constructing the revised infant charts, a great deal of attention was given to assuring that the transition from the infant charts to the charts for older children was smoother than it had been in the 1977 NCHS charts. Specifically, the weight-for-age percentile distributions are now continuous between the infant and the older child charts at 24–36 months. The length-for-age to stature-for-age, and the weight-for-length to weight-for-stature curves are parallel in the overlapping ages of 24–36 months, but have been adjusted slightly to account for the fact that recumbent length should be greater than stature for any individual. This adjustment reflects an observed average biological difference of 0.8 cm between length and stature measurements in national survey data.

The revised weight-for-stature charts were developed to accommodate children ages 2–5 years. These charts were developed for circumstances where children are evaluated only from birth to the preschool years. For example, public health clinics that participate in the USDA Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), only screen program participants up to their fifth birthday. They may find that these weight-for-stature charts meet their needs and provide a smooth transition from the weight-for-length charts.

The revised weight-for-age and stature-for-age charts for children and adolescents were developed with additional national survey data (1976–94), adding to the national data (1963–74) used in the 1977 NCHS charts. One notable difference for the revised weight- and stature-for-age charts is that they now extend to 20 years of age, whereas the 1977 charts could only be used to 18 years of age.

The most prominent change to the complement of growth charts for older children and adolescents is the addition of the BMI-for-age growth curves. The BMI-for-age charts were developed with national survey data (1963–94) excluding data from the 1988–94 NHANES III survey for children older than 6 years. NCHS sponsored its fourth growth chart workshop to solicit expert recommendations on how best to handle the influence of an increase in body weight. The conclusion of a variety of experts, including pediatricians, epidemiologists, public health nutritionists, and statisticians, was that NHANES III weight and BMI data for ages ≥ 6 years should not be included in the revised charts. This exclusion was judged necessary to circumvent the influence of increases in body weight that occurred between NHANES II and NHANES III. This observed increase in weight would have had the effect of elevating the upper percentile curves used to identify children who are at risk of overweight, or are overweight. Without this exclusion, overweight would be under classified in children and adolescents.

The sex-specific BMI-for-age charts for ages 2–20 years replace the 1977 NCHS weight-for-stature charts that were limited to prepubescent boys under 11.5 years of age and statures less than 145 cm, and to prepubescent girls under 10.0 years of age and statures less than 137 cm. As recommended by expert panels, BMI-for-age may be used to identify children and adolescents at the upper end of the distribution who are either overweight (≥ 95th percentile) or at risk for overweight (≥ 85th, and < 95th percentile) (31,32). At the lower end of the distribution, an analogous application of the BMI-for-age charts may be to assess underweight or risk for underweight, although expert guidelines do not currently exist.

Issues addressed and application of the revised charts

Since the 1977 charts became widely used, a number of issues regarding the characteristics and applicability of the NCHS growth charts were raised in various publications, meetings, and workshops. Many of these issues were addressed in the revision process.

One issue that received attention is racial differences in growth. There are differences in size and growth among the major racial/ethnic groups in the United States, but these appear to be small and inconsistent. Therefore, the revised growth charts include all infants and children in the United States, whatever their race or ethnicity. It should be noted that the most important influences on growth potential appear to be economic, nutritional, and environmental (38–43).

Mode of infant feeding can influence infant growth. Over the past two decades in the United States, approximately one-half of all infants were reported to have been ever breast-fed (NCHS 1998). Among all infants born in the last two decades in the United States, approximately one-third were breast-fed for 3 months or more (44). Therefore, compared with the 1977 NCHS growth charts, the nationally representative data on which the revised infant growth charts are

based will better represent the combined growth patterns of breast-fed and formula-fed infants in the U.S. population.

With regard to differences in the growth of breast- or formula-fed infants, other research efforts are currently ongoing to address this issue. Specifically, a Working Group of the World Health Organization is collecting data at seven international study centers to develop a new set of international growth charts for infants and preschoolers through age 5 years (13,45). These charts will be based on the growth of exclusively or predominantly breast-fed infants and will be labeled as a prescriptive growth reference. The basic assumption is that infants from healthy populations, following the current WHO feeding recommendations, are growing optimally. The WHO multicenter growth reference study was designed to be completed in 2002 (WHO 1998).

Current Internet release and future products

This report describes the development of z-scores and percentile curves. Z-scores may have advantages for detecting changes at extremes of the distributions, where growth monitoring is an important evaluation tool and greater measurement precision is necessary. Z-scores are also useful in population-based research and surveillance activities because they can be used to provide summary statistics (for example, mean and standard deviation). The L, M, and S parameters provide the necessary information to derive any percentile and its corresponding z-score. These parameters, along with age- and sex-specific data values that constitute the major smoothed percentile curves for each anthropometric variable, are available on the Internet (http://www.cdc.gov/growthcharts). Users will be able to compute the revised z-scores using *Epi Info 2000*, a package of public domain computer programs for handling epidemiologic data. The updated *Nutstat* module in *Epi Info*, currently in development, will also provide exact percentiles, compute BMI values from weight and stature data, plot data for individuals on the percentile curves, and store individual or population observations. In addition to the revised U.S. growth charts, users will have the option of selecting the 1977 NCHS/CDC growth charts. *Epi Info* is available on the Internet (www.cdc.gov/epo/epi/epiinfo.htm). An additional goal is to modify this *Epi Info* growth chart module (*Nutstat*) and produce it as an independent software program.

The National Center for Chronic Disease Prevention and Health Promotion will take the lead in developing and promoting educational materials associated with the revised growth charts. These materials will be used in the interpretation of the revised growth charts and will be targeted toward health professionals. The Maternal and Child Health Bureau at the Health Resources and Services Administration (MCHB/HRSA) and the Food and Nutrition Service at the U.S. Department of Agriculture (FNS/USDA), working collaboratively with CDC, will utilize existing State and local networks for disseminating the information.

Graphical presentations of the growth charts in a condensed format with two charts per page are recognized to be more suitable for clinical applications. These are being developed and, when completed, will be available on the Internet. Further publications are planned to present in more detail additional information regarding the development of the revised U.S. growth charts.

Created with improved data and statistical curve smoothing procedures, the revised U.S. growth charts represent an enhanced instrument to evaluate the size and growth of infants and children. It is anticipated that use over time, and subsequent evaluations of the revised charts and their performance, will determine the longevity of these charts. Additional activities such as the ongoing NHANES with data collection beginning at birth, and other research such as development of the WHO growth references based on samples of breast-fed infants, will yield new information. Data from these and other research efforts will provide future opportunities to reassess the status of the revised U.S. growth charts and may lead to further revisions.

Table 1. United States growth charts and data sources

Chart	Age (months) or height (cm) range	Primary data sources[1]	Supplemental data sources
Weight-for-age	Birth to 36 months	National surveys 3–5[2]	National birth certificate data from United States Vital Statistics[2]
Length-for-age	Birth to 36 months	National surveys 3–5[2,3]	Birth certificate data from Wisconsin and Missouri State Vital Statistics[2,4] CDC Pediatric Nutrition Surveillance System data for birth to 5 months[2]
Head circumference-for-age	Birth to 36 months	National surveys 3–5[2]	Fels Longitudinal Study data[2]
Weight-for-length	45–103 cm	National surveys 3–5[2,5]	Birth certificate data from Wisconsin and Missouri State Vital Statistics[2]
Weight-for-stature	77–121 cm	National surveys 3–5[5]	None
Weight-for-age	24 to 240 months	National surveys 1–5[5]	None
Stature-for-age	24 to 240 months	National surveys 1–5	None
BMI-for-age	24 to 240 months	National surveys 1–5[5]	None

[1]Survey 1=NHES II, Survey 2=NHES III, Survey 3=NHANES I, Survey 4=NHANES II, Survey 5=NHANES III.
[2]Excludes birth weight ≤ 1500 gm.
[3]Excludes data from NHANES III for ages < 3.5 months.
[4]Wisconsin and Missouri were the only States with available data from birth certificates.
[5]Excludes data from NHANES III for ages > 72 months.

Table 2. Data sets used to construct the United States growth charts, by age of subject and growth chart variable

Data set	Years	Data source	Subject ages (months)[1]	Sex	Chart variable[2]
Primary data sets					
NHES II	1963–65	National survey	72.0–145.9	M, F	W, S, BMI
NHES III	1966–70	National survey	144.0–217.9	M, F	W, S, BMI
NHANES I	1971–74	National survey	12.0–23.9	M, F	L
			12.0–35.9	M, F	HC
			12.0–281.9	M	W
			12.0–245.9	F	W
			18.0–305.9	M, F	S
			18.0–305.9	M, F	BMI[3]
NHANES II	1976–80	National survey	6.0–35.9	M, F	L, HC
			6.0–281.9	M	W
			6.0–245.9	F	W
			18.0–305.9	M, F	S
			18.0–305.9	M, F	BMI[3]
NHANES III	1988–94	National survey	3.0–35.9	M, F	L
			2.0–35.9	M, F	HC
			2.0–71.9	M, F	W
			18.0–305.9	M, F	S
			18.0–71.9	M, F	BMI[3]
Supplemental data sets					
United States Vital Statistics	1968–80; 1985–94	Birth certificates	Birth	M, F	W
State of Wisconsin Vital Statistics	1989–94	Birth certificates	Birth	M, F	W, L[4]
State of Missouri Vital Statistics	1989–94	Birth certificates	Birth	M, F	W, L[4]
Fels Longitudinal Study	1960–94	Hospital records†	Birth	M, F	HC
Pediatric Nutrition Surveillance System (selected clinics)	1975–95	Clinic records	0.01–4.9	M, F	L

[1]Data beyond the 2–20 years range for the child/adolescent charts were used to improve estimates at the upper and lower age boundaries. The final child/adolescent growth charts were truncated to extend only from 2.0 through 19.99 years (24.0–239.99 months). Subject ages, shown for growth chart variables, reflect the endpoints of age ranges for data actually used to construct the smoothed percentile curves.
[2]W=weight; S=stature; BMI=body mass index; L=length; HC=head circumference.
[3]BMI (wt/stature^2) includes lengths at ages 18.0–23.99 months, and stature at all other ages.
[4]Data from Wisconsin and Missouri were used at birth for the length-for-age and weight-for-length charts, but were not used in the infant weight-for-age charts (see also table 1).
†Measured in hospital by Fels staff.

