Data from the
NATIONAL HEALTH SURVEY

Series 11
Number 167

Skeletal Maturity of Youths 12-17 Years

Racial, Geographic Area, and Socioeconomic Differentials

United States, 1966-1970

Skeletal age (hand-wrist) and bone-specific skeletal ages (as assessed by the Health Examination Survey Standard, based primarily on the Greulich-Pyle Radiographic Atlas) of boys and girls age 12-17 years, by chronological age, race, geographic region, population size or land use of area of residence, annual family income, and education of parent.

DHEW Publication No. (PHS) 79-1654

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
National Center for Health Statistics
Hyattsville, Md. October 1978

Library of Congress Cataloging in Publication Data

Roche, Alex F.
Skeletal maturity of youths 12-17 years.

(Vital and health statistics: Series 11, Data from the National Health Survey, Data from the health examination survey; no. 167) (DHEW publication; no. (PHS) 79-1654)
Includes bibliographical references.
1. Skeletal maturity—United States. 2. Children in the United States—Anthropometry. 3. Health surveys—United States. I. Roberts, Jean, joint author. II. Hamill, Peter V. V., joint author. III. Title. IV. Series: United States. National Center for Health Statistics. Vital and health statistics: Series 11, Data from the National Health Survey, Data from the health examination survey; no. 167. V. Series: United States. Dept. of Health, Education, and Welfare. DHEW publication; no. (PHS) 79-1654. [DNLM: 1. Age determination by skeleton—In adolescence. 2. Bone development—In adolescence. 3. Racial stocks. 4. Socioeconomic factors. W2 A N148vk no. 167.
RA407.3.A347 no. 167 [GN63] 312'.Q973s [573'.6'710973
ISBN 0-8406-0121-2 78-502

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In accordance with specifications established by the National Health Survey, the Bureau of the Census, under a contractual agreement, participated in the design and selection of the sample, and carried out the first stage of the field interviewing and certain parts of the statistical processing.

Vital and Health Statistics-Series 11-No. 167

DHEW Publication No. (PHS) 79-1654
Library of Congress Catalog Card Number 78-502

CONTENTS

LIST OF FIGURES

LIST OF TEXT TABLES

SYMBOLS

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SKELETAL MATURITY OF YOUTHS 12-17 YEARS: RACIAL, GEOGRAPHIC AREA, AND SOCIOECONOMIC DIFFERENTIALS

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INTRODUCTION

This report presents national estimates of the levels of hand-wrist skeletal maturity among noninstitutionalized youths age 12-17 years in the United States, by race, geographic area of residence, and socioeconomic background, based on findings from the Health Examination Survey of 1966-1970. The previous report on these radiographic findings among youths,[1] which was limited to the sex differences in skeletal maturity in relation to chronological age, contains a more comprehensive description of the nature of skeletal maturation among youths and of the assessment method used in the survey.

Both the findings in these two reports on skeletal maturity among youths age 12-17 years and those from the corresponding reports among children age 6-11 years[2,3] are the first national estimates of skeletal maturity levels made for these age groups in this or any other country. These studies provide estimates of known reliability against which present assessments of children and youths can be compared and possible future changes in skeletal maturation rates, for the country as a whole, can be judged.

The Health Examination Survey (HES) is one of the major programs of the National Center for Health Statistics (NCHS), authorized under the National Health Survey Act of 1956 by the 84th Congress as a continuing Public Health Service function in determining the health status of the U.S. population.

Four types of survey programs are used to carry out the intent of the National Health Survey.[4] The Health Interview Survey collects information from samples of people by household interview and focuses primarily on the impact of illness and disability within various population groups. The programs in the Divisions of Health Resources Utilization Statistics and Health Manpower and Facilities Statistics obtain health data as well as health resource and utilization information through surveys of hospitals, nursing homes, and other resident institutions and the entire range of personnel in the health occupations. The Health Examination Survey, from which data in this report were obtained, collects health data by direct physical examinations, tests, and measurements performed on samples of the population. The latter program provides the best way of obtaining actual diagnostic data on the prevalence of certain medically defined illnesses in the general population. It is the only effective way to secure information on unrecognized and undiagnosed conditions and on many physical, physiological, and psychological measures within the population. Also it collects demographic and socioeconomic data from the sample population under study to which the examination findings may be related.

The Health Examination Survey is organized as a series of separate programs or cycles each of which is limited to some specific segment of the U.S. population and to specific aspects of health. From data collected during the first cycle, the prevalence of certain chronic diseases and the distribution of various physical and physiological measures were determined on a cross-section of the defined adult population as previously described.[5,6]

For the second examination survey program, a probability sample representative of the noninstitutionalized children age 6-11 years in the United States was selected and examined in 1963-1965. The examination in this cross-sectional study primarily assessed health factors related to growth and development, as described in a previous report.[7]

The third cycle, on which findings in this report are based, was similar in design and purpose to the preceding children's program. For this third survey, a probability sample representative of the noninstitutionalized youths age 12-17 years in the United States was selected for examination. The examination in this cross-sectional study primarily assessed health factors related to growth and development, using methods similar to those in the preceding children's study supplemented as previously described for this older age group.[1,8]

Included were examinations given by a pediatrician, assisted by a nurse, an examination by a dentist, tests administered by a psychologist, and a variety of tests and measurements by laboratory X-ray technicians.

