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Executive Summary of the Growth Chart Workshop 1992

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
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Executive Summary of the Growth Chart Workshop

Sponsored by:

National Center for Health Statistics
Division of Health Examination Statistics

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EXECUTIVE SUMMARY

OF

NCHS GROWTH CHART WORKSHOP

Sponsored by The Division of Health Examination Statistics,

National Center for Health Statistics

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Preface

The National Center for Health Statistics-Centers for Disease Control and Prevention (NCHS-CDC) has a key role in nutrition monitoring through conducting national surveys of the nutritional and health status of the U.S. population. As part of the federal government's Ten-Year Comprehensive Plan for the National Nutrition Monitoring and Related Research Program, NCHS-CDC also has lead responsibility to develop a core set of standardized nutritional status indicators and appropriate interpretive criteria for the general population and subgroups of the population The assessment and interpretation of height and weight are critical components of this core nutritional status package The third National Health and Nutrition Examination Survey (NHANES III) was specifically designed to include and oversample infants and children ages 2 months - 5 years in order to revise the NCHS Growth Charts.

A workshop, organized and sponsored by the Division of Health Examination Statistics of the NCHS, and supported by NCHS nutrition monitoring resources, was held on December 13-14, 1992 in College Park, MD The purpose of this workshop was to address issues associated with revising the current NCHS Growth Charts A group of experts, selected for their knowledge and experience with growth and growth charts, was assembled to deliver brief presentations that addressed specific issues and questions generated by the workshop chairmen A list of participants is given in Appendix A to this report Subsequent discussions were oriented toward providing expert advice and opinions to the NCHS The discussions at this workshop and the recommendations resulting from them are the subject of this executive summary

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1. Glossary

BMI = body mass index (weight/stature^2, kg/m^2)

CDC = Centers for Disease Control and Prevention

CDC revised charts = unpublished versions mainly related to disjunctions at 2 to 3 years in the NCHS charts

EC = Editorial comments

FELS = The Fels Longitudinal Study

FNB = Food and Nutrition Board

HHANES = Hispanic Health and Nutrition Examination Survey

NAS = National Academy of Sciences

NCHS = National Center for Health Statistics, Centers for Disease Control and Health Prevention

NCHS revised charts = the charts that may become available in 1996 and that will be partly based on NHANES III data

NCHS charts = Growth charts as published by Hamill et al (1977, 1979)

NHANES I, II and III = The first, second and third National Health and Nutrition Examination Surveys (1971-1974, 1976-1980 and 1988-1994 respectively)

NHES II and NHES III - The second and third cycles of the National Health Examination Survey conducted in 1963-1965 and 1966-1970 respectively

NICHD = National Institute of Child Health and Human Development

NRC = National Research Council

USDA = United States Department of Agriculture

WHO = World Health Organization

WIC = Women, Infants and Children Supplemental Feeding Program

2. Summary of Recommendations

The following recommendations were made after considerable discussion of the rationale and the feasibility of each The recommendations are in **bold** type within the text These recommendations were made on the premise that the primary purpose of the revisions of the NCHS charts is to provide a better instrument for health care professionals who evaluate the growth status of children in the United States It is possible that the revised charts will be secondarily adapted by WHO for international use Therefore, WHO should be kept appraised of NCHS plans and progress Decision making about topics for which there are divergent opinions would be assisted by a clear NCHS statement regarding (i) the aims of the revisions and (ii) the priorities for the groups to be served by the charts

Recommendations relevant to the revision of the NCHS charts

The sections where these recommendations are discussed are given in parentheses

1 that revised charts be produced by NCHS and that adequate resources be made available to perform this complex task expeditiously. It was recommended also that NHANES III data be used to revise the NCHS charts, perhaps in combination with data from earlier NCHS surveys and other sources (Section 3, pp 4-9)

2. that NCHS activities in relation to the revision of the NCHS charts and a summary of the Workshop be published in a peer-reviewed journal and summarized in a news release (Section 3; pp. 4-9)

3. that work begin now to select, obtain and manage the data sets that are needed and develop and test statistical methods and that all other necessary steps be taken to prepare for the revision of the NCHS charts (Section 4, pp 9-12)

4 that ages at examinations be used instead of ages at interviews when revising the NCHS charts (Section 4, pp 9-12)

5 that national data for birth weight be used and that data from the Iowa Studies be used from birth to 3 months, when there is a lack of NCHS data From 3 to 6 months data from the Iowa and Fels studies should be used with gradual merging to NCHS data, unless

NCHS conducts a survey of infant growth with timing that would not delay the revision It was further recommended that, without delay, NCHS elicit the help of NICHD, USDA, WIC, The Women's Health Initiative, The Maternal and Child Health Bureau, Nutrition Monitoring, and other government agencies to conduct a national or broadly representative survey of infant growth (Section 4, pp 9-12)

6. that previous analyses of secular trends be extended to include NHANES III data, this would assist the selection of data sets for the revision of the NCHS charts (Section 6, pp. 13-15)

7 that charts specific for ethnic/racial groups not be developed but that tabular data for such groups be published (Section 7, pp 15-18)

8 that a decision be made soon as to whether data from low-birthweight infants will be excluded from all the data bases used in the revision of the growth charts up to 3 years of age (Section 8, pp 19-22)

9 that the prevalence of breast feeding in NHANES III be documented (Section 9, pp 22-24)

10 that charts or adjustment factors for breast feeding not be developed partly because the NHANES III data would be inadequate for this purpose (Section 9, pp 22-24)

11. that charts specific to socioeconomic status not be developed, but, to assist interpretation of the revised NCHS charts, the possible influences of socioeconomic factors should be analyzed and published for whites, blacks, and Mexican Americans separately using NHANES III data (Section 9, pp 22-24)

12 that procedures similar to those used by CDC (Roche et al , 1989a) be applied in the revision of the NCHS charts to reduce disjunctions between percentiles for infants and those for older children (Section 10, pp 24-25)

13 that the revised charts be kept simple, as at present, but that 3rd and 97th percentile levels be added, together with other outlying percentiles if space allows and the sample sizes make this practical (Section 11, pp 25-29)

14. that the variables and age ranges be the same as in the NCHS charts except for the substitution of Body Mass Index (BMI, weight/stature^2) for weight-for-stature from 2 to 18 years Weight-for-recumbent length should be retained from birth to 3 years (Section 11; pp. 25-29).
15. that tables but not charts be developed for the available anthropometric variables used clinically and in nutrition monitoring and screening (Section 11, pp 25-29) These include sitting height/stature, skinfold thicknesses, waist-hip ratio, arm muscle area and wrist breadth
16. that NHANES III data not be used to develop sets of values that would adjust for parental statures when the statures of children are evaluated (Section 11, pp 25-29)
17 that maturity-specific charts not be developed but prevalence data for maturity status be added to the charts Furthermore, factors to adjust stature for maturity status should be calculated from NHANES III data and published but should not be added to the NCHS revised charts (Section 12, pp 29-31)
18 that mathematical/statistical procedures be used to smooth the empirical percentiles taking account of the patterns of growth in individual children These and all other procedures applied in the revision should be published (Section 13, pp 31-32)
19 that software programs be prepared that will allow public health departments and others to produce copies of the NCHS revised charts, perhaps through an electronic distribution system similar to the Wonder system at CDC, and that other user-friendly software be developed to allow interactive use of the smoothed data (Section 14, pp 32)
20. that the revised charts be accompanied by interpretive guidelines (Section 15, pp 32-34)
21. that the next NCHS survey oversample pubescent children and include hormonal measures (Section 4, p 9)

3. Development of the NCHS Growth Charts (1977)

It is 16 years since the formal publication of the NCHS Growth Charts (Hamill et al , 1977, 1979). During that time, new data and new statistical techniques have become available and attention has been directed to some aspects of the NCHS Growth Charts that might limit their accuracy and their usefulness in the US and abroad. Possible limitations of these charts and the ways in which they should be addressed were the focus of the NCHS Growth Chart Workshop. While the Workshop considered the limitations of the NCHS Growth Charts, it was stressed that these charts significantly improved the assessment of growth in the US and abroad and they have been used for longer and more widely than expected by those who developed them.

The development of the NCHS charts began in 1974 and was completed in 1976. The Working Group for this task lacked experience in the development of growth charts, but this lack was offset by fine statistical skills within the group and an enthusiasm to reach the objectives. The Working Group and others considered that the Harvard Standards, which were in general use at the time, should be replaced because (i) secular changes were likely since the data had been collected, (ii) the Harvard data were from two small regionally restricted samples, and (iii) the percentile levels were calculated with the assumption that the data were normally distributed (Stuart and Meredith, 1946) Despite these deficiencies, the Harvard Standards had been used for many years and a considerable delay was expected before the new NCHS charts would be generally accepted

There was much to be done The sets of data to be used were selected and decisions made about the variables to be included, the age ranges for particular variables and charts, and the method of adjusting weight for stature Other decisions concerned the selection of percentile levels, smoothing procedures and the units (metric or English) There was an emphasis on the documentation of all procedures which were as objective and replicable as possible (Hamill et al., 1977, 1979)

The values displayed in the tables and charts were called "reference data" rather than "standards" because the latter term describes "what should be" and implies the values are ideals or goals associated with maximum health and longevity This was not known to be true for the values in the charts which describe the distributions that were observed The term "reference data" refers to "what is," representing a cross-sectional description of a population The NCHS growth charts provide reference data for size attained at particular ages and might appropriately be called "size charts" (Hamill et al , 1977) The term "growth chart" was, however, so widely accepted that the Working Group did not attempt to change it

Work to develop the NCHS Growth Charts began shortly after this was recommended by the Committee on Nutrition Advisory to CDC, FNB, NAS-NRC (1974) and by a group convened by NICHD (Roche and McKigney, 1976) These groups recommended that data from NCHS surveys and from the Fels Longitudinal Study be used and that one set of charts be developed for all ethnic/racial groups because the known differences in body size between these groups were small The Fels data were needed because, at that time, the NCHS data did not extend to ages younger than 1 year

Two groups of charts were produced for each sex The group of charts for birth to 3 years included percentiles for weight, recumbent length, weight-for-recumbent length and head circumference These were derived from Fels Longitudinal Study data A second group of charts for the age range 2 to 18 years included percentiles for weight, stature, and weight-for-stature These were derived from NCHS survey data (National Health Examination Survey cycles II and III [NHES II and III] and first National Health and Nutrition Examination Survey [NHANES I]) The sample sizes for these data sets are given in Appendix B Within each sex, the samples were about 400 at each of 10 ages from birth through 3 years and, for each half-year, the NCHS samples were about 800 from 2 to 6 years and about 1000 from 6 to 18 years

The Fels data, which were serial, were obtained from 1929 to 1974 and the NCHS data were obtained from 1963 to 1974 The children in the Fels Study were from a general middle-class population in southwestern Ohio and the NCHS data were from multi-stage national samples (Roche, 1992) Discontinuities between the Fels and NCHS data sets were noted for the transition from recumbent length to stature and for the transition from weight-for-recumbent length to weight-for-stature, even after adjusting for the expected systematic differences between these measures (Hamill et al., 1977). Nevertheless, procedures were not applied to make percentile lines from the two data sets congruent

Seven empirical percentiles (5th, 10th, 25th, 50th, 75th, 90th and 95th) were obtained from the Fels data for weight, recumbent length and head circumference at birth, 1, 3, 6, 9 and 12 months and then at 6-month intervals to 3 years After applying the sample weighting coefficients, corresponding empirical percentiles were obtained for weight and stature from the NCHS data at 6-month intervals from 2 to 18 years The weight-for-recumbent length (birth to 3 years) and weight-for-stature empirical percentiles (2 to 18 years) were obtained for each 2 cm of recumbent length or stature For each variable, the selected empirical percentiles were arranged in order of age or stature categories and smoothed using cubic splines The number and the locations of knots (junctions between successive cubic functions) were chosen to achieve a balance between maximal smoothing and minimal distortion of the empirical data. After repeated trials, two knots were used for the infancy period and three knots for the later charts (Hamill et al, 1977) Some problems may have been caused by using the same knots for all percentile lines

Some revisions to the NCHS growth charts were made by the National Center for Chronic Disease Prevention and Health Promotion, Centers for Disease Control, Division of Nutrition (see Section 10, pp 24-25) The sample sizes were increased for ages 2 to 6 years by incorporating NHANES II stature data and calculating new sample weights for the combined data from different surveys (Roche et al, 1989a) Fels data were used to 12 months and merged gradually with NCHS data from 12 to 18 months The data from birth to 4 years were smoothed using models derived from the changes observed in individual children in the Fels Longitudinal Study

It was recommended that revised charts be produced by NCHS and that adequate resources be made available to perform this complex task expeditiously. Revisions of the current NCHS charts are needed because (i) the distributions of birthweights are too low, (ii) there are disjunctions between the percentile levels at 2 or 3 years for recumbent length-stature, (iii) weight is not adjusted for stature after the beginning of pubescence, (iv) more outlying percentile levels and/or standard deviation levels are needed, and (v) national data were not used for ages younger than 2 years. Also, there may have been secular trends in the US population since the data for the 1977 NCHS charts were collected. It was stated at the Workshop that NCHS has already designated the revision of the NCHS charts as a major objective of the childhood component of NHANES III

It was recommended that NHANES III data be used to revise the NCHS charts, perhaps in combination with data from earlier NCHS surveys and other sources The work should begin now using data from NHANES III–Phase 1 and relate to data management (e g , placing the data from various NCHS surveys in a common format, making sure that ages at examinations are included, making adjustments for variations between ages at examinations and ages for which group estimates are required), analyses of possible secular trends and ethnic/racial differences, the selection and implementation of smoothing procedures, formatting descriptive statistics into charts, and the development of software for analyses and chart formatting This work would not lead to the development of charts based on NHANES III–Phase 1 data that would be replaced a few years later when NHANES III–Phase 2 data become available because it would be confusing if several versions of the NCHS charts were circulating at the same time. This work would, however, allow the rapid development of revised charts utilizing all the NHANES III data soon after the Phase II data are available. Other NCHS data sets may be included after the development of new sample weights

It was recommended that NCHS activities in relation to the revision of the NCHS charts and a summary of the Workshop be published in a peer-reviewed journal and summarized in a news release. The publication could be in The American Journal of Clinical Nutrition or The American Journal of Public Health. Brief announcements should be made in other journals because there are different constituencies This article should include a strong statement of the reasons why the revisions will be delayed until all NHANES III data are available and it should describe NCHS plans for the analysis of anthropometric data that will not be included in the growth charts Some of these analyses should relate to secular changes and to ethnic/racial differences in growth during infancy and pubescence.

4. Data bases available in 1993; the need for data from birth to 3 months

The NCHS sample sizes now available are given in Appendix C for all ethnic/racial groups combined, Black males (the numbers for females are similar) and Mexican Americans In NCHS surveys previous to HHANES, Hispanic Americans were included with whites. This should be taken into account in analyses of possible secular trends The sample sizes for NHANES III given in Appendix C are for Phase I, they will be about twice as large when Phase 2 data collection is complete. The data from NHANES III–Phase 1 are scheduled to be ready for analysis at the end of 1993 The data from Phase 2 may be ready for analysis in the summer of 1996 With this timetable, the NCHS charts could be revised by the end of 1996

The total NHANES III data set within gender, with all ethnic/racial groups combined, for 6-month age groupings, will be about 600 from 6 months to 1 year, 300 from 2 through 5 years, 150 from 6 through 11 years and 100 from 12 through 18 years There will be sample weights for NHANES III–Phase 1, and for Phase 2, and for both phases combined **Consideration of these sample sizes led those at the Workshop to recommend that the next NCHS survey oversample pubescent children and include hormonal measures.**

It was recommended that work begin now to select, obtain and manage the data sets that are needed and develop and test statistical methods and that all other necessary steps be taken to prepare for the revision of the NCHS charts. Early initiation of these steps will allow completion of the task soon after the NHANES III–Phase 2 data become available During this preliminary phase, some topics listed in Section 15 (Guidelines for use and interpretation of the revised NCHS charts; pp. 32-34) should be investigated.

It was recommended that ages at examinations be used instead of ages at interviews when revising the NCHS charts. This is important during infancy since pairs of ages at interviews and at examinations typically differ by 3 to 4 weeks

The age ranges during which variables of interest were measured in NCHS surveys and in the Fels Study are given in Appendix D NHANES III is described as beginning at 2 months but the only data recorded at 2 months are from home interviews, measurements in NHANES III begin at 3 months with some over-sampling from 3 to 5 months Therefore, data from sources other than NCHS are needed from birth to 1 year to provide data from birth to 3 months and allow gradual merging with NHANES III data from 3 to 12 months There are numerous other data sets from US infants (Appendix P), but only a few should be selected for use in the revision The use of many data sets would lead to problems of interpretation

Given the limitations of the existing data, and the fact that growth charts are used more commonly during infancy than at any other time, consideration was given to recommending a survey to meet the need for national growth data from infants. Cross-sectional data could be obtained from a national representative sample or a group of large hospitals that serve mixed populations (region, ethnicity/race, socio-economic status) One hospital in Houston has 17,000 births a year with a good ethnic/race mix and a hospital in Los Angeles is as large It would be necessary to send teams to the hospitals with standardized equipment and after centralized training Clustering of hospitals could lead to more efficient use of teams A criterion for inclusion of a hospital could be the presence on the staff of a person active in infant growth research who would be the local Principal Investigator

It is difficult to design an adequate sampling frame One possibility is to link the study to the Hospital Discharge Survey for which there is a sampling frame and the hospitals are already enrolled The survey could not be based on birth certificates because it takes too long to achieve access to these Teams in hospitals would know of births at about the time they occur

There is a need for about 400 infants at each age (200 of each gender) and they should be measured at birth, 2, 4, 6, 8, 10 and 12 months cross-sectionally (2,800 sets of measurements) The older infants would be measured in the homes if the neighborhoods are safe This large study, that would run simultaneously in multiple hospitals, might be conducted jointly by NCHS and NICHD and, if kept to a minimal level, it might be supported by CDC It would take at least 8 months to organize the funding and there would be a delay of at least 2 years before the commencement of data collection Data collection would require 18 months Therefore this approach might delay the revision of the growth charts The delay could be reduced if a Federal Agency made the study a priority This would be more likely if there were letters of support from WHO, national organizations and individuals Developing these materials would require the dedicated time of one person for 6 months or more

An alternative is to use the combined Iowa and Fels data for white infants This is not ideal since the Iowa and Fels studies included samples of convenience The nature of the data base from birth to 3 months is likely to receive more critical attention internationally than in the US With this approach, birthweights would be obtained for the Iowa subjects and the Iowa and Fels data would be adjusted for the national distribution of birth weights It was stated that this adjustment is not a major statistical problem, but the procedure should be tested empirically This combined Iowa-Fels data set, as reported by Guo et al (1991) and Fomon (1993), is entirely from Iowa from birth to 3 months, from Iowa and Fels combined from 3 to 6 months and entirely from Fels for 6 to 12 months Both sets could be used to 6 months The raw data and summary statistics for status values are available **It was recommended that national data for birth weight be used and that data from the Iowa Studies be used from birth to 3 months, when there is a lack of NCHS data. From 3 to 12 months data from the Iowa and Fels studies should be used with gradual merging to NCHS data, unless NCHS conducts a survey of infant growth with timing that would not delay the revision.**

It is not feasible to make rapid changes in the NHANES III protocol to allow the measurement of young infants in the homes Such changes would involve alterations in staffing and budgets that would require a long delay before they could be implemented **It**

was recommended that, without delay, NCHS elicit the help of NICHD, USDA, WIC, The Women's Health Initiative, The Maternal and Child Health Bureau, Nutrition Monitoring and other government agencies to conduct a national or broadly representative survey of infant growth.