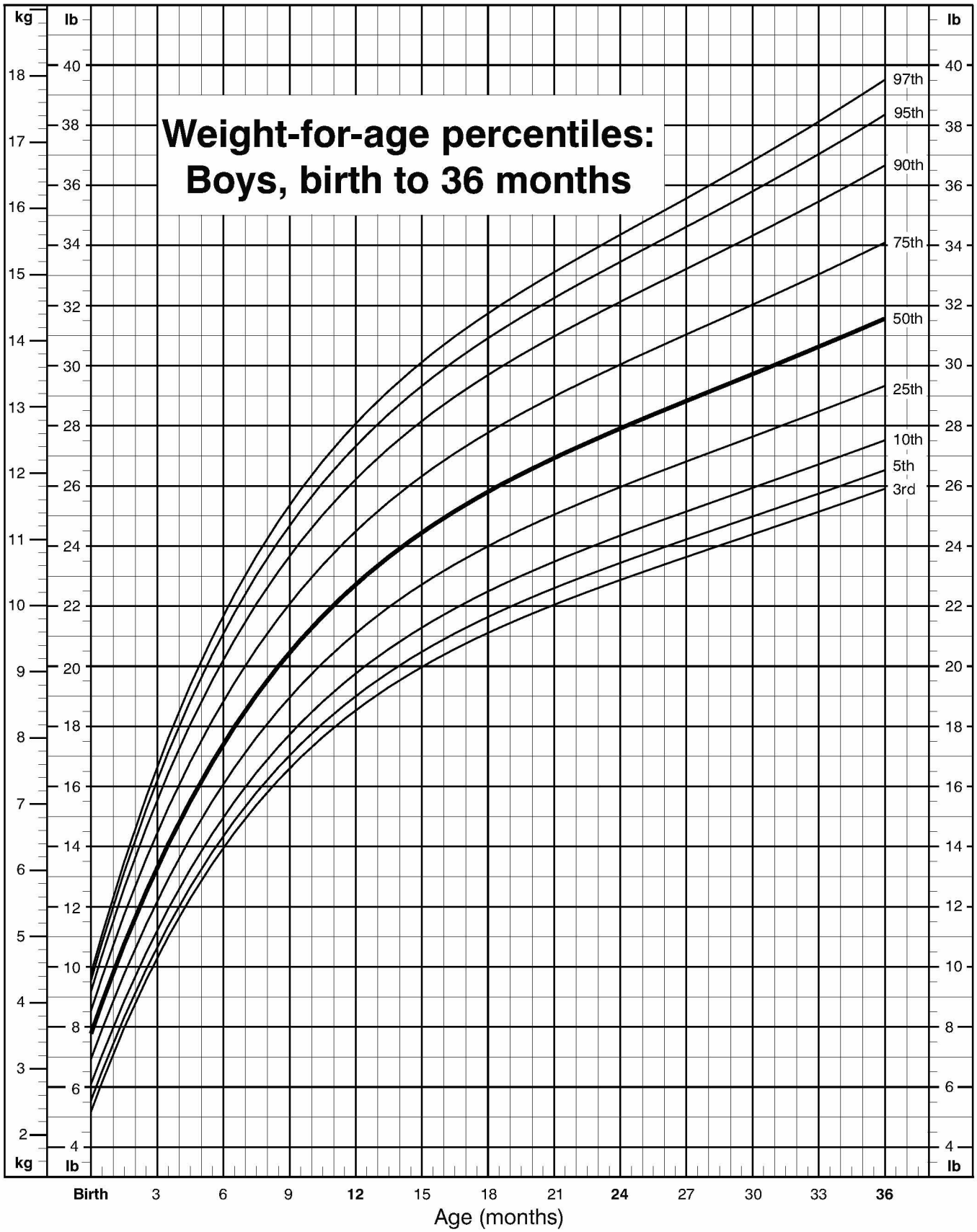
Table 3. Summary of curve smoothing procedures

Curve variables	Curve smoothing procedures
Weight-for-age Birth to 36 months	3 parameter linear model fit to empirical percentile points for weight at midpoints of age intervals, and anchored (i.e., forced) at birth.
2–20 years	Locally weighted regression based on 15 point smoothing for boys and 17 point smoothing for girls. Fit to empirical percentile points for weight at midpoints of age intervals.
Birth to 20 years	Merged infant and older child curves from birth to 20 years by combining weighted averages of empirical percentiles at ages 24.00–29.99 and 30.00–35.99 months. Further smoothed combined data with a family of 10 parameter polynomial regression models for boys and 9 parameter polynomial regression models for girls, fit to smoothed percentile points for weight at midpoints of age intervals.
Length-for-age Birth to 36 months	3 parameter linear model fit to empirical percentile points for length at midpoints of age intervals and to birth data.
Stature-for-age 2–20 years	10 parameter nonlinear model fit to empirical points for stature at midpoints of age intervals. Nonlinear model used to ensure a monotonic increase in stature during pre-pubertal, pubertal, and post-pubertal growth periods.
Length-for-age and stature-for-age Birth to 20 years	Adjusted length-for-age curves, smoothed with a 3 parameter linear model, by subtracting 0.8 cm from length to make length continuous with stature in the overlapping age interval of 24 to 36 months. Averaged percentiles in the overlap period by assigning weights of 1, 11/12, ..., 1/12, 0 at 24, 25, ..., 35, 36 months, respectively, to length-for-age. Assigned opposite weights of 0, 1/12, ..., 11/12, 12/12 at 24, 25, ..., 35, 36 months, respectively, to stature-for-age smoothed with a 10 parameter nonlinear model. The modified LMS smoothing procedure was applied to the combined data, and length-for-age was readjusted by adding back 0.8 cm to length, producing separate length-for-age and stature-for-age curves.
Head circumference-for-age Birth to 36 months	3 parameter linear model fit to empirical percentile points for head circumference at midpoints of age intervals and to birth data.
Weight-for-length and weight-for-stature 45–121 cm	Adjusted empirical weight-for-length data by subtracting 0.8 cm from length to make length continuous with stature in the overlapping age interval of 24–36 months. Merged empirical weight-for-length and weight-for-stature data. Smoothed combined data with a 5 parameter polynomial regression model, fit to empirical percentile points for weight at midpoints of 2 cm intervals for length and stature. Readjusted weight-for-length curves by adding 0.8 cm back to length, producing separate weight-for-length and weight-for-stature curves.
BMI-for-age 2–20 years	Locally weighted regression model based on a 5 point smoothing at midpoints of age intervals for ages 2–12.5 years, and a 25 point smoothing for boys and a 27 point smoothing for girls for ages 13–20 years. Further smoothed with a 4 parameter polynomial regression model fit to smoothed percentile points for BMI at midpoints of age intervals.

Table 4. Comparison of characteristics for 1977 charts and revised charts

Chart variables	1977 NCHS growth charts	United States growth charts
Weight-for-age	Birth to 36 months 2–18 years	Birth to 36 months 2–20 years
Length-for-age	Birth to 36 months	Birth to 36 months
Weight-for-length	Birth to 36 months Boys (49–103 cm) Girls (49–101 cm)	Birth to 36 months Boys (45–103 cm) Girls (45–103 cm)
Head circumference-for-age	Birth to 36 months	Birth to 36 months
Stature-for-age	2–18 years	2–20 years
Weight-for-stature*	(Prepubescent) Boys (90–145 cm) Girls (90–137 cm)	Boys (77–121 cm) Girls (77–121 cm)
BMI-for-age	Not available	2–20 years

*Weight-for-stature: The 1977 charts are applicable to boys with stature 90–145 cm *and* age < 11.5 years, and to girls with stature 90–137 cm *and* age < 10.0 years. They are not applicable for any child showing the earliest signs of pubescence. The revised charts have no similar age or pubescence restrictions. Although the revised charts were developed for children ages 2–5 years, in practice they may accommodate some shorter children with chronologic ages ≥ 5.0 years.