Field collection operations for this youths' cycle, which started in March 1966, were completed in March 1970. Of the 7,514 youths selected in the sample, 6,768 youths, or 90 percent, were examined. The response rate was higher among Negro youths (96.6 percent) than among white youths (89.1 percent) and lower among white girls, particularly at 17 years of chronological age, than among white boys, Negro boys, or Negro girls. The extent to which these differential response rates will affect the precision of the national estimate for white and Negro youths is discussed in greater detail in appendix I. This national sample is representative, and the examined group closely representative, of the 22.7 million noninstitutionalized youths age 12-17 years in the United States with respect to age, sex, race, geographic region, population size of place of residence, and rate of change in population size of place of residence from 1950 to 1960. The sample design for the youths' survey used the same sampling areas and housing units as the preceding survey among children. As a result, nearly one-third of the youths in the present study had also been examined in the children's survey.

The examinations were conducted consecutively in 40 different locations throughout the United States. During the single visit, each youth was given a standardized examination by the team in the mobile units specially designed for use in the survey. Prior to this examination, demographic and socioeconomic data on household members as well as medical history, behavioral, and related data on the youths to be examined were obtained from their parents. Ancillary data were requested from the schools attended by the youths, including their grade placement, school behavior, adjustment, and health problems known to their teachers. An additional Health Habits and History form was completed by the youth before he or she arrived for the examination, and a Health Behavior form was completed by the examinee while in the examining center. Birth certificates of the youths were obtained for verification of age and for information related to their condition at birth.

The same methods and measure of skeletal maturation were used in the examination surveys among children and youths. In planning for both survey programs, the advice of clinicians and directors of long-term studies of skeletal development had been obtained about possible uses of skeletal maturity levels and methods of assessing skeletal age from radiographs. The directors of growth studies conducted independently from 1929 to 1962 at the Brush Foundation in Cleveland, Ohio, and the Department of Maternal and Child Health at Harvard University in Boston, Massachusetts—Drs. William Walter Greulich and Harold C. Stuart—recommended that Dr. S. Idell Pyle prepare a single standard from their radiographic series specifically for use in the Health Examination Survey. The 1964 Manual—the preliminary edition of *A Radiographic Standard of Reference for the Growing*

Hand and Wrist[9]—was prepared for this purpose by Drs. Pyle and Greulich. This will be referred to in this report as the "HES Standard."

The general concept of skeletal maturity, the methodology by which radiographs were taken and later assessed, and the quality control measures used have been described in detail and discussed in the first reports on skeletal maturity of children 6-11 years[2] and youths 12-17 years.[1]

A brief description of the sample design, quality control methods, and reliability of the data, as well as the population and sampling error estimation procedures used in reporting the findings of this study, is contained in appendix I. Definitions of the demographic terms used in this report are included in appendix II, and an evaluation of the reliability of the assessments is shown in appendix III.

EXAMINATION METHOD

At each of the preselected locations throughout the United States used in this study, the youths were brought to the centrally located mobile examination center for a standardized examination which lasted about 3-1/2 hours. Six youths were examined in the morning and six in the afternoon. When each youth entered the examination center, an oral temperature was taken and a screening for acute illness was made. If such illness was detected, the youth was sent home and reexamined later. All six proceeded to designated but different stations for the start of the examination after changing into gymnasium-type shorts, cotton sweat socks, a robe and (for girls only) a light sleeveless topper. The sequence of elements in the examination differed for each youth so that all six could be examined simultaneously during the half day. The time of each part of the examination was recorded, but there is no reason to believe that time of day or sequence of examination would affect the composition or quality of the radiographic data.

Field Radiography

Each youth was scheduled to have a 10″ x 12″ radiograph of the right hand and wrist for which the positioning was in accordance with specifications in the Greulich-Pyle Atlas.[10] Although some radiographs were made using other film sizes when the 10″ x 12″ size was scarce, this would not have influenced the findings in the assessment method used. Technically inadequate films could be repeated because they were developed immediately in the field. Hence each youth's record contained a single radiograph showing the dorso-palmar view of his or her entire hand-wrist with its full complement of ossifying parts at the time of the examination.