If secular trends are absent or slight, much would be gained from increasing the sample sizes by combining NHANES III data with data from other NCHS surveys This combination would require a new set of sample weights because the sampling strategy differed among surveys, but there has not been any change in measurement techniques for the variables being considered The combination of data from various surveys would not be difficult but new sample weights would be needed It may be desirable to constrain these sample weights to the 10th-90th percentile range for each age-and gender-group When relatively few are measured in an age-gender group, the individuals can be assigned very large sample weights that can have large effects on the data if the individuals are unusual in size

The possible combination of NHANES III data, and other NCHS data, with data from broadly representative groups in other countries, particularly Holland, England and Hungary, was discussed It was agreed that, as far as possible, the revised charts should be based on NCHS data. The amalgamation of the revised NCHS charts with data sets from other countries may be pursued by WHO because of political considerations and concerns that body weights are too high in the US. The selection of data sets from other countries should be based on sampling, data quality and evidence that growth was not constrained by environmental conditions

5. Sample size considerations

The necessary sample size depends on the variable, age, the percentile level to be estimated, and whether the distribution is normal or can be normalized In a recent statistical analysis, data from NHANES I were used to address some questions about sample size Sets of data of different sizes (10, 50, etc) were chosen at random and, after the 5th and 95th percentiles for BMI were obtained from each set, it was returned to the pool and another random set selected. This procedure was repeated 3,000 times and the mean and s.d obtained for the repeated estimates of each selected percentile (Guo, unpublished data) Appendix E shows the findings for white boys aged 9 years. The confidence intervals are much narrower for the 5th than for the 95th percentile. For the 5th percentile, there is little decrease in the confidence limits as the set size increases above 150 but for the 95th percentile there is a marked decrease in the confidence limits until the set size is 200 Corresponding analyses should be made, using NHANES III–Phase 1 data, for one gender at about 4 ages for the 3rd, 5th, 95th, and 97th percentiles These analyses might support the use of data from multiple NCHS surveys

There will be about 100 of each gender for each month from 3 to 12 months in the total NHANES III survey This is not enough to estimate the 3rd and 97th percentiles unless the data are normalized and/or grouped for a few months of age There will be even smaller samples at older ages (see Section 4 and Appendix B). The limitations of sample size can be overcome to some extent if the NCHS data were adjusted to fixed central ages within intervals of 2 to 4 months Empirical tests would show how wide the intervals can be The intervals should be moved forward by one month of age at a time to obtain a series of monthly estimates that will be partly smoothed This procedure was used in the CDC revisions of the charts

6. Possible secular trends in the US

Secular trends are alterations in a population with the passage of time In the context of child growth, secular trends relate to differences in size when data from past decades are compared with more recent data Secular trends in growth indicate environmental changes if the population is unaffected by migration or selective mortality.

The clinical importance of an observed secular trend in relation to the revision of the NCHS growth charts can be determined from the differences in classification, e g , below the 5th percentile, when the 1977 NCHS charts and NHANES III–Phase 1 tabular data are used to evaluate NHANES III–Phase 1 subjects The prevalence of such differences should be obtained at all ages for each variable To determine whether the observed secular trends justify revisions to the NCHS growth charts for research situations, it is necessary to show that the means and percentile levels in the NCHS data (1977) differ from those in NHANES III–Phase 1 by amounts that exceed the measurement errors This decision should not be based on the statistical significance of differences between means or percentile levels because trivial differences may be statistically significant due to the large sample sizes

Data from NCHS surveys indicate that there has not been a secular trend from NHES to NHANES II for whites or blacks in stature or weight except for a slight increase in weight for girls that was more marked for blacks than whites These findings are tentative because there are few blacks in these surveys and the findings are not in agreement with the report of Gortmacher et al (1987) The near absence of secular trends for most major ethnic groups in the US from NHES through NHANES II supports the possibility of combining these data with those from NHANES III to revise the NCHS charts but a firm recommendation is not possible until the NHANES III data have been analyzed The larger representation of blacks and Mexican Americans in NHANES III than in earlier NCHS surveys is not a problem because the sample weights provide total national estimates

There have, however, been large positive secular trends from 1977 to 1990 in the growth of low socioeconomic children aged 14 to 15 years in Louisiana and Michigan (Yip et al , in press) Also Malina et al (1987b) have reported positive secular trends from 1928 to 1983 in Mexican-Americans living in South Texas The trends were marked for stature from 6 to 14 years, particularly in boys, and they were large for weight and BMI in each gender (Appendix F) There are similar findings for Mexican-American girls in Southern California but the findings may not be generalizable to all Mexican Americans These secular trends in Mexican Americans may reflect environmental changes as indicated by unpublished data from the San Antonio Heart Study of large differences (4-5 cm) between the mean statures of young Mexican-American adults who are well-off and those living in Barrios (Malina and Stern, unpublished data), these groups differ, however, not only in socioeconomic status but in the proportions of Indian admixture In women, in the San Antonio Heart Study, weight tended to be lower for well-off groups than for those living in Barrios, but a corresponding trend was not evident for the men.

Secular trends in NCHS data could be studied within about 50 age-, sex- and ethnic/racial-groups, the age groupings are for several years and may differ among surveys. Caution will be necessary to ensure that corresponding ethnic/racial groups are compared Additionally, the population of Mexican Americans to which the sample weights relate changed from the Southwest states for HHANES to all Mexican Americans in NHANES III **It was recommended that previous analyses of secular trends be extended to include NHANES III data; this would assist the selection of data sets for the revision of the NCHS charts.**

7. Possible ethnic/racial differences in the US

Whether growth charts specific for ethnic/racial groups are justified relates to the size of the differences associated with ethnicity/race and the probable reasons for these differences If the differences were genetically determined, ethnic/racial-specific charts might be justified If the differences are environmental in origin (socioeconomic, health care, nutrition), the environment should be improved and charts specific for ethnicity or race may obscure this need

The discussion of ethnic/racial differences was restricted to whites, blacks and Mexican Americans because the sample sizes for other ethnic groups in NHANES III will be small The data base for the NCHS charts was mainly for whites unlike the NHANES III data base Charts constructed from the total NHANES III data set would not vary from the NCHS charts due to differences in ethnic/racial representation because, in each survey, the sample weights provide national estimates

If data become available from a special NCHS infant growth survey (see Section 4, pp 9-12), analyses should be made to assist decisions about the need for infant growth charts that are specific for ethnic/racial groups The distributions of birthweights are lower for blacks than for whites with a difference of about 150 g at the median level Some consider these differences are genetic because little of the variance is explained by the usual environmental variables (maternal age, gestational age, prepregnancy weight, weight gain during pregnancy, use of tobacco and alcohol, Wilcox and Russell, 1986) Others consider the differences are mainly due to variations in prenatal care and other environmental factors (Kleinman and Kessel, 1987) This ethnic/racial difference in birthweight is greater than the male-female difference which is about 100 g at the median level

There are differences in growth status and growth patterns between white and black infants that may be partly due to hormonal differences, but little of the difference is due to gestational age at birth or to sitting height/recumbent length differences Despite lower birthweights among blacks, there is catch-up growth during infancy. Some have reported that the period during which this catch-up occurs extends from birth to 2 months and others report that it extends to 9 months (Wingerd et al , 1971, Yip et al , in press) Differences in the duration of catch-up may be related to socioeconomic status Even if it were desirable to develop charts for the period from birth to 12 months that are specific for ethnic/racial groups, there is a lack of suitable data.

In NHANES I data, there are only small differences in stature between white and blacks boys but blacks girls tend to be taller from 3 to 12 years. This may be associated with more rapid maturation There are no differences in weight between whites and blacks, except during pubescence when weights for whites tend to be larger for boys but smaller for girls.

Median BMI values for boys at all ages and for girls from 6 to 10 years tend to be larger for whites than for blacks, there is a reverse difference for girls at 15 to 17 years. There are no differences in BMI at the 10th percentile level between whites and blacks. The 90th BMI percentile is higher for white boys than for black boys after 6 years (NHANES I and II but not NHES) but there is a large reverse difference for girls after 9 years (Cronk and Roche, 1982, Frisancho, 1990) Ethnic/racial differences in BMI, with lower values in blacks than whites and slightly greater values in Mexican-Americans would be expected due to ethnic variations in sitting height/stature that appear to be, in part, genetically determined (Malina et al., 1987a; Martorell et al , 1988) The differences between whites and blacks in sitting height/recumbent length are small at one year but they are evident by 2 years (Kautz and Harrison, 1981; Martorell et al , 1988).

Data from Mexican Americans in HHANES were compared with data from whites in NHANES II Medians for stature in Mexican-American boys are low from 4 to 10 years and from 14 to 18 years, but there are no differences at the 10th and 90th percentile levels except that these percentiles are low in Mexican/Americans at 14 to 18 years (Martorell et al , 1989; Roche et al , 1990) Stature is similar in Mexican American and white girls except at 12 to 18 years when the medians for Mexican Americans decrease with age until they are at about the 25th percentiles for whites The deficit is similar to that noted earlier between upper and lower socioeconomic groups of young Mexican-American adults. There are no consistent differences between Mexican-Americans and whites in weight or BMI percentiles except that the 90th percentile levels for BMI are consistently higher in Mexican-American boys and girls than in whites.

These observations for Mexican-American children and young adults are not easily explained by their slightly more rapid rates of maturation compared to whites (Faulhaber, E S , 1981, Faulhaber, J , 1981; Roche et al , 1990) Either those measured in pubescence had constrained growth due to socioeconomic influences at young ages, and the resulting deficiencies persisted into pubescence, or growth during pubescence in Mexican Americans is limited for genetic reasons. The genetic explanation is supported by reports of similar growth patterns in Mexican Americans, Mexicans and Guatemalans (Martorell et al , 1989) If these findings were replicated in NHANES III, it would be concluded that the deficits develop during pubescence and that they are likely to be genetically determined or that similar environmental conditions persisted from the HHANES survey to the NHANES III survey If the NHANES III data do not confirm previous findings, it must be concluded that the shortness noted during pubescence for Mexican Americans in HHANES was due to retarding environmental influences in the early 1970s and that catch-up growth did not occur

Any differences in growth among ethnic groups in the NHANES III data set could be due to genetic influences, socioeconomic effects or recent migration In previous analyses of NCHS survey data, the demonstrated socioeconomic effects on growth have been small (Martorell et al , 1989, Jones et al , 1985, Ryan et al , 1990) Recent migration would have larger effects on the data for whites because of the migration of Asians, who are included with whites in most NCHS descriptions, and on the data for Mexican Americans because of migration from Mexico, than on the data for blacks There is a high prevalence of children with short stature among Asian Americans aged 2 to 5 years in the Nutrition Surveillance Program data set but this prevalence decreased from 1980 to 1989 indicating the importance of socioeconomic influences (Yip et al , 1992, in press)

It may be difficult to apply charts specific for ethnic/racial groups In NCHS surveys, ethnicity/race is by self-report for adults and older children and by maternal report for younger children Similar operating rules should be applied when using charts that are specific for ethnicity/race but the appropriate categorization is not always easy, e g , mother not present, ethnically mixed marriages If there were separate NCHS revised charts for Mexican Americans, it would be necessary to establish whether they were applicable to Cuban Americans and Puerto-Rican Americans Analyses of HHANES data indicate that these groups differ little in growth but the sample sizes for Cuban Americans and Puerto-Rican Americans were small

The clinical need for charts specific for ethnic/racial groups should be determined by analyses of the prevalence of differences in classifications, especially of values < 5th percentile and of values > 95th percentile when black and Mexican-American children are assessed using (i) the total NHANES III data set and (ii) reference data specific to ethnic/racial groups from NHANES III This may be difficult because the sample sizes for ethnic groups in NHANES III may be too small to provide accurate estimates of the 5th and 95th percentiles **It was recommended that charts specific for ethnic/racial groups not be developed but tabular data for such groups be published.**

8. Possible exclusion of low-birthweight infants

Low-birthweight infants (4 6% with birthweights < 2500 g) were included in the Fels data set that was used to construct the NCHS charts for birth to 3 years Since low-birthweight infants differ in growth status during the first 2 to 3 years of life from those with birthweights > 2500 g, consideration was given to the exclusion of low-birthweight infants from the data base that will be used to revise the charts for the period from birth to 3 years There was considerable discussion of this topic but there was a lack of general agreement **It is recommended that a decision be made soon as to whether data from low birthweight infants will be excluded from all data bases used in the revision of the growth charts up to 3 years of age.** Their exclusion from the NHANES I and NHANES II data bases is not possible Issues relating to the availability of data are involved since low-birthweight infants were not included in the Iowa Study Low birthweight infants could be included in the multi-center survey of infant growth that is proposed

Those at the Workshop who work in lesser developed countries would prefer the inclusion of data from all infants when the charts are revised It is commonly difficult to obtain birthweights during surveys of infants, particularly in lesser developed countries This view should be judged with reference to the primary purpose of the planned revisions, namely to provide a better evaluative instrument for US health care professionals Some consider the inclusion of all infants irrespective of birthweight has epidemiological appeal since a "total population" would be described but the NCHS surveys are not of total populations Rather they are surveys of nationally representative populations that meet certain criteria (a place of residence, not institutionalized, not residing on military reservations, able to come to trailers for examinations) By excluding low-birthweight infants, another criterion would be added to the population for which the data are nationally representative

Alternative A That data from all infants, irrespective of birthweight, be included in the data set for the revision of the NCHS charts One advantage is that the revised charts for ages birth to 3 years would be based on a population defined similarly to that used for the NCHS charts but there will be other major differences between the 1977 and "revision" populations since the latter will mainly be from national samples Whether or not data from low-birthweight infants are included, it will not be possible to evaluate secular trends by comparing the NCHS charts and the revised NCHS charts for the period from birth to 3 years. If Alternative A were adopted, some infants identified as small would be normal in size for their birthweights because growth during infancy is affected by birth weight

Alternative B That data from low-birthweight infants be excluded from the data set for the revision of the NCHS charts These exclusions would be based on birthweight only (<2500 g) and not on gestational age because of uncertainties about the accuracy of recorded gestational ages Differences in size associated with low birthweight persist to 5 years in the Pediatric Nutrition Surveillance System data (Binkin et al , 1988) These data are from a low socioeconomic population, catch-up may occur earlier for other groups (Brandt, 1978) If catch-up growth is incomplete at 3 years, there would be a larger disjunction between the data for birth to 3 years and those for 2 to 18 years with Alternative B than with Alternative A, but this could be overcome by gradual merging of the data sets

In the US, clinicians use special charts for low-birthweight infants to 12 months An example of a chart for preterm infants is included as Appendix G Therefore, the exclusion of low-birthweight infants up to 1 year was suggested, but received little support at the Workshop There are several sets of charts in current use to evaluate low-birthweight infants and others are being developed from the Casey data for two groups of such infants (birthweights < 1500 g and birthweights 1500-2500 g, Guo, personal communication) The Casey growth charts for low-birth weight preterm infants extend to 3 years (Casey et al., 1990, 1991)

If Alternative B were adopted, epidemiologists and research workers, like clinicians, would use the revised NCHS charts to evaluate infants of normal birthweight and special charts or tabular data for low-birthweight infants If the special charts extend to only 1 year, each low-birthweight infant would be plotted on two charts (special chart for birth to 1 year, revised NCHS charts for 1 to 3 years) Attention should be given to the junction at 1 year or 2 to 3 years between special charts and the revised NCHS charts, perhaps by using merging procedures or by supplying interpretive data in the Guidelines (Section 15; pp 32-34)

The exclusion of low-birthweight infants would elevate the lower percentile levels particularly near birth and thereby increase the apparent prevalence of small infants if the special charts were not used but would not alter the prevalence of low birthweights (< 2500 g). Such charts would be more sensitive for the identification of infants with normal birthweights who are growing slowly than those developed in accordance with Alternative A If Alternative B were adopted, the interpretive guidelines with the revised NCHS charts should emphasize the population to which the charts apply and recommend the use of special growth charts for low-birthweight infants from birth to 3 years It would be desirable to recommend more than one special chart and give reasons for the selection of these charts. The Casey data are recent, from a large sample of various ethnic groups in multiple centers, there was good quality control after birth, and few other sets extend to 3 years Data from the proposed multi-center infant growth survey could be preferred because they would be cross-sectional but they would not extend to three years

If Alternative B were adopted, this would tend to change the growth charts from representations of reference data towards representations of normative data ("standards") The basis for exclusion of low-birthweight infants is that they grow differently Exclusions are possible for other groups of children that grow differently, e g , overweight, those with gross abnormalities or chronic diseases, children of short parents, and rapidly maturing children. The exclusion of any groups other than low-birthweight infants was not supported. Adoption of Alternative B would exclude more blacks than whites from the NCHS data base for the age range 3 months to 3 years but this should not cause problems On the assumption that low-birthweight infants would be included in NCHS reports for many other variables, separate sets of sample weights would be required for survey data with and without low birthweight infants for the period from birth to 3 years

To implement Alternative B, NCHS would need to obtain the necessary agency approval and funding, and then acquire birth certificates for all NHANES III infants up to the age of 3 years as quickly as possible so that data from low-birthweight infants can be excluded If NCHS conducts a special infant growth survey in which birthweight is recorded, growth data would be provided to 1 year (see Section 3, pp 4-9) The Iowa data, that could be used to bridge the gap from birth to 3 months, are from infants with birthweights > 2500 g, their birthweights can be obtained The Fels data base can be constructed for all infants or for those with birthweights > 2500 g Both the Iowa and Fels data can be adjusted to the national distribution of birthweights with or without truncation of the national distribution to values > 2500 g.

Alternative C That data from infants with birthweights < 2000 g be excluded, but those with birthweights of 2001 to 2500 g be included, when the NCHS charts from birth to 3 years are revised This would be justified if growth does not differ between those with birthweights 2001 to 2500 g and those with birthweights > 2500 g This could not be determined from NHANES III data Taking 1-year-old boys as an example, the expected sample in NHANES III (323 for Phases I and II combined) is likely to include only 9 boys with birthweights 2001-2500 g (Casey et al , 1990) There was little support for the choice of a cut-off at 2000 g mainly because this cut-off is not in common clinical use

9. Breast-feeding and socioeconomic status

Breast-feeding It was noted that a WHO Committee (Cutberto Garza, Cornell University, Chair) is considering whether separate growth charts should be developed for breast-fed infants **It was recommended that the prevalence of breast feeding in NHANES III be documented** but it is not possible to use NCHS data to construct charts for breast-fed infants This could, however, be a secondary aim of a national infant growth survey

Dewey et al (1992), from a well-controlled study, reported slower rates of growth in infants who were exclusively breast-fed to 4 months than those indicated in the NCHS charts which were mainly from formula-fed infants Some of these differences may be due to the smoothing of NCHS data This Dewey study has received considerable attention but the literature contains conflicting reports of (i) an absence of differences in growth between breast-fed and formula-fed infants, (ii) that breast-fed infants tend to be larger than formula-fed infants, and (iii) that the differences in growth between breast-fed and formula-fed infants are age-dependent (references in Roche et al , 1989b) The findings from such studies are difficult to interpret because assignment is non-random and there are variations among studies in the criteria for classification as breast-fed **It was recommended that charts or adjustment factors for breast-feeding should not be developed partly because the NHANES III data would be inadequate for this purpose.**

Any differences in growth between breast-fed and formula-fed infants are more likely at 6 to 12 months than at other ages and the prevalence of breast-fed infants is only about 12% after 6 months, almost all these infants receive solid foods after 6 months Therefore, the potential usefulness of such charts would be restricted to a relatively small group of infants The use of such charts would be complicated when infants change feeding categories and the selection of charts should change It is not known how many infants would be classified differently in regard to growth status by using revised charts derived from both breast-fed and formula-fed infants in contrast to using feeding-specific charts

Socioeconomic influences Some previous analyses of NCHS survey data have shown that variations in socioeconomic status are associated with only small differences in growth (Martorell et al , 1989, Ryan et al , 1990) which may reflect the inadequacy of most indices of socioeconomic status Others have reported associations between a poverty index and short stature from 2 to 5 years in data from the Pediatric Nutrition Surveillance System (Yip et al , in press) **It is recommended that charts specific to socioeconomic status not be developed but, to assist interpretation of the revised NCHS charts, the possible influences of socioeconomic factors should be analyzed**

and published for whites, blacks and Mexican Americans separately using NHANES III data.