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

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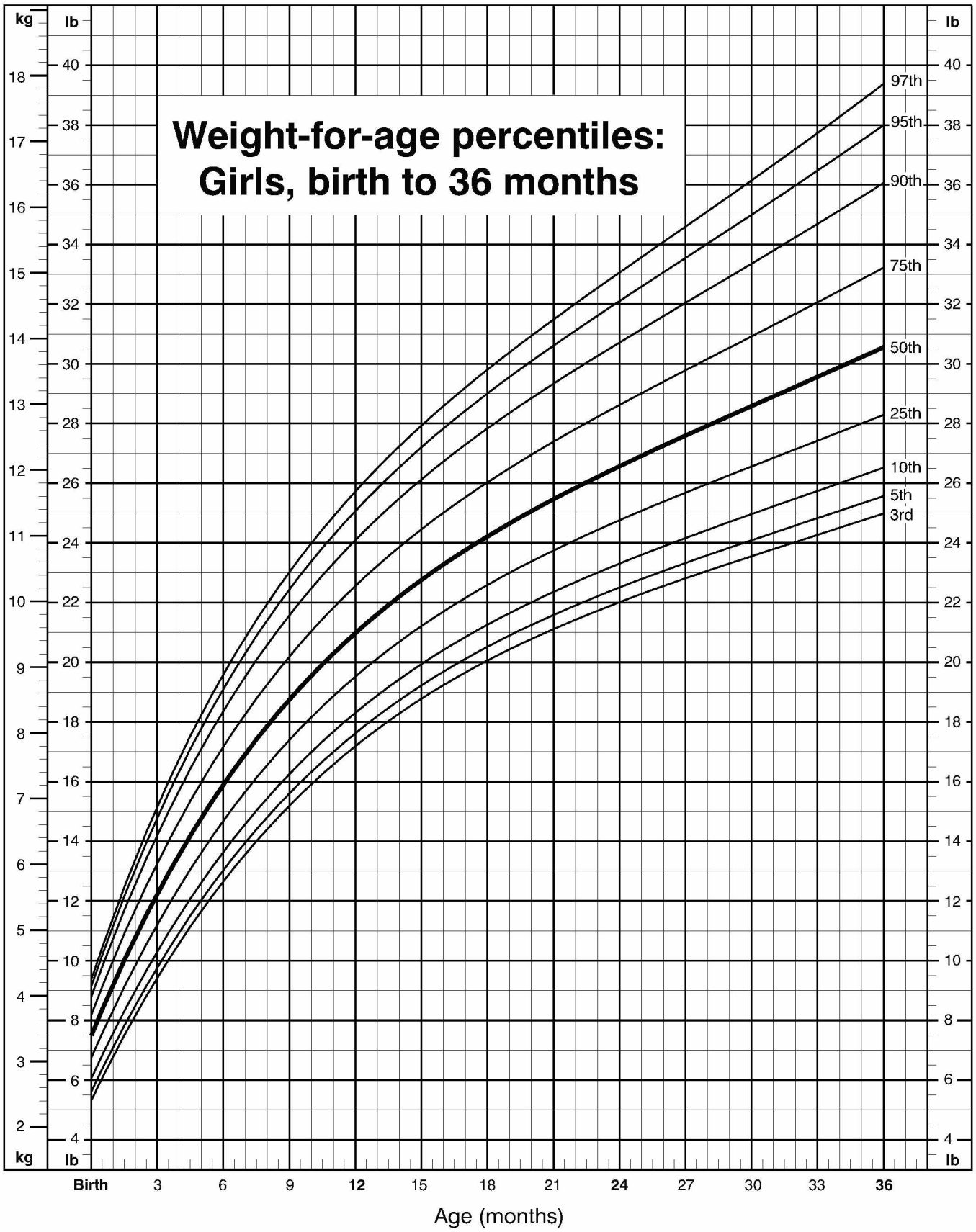
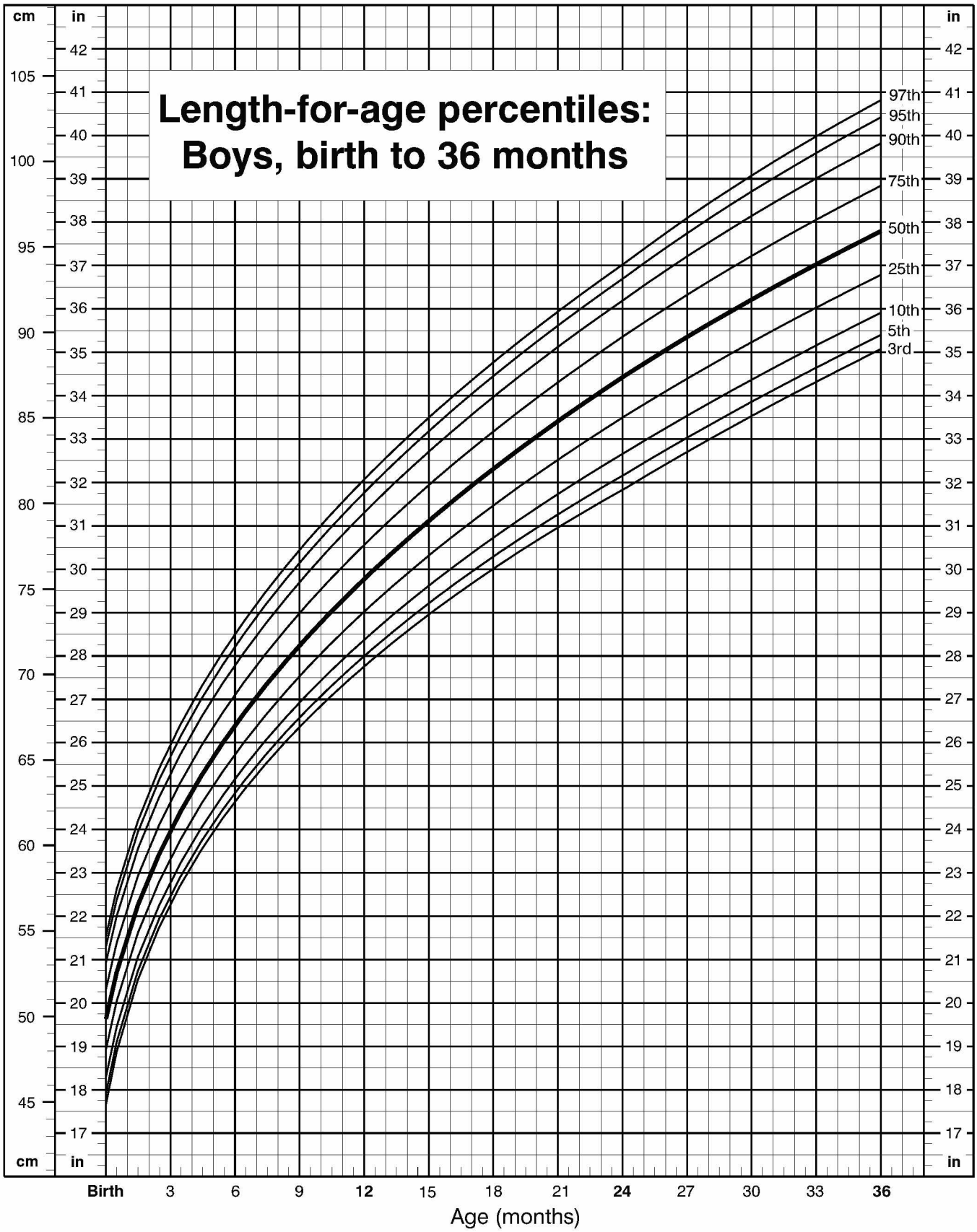
Figure 1. Weight-for-age percentiles, boys, birth to 36 months, CDC growth charts: United States



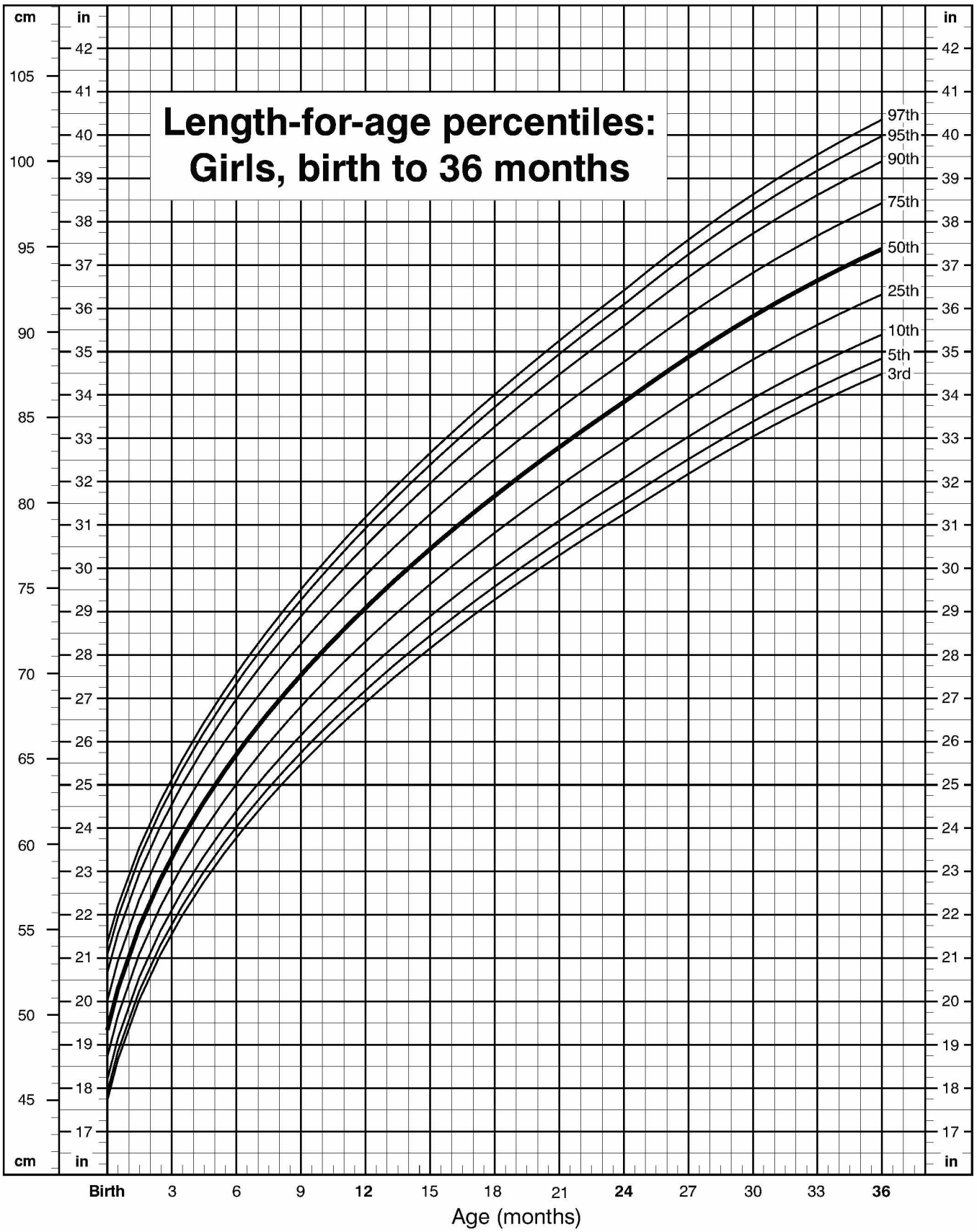
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 2. Weight-for-age percentiles, girls, birth to 36 months, CDC growth charts: United States