As indicated previously, the decision to radiograph the right hand-wrist rather than the left, which is the more frequent anthropometric practice, was made on the advice of anthropologist consultants who were interested also in the use of related measurement data for equipment design in which right-side measurements were preferred. When the selected radiographs used in the plates from the Greulich-Pyle Atlas and those from other sources were reproduced in the HES Standard, they were reversed photographically so they could be used in right-side assessments. Previous reports on lateral differences in skeletal maturity of the hand-wrist, either for the area as a whole or bone by bone, have shown that these are too small to be of practical importance.[11]

Training of Assessors

The assessments of skeletal age from the hand-wrist radiographs of youths age 12-17 years in the Health Examination Survey of 1966-1970 were made by nine medical students at Case Western Reserve University. These included five of the medical students who had done the assessments in the 1963-1965 national survey among children age 6-11 years. This work was administered under a contract, with Dr. C. Wesley Dupertuis as project director, for the National Center for Health Statistics. Under the direct supervision of Dr. Pyle, training of the assessors and the implementation of related quality control procedures were done in the meticulous manner described previously.[1] When the ratings and reliability for the new assessor reached good agreement with those of Dr. Pyle—the majority of differences within 4 months—that new assessor started his assessment of the survey radiographs. Reported evidence from

another study[12] suggests that at the end of this training procedure the interobserver and intraobserver differences in skeletal maturity ratings would be similar to those for experienced assessors.

Assessment Procedure

As previously described,[1,2] the radiographs were assessed by comparison with prints of the series of standards for the male hand-wrist selected from those in the 1959 Greulich-Pyle Atlas[10] and other sources which have been reversed so they appear to be of the right hand-wrist as shown in the 1971 *Radiographic Standard of Reference* of Pyle et al.[9] The male skeletal age equivalent values shown in that standard were those used for the assessment of radiographs in both the national surveys among children and youths, with some very slight modification to smooth the skeletal age trend for a few of the bones.

In making the assessments, the readers did not have access to the chronological age, the sex, or other information about the youth. Each bone on the radiograph of the hand-wrist was rated separately and interpolation was made between standards to monthly intervals when appropriate.

As a quality control measure and to permit determination of the level of reliability of the assessments throughout this study, independent replicates were obtained on approximately 1 out of each 11 films. One randomly selected radiograph in each 23 was rated independently by another assessor for a measure of interobserver variability, and one randomly selected radiograph among each 20 was rated independently a second time by the same reader to give a measure of intraobserver variability. For the latter set, the time lapse between the first assessment and the reassessment was sufficiently long that there was little likelihood of recall. There was also no indication to the assessor that he was making a reassessment. Information on the degree of reliability of these assessments is given in appendix III.

The order in which the bones were assessed within each radiograph was as listed in table A. This table also contains the minimum and maximum bone-specific skeletal ages allowed in the male standard values for this study and in the preceding one among children. The lower limit for the bone-specific skeletal age was arbitrarily set midway between the last standard in which the particular bone was not radio-opaque and the first in which it was radio-opaque. Exceptions were made for the three later-ossifying bones: the pisiform and the adductor and flexor sesamoids. For these bones the minimum values allowed were 2 months above the last standard in which the bones were not radio-opaque.

At the upper end of the range when epiphyseal fusion or maturation was complete for a particular bone, only the designation "adult" and not a skeletal age in months could be assigned. The median ages in months, from the HES Standard, at which this occurs in boys were used as the bone-specific skeletal age beyond

Table A. Minimum and maximum acceptable skeletal ages in months using the HES male standards: Health Examination Survey, 1966-1970

Hand-wrist bone	Minimum[1]	Maximum[2]
	Skeletal age in months	
Radius	15	228
Ulna	70	215
Capitate	---	197
Hamate	---	197
Triquetral	17	197
Lunate	35	197
Scaphoid	68	197
Trapezium	51	197
Trapezoid	68	197
Metacarpal I	25	191
Metacarpal II	17	215
Metacarpal III	16	209
Metacarpal IV	17	209
Metacarpal V	24	215
Proximal phalanx I	33	215
Proximal phalanx II-V	15	209
Middle phalanx II-IV	23	209
Middle phalanx V	39	209
Distal phalanx I	15	191
Distal phalanx II, V	39	191
Distal phalanx III	22	191
Distal phalanx IV	32	191
Pisiform	110	197
Adductor sesamoid	146	197
Flexor sesamoid	158	197

[1]Minimum age (according to standard) of radio-opacity of epiphysis or carpal.
[2]One month below "adult" age.

which only this designation "adult" could be applied. The maximum allowable values 1 month below this "adult" skeletal age are shown in table A.

As expected within chronological age intervals, the skeletal ages assigned to the girls were more advanced than those assigned to the boys. This occurs because, although boys and girls pass through essentially the same skeletal maturity stages, girls tend to mature more rapidly than boys. Bone-specific female equivalent skeletal ages were determined during the preparation of the HES Standard but were not used in the assessment of the survey radiographs. The method by which these female equivalent skeletal age values were obtained is described in detail in Pyle et al.[9] In summary, these ages were estimated using three sets of serial radiographs of normal U.S. girls. The modal radiograph (in maturity) for each chronological age group in each set was assessed against the female standards in the Greulich-Pyle Atlas[10] and against the HES Standard (male). Later these sequential female equivalent skeletal ages were smoothed.