10. Junction between infancy and childhood (2 to 3 years).

Hamill et al (1977) recognized some systematic differences between Fels data and NCHS data at about 2 to 3 years The distributions of Fels data were more restricted for weight and weight-for-length and the differences between recumbent length data from Fels and stature data from NCHS were larger than expected They noted, "The judgment of the NCHS task force was to adhere strictly to a policy of no data adjustments "

There is an overestimation of recumbent length from birth to 36 months and a corresponding underestimation of weight-for-recumbent length in the 1977 NCHS charts These errors are due to less than ideal smoothing procedures and the way in which recumbent length was measured at the Fels Research Institute In recent NCHS surveys, the median difference between recumbent length and stature at 2 to 3 years is about 0 5 cm but the corresponding median difference was about 1 5 cm in the Fels data available in 1977 (Hamill et al , 1977; Roche and Davila, 1974) The disjunctions at 2 to 3 years between percentile lines on the infant charts and on the charts for older children cause large changes with age in the prevalence of low percentile levels, especially when the charts are used in surveys of lesser developed countries (Dibley et al., 1987a, b).

A group, led by scientists in the Division of Nutrition of the National Center for Chronic Disease Prevention and Health Promotion at CDC smoothed this disjunction by (i) anchoring the data to the national distribution of birthweights, (ii) normalizing the distributions after assuming the upper and lower halves of the distributions matched halves of normal distributions, (iii) including data from NHANES II at ages after 12 months, (iv) using improved smoothing procedures, (v) matching the fitted curves to the growth patterns of individual infants, and (vi) smoothing the transition between the infant and childhood percentile lines by gradually altering the weighting assigned to each (Roche et al , 1989a) These revised CDC charts increase the recorded prevalence of short infants to 6 months compared with the NCHS charts because the 5th and 10th percentiles are higher. When this revision was applied to data from some lesser developed countries, the prevalence of children below particular cut-off levels changed with age in a regular acceptable fashion These revised charts will be published by CDC in an electronic format only, together with software to support them, because they could be useful in some clinical and research situations These charts are not intended for use in the US but it may be difficult to prevent their use

It was recommended that procedures similar to those used by CDC be applied in the revision of the NCHS charts to reduce disjunctions between percentiles for infants and those for older children.

11. Possible content and format of revised NCHS charts

Photocopies of two examples of the original (1976) NCHS growth charts and examples of the NCHS charts in current use, as formatted by Ross Laboratories and by Mead Johnson Canada, are included as Appendices H and I respectively. All formats present the same reference data. The major differences are (i) the NCHS format uses a folded double-sized sheet but the Ross Laboratories and Mead Johnson Canada formats require only one regular-size sheet (8 1/2 x 11"), (ii) the percentile lines are closer together in the Ross Laboratories and Mead Johnson Canada formats which makes plotting difficult especially between birth and 3 months, and (iii) some instructions and interpretive guidelines were included in the NCHS format but not in the other formats There is space to record numerical data with each format. This space allows for recording gestational age and parental statures in the Ross Laboratories format but not in the NCHS or Mead Johnson formats This space allows for 16 visits in the NCHS format and 10 visits in the Ross Laboratories and Mead Johnson Canada formats The Ross Laboratories and Mead Johnson Canada formats are cheaper to print and easier to file but the NCHS format provides more space to add outlying percentile lines and s d levels

The planned revisions may result in charts that remain unchanged for 20 years, therefore major changes should be made if they are justified On the other hand, if any changes are made that are later shown to be poorly justified, it will be difficult to correct them. The possible separation of the 2 to 18 year charts into two age ranges (2 to 9 years; 9 to 18 years) was discussed but there was little support for this change The inclusion of 1st and 3rd percentiles and/or standard deviation levels (Z scores) would make the charts more useful to pediatric endocrinologists and to epidemiologists working in lesser developed countries Despite their possible inaccuracy, extreme standard deviation levels, e g , -4.0 s d., are important because most children with statures or head circumferences beyond -4 0 s.d. have pathological conditions. The interpretation of standard deviation levels requires that the distributions be normal which is unlikely for the raw data with the exception of stature and head circumference. Skewness in weight, and presumably in variables derived from it (weight-for-recumbent length, weight/stature^2), is less marked up to 4 years than at older ages As part of the revision process, the data may be normalized Normalizing methods are complex but the users need not be aware of the mathematical/statistical details (Chinn, 1992, Cole and Green, 1992).

It was recommended that the revised charts be kept simple, as at present, but that 3rd and 97th percentiles be added together with other outlying percentiles, if space allows. The 3rd and 97th percentiles are in common use internationally where the 3rd percentile is a common cut-off for malnutrition The 5th, 10th, 25th, 75th, 90th and 95th percentiles should be retained because some clinical judgments are based on whether serial data for a child cross two percentile lines The addition of the 3rd and 97th percentiles is recommended although some pairs of adjacent lines (3rd and 5th, 95th and 97th) will be close especially in infancy The difference between these paired percentiles is only about 0 2 s d. but the 3rd and 97th are more sensitive than the 5th and 95th respectively The addition of these percentiles may lead to spacing problems on the charts Further discussion is needed about which extreme levels are the most useful – perhaps lower extremes only for recumbent length, stature and weight

The overlapping age ranges of the 1977 NCHS charts (birth to 3 years, 2 to 18 years) could be eliminated by commencing the chart for older children at 3 years instead of 2 years This would force users to measure recumbent length to 3 years which is desirable because few children younger than 3 years can adopt the standard position for the measurement of stature In addition, it is commonly stated that precision is greater for recumbent length than for stature from 2 to 3 years This is not the case in the Fels Study (Roche and Guo, unpublished data, Appendix J) This possible change in the age ranges for the charts was not recommended partly because it would be difficult to educate users as to the need to measure recumbent length to 3 years and difficulties would result because stature has been measured from 2 to 3 years in many surveys.

The positive correlations between weight and stature make it desirable to adjust weight for stature, these adjustments assist the interpretation of weight data The NCHS charts provide weight-for-recumbent length reference data (birth to 3 years) and weight-for-stature reference data (prepubescence) The distributions of these variables are, for all practical purposes, age-independent until pubescence which is a significant advantage especially for public health workers and epidemiologists in lesser developed countries where age may not be known Many have expressed dissatisfaction with the restriction of weight-for-stature in the NCHS charts to the prepubescent period which, using attained stature as a surrogate for the commencement of pubescence, was terminated at statures of 146 cm for boys and 137 cm for girls Weight-for-stature reference data could be provided for pubescent children but the distributions would differ with age. Consequently, age-specific charts would be required making clinical use impractical The lower limit of the NCHS weight-for-stature charts is at 90 cm for stature which also causes a problem Few children with shorter statures than 90 cm were measured standing in NCHS surveys but there are many such children in lesser developed countries The weight-for-stature reference data could be extended to shorter statures by using data for children aged 2 to 3 years in NHANES III and adjusting recumbent lengths to statures NCHS could develop charts or tables to assist those who need to assess weight in relation to stature in children whose birthdates are unknown. These charts and tables would not be recommended for general use

It is recommended that the variables and age ranges be the same as in the NCHS charts except for the substitution of Body Mass Index (BMI; weight/stature^2) for weight-for-stature from 2 to 18 years. Weight-for recumbent length should be retained from birth to 3 years.

A large literature relates BMI values to risk of disease and mortality rates in adults and BMI values track from childhood to adulthood (Guo et al., under review) The distributions of BMI could be provided in one chart for each gender (2 to 18 years). BMI is more highly correlated with body fatness than other common weight-stature indices and these relationships are not reduced in pubescence (Womersley and Durnin, 1977, Roche et al , 1981, Rolland-Cachera et al , 1982) Nevertheless, the correlations between BMI and body fatness are only low to moderate and the levels of these correlations vary depending on whether the group is lean or obese (Wellens, unpublished data) Relative weight was considered in place of BMI but was not recommended because it is influenced by the choice of reference data and therefore is less useful for group comparisons A value for BMI of 20 kg/m^2 has a meaning inherent in the value, a relative weight of 115 must be judged by reference to the data base from which it was calculated

It was recommended that tables but not charts be developed, using NHANES III data, for the available anthropometric variables used clinically and in nutrition monitoring and screening. The most important of these are sitting height/stature, skinfold thicknesses, waist-hip ratio, arm muscle area and wrist breadth. The smoothed tabular data for these variables for the total NHANES III sample and for major ethnic groups should be published and software to facilitate their use should be developed. The smoothed and unsmoothed data should be available electronically or in an NCHS publication Tabular data for head circumference to 7 years should be published

It was suggested that the distribution of birthweights be added to the infant charts in this format·

g	1500	2500	3000	3500	4000
percentiles	3	10	50	75	95

It is not clear what purpose would be served given that the national birthweight percentiles will be displayed on the revised charts as the left hand ends of the percentile lines

It was recommended that NHANES III data not be used to develop sets of values that would adjust for parental statures when the statures of children are evaluated. This was not recommended because the sample of triads or larger groups (two parents to obtain mid-parent stature and one or more children) within households in NHANES III would be too small Furthermore, satisfactory data have been published (Appendix K, Himes et al , 1981).

12. Timing of pubescence

Children differ in growth status dependent on maturity status Therefore, the NCHS charts, while suitable for group comparisons, may lead to errors in the classification of individuals because maturity is not taken into account. Particularly during pubescence, maturity status must be considered for accurate assessments of the growth status of individuals or populations Common clinical conditions for which factors that adjust for maturity level could be useful include slowly maturing boys who decrease in percentile levels for stature during the usual age range for pubescence and early maturing girls who gain in percentile levels for stature and weight prior to the usual time of pubescence

Physical maturation includes a group of somewhat independent physiological processes Consequently, decisions are needed about the selection of maturational variables Furthermore, maturational data will not always be available, particularly for health workers in lesser developed countries The major indices of maturity are menarche and the development of secondary sexual characteristics, although the grading of secondary sexual characteristics may lack precision Skeletal age data are not available for the US population from assessments made by an accepted method The assessment of skeletal age involves radiation, and few are trained to make precise assessments

It was recommended that maturity-specific charts not be developed, but prevalence data for maturity status be added to the charts. The NHANES III sample would not be large enough to provide outlying percentiles for rapidly and slowly maturing children, but the sample could be increased by the addition of data from other NCHS surveys. There are problems in the application and interpretation of such data due to the occurrence of different stages for genitalia, breast and pubic hair within individuals and possible interactions that may make it difficult to develop simple adjustment factors Charts for pre-menarcheal and post-menarcheal girls could be provided but only for a very narrow age range (about 11 to 14 years)

An alternative is to provide adjustment factors that would compensate for unusual rates of maturation Such factors have been calculated using NHES cycle III data (Appendix L, Wilson et al , 1987) The factors reported by Wilson have not been applied widely perhaps because this approach requires an invasion of privacy and assessments of secondary sexual characteristics may not be precise The adjustment factors that might be developed from NCHS data to adjust for maturity would be complex Probably they would vary with gender, age, percentile level and the maturity index chosen The extent of the expected complexity is shown by an extract of adjustment factors for stature dependent on parental stature (Appendix K)

The distributions of ages at which menarche and stages of secondary sexual characteristics are reached in the NHANES III sample could be added to the revised NCHS charts An example of such an addition is given in Appendix M, as a guide to format Some considered the stages should be restricted to breast in girls and pubic hair in boys because the staging of these is said to be more precise Furthermore, age at peak height velocity is more closely related to the development of pubic hair Stage 2 in boys and breast Stage 2 in girls than to other stages of pubic hair or breast development or to grades of other aspects of secondary sexual development (Marshall and Tanner, 1969, 1970) It is important for NCHS to include prevalence data for maturity status in the revised charts before this is done by others who may choose inappropriate criteria The relationships of all available maturity indices to growth status using NHANES III data should be determined before a choice is made.

It was recommended that factors to adjust stature for maturity status should be calculated from NHANES III data and considered for publication but they should not be included in the NCHS revised charts.

13. Smoothing procedures.

The topic "smoothing procedures," in this context, relates to smoothing empirical percentiles across age. These empirical percentiles are typically obtained at each 6 months of age. The purpose of smoothing is to reduce the irregularity of the percentile levels by utilizing information from nearby ages when estimating values for a particular age Smoothing improves the esthetic qualities of the curves but, more importantly, it increases their sensitivity and specificity for the identification of children with unusual growth status or unusual changes in growth status It is necessary to ensure that the smoothed curves are biologically acceptable. Consequently, the patterns of change in the smoothed percentile levels should be compared with those in recent publications that show percentile levels derived from serial data to which non-parametric models were fitted, e g , Prader et al (1989). At the upper end of the age range, smoothing may require the use of data at ages older than 18 years Truncating the distributions of sample weights and estimating at target ages within age intervals will assist smoothing.

The smoothing methods considered at the Workshop can be grouped into six categories: (i) polynomials, (ii) running medians, (iii) weighted least squares, (iv) splines, (v) the combined method of Healy et al (1988), and (vi) the LMS method that employs smoothed values for the coefficient of a Box-Cox transformation (L), the medians (M), and the coefficients of variation (S) These methods are described briefly in Appendix Q

It was recommended that mathematical/statistical procedures be used to smooth the empirical percentiles taking account of the patterns of growth in individual children. These, and all other procedures applied in the revision, should be published.

14. Distribution of revised charts.

At present, pharmaceutical companies distribute 12,000,000 NCHS charts annually but this distribution may be curtailed by major changes in the US health care system It will be important to distribute the revised NCHS charts widely soon after they are available so that they will quickly replace the current NCHS charts The availability of software is important for the widespread use of the revised NCHS charts The development of this software will be time-consuming and mechanisms will be needed for its support and distribution

It was recommended that software programs be prepared that will allow public health departments and others to produce copies of the NCHS revised charts, perhaps through an electronic distribution system similar to the WONDER system at CDC, and that other user-friendly software be developed to allow interactive use of the smoothed data. These copies would probably be black-and-white versions and be similar in appearance to the photocopy of a Ross Laboratories format NCHS chart shown in Appendix N Although less attractive visually, these would be effective if colored pencils or markers were used to record the measurements It is recognized that this distribution mechanism would not meet all needs, e g , physicians offices

15. Guidelines for use and interpretation of the revised NCHS charts.

It was recommended that the revised charts be accompanied by interpretive guidelines. The original NCHS charts included brief guidelines related to measurement and recording procedures and interpretation (Appendix H) Other guidelines from the Michigan Department of Public Health are included in Appendix O. The recommended guidelines should be prepared taking account of the several purposes that the revised NCHS charts will be expected to serve These are (i) to evaluate growth in individuals for screening and to monitor the effects of intervention, (ii) to compare groups, and (iii) for triage in emergencies to target interventions

There was concern lest the guidelines become voluminous. Different versions may be needed for those who assess individuals (physicians and other health care professionals) and those who assess groups by utilizing tabular data (public health workers, epidemiologists) It may be possible to publish the guidelines in an issue of the CDC Morbidity and Mortality Weekly Reports and/or to provide an abstract of the guidelines on a wall chart

The topics suggested for inclusion include

– selection of charts (there are charts for some specific diseases and for low birthweight infants)

– methods of measurement (instruments, procedures) with emphasis on the desirability of measuring recumbent length instead of stature between 2 and 3 years, numerical differences between recumbent length and stature

– method of plotting

– how to obtain body mass index

– interpretation of percentile levels including the difference between a reference and a standard, the revised NCHS charts will not allow the diagnosis of diseases or abnormalities, the percentiles for weight may not match desirable levels, the concept of tracking and its applicability

– interpretation of changes in percentile levels, particularly during pubescence, with the note that the revised NCHS charts will be less sensitive for monitoring growth rates than increment charts (Guo et al., 1988, 1991, Roche et al , 1989b, Roche and Himes, 1980) Changes in percentile levels are not necessarily due to pathological conditions

– interpretation of body mass index in relation to (i) sitting height/stature, (ii) increases during pubescence that are likely to be due to fat-free mass in boys and fat in girls, (iii) tracking and, (iv) associations with risk.

– the influence of maturational status on growth status, overweight in pubescent girls may be due to rapid maturation. Slow maturation (constitutional delay) is common in teenage boys and is associated with slow growth and often with psychosocial distress

– differences in growth associated with birthweight, breast feeding, ethnicity, parity, socioeconomic status, altitude, tobacco use, and parental size. It was stated that parental stature adjustments are for familial effects that are not necessarily genetic and it was stated that these adjustments may not be applicable to the poor This appears unlikely since parent-child correlations are similar in many population groups (Mueller, 1976).

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APPENDICES

APPENDIX A

NCHS GROWTH CHART WORKSHOP

SPONSORED BY THE DIVISION OF HEALTH EXAMINATION STATISTICS

December 12-15, 1992

LIST OF PARTICIPANTS AND GUESTS

CO-CHAIRMEN:

DR. ROBERT KUCZMARKSI
National Center for Health Statistics - CDC

DR. ALEXANDER ROCHE
Wright State University

PARTICIPANTS:

DR. FREDERICK TROWBRIDGE
Division of Nutrition, National Center for Chronic Disease Prevention and Health Promotion - CDC

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DR. REYNALDO MARTORELL
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DR. ROBERT MALINA
University of Texas at Austin

DR. FRANK JOHNSTON
University of Pennsylvania

DR. ALAN ROGOL
University of Virginia

DR. JOHN HIMES
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National Institute of Child Health and Human Development - NIH

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Children's Nutrition Research Center - USDA

MR. ROBERT MURPHY; DR. RONETTE BRIEFEL
National Center for Health Statistics - CDC

APPENDIX B

SAMPLE SIZES FOR NCHS/CDC CHARTS (1977) BASED ON DATA FOR WEIGHT

BIRTH TO 3 YEARS (FELS DATA)

Ages	Males	Females
Birth	156	142
1 month	274	251
3 months	438	426
6 months	425	409
9 months	365	347
1 year	374	335
1 1/2 years	472	463
2 years	425	410
2 1/2 years	392	383
3 years	364	357

Appendix B (continued)

SAMPLE SIZES FOR NCHS/CDC CHARTS (1977) BASED ON DATA FOR WEIGHT 2-18 YEARS (NHES CYCLES II AND III, NHANES I COMBINED)

Age in years	Males	Females
2 75 to 3 25	147	110
3 25 to 3 75	146	149
3 75 to 4 25	152	135
4 25 to 4 75	162	145
4 75 to 5 25	135	146
5 25 to 5 75	146	154
5 75 to 6 25	126	141
6 25 to 6 75	375	359
6 75 to 7 25	383	398
7 25 to 7 75	411	376
7 75 to 8 25	375	394
8 25 to 8 75	381	403
8 75 to 9 25	386	377
9 25 to 9 75	392	358
9 75 to 10 25	393	407
10 25 to 10 75	386	378
10 75 to 11 25	373	351
11 25 to 11 75	387	321
11 75 to 12 25	90	102
12 25 to 12 75	447	375
12 75 to 13 25	435	400

(Data corrected November 1999)

Appendix B (continued)

SAMPLE SIZES FOR NCHS/CDC CHARTS (1977) BASED ON DATA FOR WEIGHT 2-18 YEARS (NHES CYCLES II AND III, NHANES I COMBINED)

Age in years	Males	Females
13 25 to 13 75	414	397
13 75 to 14 25	362	388
14 25 to 14 75	412	371
14 75 to 15 25	411	362
15 25 to 15 75	394	339
15 75 to 16 25	362	358
16 25 to 16 75	336	320
16 75 to 17 25	357	377
17 25 to 17 75	326	299
17 75 to 18 25	63	72

(Data corrected November 1999)

APPENDIX C

NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEYS SAMPLE SIZES

FEMALES

AGE	NHES II	NHES III	NHANES I	NHANES II	HHANES (MA)	PHASE I NHANES III
2-5 m						234
6-11 m				177	63	290
1 yr			267	336	123	366
2 yr			272	336	121	324
3 yr			292	366	99	319
4 yr			281	396	96	284
5 yr			314	364	109	281
6 yr	536		176	135	118	152
7 yr	609		169	157	96	150
8 yr	613		152	123	108	156
9 yr	581		171	149	125	159
10 yr	584		197	136	94	147
11 yr	564		166	140	115	152
12 yr		547	177	147	103	81
13 yr		582	198	162	90	99
14 yr		586	184	178	75	112
15 yr		503	171	145	85	94
16 yr		536	175	170	99	98
17 yr		469	157	134	75	104
18 yr			(140)	170	78	96