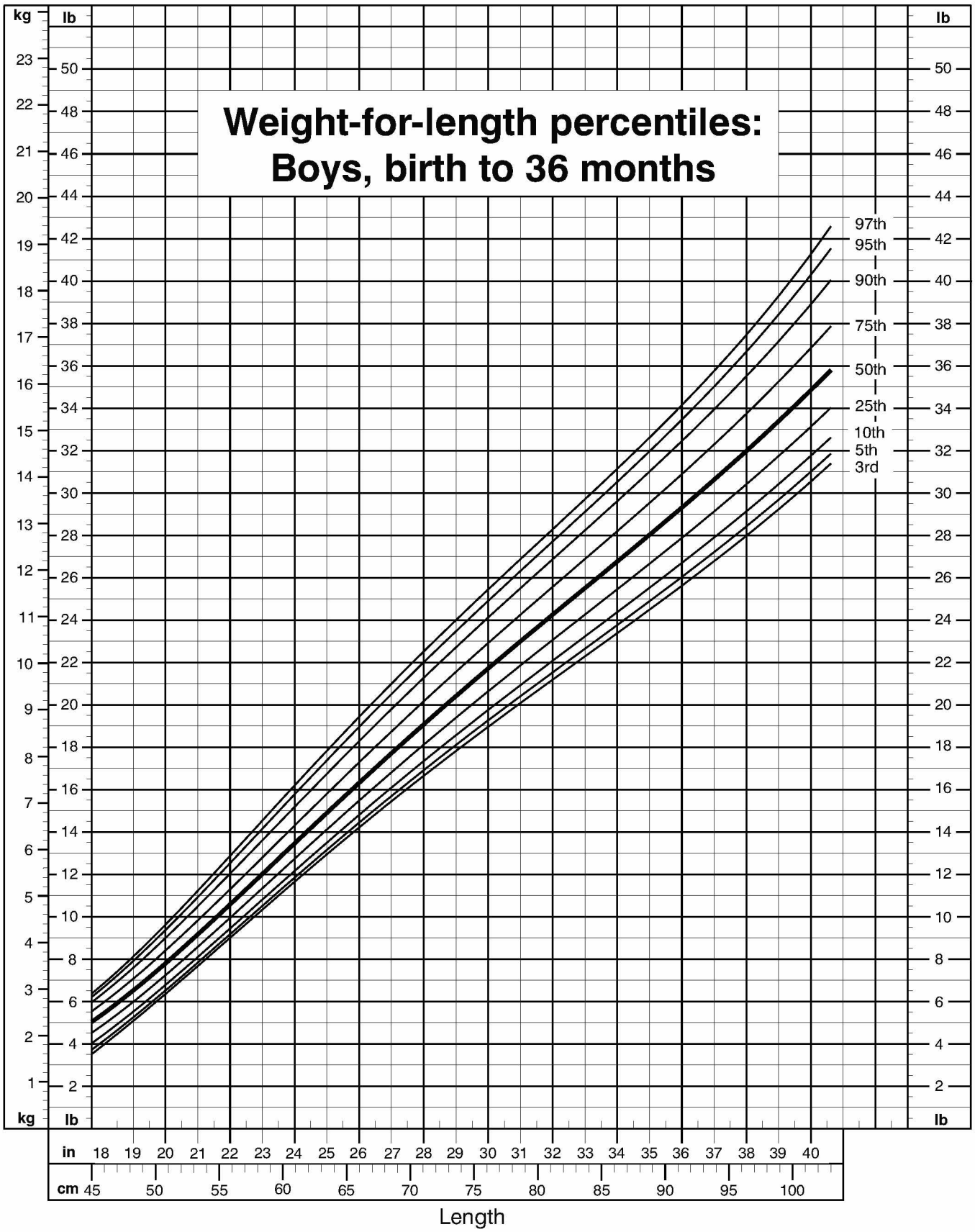
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 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).

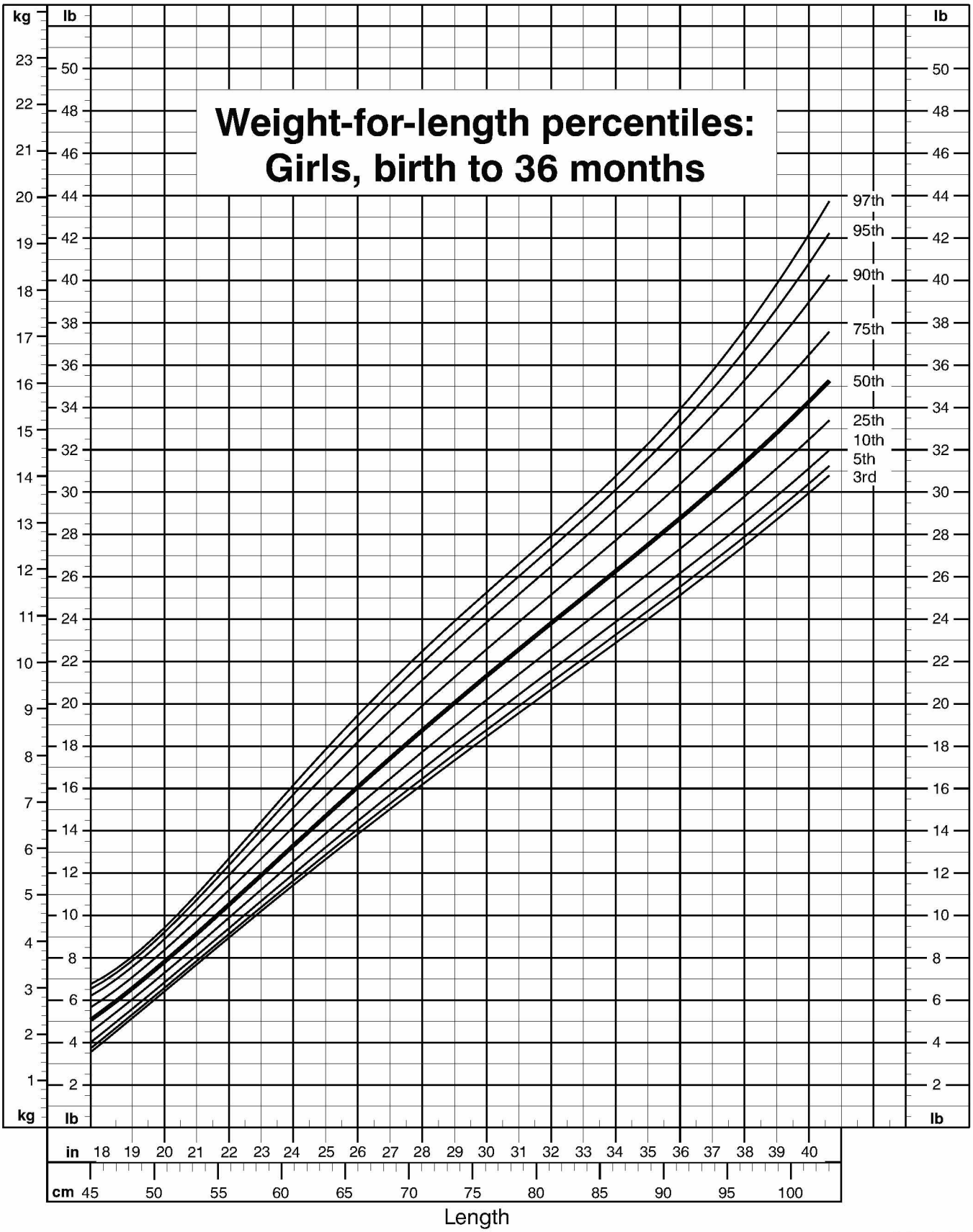
Figure 4. Length-for-age percentiles, girls, birth to 36 months, CDC growth charts: United States



Revised and corrected June 8, 2000.

SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

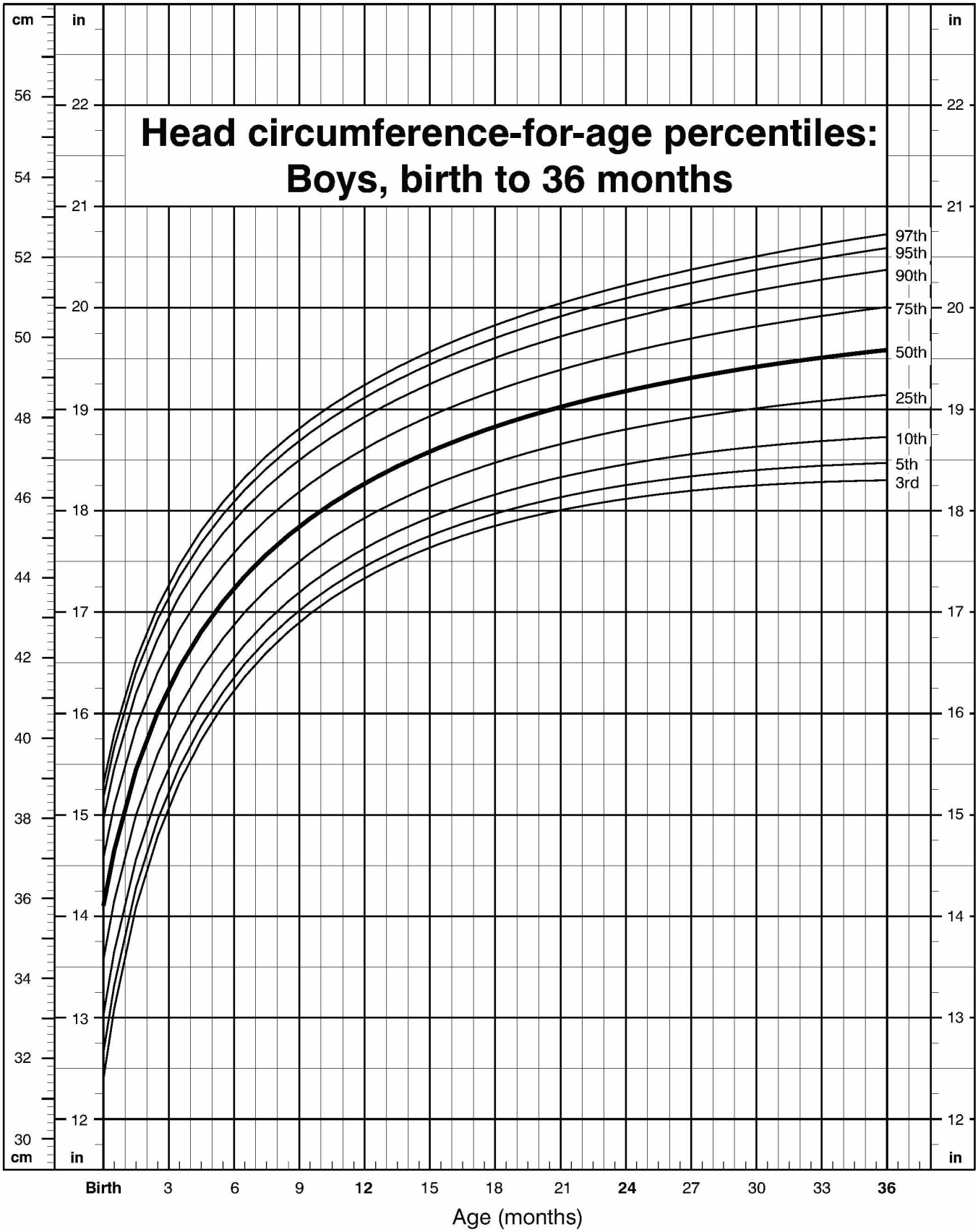
Figure 5. Weight-for-length percentiles, boys, birth to 36 months, CDC growth charts: United States



Revised and corrected June 8, 2000.

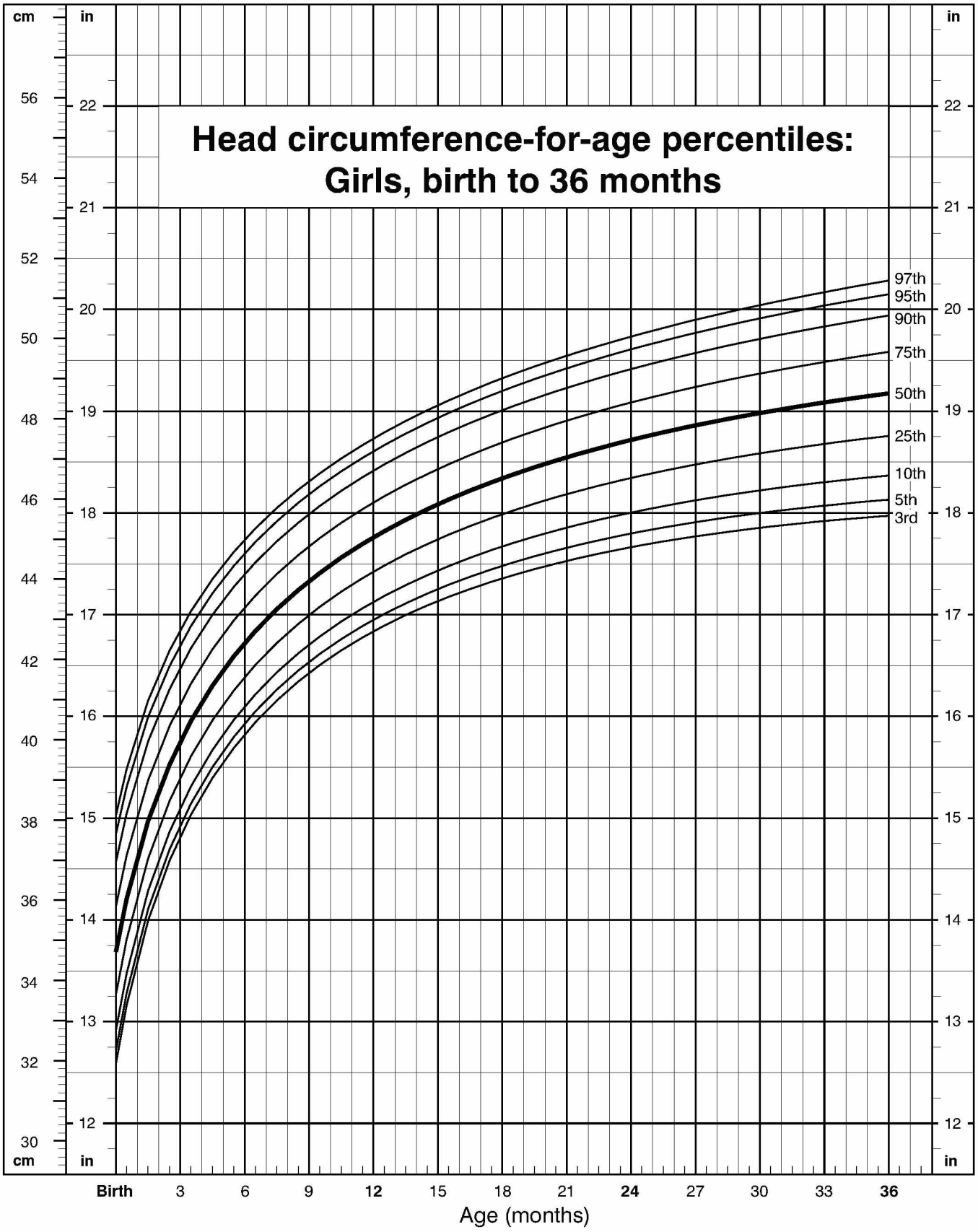
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 6. Weight-for-length percentiles, girls, birth to 36 months, CDC growth charts: United States



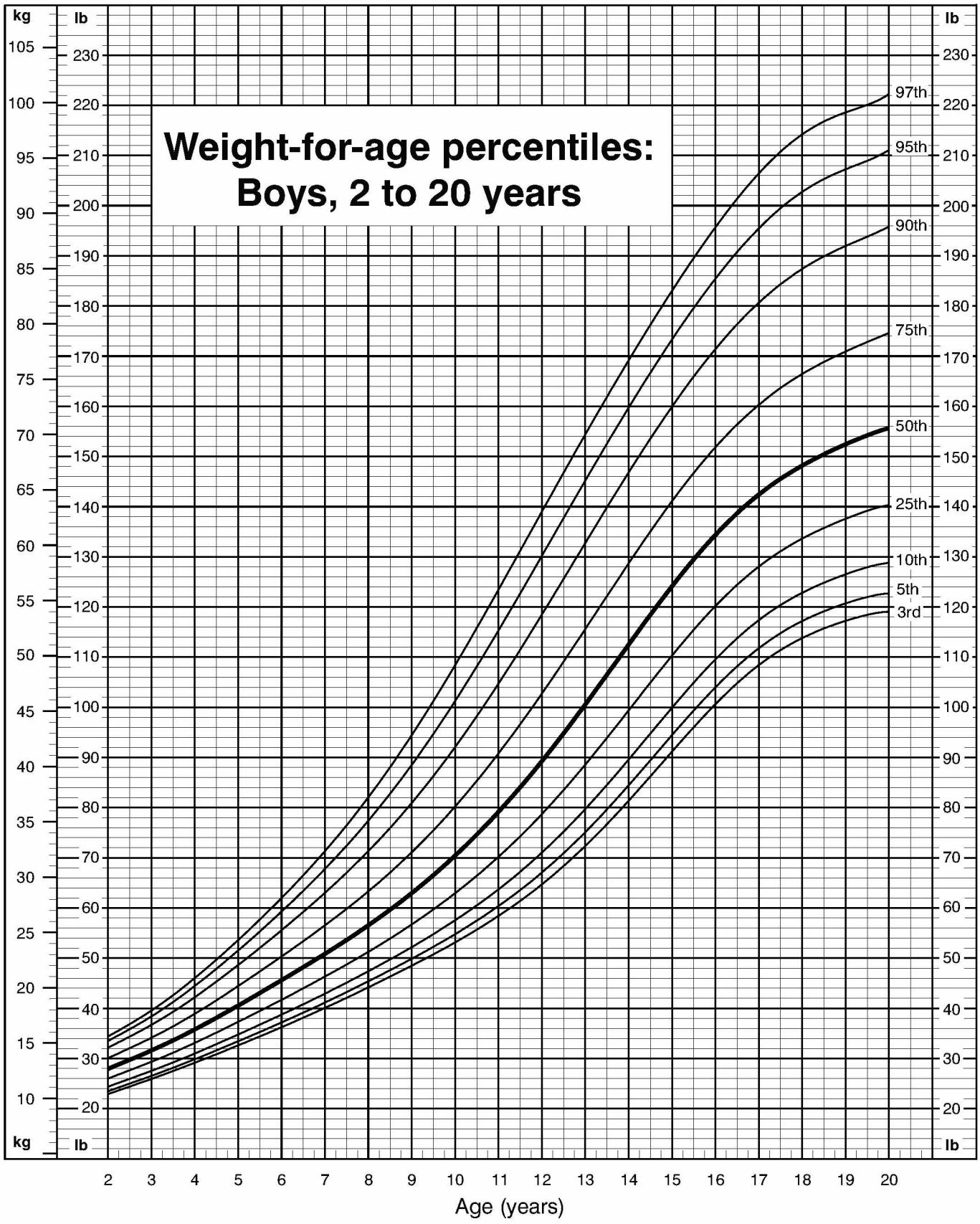
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 7. Head circumference-for-age percentiles, boys, birth to 36 months, CDC growth charts: United States