The skeletal age data for girls in the detailed tables of this report are given both in terms of the male standards, as originally assessed, and in terms of the female equivalent skeletal ages that were obtained by converting the data recorded originally. The skeletal age values for the whole hand-wrist for boys and girls in this report were determined by computer from the original bone-specific assessments by averaging the ages assigned the hand-wrist bones for each youth.

SKELETAL AGE (HAND-WRIST) FINDINGS

The preceding report on the skeletal maturation of youths age 12-17 years in the United States[1] describes and analyzes the trend and extent of variation in the timing and velocity of this aspect of osseous development by age and sex, without regard to racial or socioeconomic classification. It includes a further analysis of these trends across the entire age range 6-17 years for boys and girls in the United States, as well as comparisons with findings from the previous more geographically limited studies in this and other countries. The national estimates of skeletal maturity among U.S. children and youths are based on findings from the Health Examination Surveys of 1963-1965 and 1966-1970 in which hand-wrist radiographs obtained for the national probability samples of examinees were assessed against the HES Standard for the hand-wrist using the Greulich-Pyle method, as previously described.

In brief, among youths 12-17 years of age, the mean skeletal age (hand-wrist) of boys in the United States has been shown to increase consistently with chronological age from 11.7 years (140.2 months) for those 12 years of age at their last birthday (mean chronological age 12.5 years or 150 months) to 17.1 years (205.4 months) at chronological age 17 years (mean chronological age 17.5 years or 210 months). The yearly increment in skeletal age is at a maximum among boys age 12-14 years and then decreases at ages 16 and 17 years to the same levels found among boys age 6-11 years. When assessed against the male standard, the mean skeletal age (hand-wrist) of girls in the United States increases from 14.6 years (174.9 months) at chronological age 12 years to 17.6 years (211.3 and 211.5 months) at ages 16 and 17 years. During the 6-year time span the yearly increment in skeletal age for girls is consistently less than that for boys of comparable chronological age and steadily decreases from a maximum at ages 12 and 13 years across the remainder of the age range as proportionately more of the girls had reached the point at which epiphyseal fusion in their hand-wrists is completed—the upper limit of skeletal maturation.

On transformation to female equivalent values, which compensate for the more rapid skeletal development of girls compared with boys, the mean skeletal age (hand-wrist) of girls in the United States increases with chronological age from 11.9 years (142.9 months) at age 12 years to 15.5 years (185.6 and 186.0 months) at chronological ages 16 and 17 years, respectively.

The mean lag of skeletal age (hand-wrist) behind chronological age for boys drops from a peak of 13.8 months at age 11 years (from the 1963-1965 national survey) to 9.8 months at age 12 years and continues to decrease to less than 1 month at 14 and 15 years before increasing again to nearly 5 months at age 17 years. Among girls, the lag of skeletal age (female equivalent

values) behind chronological age at 12 years (7.1 months) is slightly less than the maximum value of 9.8 months at age 11 years (from the 1963-1965 national survey) and decreases slightly to a minimum of 6.0 months at age 14 years. For girls from age 15 years on, the lag of skeletal age behind chronological age becomes progressively greater, reaching a maximum of 24 months at age 17 years. The reasons for these somewhat inconsistent patterns among older youths have been discussed in detail in a previous report.[1]

Race

White.—The mean skeletal age (hand-wrist) of white boys in the United States increases with chronological age from 11.7 years (140.4 months) for those 12 years of age at their last birthday (mean chronological age 12.5 years or 150 months) to nearly 17.2 years (205.8 months) at chronological age 17 years (mean chronological age 17.5 years or 210 months) as shown in table 1. Among these white boys, the yearly increment in mean skeletal age is at a maximum of 16.9 months between chronological ages 13 and 14 years and then decreases to 8.8 months between ages 16 and 17 years.

The mean lag of skeletal age (hand-wrist) behind chronological age for U.S. white boys drops from 9.6 months at age 12 years to 0.3 months at age 14 years. The mean skeletal age exceeds the chronological age by 1.1 months at age 15 but again lags 1.0 month behind the chronological age at age 16 and lags by 4.2 months at age 17 years (figures 1 and 2).

Across the entire age range 6-17 years, mean skeletal age of white boys increases consistently with chronological age from 6.2 years (74.9 months) at age 6 years to nearly 17.2 years (205.8 months) at age 17 years (table 1 and reference 3). The yearly increment is maximal