Cliff Johnson 12/14/92

NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEYS
SAMPLE SIZES

MALES

AGE	NHES II	NHES III	NHANES I	NHANES II	HHANES (MA)	PHASE I NHANES-III
2-5 m						207
6-11 m				179	57	319
1 yr			286	370	106	313
2 yr			298	375	111	338
3 yr			308	418	131	267
4 yr			304	404	118	285
5 yr			273	397	116	267
6 yr	575		179	133	110	153
7 yr	632		164	148	110	142
8 yr	618		152	147	102	144
9 yr	603		169	145	106	156
10 yr	576		184	157	88	167
11 yr	628		178	155	115	151
12 yr		643	200	145	115	93
13 yr		626	174	173	98	96
14 yr		618	174	186	97	72
15 yr		613	171	184	69	88
16 yr		556	169	178	76	94
17 yr		489	176	173	71	105
18 yr			(130)	164	64	99

Cliff Johnson 12/14/92

APPENDIX C (continued)

NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEYS
SAMPLE SIZES
Black Males

Note The sample sizes for Black males and females are closely similar

AGE	NHES II	NHES III	NHANES I	NHANES II	HHANES (MA)	PHASE I NHANES III
2-5 m						43
6-11 m				42		43
1 yr			72	77		114
2 yr			77	67		78
3 yr			72	79		105
4 yr			74	76		82
5 yr			64	58		87
6 yr	84		52	13		39
7 yr	79		38	27		41
8 yr	79		33	19		36
9 yr	74		52	19		34
10 yr	65		33	31		42
11 yr	83		43	27		33
12 yr		101	47	21		27
13 yr		80	45	32		24
14 yr		88	39	26		26
15 yr		84	43	22		22
16 yr		57	41	26		30
17 yr		69	35	30		26
18 yr			(26)	23		30

Cliff Johnson 12/14/92

APPENDIX D

RANGES OF AGES AT WHICH VARIABLES OF INTEREST WERE MEASURED IN SELECTED DATA SETS

<u>Fels Study</u>

W, RL, HC	0-18 years
S	2-18 years

<u>NHES II & III</u>

W, S	6-18 years

<u>NHANES I</u>

W.	1-18 years
S	2-18 years
RL.	1-2 years
HC	1-7 years

<u>NHANES II AND HHANES</u>

W	6 mo-18 years
RL	6-mo-3 years
S	2-18 years
HC.	6 mo-7 years

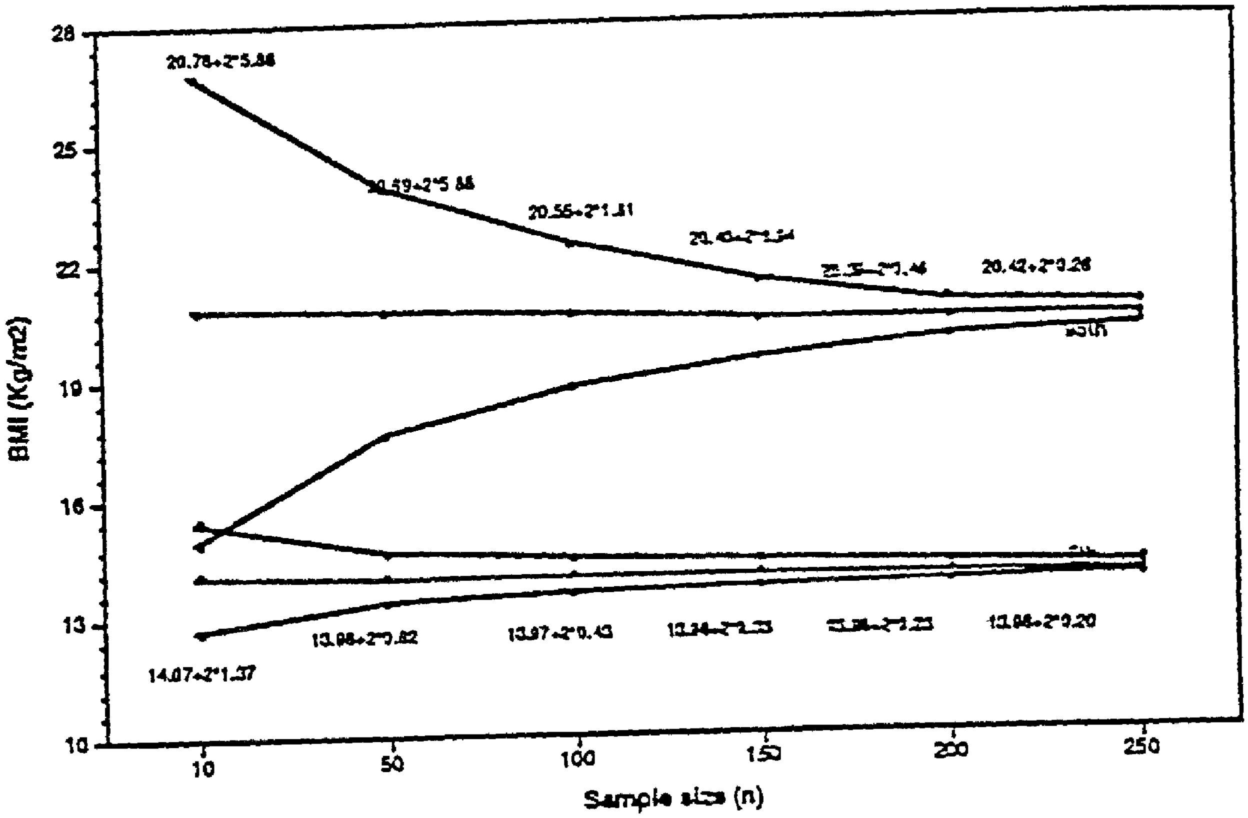
<u>NHANES III</u>

W	3 mo-18 years
RL.	3 mo-3 years
S.	2-18 years
HC:	3 mo-7 years

W = weight; RL = recumbent length, S = stature and HC = head circumference

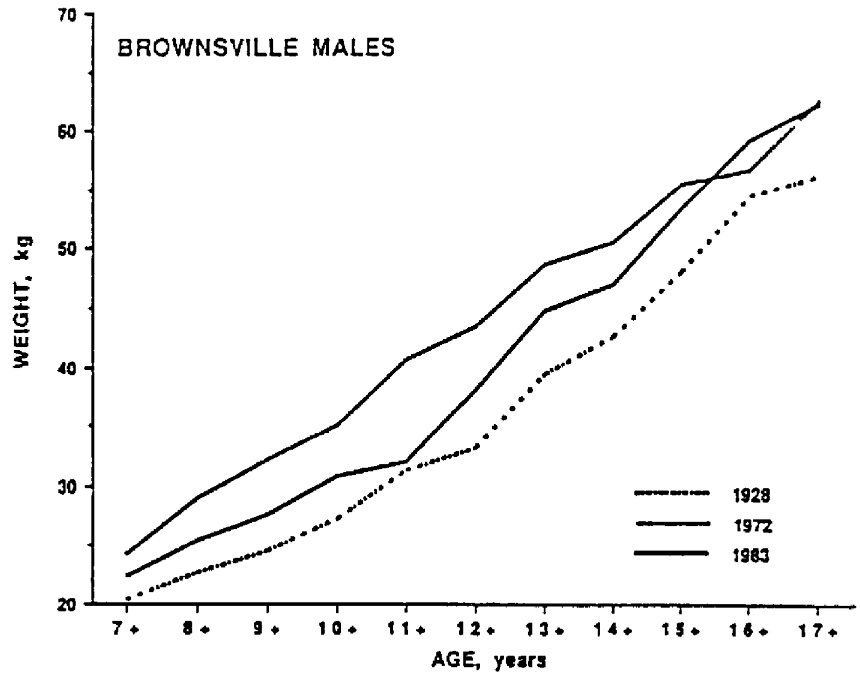
APPENDIX E

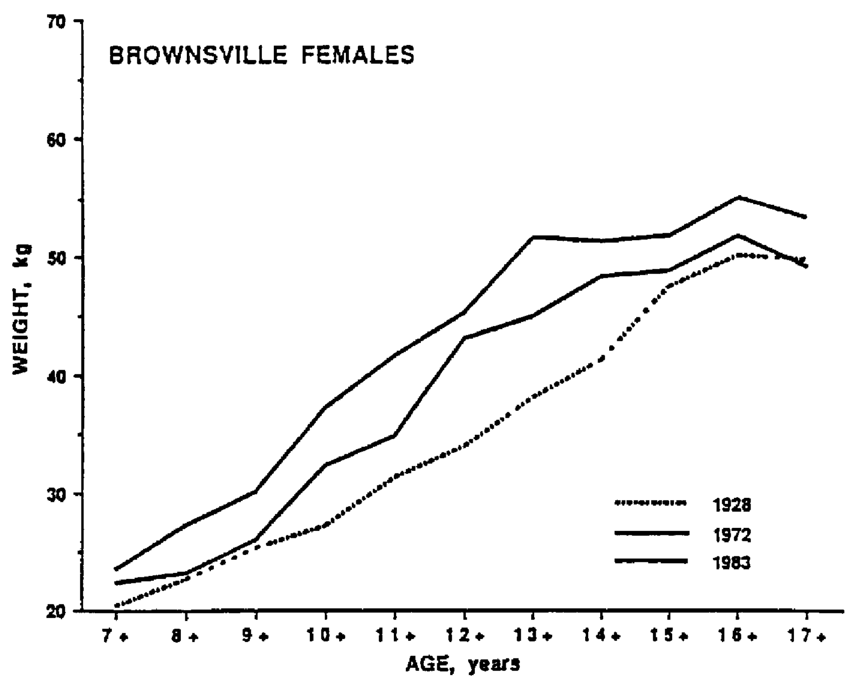
Mean ± 2 s.d. for percentiles from repetitive random sampling of BMI data for boys aged 9 years (NHANES I, Guo, unpublished data)



APPENDIX F

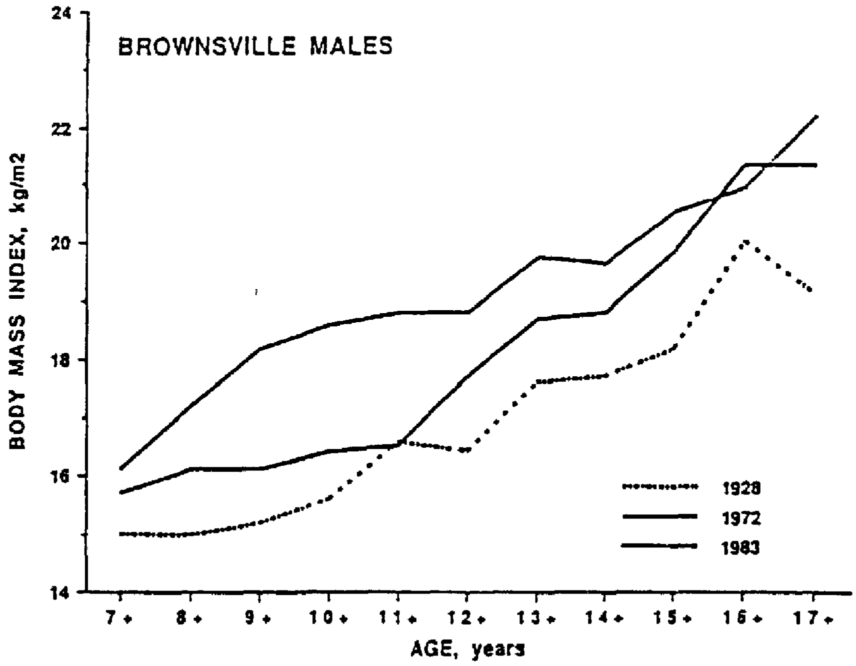
Secular changes in weight for Mexican Americans in Brownsville, TX (data from Malina et al., 1987)

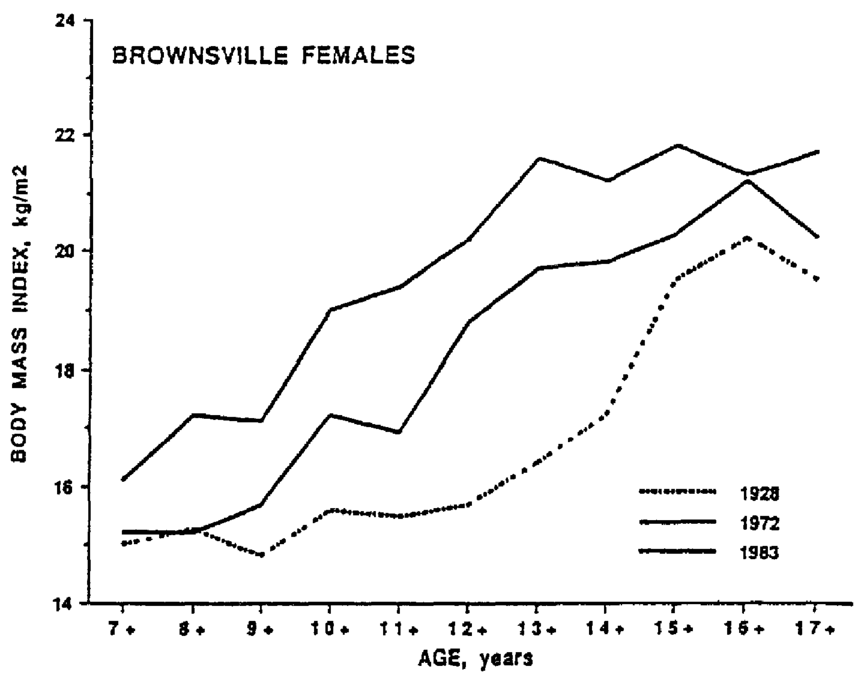




APPENDIX F

Secular changes in BMI for Mexican Americans in Brownsville, TX (data from Malina et al , 1987)





Ross
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Development
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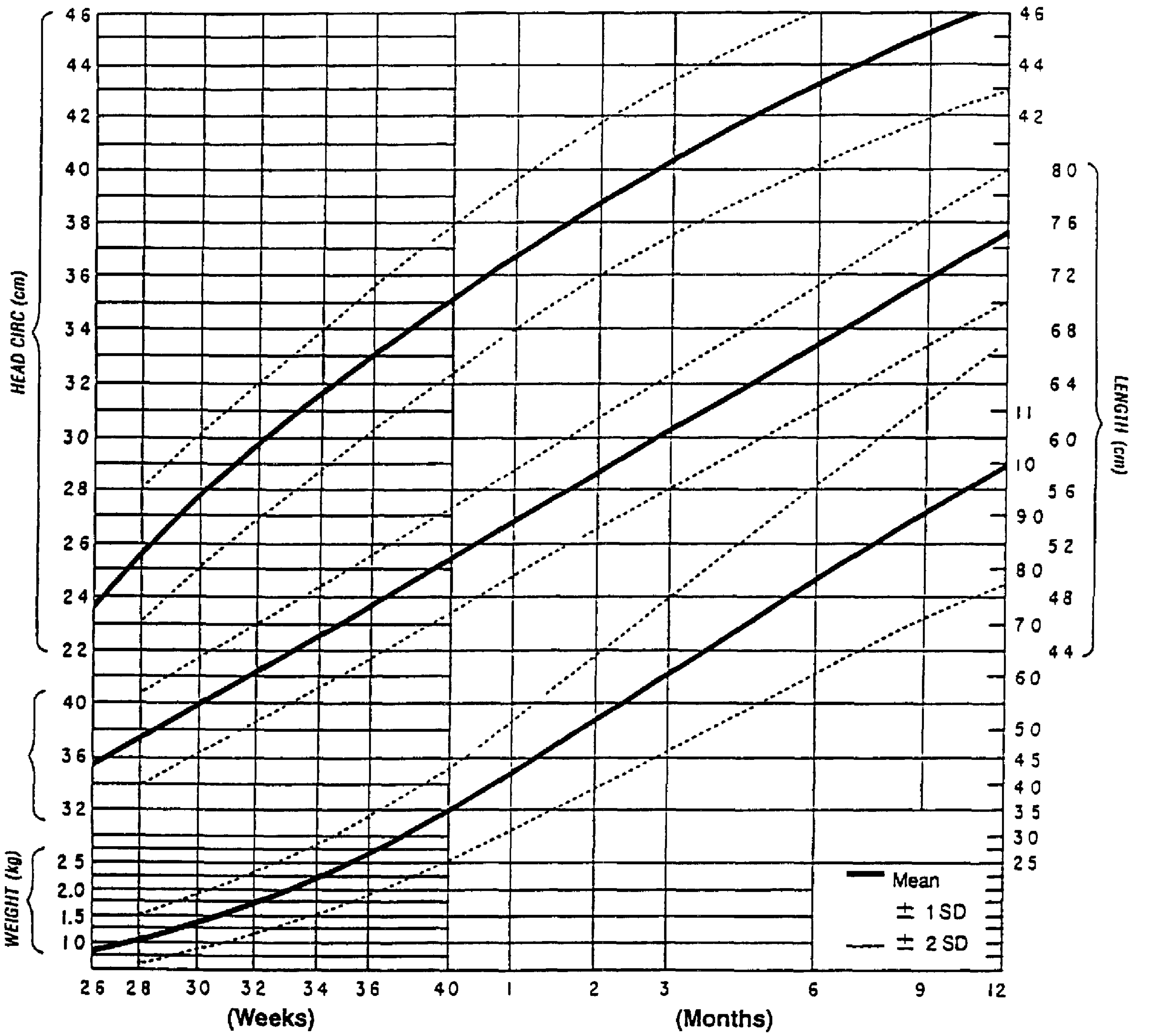
APPENDIX G

GROWTH RECORD FOR INFANTS*
BIRTH TO 1 YEAR, SEXES COMBINED

NAME ____________________

DATE OF BIRTH ____________________

I D NO ____________________



DATE	AGE	LENGTH	WEIGHT	HEAD CIRC	DATE	AGE	LENGTH	WEIGHT	HEAD CIRC

*Adapted with permission: Babson SG, Benda GI: Growth graphs for the clinical assessment of infants of varying gestational age. J Pediatr 89:814-820, 1976.

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COLUMBUS, OHIO 43216
Division of Abbott Laboratories, USA

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APPENDIX H

Examples of the format of the original NCHS charts, 1976

Male—Age < 36 Months

NAME ______________________ REC# ______________________

SEX ______________________ BIRTHDATE ______________________

Date	Age	Recum Length	Weight	Head Circ	

These personal charts for each infant were constructed by The National Center for Health Statistics, U S Public Health Service, using data from the Fels Research Institute, Yellow Springs, Ohio. These data are appropriate for the general United States population Their use will direct attention to unusual body size that may be due to disease or poor nutrition.

MEASUREMENTS. These should be made with minimal indoor clothing and without shoes. Two people are needed to measure recumbent length. For weight a beam scale should be used if possible.

To record a measurement, make a mark with a pencil. Be careful to place each mark for weight, length and head circumference vertically above the age and at the horizontal level of the measurement. Marks for weight/length are placed vertically above the observed length and at the same level as the weight. When the infant is measured again, join the marks by straight lines.

INTERPRETATION: Many factors influence growth. Therefore, growth data cannot be used alone to diagnose disease but they allow the identification of some unusual infants.