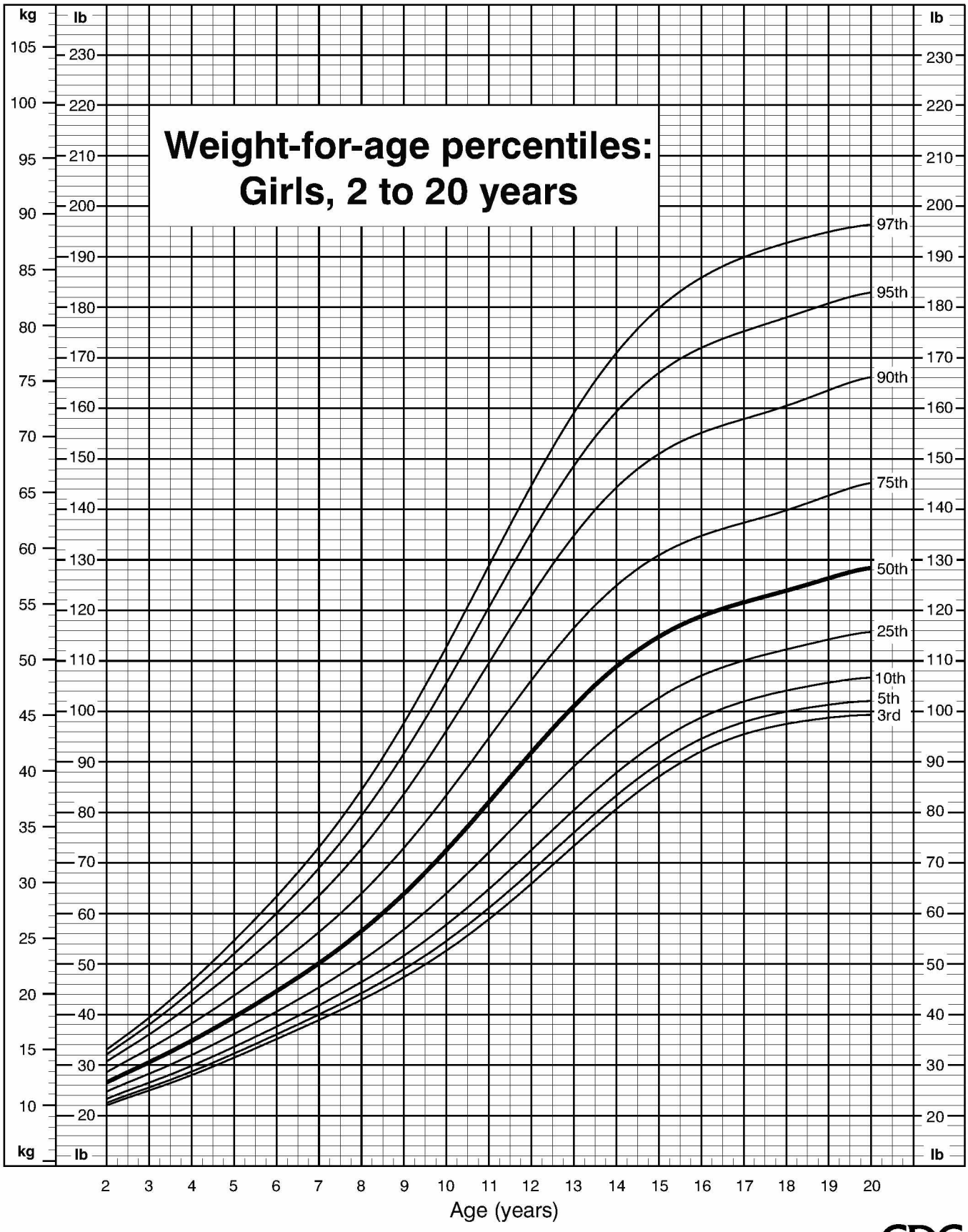
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 8. Head circumference-for-age percentiles, girls, birth to 36 months, CDC growth charts: United States



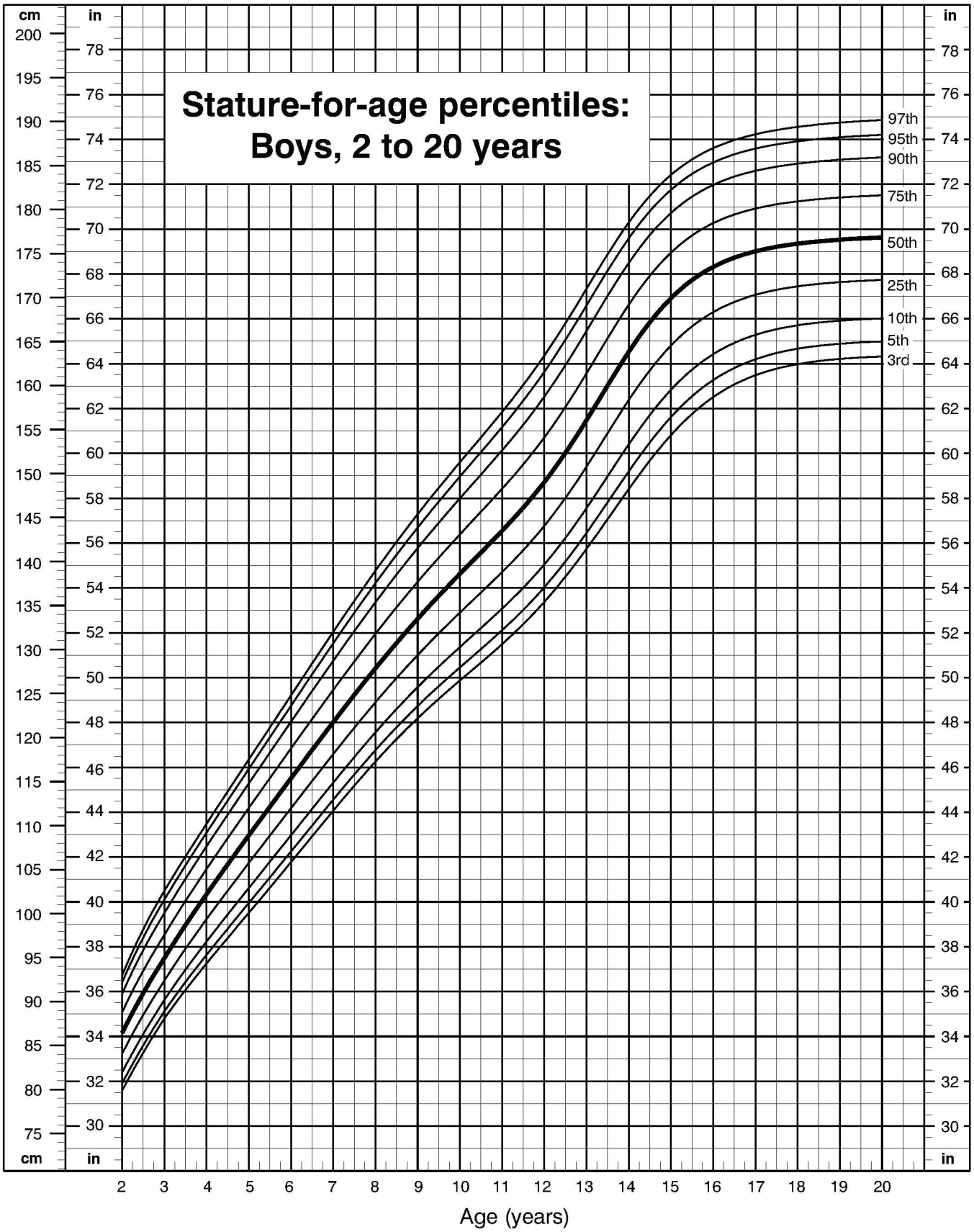
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 9. Weight-for-age percentiles, boys, 2 to 20 years, CDC growth charts: United States