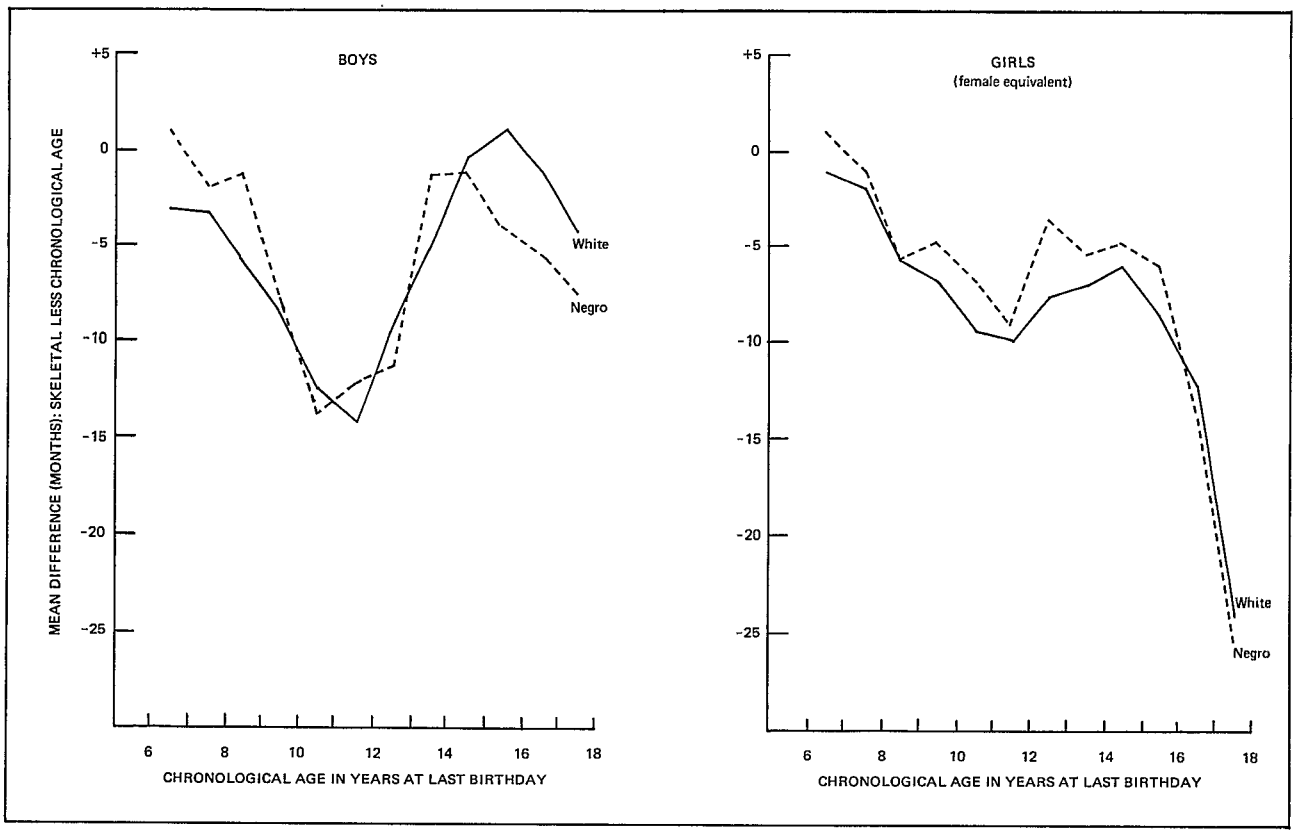

Figure 1. Mean difference in months between skeletal age (hand-wrist) and chronological age for white and Negro boys and white and Negro girls age 6-17 years by chronological age in years: United States, 1963-1970