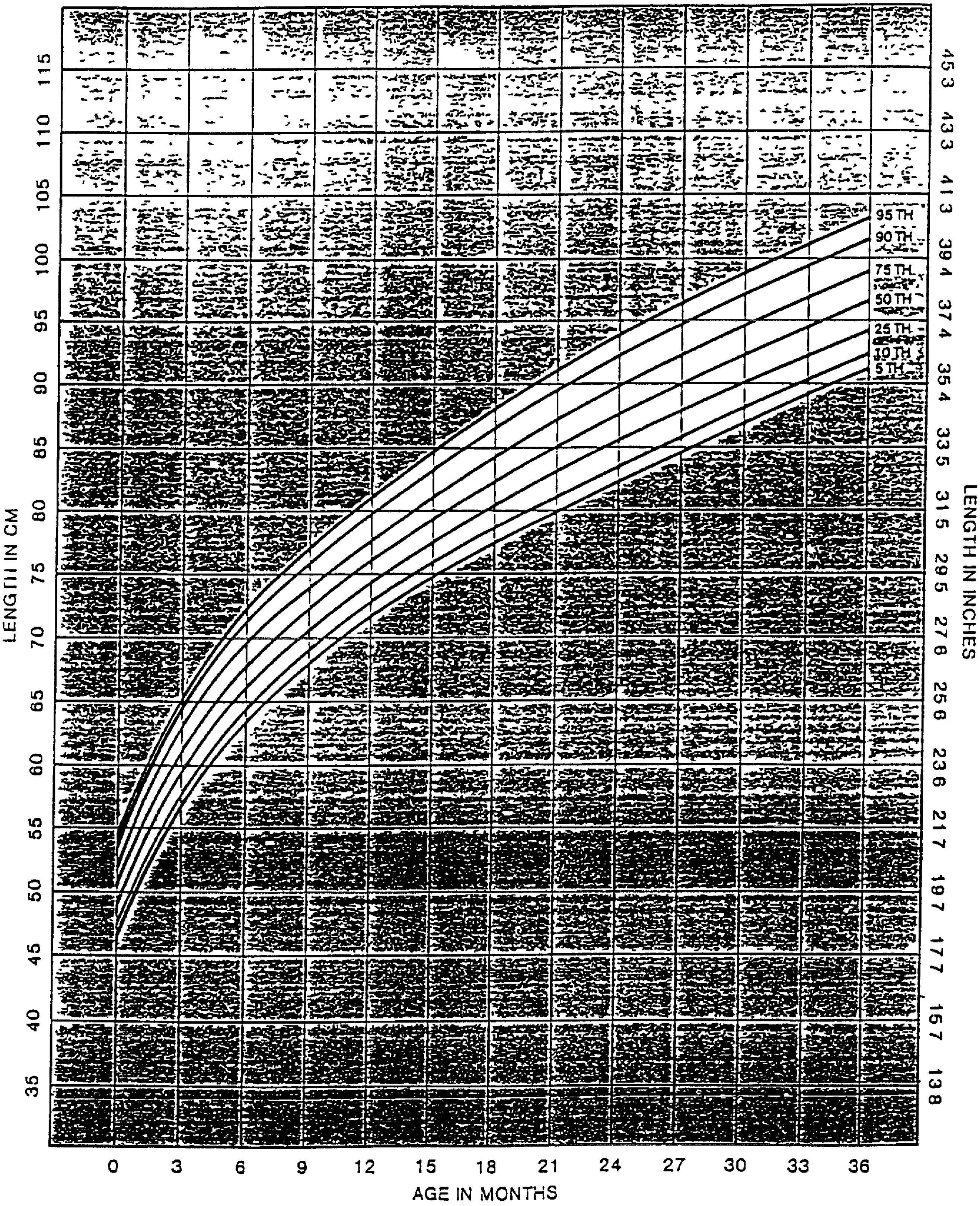
Each chart contains a series of curved lines that show percentiles These refer to the rank of a measure in a group of 100. Thus, when a mark is on the 95th percentile line for weight it means that only 5 infants among 100 of the corresponding age and sex have weights greater than recorded

Inspect the most recent set of marks. If any are particularly high or low, for example, above the 90th percentile or below the 10th percentile, you may want to refer the infant to a physician. *Compare* the recent set of marks with earlier sets for the same infant. If the infant has changed rapidly in percentile levels, you may want to refer him to a physician. Rapid changes are less likely to be significant when they occur within the range from the 75th to the 25th percentile

NATIONAL CENTER FOR HEALTH STATISTICS

BOYS LENGTH BY AGE PERCENTILES

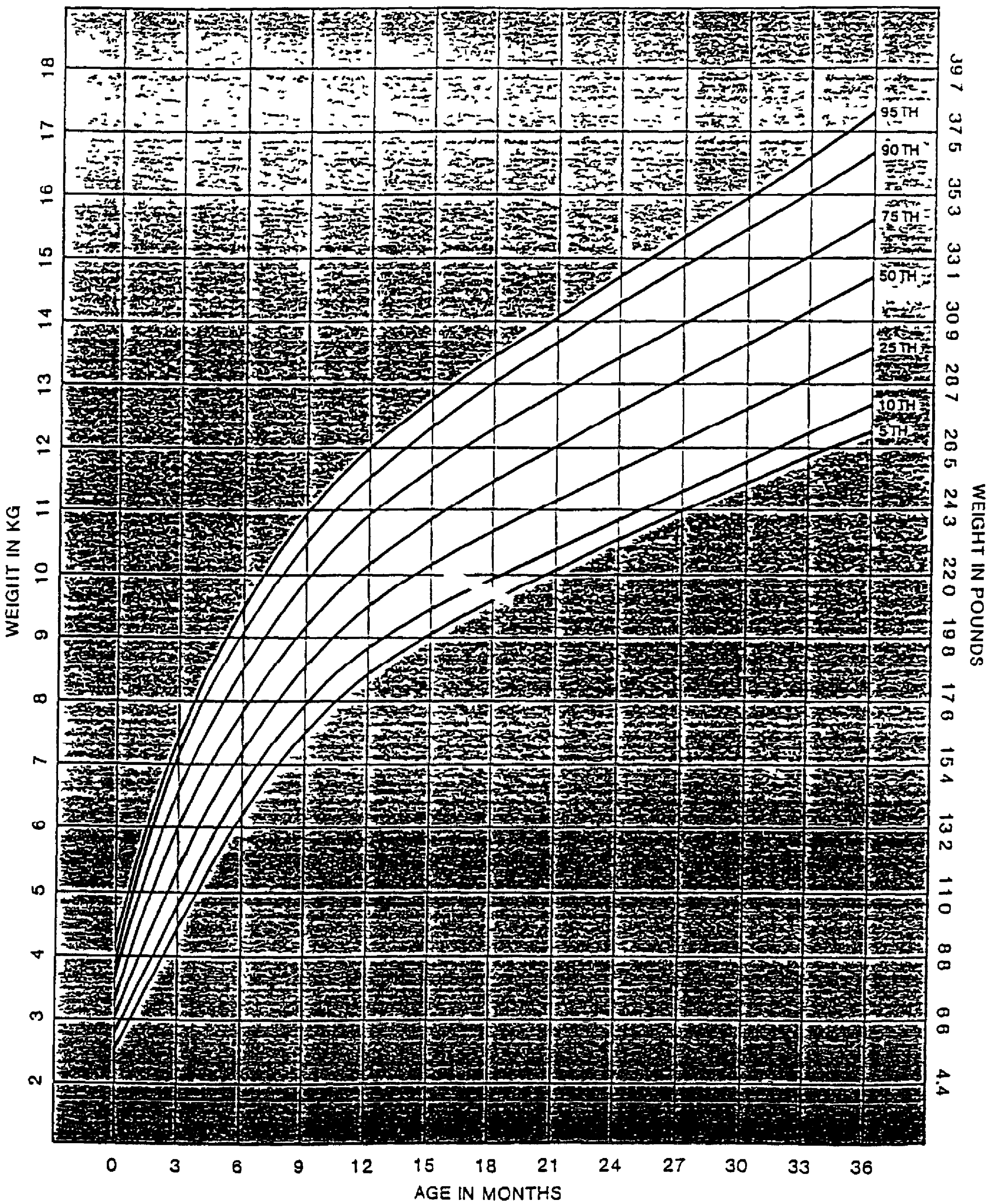
AGES BIRTH-36 MONTHS



NATIONAL CENTER FOR HEALTH STATISTICS

BOYS WEIGHT BY AGE PERCENTILES

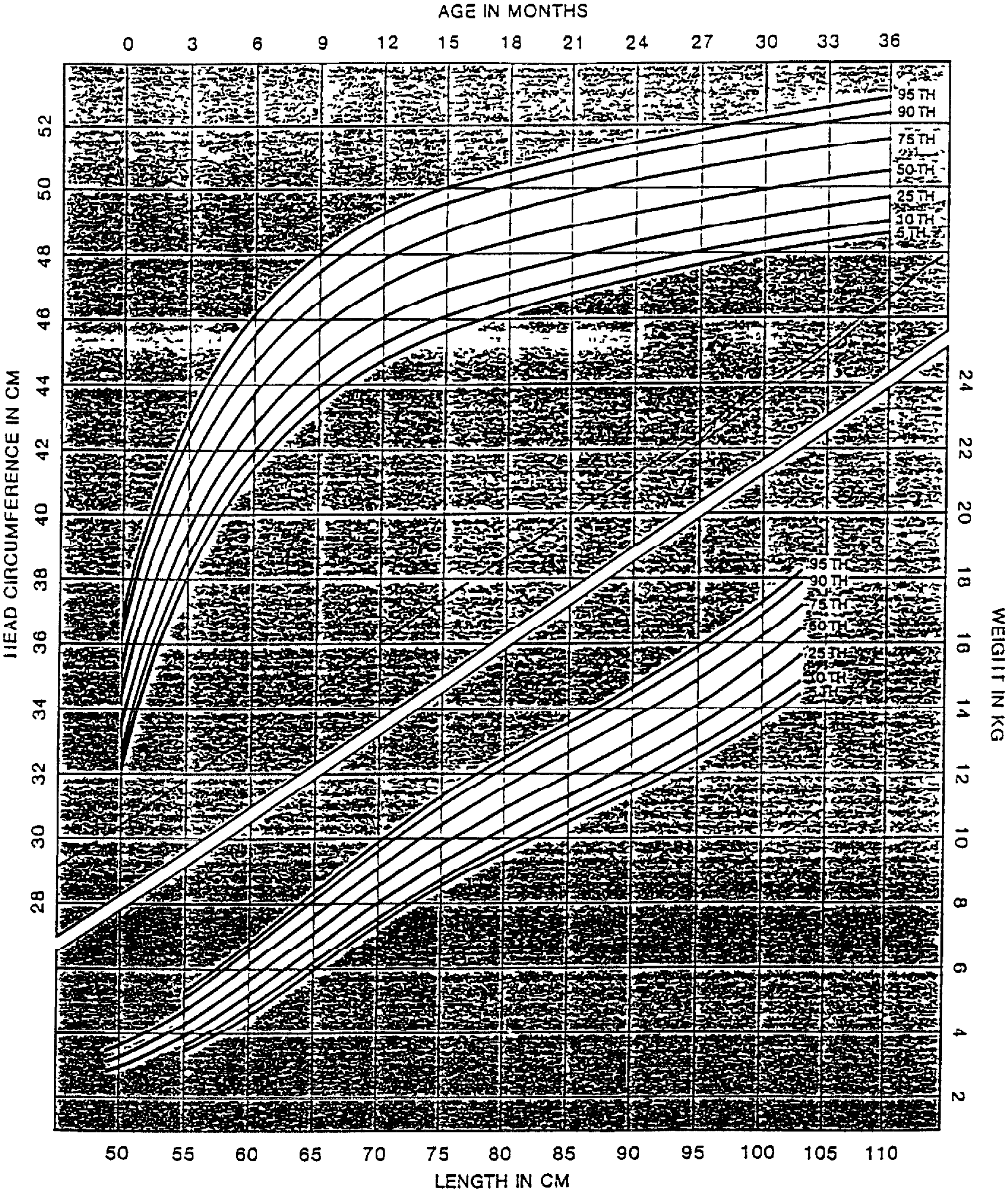
AGES BIRTH-36 MONTHS



NATIONAL CENTER FOR HEALTH STATISTICS

BOYS HEAD CIRCUMFERENCE BY AGE PERCENTILES

AGES BIRTH-36 MONTHS



NATIONAL CENTER FOR HEALTH STATISTICS

BOYS WEIGHT BY LENGTH PERCENTILES

AGES BIRTH-36 MONTHS

Female—Age <36 Months

NAME ______________________ REC# ______________________

SEX ______________________ BIRTHDATE ______________________

Date	Age	Recum Length	Weight	Head Circ	

These personal charts for each infant were constructed by The National Center for Health Statistics, U S Public Health Service, using data from the Fels Research Institute, Yellow Springs, Ohio These data are appropriate for the general United States population Their use will direct attention to unusual body size that may be due to disease or poor nutrition.

MEASUREMENTS. These should be made with minimal indoor clothing and without shoes Two people are needed to measure recumbent length For weight a beam scale should be used if possible

To record a measurement, make a mark with a pencil Be careful to place each mark for weight, length and head circumference vertically above the age and at the horizontal level of the measurement. Marks for weight/length are placed vertically above the observed length and at the same level as the weight. When the infant is measured again, join the marks by straight lines

INTERPRETATION Many factors influence growth. Therefore, growth data cannot be used alone to diagnose disease but they allow the identification of some unusual infants.

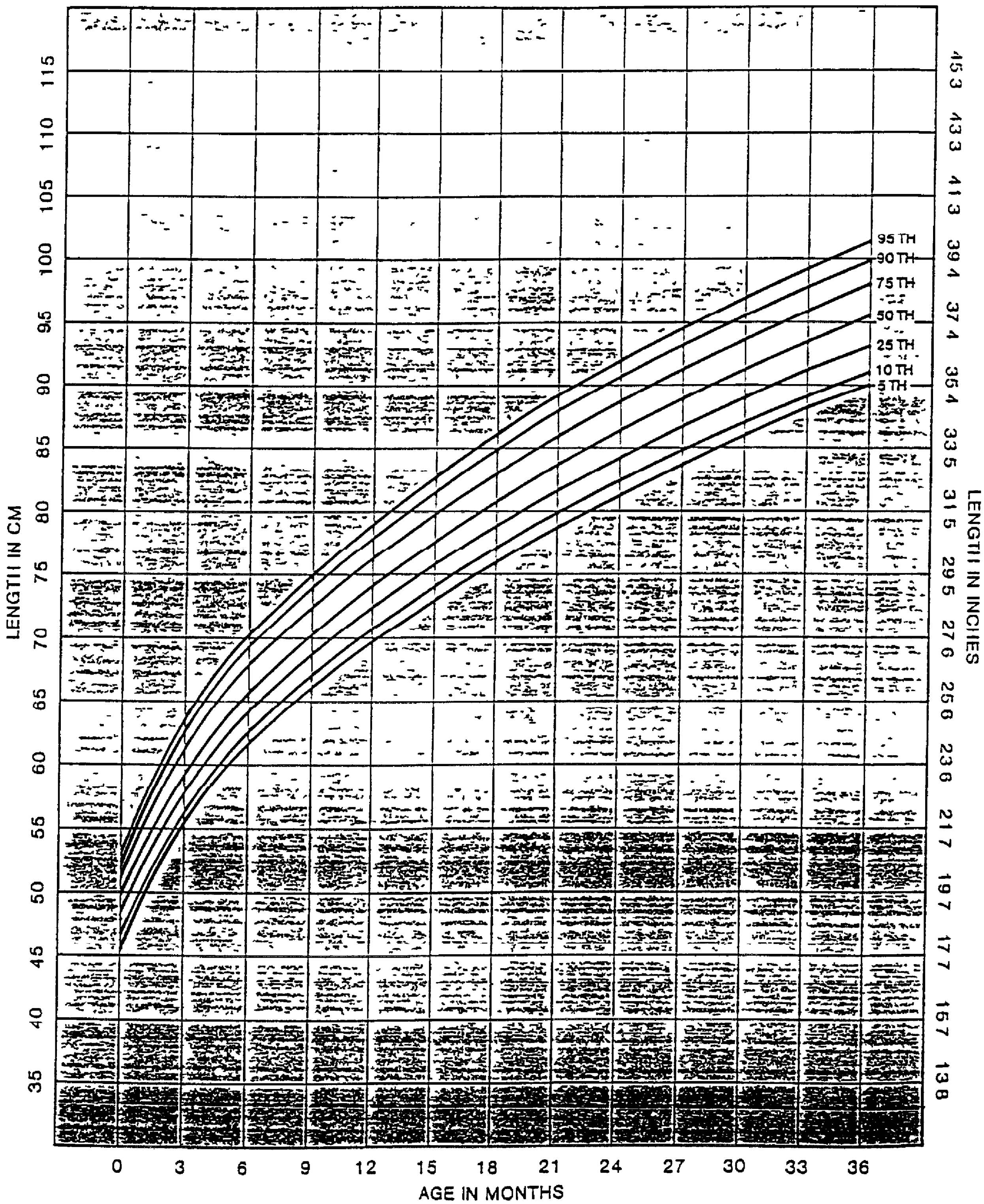
Each chart contains a series of curved lines that show percentiles These refer to the rank of a measure in a group of 100 Thus, when a mark is on the 95th percentile line for weight it means that only 5 infants among 100 of the corresponding age and sex have weights greater than recorded

Inspect the most recent set of marks. If any are particularly high or low, for example, above the 90th percentile or below the 10th percentile, you may want to refer the infant to a physician. *Compare* the recent set of marks with earlier sets for the same infant. If the infant has changed rapidly in percentile levels, you may want to refer her to a physician. Rapid changes are less likely to be significant when they occur within the range from the 75th to the 25th percentile