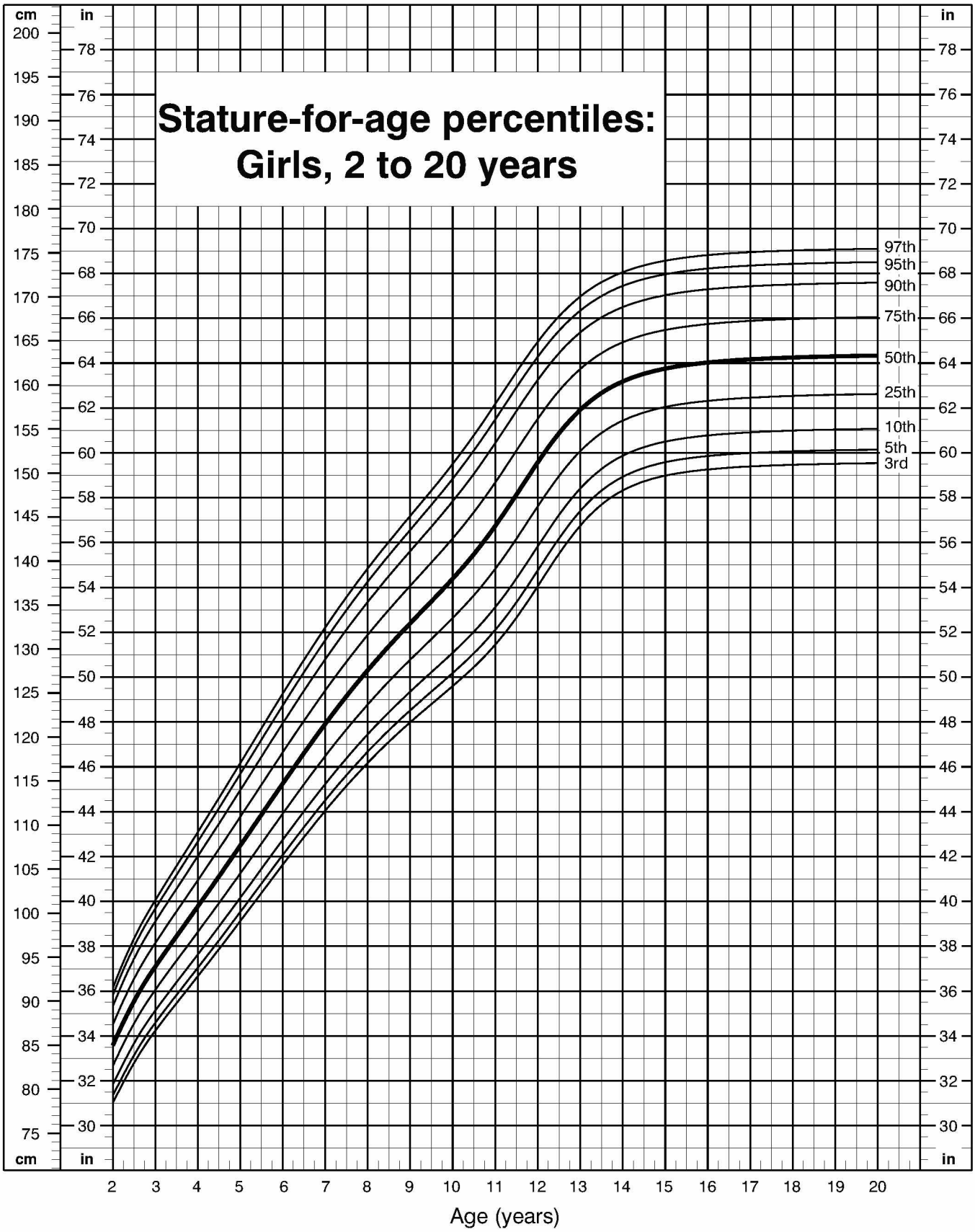
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 10. Weight-for-age percentiles, girls, 2 to 20 years, CDC growth charts: United States



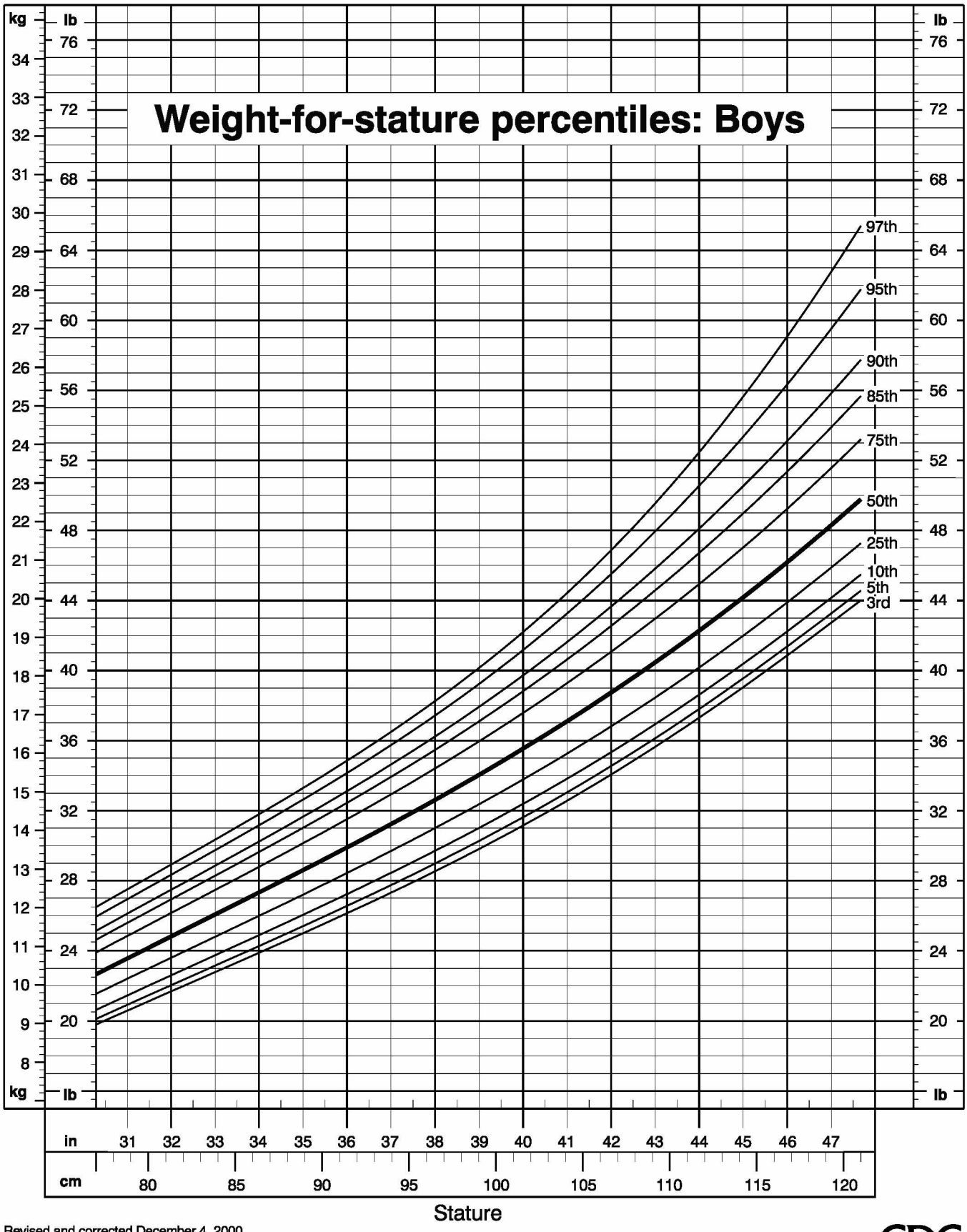
SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 11. 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 12. Stature-for-age percentiles, girls, 2 to 20 years, CDC growth charts: United States



Revised and corrected December 4, 2000.

SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

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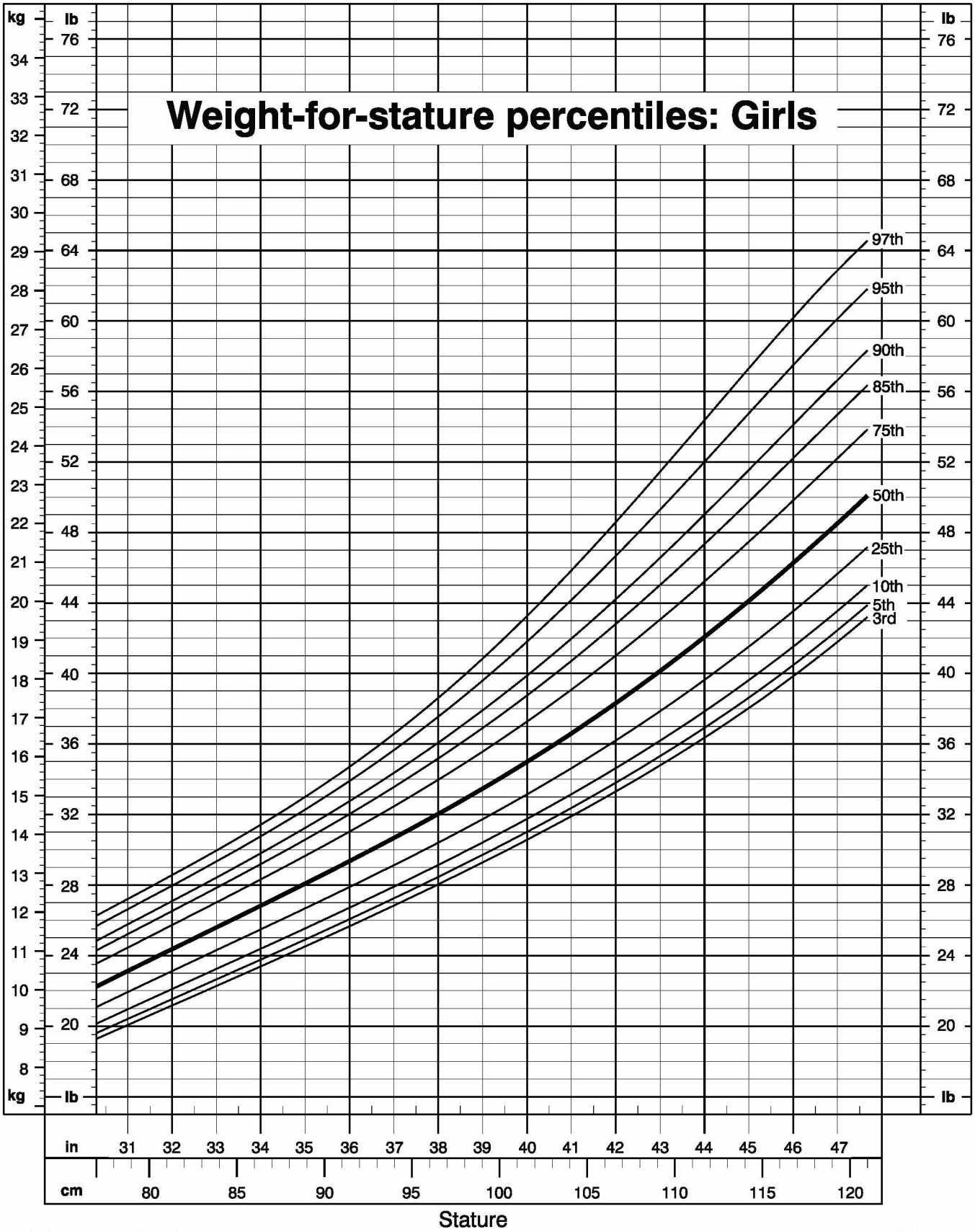
Figure 13. Weight-for-stature percentiles, boys, CDC growth charts: United States



Revised and corrected December 4, 2000.

SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

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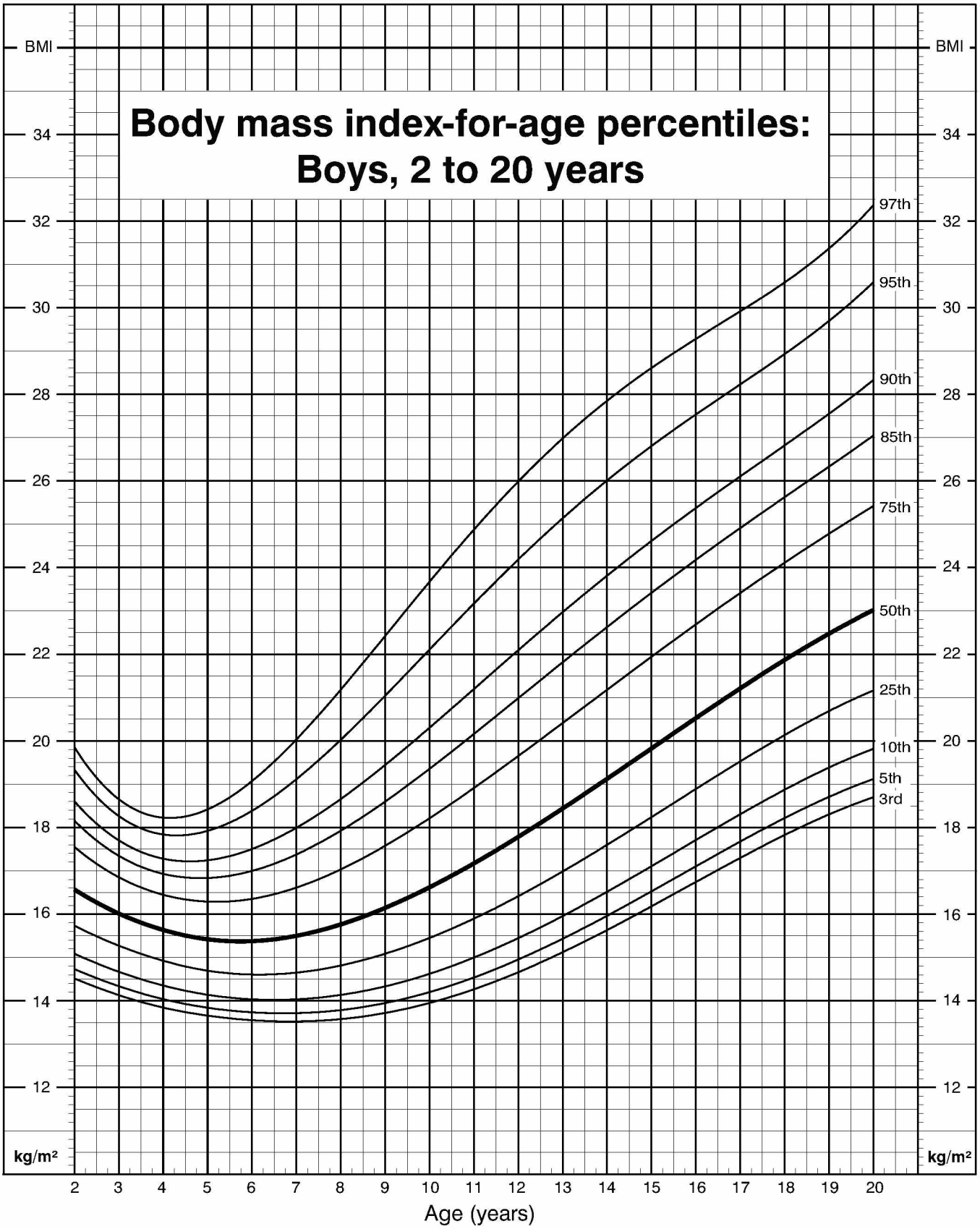
Figure 14. Weight-for-stature percentiles, girls, CDC growth charts: United States



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

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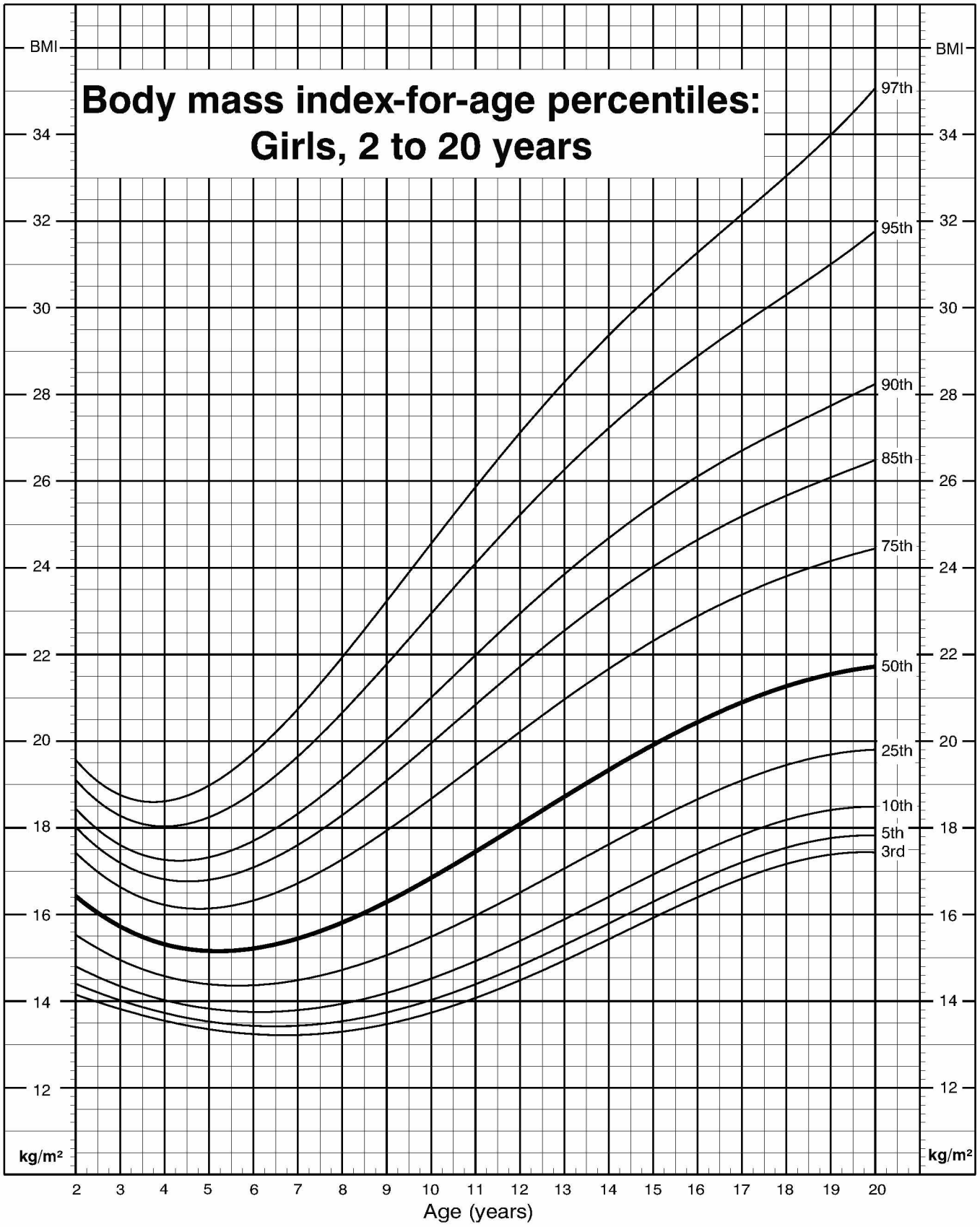
Figure 15. Body mass index-for-age percentiles, boys, 2 to 20 years, CDC growth charts: United States



SOURCE: Developed by the National Center for Health Statistics in collaboration with the National Center for Chronic Disease Prevention and Health Promotion (2000).

Figure 16. Body mass index-for-age percentiles, girls, 2 to 20 years, CDC growth charts: United States

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ERRATA

The following changes were made after the original report was published. Figures 5 and 6 were revised and corrected June 8, 2000, and figures 13 and 14 were revised and corrected December 4, 2000.

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