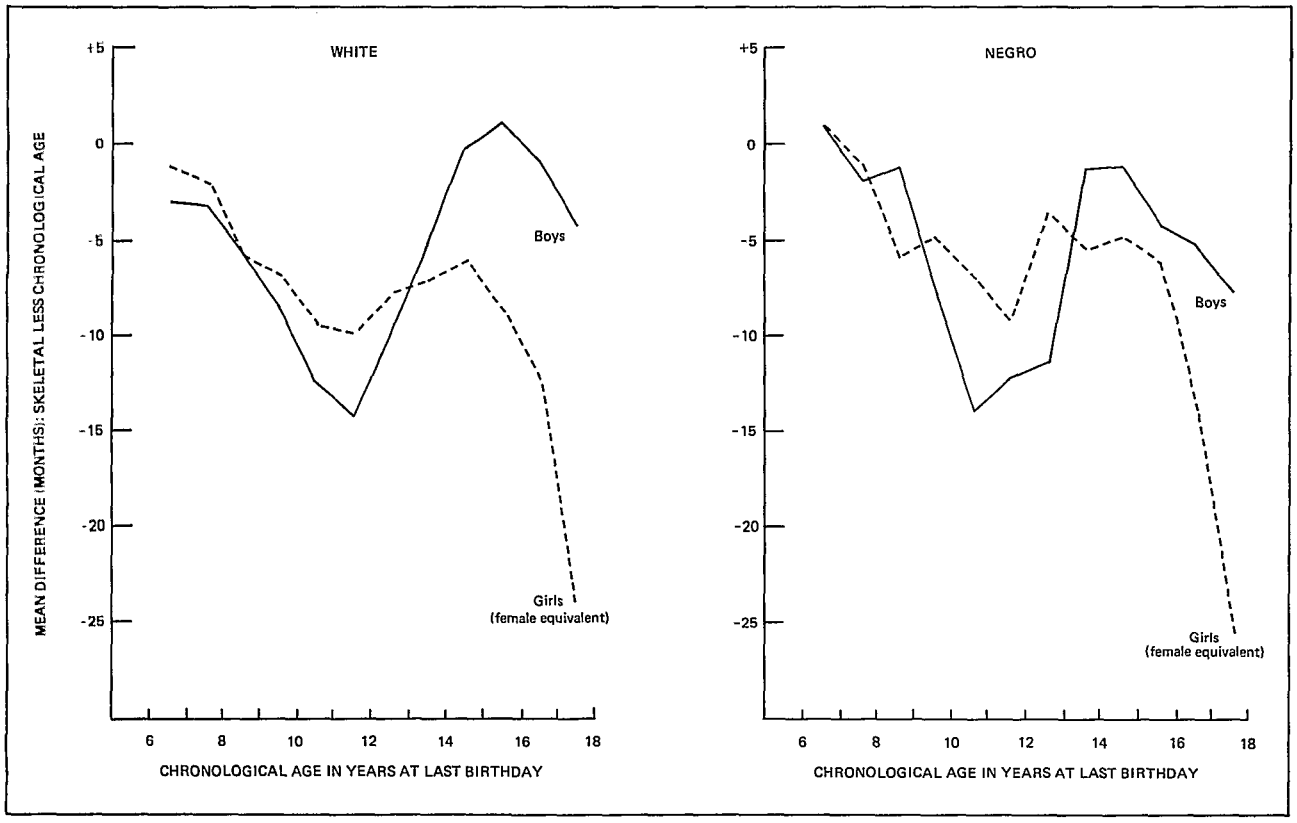

Figure 2. Mean difference in months between skeletal age (hand-wrist) and chronological age for white boys and girls and Negro boys and girls age 6-17 years by chronological age in years: United States, 1963-1970

(16.6, 16.4, and 16.9 months) from age 11 to 14 years and minimal (8.0 months) between 9 and 10 years of chronological age. The maximum lag of mean skeletal age behind chronological age is the 14.2 months difference at age 11 years (from the 1963-1965 national survey).

As measured by the standard deviation, the variability in skeletal maturity (hand-wrist) among white boys decreased with chronological age from maximum values of 17.17 months and 17.77 months at ages 12 and 13 to 10.97 months at age 17 years. The standard deviation is substantially greater among boys age 12-15 years than among those younger (6-11 years) or older (16 or 17 years). The relative variability (i.e., 100 times standard deviation divided by the mean) among white boys decreases during ages 6-10 years (from 15.3 to 9.0), is slightly greater again at ages 11-13 years (10.5, 12.2, 11.3), and decreases steadily from age 14 years to 18 years (from 8.5 to 5.3).

Among white girls in the United States, the mean skeletal age (hand-wrist), *assessed against the male standards,* increases from 14.5 years (174.3 months) at age 12 years to 17.6 years (211.7 months) at age 17 years. Across the entire age span 6-17 years in the two national surveys, the mean skeletal ages (male standard) for white girls increase from 7.5 years (89.7 months) at age 6 to 17.6 years (211.7 months) at age 17. The yearly increment in mean skeletal age for white girls in the youth age range is at a maximum of 12.2 months between ages 12 and 13 years and decreases to the minimum of 0.2 month at age 17. In the earlier survey of children, the largest annual increment was 19.2 months for the interval 10-11 years. The mean skeletal age (male standard) of white girls is about 2 years in advance of their chronological ages at 12, 13, and 14 years (24.3, 24.5, and 23.9 months, respectively). This advancement decreases to a minimum of 1.7 months at 17

years. The means of the girls (male standard) are consistently in advance of chronological age for the entire 6-17-year range by values that are maximal (about 24 months) at ages 12-14 years and minimal at age 17 years.

The variability of skeletal age (hand-wrist), as measured by the standard deviation, is greater among younger white girls of 12 and 13 years (14 and 13 months) than among those 14-17 years, where the standard deviations are 9 to 10 months. The variability, relative to the mean, decreases from a maximum at age 12 and levels off from ages 15-17 years. The variability in skeletal age for white girls, when considered across the entire age span 6-17 years, is greatest at age 10 (s_x = 17.28 months) and least from 14 years on (9-10 months). When considered in relation to the size of the mean, the relative variability is greatest at age 6, somewhat higher at 7-10 years, and then declines to minimum values at ages 15-17 years.

When conversion is made to the female equivalent values for white girls in the youth age range, the mean skeletal ages increase from 11.9 years (142.3 months) at 12 years to 15.5 years (186.0 months) at age 17. The yearly increment in these mean values is slightly greater at ages 12 and 13 years (12.5 and 13.1 months) than at other ages and later decreases to the minimum (0.2 month) at age 17.