NATIONAL CENTER FOR HEALTH STATISTICS

GIRLS LENGTH BY AGE PERCENTILES

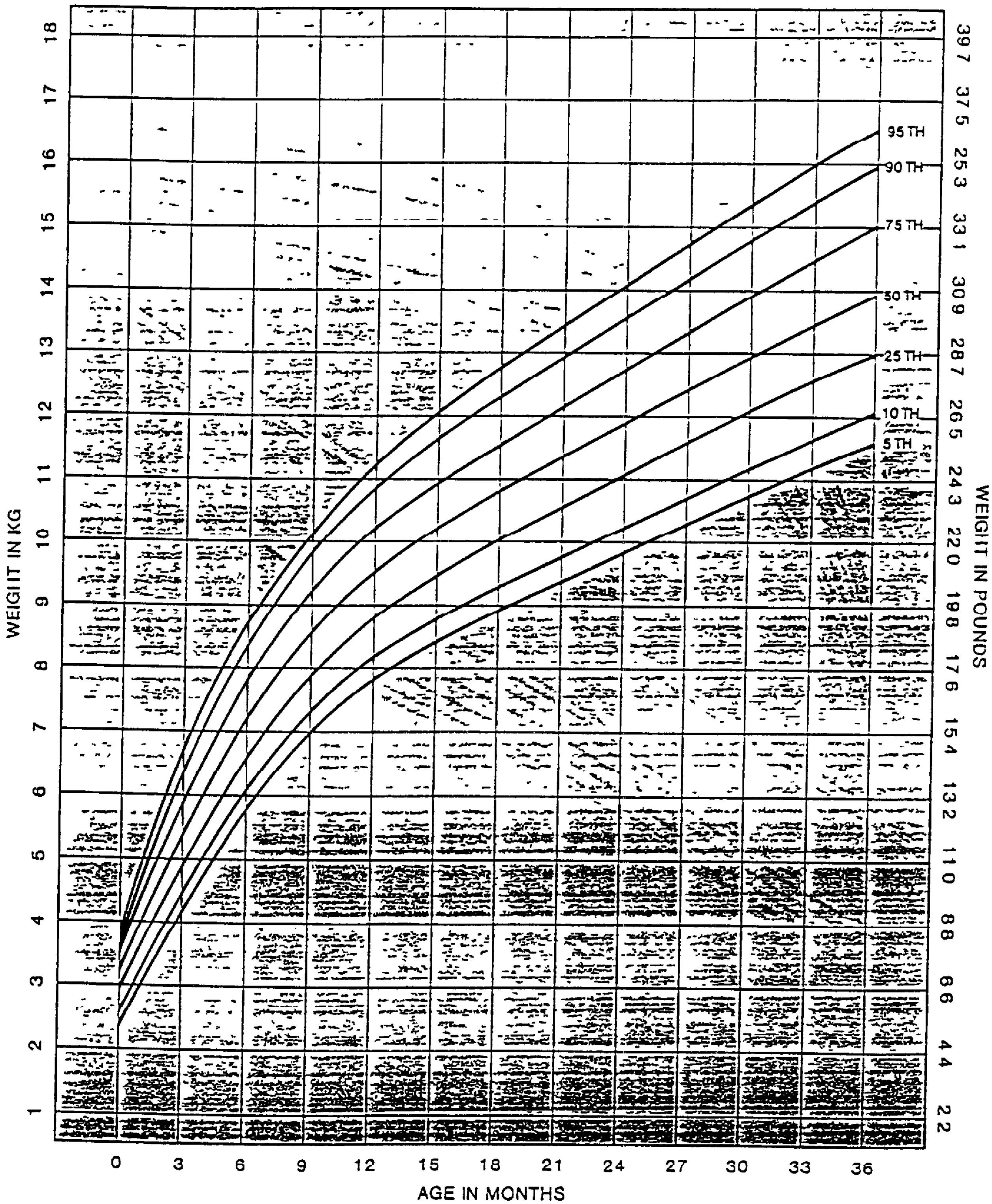
AGES BIRTH-36 MONTHS



NATIONAL CENTER FOR HEALTH STATISTICS

GIRLS WEIGHT BY AGE PERCENTILES

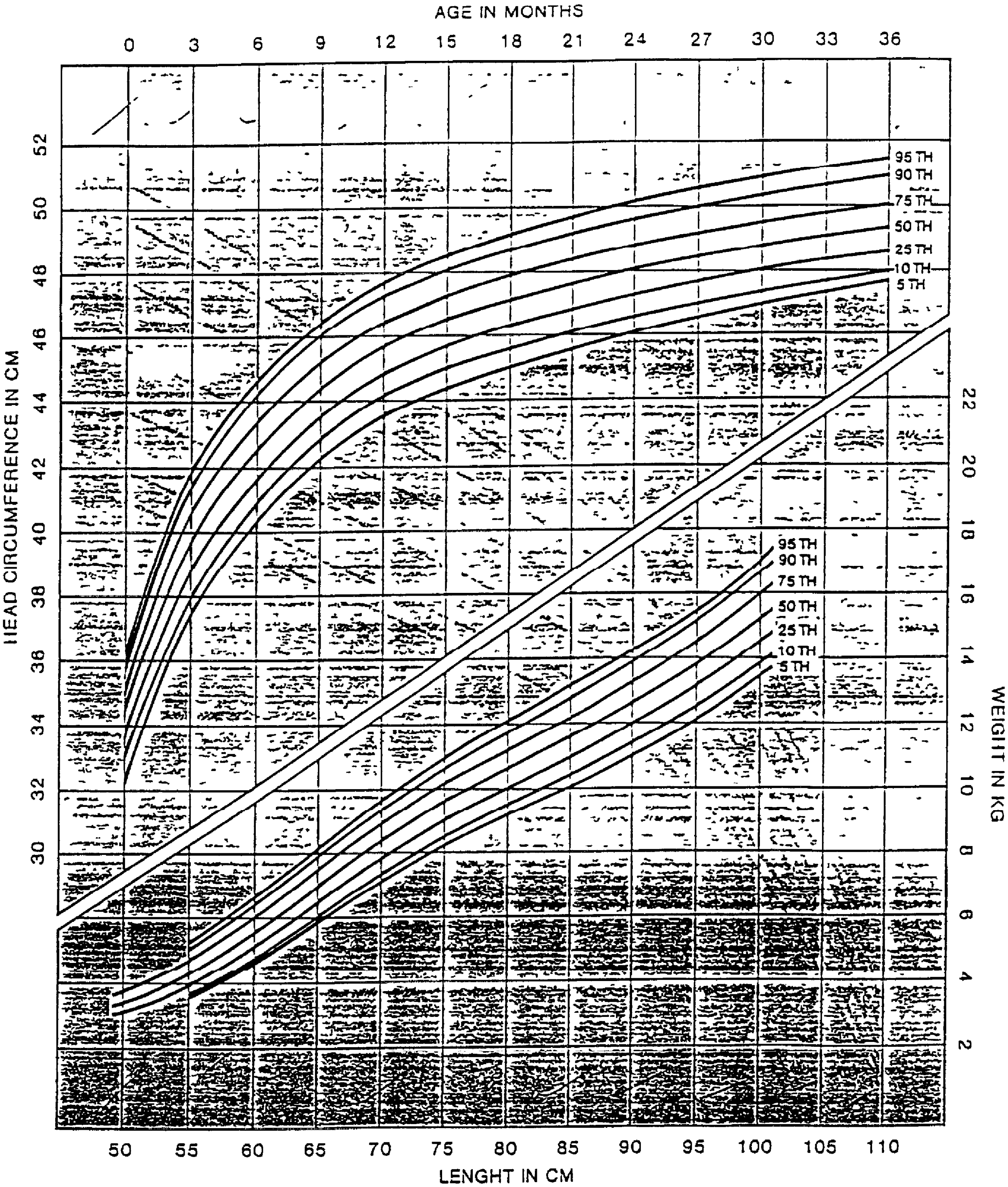
AGES BIRTH-36 MONTHS



NATIONAL CENTER FOR HEALTH STATISTICS

GIRLS HEAD CIRCUMFERENCE BY AGE PERCENTILES

AGES BIRTH-36 MONTHS



NATIONAL CENTER FOR HEALTH STATISTICS

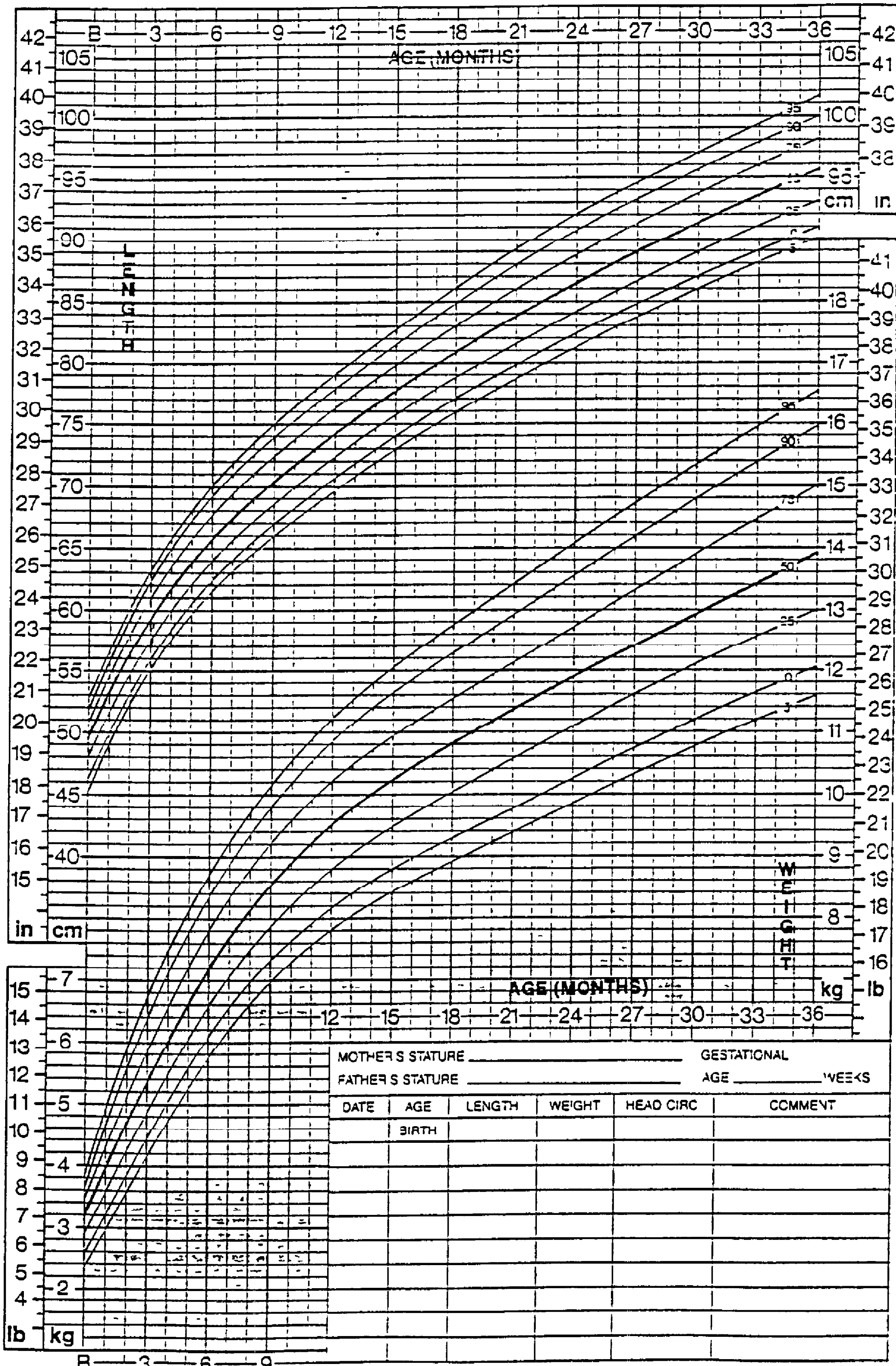
GIRLS WEIGHT BY LENGTH PERCENTILES

AGES BIRTH-36 MONTHS

APPENDIX I

GIRLS: BIRTH TO 36 MONTHS
PHYSICAL GROWTH
NCHS PERCENTILES*

NAME ________________ RECORD # ________



MOTHER'S STATURE ________ GESTATIONAL AGE ______ WEEKS

FATHER'S STATURE ________

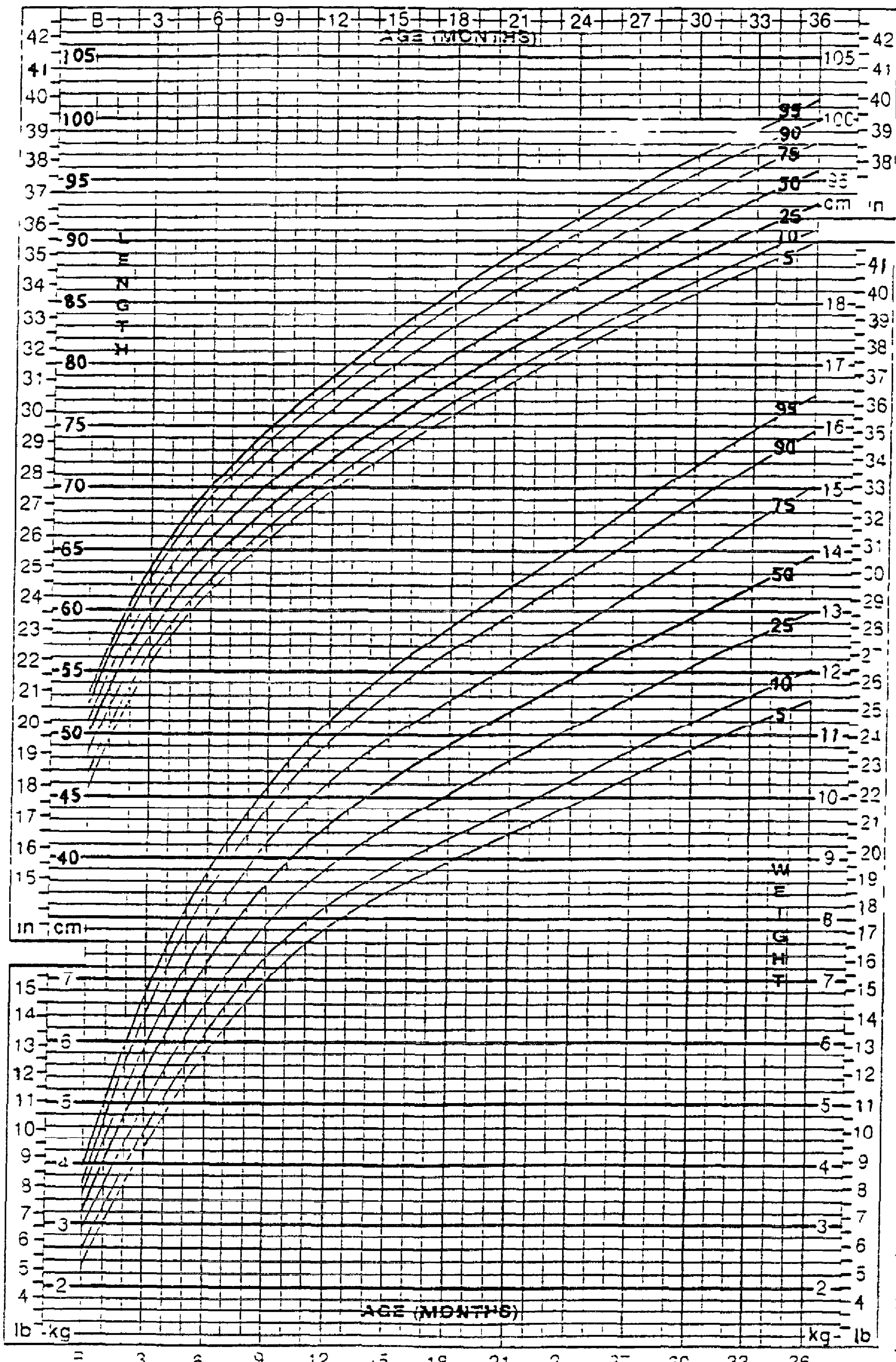
DATE	AGE	LENGTH	WEIGHT	HEAD CIRC	COMMENT
	BIRTH				

Ross Growth & Development Program

*Adapted from: Hamill PVV, Drizd TA, Johnson CL, Reed RB, Roche AF, Moore WM: Physical growth: National Center for Health Statistics percentiles. AM J CLIN NUTR 32:607-629, 1979. Data from the Fels Longitudinal Study, Wright State University School of Medicine, Yellow Springs, Ohio

GIRLS BIRTH TO 36 MONTHS
PHYSICAL GROWTH
NCHS PERCENTILES

NAME ______________________________ RECORD # ______________

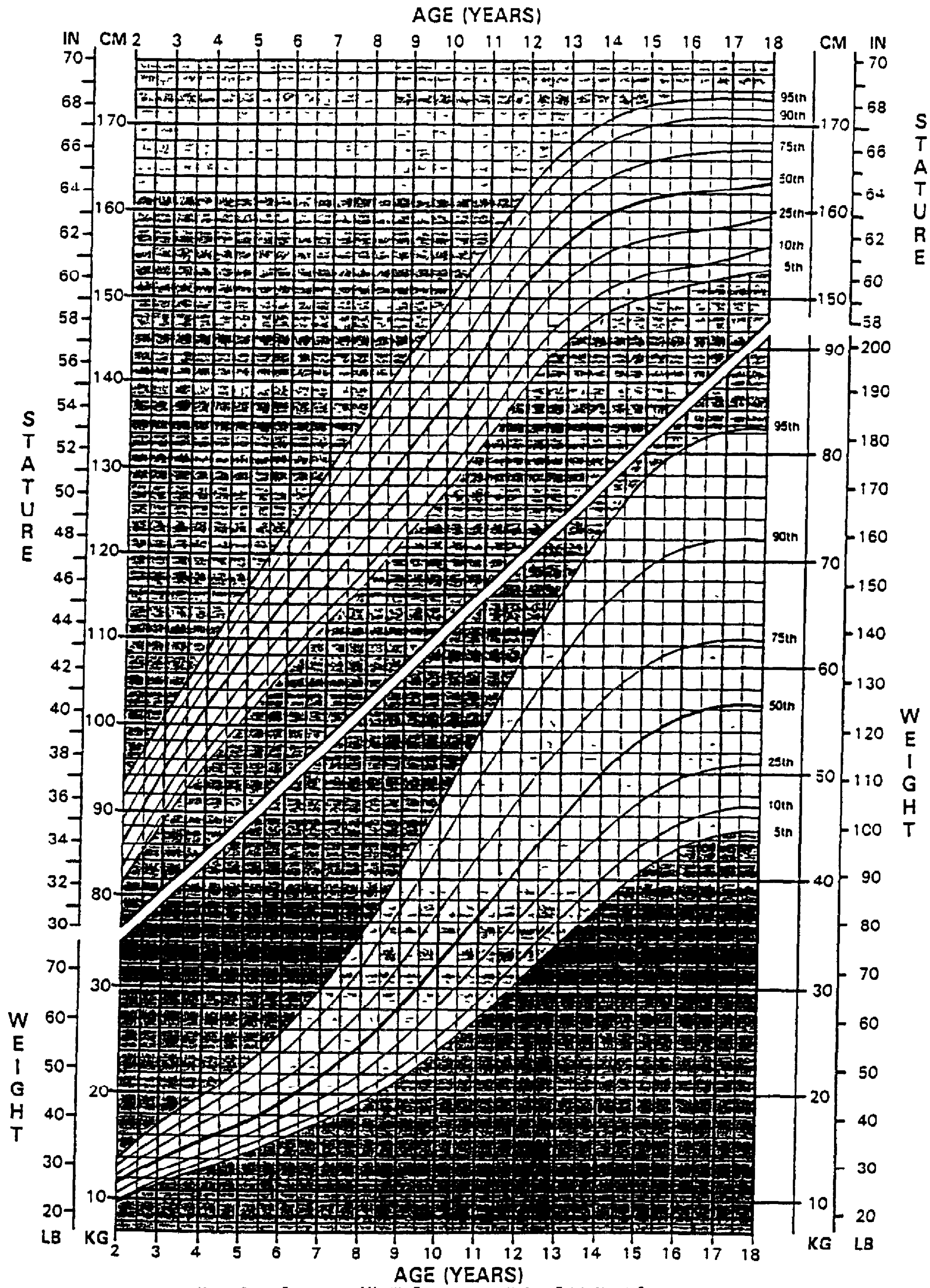


Adapted from: Hamill PVV, Drizd TA, Johnson CL, Reed RB, Roche AF, Moore WM: Physical growth: National Center for Health Statistics percentiles. AM J CLIN NUTR 32:607-629, 1979. Data from the Fels Research Institute, Wright State University School of Medicine, Yellow Springs, Ohio.