The lag of mean skeletal age (hand-wrist) behind chronological age, in terms of the female equivalent values, for white girls decreases very slightly from 12 years (7.7-month lag) to 14 years (6.1 months) then steadily increases to a maximum at age 17 (24.0 months).

From the two national studies, during the age span 6-17 years (reference 1-3 and table 1), the mean skeletal age (hand-wrist, female equivalent values) for white girls increases from 6.4 years (76.7 months) at age 6 years to 15.5 years (186.0 months) at chronological age 17 years. The yearly increment in these values is maximal (14.2 months) between ages 11 and 12 years and nearly as great between 13 and 14 years, then from 14-16 years decreases to levels that do not differ significantly from those in the younger, 6-11-year, age groups. The lag of skeletal age (hand-wrist, female equivalent values) behind chronological age for white girls, which increases from 1.3 months at age 6 to 9.9 months at age 11, becomes slightly smaller at ages 12-14 (lags of 7.7, 7.2, and 6.1 months) and then increases to the maximum value of 24 months at age 17 years (figures 1 and 2).

White girls consistently are more advanced in skeletal maturity than white boys across the entire 6-17-year age range when both are assessed against the single male standard. However, when the female equivalent values for girls are used in this comparison (figure 2), the mean values for younger white girls generally tend to exceed those for white boys up to age 12 years, although these mean differences are negligible at ages 7-9 years. From 13 years on, the mean skeletal ages for white girls are significantly lower than those for white boys; these mean differences increase steadily with chronological age from 2.0 months at age 13 years to 19.8 months at age 17 years. This disparity is due, in part, to the fact that there are progressively fewer girls in the older age groups whose hand-wrist bones are still maturing; hence these comparisons are made between the majority of boys and only the later maturing girls, as discussed in a previous report.[1]

Negro.—Among Negro boys in the United States, the mean skeletal age (hand-wrist) values increase steadily from 11.6 years (138.7 months) at age 12 to 16.9 years (202.4 months) at age 17 years. Across the age range 6-17 years in the two national surveys (references 1-3 and table 1), mean skeletal age (hand-wrist) for Negro boys increases from 6.6 years (79.0 months) at age 6 years to 16.9 years (202.4 months) at age 17 years. The yearly increment is maximal (21.9 months) between ages 12 and 13 years and minimal (9.0 months) between ages 14 and 15 years. When considered over the entire age range of the two surveys combined, the yearly increment is maximal (21.9 months) between ages 12 and 13 years and minimal between 8 and 10 years (5.5 and 5.9 months). The mean lag of skeletal behind chronological age for Negro boys is greatest (11.3 months) at age 12, decreases to only 1 month at 13-14 years, and then consistently increases to 7.6 months at age 17.

Skeletal maturity (hand-wrist) of Negro boys is more variable at age 13 years (s_x = 19.69 months) and least variable at 17 years (standard deviation of 11.37 months). The variability relative to the mean for Negro boys shows a similar

pattern of change but decreases more consistently with chronological age from 13 to 17 years than does the standard deviation.

For the age span of the children's and youths' surveys combined, variability, as determined by the standard deviation, is greatest at age 13 and least at ages 8-10 years (10.11, 10.58, and 10.27 months). However, relative variability is greatest among the Negro boys 7 and 6 years old and least among the oldest age group (17 years).

For Negro girls age 12-17 years, mean skeletal age (hand-wrist, male standard) increases from 14.9 years (178.4 months) at chronological age 12 years to 17.5 years (210.5 months) at chronological age 17 years. Across the 6-17-year age span from the two national surveys, the mean skeletal age (hand-wrist, male standard) for Negro girls increases consistently from 7.7 years (91.9 months) at chronological age 6 years to 17.5 years (210.5 months) at age 17 years. The mean skeletal ages (hand-wrist, male standard) for these Negro girls are consistently in advance of their chronological ages across the 6-17-year span by amounts that increase consistently from a minimum of 9 months among 8-year-olds to values in excess of 24 months at 12-14 years. Later this advancement decreases to less than 1 month at age 17 years.

The yearly increment for Negro girls is greatest at ages 12-15 years (9-11 months) and then decreases to less than 1 month (0.3 month) between chronological ages 16 and 17 years. The maximum yearly increase, for the total span 6-17 years, is between ages 9 and 11 years (16.3 and 16.1 months), and the minimum is among the oldest Negro girls (0.3 month between 16 and 17 years).

The variability and the relative variability in skeletal age (hand-wrist, male standard) among Negro girls is largest at age 12 and least at 15 years in the survey of youths. When the data from both surveys are considered, the standard deviation is greatest at ages 9-12 years (18.33, 17.65, 17.28, 16.72 months) and least at ages 15 and 16 years (8.35 and 9.36 months, respectively) for Negro girls.

On conversion to female equivalent values, the mean skeletal age (hand-wrist) of Negro girls in the youth age range increases from 12.2 years (146.4 months) at age 12 to 15.4 years (184.5 months) at age 17 years. The yearly increment in these mean values is largest between 13 and 14 years (12.6 months) and later decreases to less than 1 month (0.3 month) between ages 16 and 17 years. The lag of mean skeletal age (hand-wrist, female equivalent values) behind chronological age for Negro girls is 6 months or less from 12 to 15 years and later increases to exceed 25 months at age 17.