GIRLS: 2 TO 18 YEARS
STATURE FOR AGE &
WEIGHT FOR AGE

NAME ______________________

RECORD # ______________________



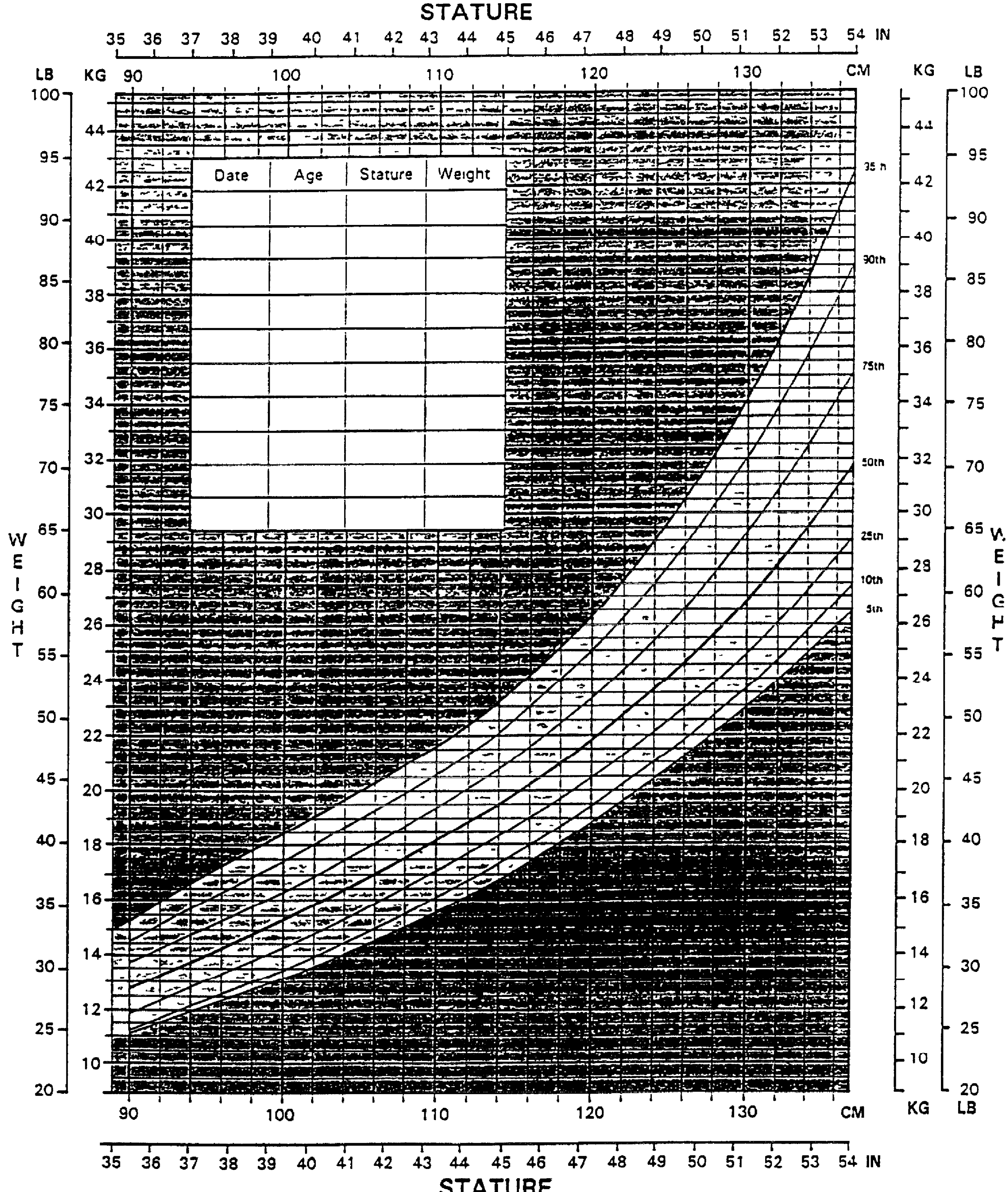
United States Department of Health Education and Welfare Public Health Service
Health Resources Administration National Center for Health Statistics, and Center for Disease Control

PRE-PUBERTAL GIRLS: 2 TO 10 YEARS

APPENDIX I (continued)

WEIGHT FOR STATURE

NAME ______________________ RECORD# ____________



Enfalac
Infant Formula

Enfalac WITH IRON
Infant Formula

ProSobee
Milk-Free Soy-Base
Infant Formula

Distributed by
Mead Johnson CANADA

May 20, 1993

Fels Longitudinal Study
Sexes Combined
Inter-observer differences (01/01/89 - 11/30/92)
Ages 2.0 to 2.99 years

Variable	n (pairs)	Mean absolute difference	Standard deviation	t.e	c v	c r
recumbent length (cm)	86	0 24	0 26	0 25	108 2	99 64
stature (cm)	60	0 15	0 23	0 19	151 8	99 74
weight (kg)	92	0 08	0 03	0 02	400 9	99 98
head circumference (cm)	90	0 16	0 14	0.15	86.4	99 16

t.e = technical error
c.v = coefficient of variation
c.r = coefficient of reliability

(Roche and Guo, unpublished data)

APPENDIX K

An extract from data of Himes et al. (1981), format by Ross Laboratories

Table 3. Parent-Specific Adjustments (cm) for Stature of Girls From 3 to 18 Years

Age (Years)	Stature (cm)	Midparent Stature (cm)																	
		150	152	154	156	158	160	162	164	166	168	170	172	174	176	178	180	182	184
3	82 0– 83 9	6	5	4	4	3	2	1	1	0	1	−1	−2	−3	−3	−4	−5	−6	−6
	84 0– 93 9	6	6	5	4	3	3	2		1				2	−3	−4	−4	−5	−6
	94 0–[illegible]	7	7	6	5	4	4	3	2	2		0			2	3	−3	−4	−5
4	92 0– 93 9	6	6	5	4	3	3	2	1	0	0	−1	−2	−3	−3	−4	−5	−6	−7
	94 0–103 9	7	6	6	5	4	3	2	2	1	0	−1	−1	−2	−3	−4	−4	−5	−6
	104 0–112 9	8	7	7	6	5	4	3	3	2	1	0	0	−1	−2	−3	−3	−4	−5
5	100 0–10[illegible] 9	8	7	6	5	4	3	2			0	−1	−2	−3	−4	−5	−5	−6	−7
	102 0–111 9	8	7	6	6	5	4	3	2	1	0	−1	[illegible]	−2	−3	−4	−5	−6	−7
	112 0–120 9	9	8	7	[illegible]	6	5	[illegible]	3	2	1	1	0	−1	−2	−3	−4	−6	−6
6	106 0–109 9	9	8	7	6	5	4	3	2	1	0	−1	−2	−3	−4	−5	−6	−7	−8
	110 0–119 9	9	9	8	7	6	5	4	3	2	1	0	−1	−2	−3	−4	−5	−6	−7
	120 0–128 9	11	10	9	8	7	6	5	4	3	2	1	0	−1	−2	−3	−4	−5	−6
7	112 0–117 9	9	8	7	6	5	[illegible]	3	2	[illegible]	0	−1	−2	−3	−4	−5	−5	−7	−8
	118 0–127 9	10	9	8	7	6	5	4	3	2	1	0	[illegible]	−2	−3	−4	−5	−6	−7
	128 0–136 9	11	10	9	8	7	6	5	4	3	2	1	0	−1	−2	−3	−4	−5	−6
8	116 0–123 9	9	8	7	6	5	4	3	2	1	0	−1	−2	−3	−4	−5	−6	−8	−9
	124 0–133 9	10	9	8	7	6	5	4	3	2	1	0	−1	−2	−3	−4	−5	−7	−8
	134 0–142 9	11	10	9	8	7	6	5	4	3	2	1	0	−1	−2	−3	−4	−6	−7
9	122 0–131 9	10	9	8	7	6	5	3	2	1	0	−1	−2	−3	−4	−5	−6	−7	−9
	132 0–141 9	11	10	9	8	7	6	4	3	2	1	0	−1	−2	−3	−4	−5	−7	−8
	142 0–150 9	12	11	10	9	8	6	5	[illegible]	3	2	1	0	−1	−2	−3	−5	−6	−7
10	126 0–127 9	10	9	7	6	5	4	3	2	1	0	−1	−2	−3	−5	−6	−7	−8	−9
	128 0–137 9	10	9	8	7	6	5	4	2	1	0	−1	−2	−3	−4	−5	−6	−7	−8
	138 0–147 9	11	10	9	8	6	5	4	3	2	1	0	−1	−2	−3	−4	−5	−7	−8
	148 0–156 9	12	10	9	8	7	6	5	4	3	2	1	0	−1	−3	−4	−5	−6	−7
11	130 0–133 9	10	9	8	6	5	4	3	2	1	0	−1	−2	−3	−4	−6	−7	−8	−9
	134 0–143 9	10	9	8	7	6	5	4	3	1	0	[illegible]	−2	−3	−4	−5	−6	−7	−8
	144 0–153 9	11	10	9	[illegible]	6	5	4	3	2	1	0	−1	−3	−3	−5	−6	−7	−8
	154 0–162 9	11	10	9	8	7	6	5	[illegible]	3	1	0	−1	−2	−3	[illegible]	−5	−6	−7
12	134 0–139 9	10	9	8	7	6	5	3	2	1	0	−1	−3	−4	−5	−6	−7	−8	−10
	140 0–149 9	11	10	9	7	6	5	4	3	2	0	−1	−2	−3	−4	−6	−7	−8	−9
	150 0–159 9	12	10	9	8	7	6	5	3	2	1	0	−1	−3	−4	−5	−6	−7	−8
	160 0–168 9	12	11	10	9	8	6	5	4	3	2	0	−1	−2	−3	−4	−5	−7	−8
13	140 0–145 9	10	9	8	7	6	4	3	2	1	0	−1	−3	−4	−5	−6	−7	−8	−10
	146 0–155 9	11	10	9	7	6	5	4	3	2	0	−1	−2	−3	−4	−6	−7	−8	−9
	156 0–165 9	12	10	9	8	7	6	5	3	2	1	0	−1	−3	−4	−5	−6	−7	−8
	166 0–174 9	[illegible]	[illegible]	[illegible]	9	8	6	5	4	3	2	[illegible]	[illegible]	−2	−3	[illegible]	−5	−7	−8
14	146 0–149 9	10	9	8	6	5	4	3	2	1	0	−1	−3	−4	−5	−6	−7	−8	−9
	150 0–159 9	11	9	8	7	6	5	4	3	1	0	−1	−2	−3	−4	−5	−7	−8	−9
	160 0–169 9	11	10	9	8	7	6	5	3	2	1	0	−1	−2	−3	−5	−6	−7	−8
	170 0–178 9	12	11	10	9	8	6	5	4	3	2	1	0	−2	−3	−4	−5	−6	−7
15	146 0–151 9	10	9	8	7	5	4	3	2	1	−1	−2	−3	−4	−5	−6	−8	−9	−10
	152 0–161 9	11	10	9	7	6	5	4	3	1	0	−1	−2	−3	−4	−6	−7	−8	−9
	162 0–171 9	12	11	10	8	7	6	5	4	2	1	0	−1	−2	−4	−5	−6	−7	−8
	172 0–180 9	13	12	11	9	8	7	6	5	3	2	1	0	−1	−3	−4	−5	−6	−7
16	146 0–151 9	11	10	8	7	6	5	3	2	1	−1	−2	−3	−4	−6	−7	−8	−10	−11
	152 0–161 9	12	10	9	8	7	5	4	3	2	0	−1	−2	−4	−5	−6	−7	−9	−10
	162 0–171 9	13	12	10	9	8	6	5	4	3	1	0	−1	−3	−4	−5	−6	−8	−9
	172 0–180 9	14	13	11	10	9	7	6	5	4	2	1	0	−2	−3	−4	−5	−7	−8
17	148 0–153 9	11	10	9	7	6	5	3	2	1	0	−2	−3	−4	−6	−7	−8	−10	−11
	154 0–163 9	12	11	10	8	7	6	4	3	2	0	−1	−2	−4	−5	−6	−8	−9	−10
	164 0–173 9	13	12	11	9	8	7	5	4	3	1	0	−1	−3	−4	−5	−6	−8	−9
	174 0–182 9	14	13	12	10	9	8	6	5	4	2	1	0	−1	−3	−4	−5	−7	−8
18	148 0–149 9	10	9	8	7	5	4	3	2	1	−1	−2	−3	−4	−6	−7	−8	−9	−10
	150 0–159 9	11	10	8	7	6	5	4	2	1	0	−1	−3	−4	−5	−6	−7	−9	−10
	160 0–169 9	12	11	9	8	7	6	4	3	2	1	0	−2	−3	−4	−5	−6	−8	−9
	170 0–178 9	13	11	10	9	8	7	5	4	3	2	1	−1	−2	−3	−4	−5	−7	−8

APPENDIX L

An example of a growth chart including reference data for the timing of maturation (Tanner and Davies, 1985)

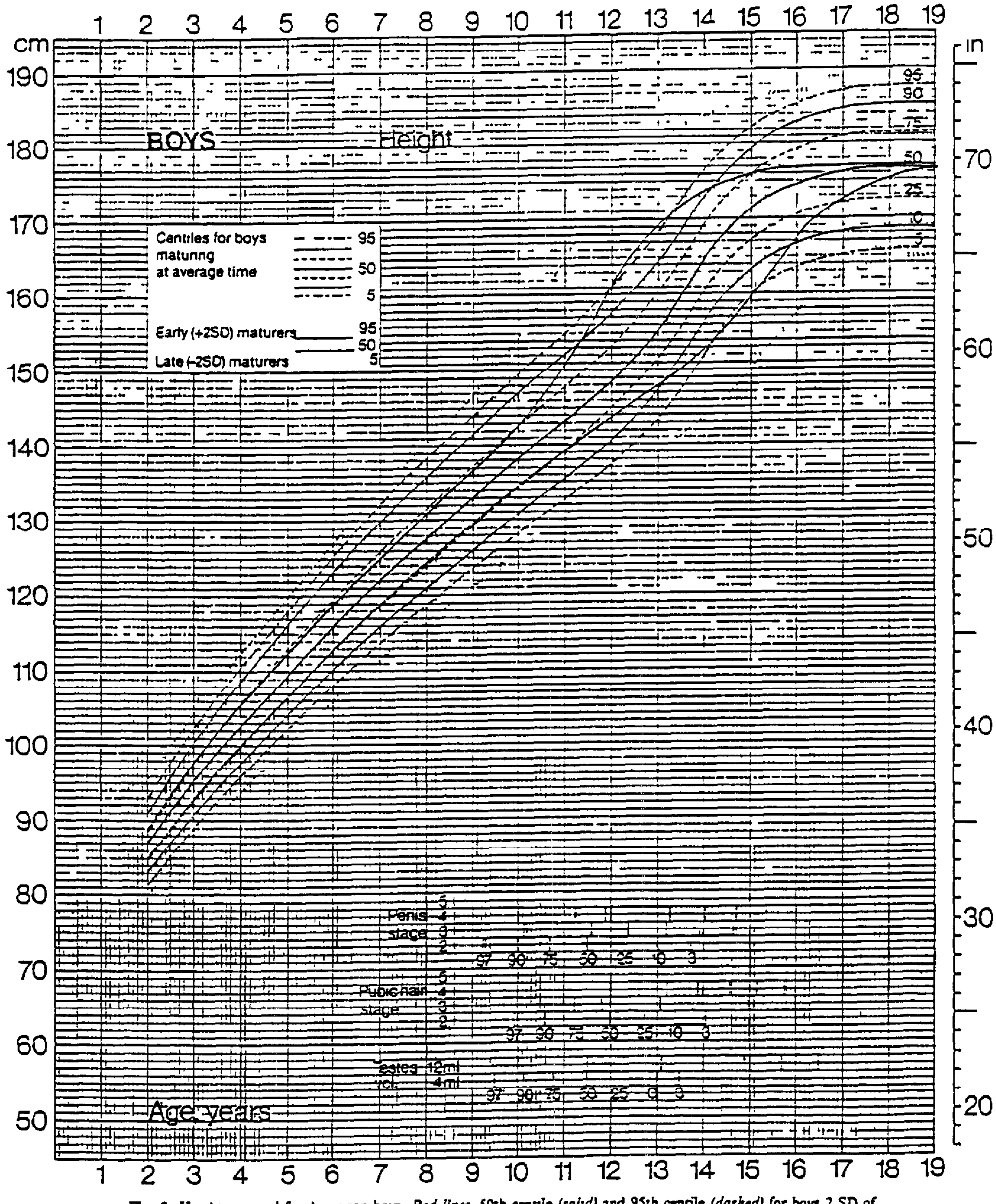


Fig. 3. Height attained for American boys. *Red lines*, 50th centile *(solid)* and 95th centile *(dashed)* for boys 2 SD of tempo early; *green lines* 50th centile *(solid)* and 5th centile *(dashed)* for boys 2 SD of tempo late.

Adjustments to observed statures for maturity status derived from NHES Cycle III data (Wilson et al., 1987)

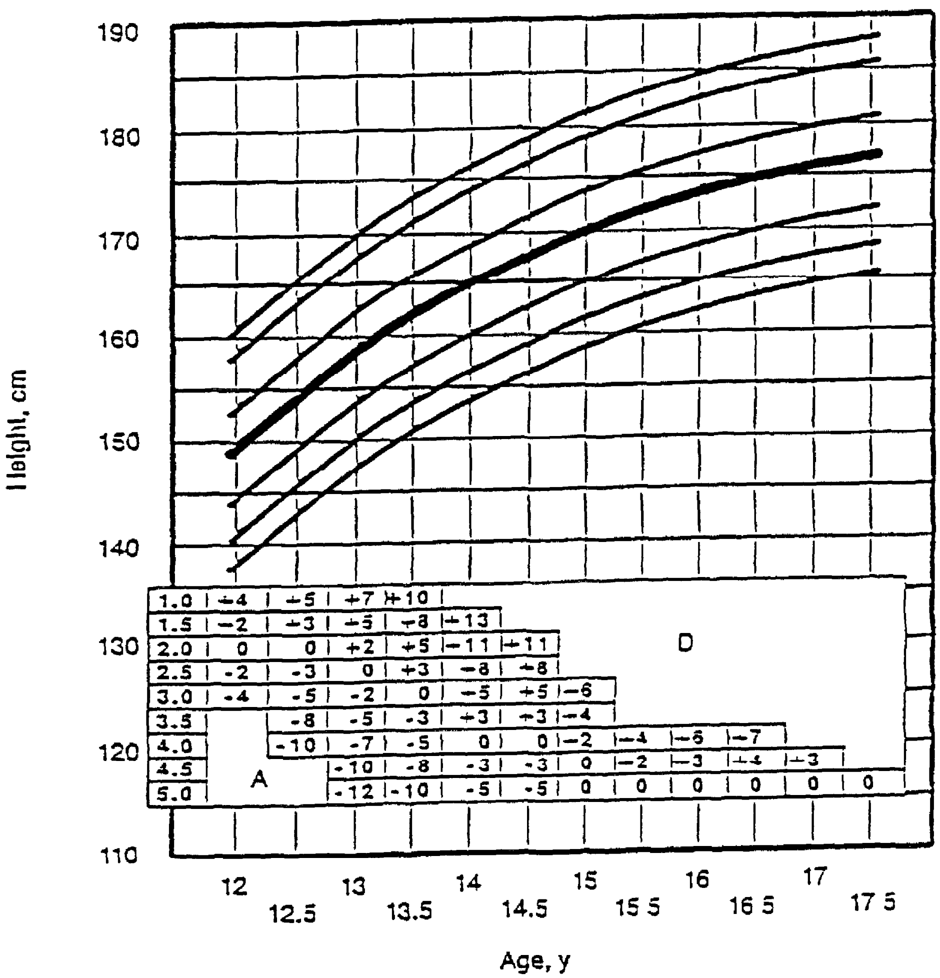


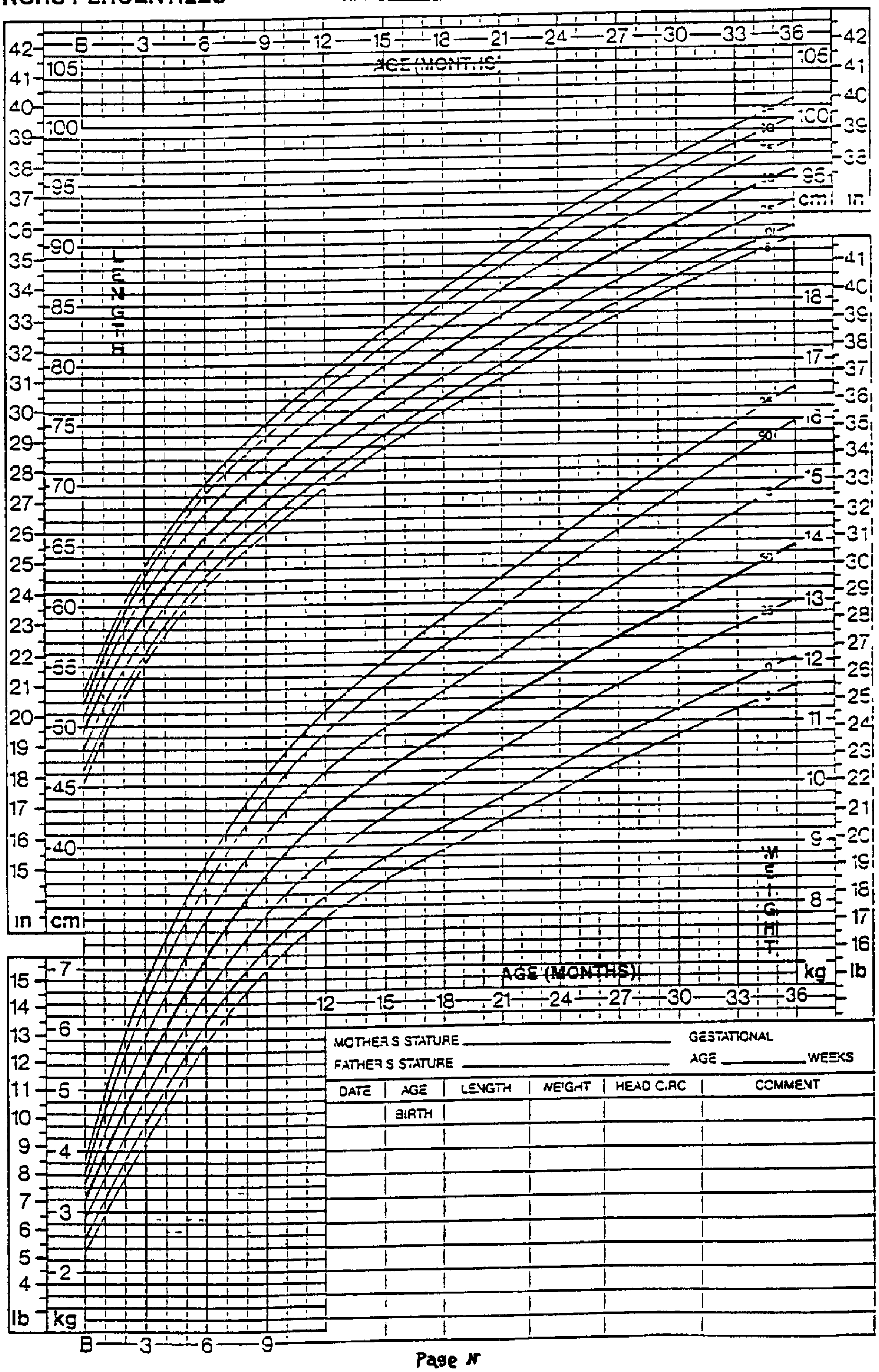
Fig 1.—Growth curve and correction table for male adolescents. Mean height (bold line) and distribution (95th, 90th, 75th, 25th, 10th, and 5th percentile lines) for adolescents maturing at modal rate (see text). Correction table below curves shows mean difference in height between subjects of same age at different stages of puberty (indicated by left column). To obtain a height percentile adjusted for rate of pubertal maturation, first average Tanner stages for pubic hair and genitalia to form sexual maturity index score and then determine correction factor for patient's age from correction table. Add (or, if correction factor is negative, subtract) correction factor to (from) measured height and plot adjusted height onto curves. To estimate final adult height, extrapolate adjusted height percentile to adulthood.

GIRLS: BIRTH TO 36 MONTHS
PHYSICAL GROWTH
NCHS PERCENTILES*

APPENDIX N

A black and white photocopy of the growth chart in Appendix I

NAME ______________________ RECORD # ____________



MOTHER'S STATURE ______________ GESTATIONAL

FATHER'S STATURE ______________ AGE ________ WEEKS

DATE	AGE	LENGTH	WEIGHT	HEAD CIRC	COMMENT
	BIRTH				

Ross Growth & Development Program

* Adapted from: Hamill PVV, Drizd TA, Johnson CL, Reed RB, Roche AF, Moore WM: Physical growth: National Center for Health Statistics percentiles. AM J CLIN NUTR 32:607-629, 1979. Data from the Fels Longitudinal Study, Wright State University School of Medicine, Yellow Springs, Ohio.

APPENDIX O (about 1977)

Guidelines from Michigan Department of Public Health in regard to the use of NCHS/CDC charts

ANTHROPOMETRIC MEASUREMENT GUIDELINES FOR HEIGHT, WEIGHT, HEAD CIRCUMFERENCE

MEASUREMENTS

LENGTH/STATURE

Birth to Two Years

Children from birth to two years should have height measured as length (recumbent-heel-to-crown) and recorded on the appropriate growth chart. Before plotting the measurement on the growth chart, it should be adjusted to the nearest one-fourth (1/4) inch.

Taking recumbent length requires two persons--one to hold the infant's head in contact with the fixed headboard and another to straighten the knees and flex the infant's foot against the movable end. The length is determined after locking the infantometer in place.

Two Years and Older

Children two years and older should have stature/height taken without shoes and measured by a steel tape fixed to a true vertical flat surface wall. The child should stand with heels together, back straight, and shoulders touching the wall. A plane should be brought to the crown of the head and the measurement recorded on the appropriate growth chart. Before plotting the measurement on the growth chart, it should be adjusted to the nearest one-half (1/2) inch.

Plotting the Results

Birth to Two Years

LENGTH should be plotted at 1/4 INCH intervals.

1/8"	drop
2/8"	plot as 1/4 inch
3/8 through 5/8"	plot as 1/2 inch
6/8"	plot as 3/4 inch
7/8"	plot as next higher inch

1/16 through 2/16"	drop
3/16 through 5/16"	plot as 1/4 inch
6/16 through 10/16"	plot as 1/2 inch
11/16 through 13/16"	plot as 3/4 inch
14/16 through 15/16"	plot as next higher inch

Two Years and Older

STATURE should be plotted at 1/2 INCH intervals.

1/16 through 5/16"	drop
6/16 through 10/16"	plot as 1/2 inch
11/16 through 15/16"	plot as next higher inch

Birth to Two Years

Children from birth to two years of age should be weighed without clothing or diaper. They should be weighed on an infant beam or balance scale while lying or sitting. The actual weight should be recorded on the appropriate growth chart.

Before plotting the measurement on the growth chart, it should be adjusted to the nearest one-fourth (1/4) pound.

Two Years and Older

Children age two and older should be weighed without shoes and wearing only light indoor clothing. They should be weighed on an adult balance scale and the measurement recorded on the appropriate growth chart.

Record measurement on the growth chart to the nearest one-fourth (1/4) pound. Before plotting the measurement it should be adjusted to the nearest even number of pounds.

Recording the Results

WEIGHT to be recorded at 1/4 POUND intervals.

From 1 to 2 ounces	drop
From 3 to 5 ounces	record as 1/4 pound
From 6 to 10 ounces	record as 1/2 pound
From 11 to 13 ounces	record as 3/4 pound
From 14 to 16 ounces	record as next higher pound

WEIGHT continued

Plotting the Results

Birth to Two Years

Weight-For-Age Chart

WEIGHT shall be plotted at 1/2 POUND intervals.

From 1 to 5 ounces	drop
From 6 to 10 ounces	plot as 1/2 pound
From 11 to 15 ounces	plot as next higher pound

Weight-For-Length Chart.

WEIGHT should be plotted at 1/2 POUND intervals.

LENGTH should be plotted at 1/4 INCH intervals.

Two Years and Older

Weight-For-Age Chart:

WEIGHT should be plotted in EVEN NUMBERED POUNDS.

Between 1 and 3 pounds	round to 2 pounds
Between 3 and 5 pounds	round to 4 pounds
Between 5 and 7 pounds	round to 6 pounds
Between 7 and 9 pounds	round to 8 pounds
Between 9 and 11 pounds	round to 10 pounds

Weight-For-Stature Chart:

WEIGHT should be plotted at ONE (1) POUND intervals.

Up to and including 1/2 pound	drop
Over 1/2 pound	plot as the next higher pound

LENGTH should be plotted at 1/2 INCH intervals.

Accuracy

The beam scale must be "zeroed in" daily. If children are active on the scale, "zero in" frequently. "Zero in" is the procedure of checking to see that the scale is in balance. Consult manufacturer's directions.

All scales should be re-calebrated by manufacturer at least 2 or 3 times per year. In Michigan, the Michigan Department of Agriculture, Weights and Measure Section, can test the scale for accuracy.

Birth to Two Years

All children from birth to 24 months of age should have their head circumference measured A flexible steel tape or individual disposable paper tape is firmly applied to the head above the eyebrows and around the most prominent portion of the head

The measurement is recorded and plotted to the nearest one-fourth (1/4) inch

Plotting the Results

HEAD CIRCUMFERENCE should be plotted at 1/4 INCH intervals.

8 gradations per inch

1/8 "	drop
2/8 "	plot as 1/4 inch
3/8 " through 5/8"	plot as 1/2 inch
6/8 "	plot as 3/4 inch
7/8 "	plot as next higher inch

16 gradations per inch

1/16 through 2/16"	drop
3/16 through 5/16"	plot as 1/4 inch
6/16 through 10/16"	plot as 1/2 inch
11/16 through 13/16"	plot as 3/4 inch
14/16 through 15/16"	plot as next higher inch

SUMMARY

PLOTTING UNIT INTERVALS

AGE \ GROWTH CHARTS	LENGTH/STATURE-FOR-AGE	WEIGHT-FOR-AGE	HEAD CIRCUMFERENCE	WEIGHT-FOR-LENGTH/STATURE
Birth to 36 Months	1/4 inch	1/2 pound	1/4 inch	Length. 1/4 inch Weight: 1/2 pound
2 to 18 Years	1/2 inch	2 pounds		Stature 1/2 inch Weight 1 pound

NCHS GROWTH CHARTS FOR INFANTS (BIRTH TO 36 MONTHS)

CHART	VERTICAL LINE	HORIZONTAL LINE
Length-For-Age	Age: 1 Month Intervals	Length: 1/4 inch Intervals
Weight-For-Age	Age. 1 Month Intervals	Weight: 1/2 pound Intervals
Head Circumference-For-Age	Age: 1 Month Intervals	Head Circumference· 1/4 inch Intervals
Weight-For-Length	Length. 1/4 inch Intervals	Weight. 1/2 pound Intervals

NCHS GROWTH CHARTS FOR BOYS/GIRLS (2 TO 18 YEARS OF AGE)

CHART	VERTICAL LINE	HORIZONTAL LINE
Stature-For Age	Age: 1/2 Year Intervals	Stature: 1/2 inch Intervals
Weight-For-Age	Age: 1/2 Year Intervals	Weight: 2 pound Intervals
Weight-For-Stature Boys (2 to 11 1/2 years) Girls (2 to 10 years)	Stature: 1/2 inch Intervals	Weight: 1 pound Intervals

CALCULATING THE CHILD'S AGE

1. Ask the birthdate of the child.

2. Using the following formula, obtain the age of the child
Date of test minus birthdate equals the age of the child

3. Start calculation on the right of the paper, figuring days, then months, and then years. For example

	Year	Month	Day
Date of Test	70	7	15
Birthdate	- 68	- 3	- 10
Age of Child	2	4	5

This child is 2 years, 4 months, and 5 days of age.

When it becomes necessary to "borrow" in the subtraction, make certain 30 days are borrowed from the month column and 12 months are borrowed from the year column, as in the following example·

	Year	Month	Day
	69	6 18	45
Date of Test	~~70~~	~~6~~ ~~7~~	~~15~~
Birthdate	- 68	- 10	- 28
Age of Child	1	8	17

Step 1 Subtract 30 days (1 month) from 7 months to make 6 months and 45 days (30 + 15).

Step 2. Subtract 28 days from 45 days = 17.

Step 3. Subtract 12 months (1 year) from 70 to make 18 months (7 - 1 = 6 and 6 + 12 = 18).

Step 4. Subtract 10 months from 18 months = 8.

Step 5. Subtract 68 from 69 = 1 (70 - 1 = 69)

The child is, therefore, 1 year, 8 months, and 17 days of age.

Age calculation is an area where many errors are often made. Check your calculation carefully.

DETERMINING CHILD'S AGE FOR PLOTTING MEASUREMENTS

Birth to Two Years

The NCHS growth chart age is divided into one month intervals.

After calculating the age of the child, age is then rounded to the nearest month. For example a child who is older than 1 month and 15 days, but not older than 2 months 15 days is assigned the age of 2 months.

Therefore, a child who is 1 year, 8 months, and 17 days of age is assigned the age of 1 year and 9 months or 21 months.

Two Years and Older

The NCHS growth chart age is divided into 6 month intervals.

Due to the limitations of the growth chart and for plotting measurements data, it will be necessary to round the age to the nearest one-half (1/2) year. For example:

1 through 2 1/2 months	drop
2 1/2 through 7 1/2 months	plot as 6 months
7 1/2 through 12 months	plot as next higher year

Therefore, a child who is 3 years, 6 months, and 20 days of age is assigned the age of 3 years and 7 months.

For plotting purposes, the assigned age 3 years and 6 months.

APPENDIX P

US Studies of Infant Growth

a. National data for birthweights These are available from NCHS Natality Surveys and are based on birth certificates and measurements in hospitals These national data could be used to anchor the curves for weight at birth, the other variables could be adjusted up to 3 years for the national distribution of birthweights. Alternatively, NCHS could obtain birthweights from birth certificates for NHANES III subjects but it has neither funding nor agency approval for this. There is concern about the accuracy of other measurements (recumbent length, head circumference) on birth certificates.

b. Iowa Growth Studies (Guo et al , 1991) These are serial data for 1142 normal white infants (414 breast-fed, 728 formula-fed) born at term with birthweights of 2500 g or more and measured by a group led by Fomon They were born between 1965 and 1987 and were measured at 7 ages from 8 days to 112 days Quality control was good.

c. Fels Longitudinal Study (Hamill et al., 1977, Roche, 1992). Data have been added since 1977 These serial data are from white infants measured at birth, 1, 3, 6, 9 and 12 months and then at 6-month intervals. Quality control was good. [E C . *The original 1977 data base has been lost If a decision is made to use these data, a up-to-date file should be constructed*].

d. Ross National Survey (Ryan and Martinez, 1987). In this cross-sectional study, data were collected from 1,100 infants aged 7 to 13 months (746 white, 354 Black) who were selected by multi-stage sampling to be nationally representative All the infants were born at term and weighed 2500 g or more at birth Quality control was good.

e. Darling Study (Dewey et al., 1992) This was a small study to compare growth and health in breast-fed and formula-fed infants. They enrolled 144 at birth of whom 80 remained in the study at 18 months These infants were measured monthly from birth to 18 months. The group was 87% white (non-Hispanic). Data quality was not documented. [E C *These* *data may be useful in developing the interpretive notes (see Section 15) but would not be useful in revising the NCHS charts*].

e <u>Berkeley Growth Study</u> (Bayley and Davis, 1935) [E C *These are serial data for 61 infants measured in the early 1930s with good quality control The measurements were made at one-month intervals from 1 to 12 months, and at 15 and 18 months and then each 6 months to 3 years*] These could be used to replicate patterns of growth for individual infants derived from Fels data.

f. <u>Kaiser Permanente Study</u> (Wingerd et al , 1971). [E. C.: *These authors reported serial data from more than 15,000 infants from birth to 2 years for whom there were 105,642 examinations The sample was middle class (60% white, 23% Black) and enrolled in a prepaid medical care program. Evidence of quality control was not reported and the data for recumbent length and stature were combined The reported tabular data could be useful for ethnic comparisons*]

g. <u>Chicago data</u> (Binns et al.(unpublished) [E. C.. *These authors analyzed data from 2024 white infants who were healthy and born at term with birthweights of 2,000 g or more The data were collected at private pediatric clinics in the Chicago area. The infants were measured monthly from 1 through 12 months but there was attrition (about 30%) and there are fewer data points at 3, 5, 7, 8, 10 and 11 months than at other ages There were data for Black infants but due to high attrition and questionable data quality these infants were excluded. There are also some data for Hispanic Americans (total of Blacks and Hispanic Americans = 550). The data quality is fair*]

h. <u>New York data</u> (Pomerance, 1979). Pomerance reported data from 3995 infants, almost all white, examined serially in a pediatric practice in New York City Data quality was not reported.

APPENDIX Q

Selected Smoothing Methods

(i) Fitting polynomials is the classical procedure for smoothing curves This procedure is inflexible since a mathematical function is imposed on the empirical curve and the behavior of the smoothed values in a small region determines the properties of the curve Commonly polynomials perform poorly if the data are spaced irregularly in relation to age but they allow the derivation of variables, such as age at inflexion.

(ii) Running medians of 3 begins by (a) considering sets of three successive observations, i.e., 1 to 3, 2 to 4, (b) taking the median of each set, and (c) repeating the procedure until there is no further change in the medians. This method uses only ordinal information (running medians of three), it has an end-value smoothing component, and it is rather resistant to outliers (Tukey, 1977).

(iii) Weighted least square methods include kernel estimation which calculates weighted averages of the observations (Guo et al , 1990) The weights are obtained from integration of a prespecified kernel function within an interval of adjacent times at measurements (band width). This interval is determined by a smoothing parameter that is positively related to the smoothness of the fitted curve. Values near the age for which the estimate is required receive a larger weight.

(iv) A cubic spline function is a piecewise 3rd degree polynomial. This flexible procedure begins by (a) dividing the X axis into intervals and endpoints (knots), (b) expressing the smoothed cubic spline function as a regression function, for example, a three-knot function

$$S(x) = \sum_{j=0}^{3} \beta_{0j} x^j + \sum_{i=1?}^{k} \sum_{j=0}^{3} \beta_{0j} (x - t_j)_+^j$$

where $\beta_{ij} = 0$ for $i=1,\ldots,k$. $j = 0, 1, 2$, and $(u)_+^3 = u^3$ if $u > 0$. 0 otherwise, β_{ij} can be estimated using ordinary least squares, and (c) estimating the parameters by least squares This estimation can be very difficult. The locations and the number of knots depend on the number of data points (ages) and the shapes of the curves. With fixed-knot cubic splines. the number and location of knots are determined by inspection of the unsmoothed curve The final curve is very sensitive to knot placement. Fixed-knot cubic splines produce smooth curves and behavior in a small region does not determine behavior everywhere (flexible) A procedure has been developed to deal with the endpoints.

(v) The combined method of Healy et al. (1988) calculates age-related percentiles and smoothes them. There are several steps. Step 1 for example, the first 10% of the observations are selected, regressed on age and the residuals calculated. These residuals are sorted in an ascending order and their percentiles obtained. These percentiles of residuals are plotted against k+2,...until all data have been covered. Step 2. the percentiles from Step 1 are smoothed using polynomials. Step 3 the coefficients of each specific term from Step 2 (i.e., intercept, linear term,...) for all the percentiles are fitted by a polynomial function of Z_1, where Z_1 is a standard normal deviate corresponding to each percentile, i.e., for 50th percentile, Z_1 = 0, for 97th percentile, Z_1= 1 88 This step assumes normality in the data and the results are vulnerable to outlying observations The implementation is computation-intensive. The coefficients from Step 2 are correlated but this is not taken into account.

(vi) The LMS method is appropriate if the data are not normally distributed (Cole, 1988, 1990; Cole and Green, 1992) This method normalizes the data at each age and smoothes the percentiles across age. There are several steps. Step 1: the data are separated into age groups and then transformed by the Box-Cox method to estimate L and then estimate M, and S for each age group, where L is the parameter of a Box-Cox transformation, M is the median, and S is the coefficient of variation. Step 2: the L, M, and S curves are smoothed separately across age employing spline functions. Step 3· percentiles are estimated from normal Z scores. This approach assumes the data are log normally distributed after the Box-Cox transformations. The division of data into age groups is somewhat arbitrary and the degree of smoothness in Step 2 is subjective and may be biased due to a lack of prior information on the behavior of L. Information is not obtained about the goodness of fit.

All these methods give equal value to each data point (empirical estimate at an age) despite variations in sample sizes Sample size variations could be taken into account in kernel estimation by adding a sample weight to the kernel function and using a weighted least squares approach With any method, the data should not be over smoothed, after smoothing, the residuals should be slightly greater than the measurement errors. In developing smoothed percentile levels for BMI, the unsmoothed weighted data for weight and stature should be used and the empirical BMI percentiles should be smoothed later

Smoothing procedures can be cross-validated by applying the PRESS procedure (predicted sum of squares of residuals; Wahba and Wold, 1975). In the PRESS procedure, one point (a percentile level at an age) is omitted at a time and the remaining points are smoothed. The omitted point is predicted from the smoothed curve and the residual (error) is obtained. The method with the smallest PRESS statistic is chosen. Truncating the sample weights will assist smoothing