Across the age span 6-17 from the two national surveys, the mean skeletal age (hand-wrist, female equivalent values) for Negro girls increases from 6.6 years (78.9 months) at age 6 to 15.4 years (184.5 months) at age 17 years. The yearly increase is greatest between ages 11 and 12 years (17.6 months) and slows to a negligible amount (0.3 month) between ages 16 and 17 years. Only at age 6 years does the mean skeletal age exceed the chronological age for Negro girls, and then by less than 1 month. From 7 to 17 years, these female equivalent values lag behind chronological age. As seen in figure 2, the lag increases from 7 to 11 years, and decreases to less than 6 months at ages 12-14 years, after which it increases to the maximum of more than 25 months at age 17.

When both Negro girls and boys are assessed against the male standards, the girls are consistently more advanced in skeletal maturity than the boys are across the entire age range 6-17 years. This is similar to the findings among white children and youths. When comparison is made with the female equivalent skeletal ages of girls, the mean skeletal ages for Negro boys consistently exceed those for Negro girls from age 13 to 17 years, which is consistent with the findings among white youths. Only for the two oldest groups (16 and 17 years) are the mean differences large enough to exceed the 95-percent confidence limit for the national estimates (statistically significant at the 5-percent level). Among the younger age groups, 6-12 years, the mean skeletal ages for Negro girls slightly exceed those for Negro boys except at 6 and 8 years.

White-Negro.—White boys age 6-11 years are, on the average, generally slightly less mature skeletally than Negro boys. However, the pattern is reversed at age 12-17 years, when the mean skeletal ages of white boys generally tend to exceed those for Negro boys in the United States (figures 1 and 3). Only at ages 10 and 13

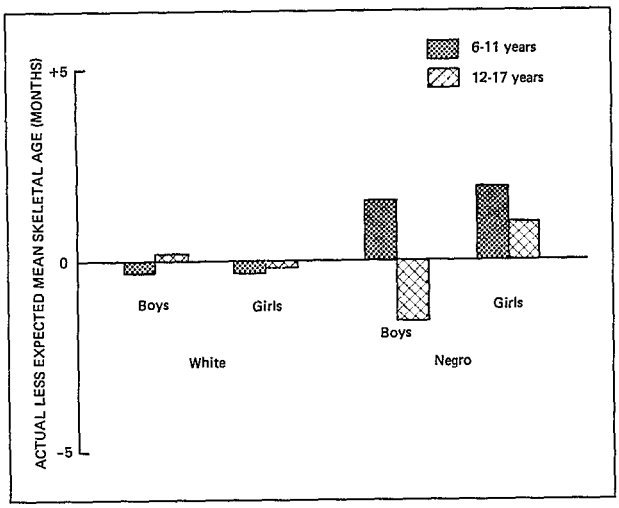

Figure 3. Difference between actual and expected mean skeletal age (hand-wrist) for white and Negro boys and girls 6-17 years of chronological age: United States, 1963-1970

years do exceptions to the above trends occur. By contrast, white girls are slightly but consistently less mature skeletally than Negro girls, 6 through 15 years except at 8 years where the mean values are identical. Only among 16- and 17-year-old girls is this pattern reversed, and the differences are slight at these older ages.

These white-Negro differences can be compared with the corresponding differences for height and weight of U.S. children and youths from these national surveys.[13] Negro boys were slightly taller at 7-9 years and white boys were slightly taller from 9 to approximately 12 years; Negro girls were consistently taller than white girls were from 7 to 14 years, after which the white girls were consistently taller. The mean weights of Negro boys were less than those of white boys at all ages except 13 to 14 years; the mean weights of Negro girls were greater than those of white girls at 11 to 15 years. It is also relevant to note that the Health Examination Survey data yield estimates of median age at menarche of 12.80 years in white girls and 12.52 years in Negro girls[14] since age at menarche is known to be associated closely with the rate of skeletal maturation.[15]

There is no significant or consistent pattern of racial differences in variability of skeletal maturity among either boys or girls across the age span 6-17 years (figure 4). However, Negro boys and girls tended to be slightly more variable in skeletal maturity than white boys and girls.

Comparisons with other studies in the United States.—Some previously reported skeletal maturity data for white children in the United States are shown graphically in figures 5-8. These data have been adjusted to a common Greulich-Pyle zero line to facilitate comparison. This is necessary because there are only quasi-units of skeletal maturity. The data relate to modal skeletal ages within chronological age groups, that is, those above the zero line are advanced (modal skeletal age exceeds mean chronological age) and those below the zero line are retarded in comparison with the Greulich-Pyle standards. The Greulich-Pyle standards[10] were derived from a selected group of white Cleveland youths of upper socioeconomic status who were born between 1917 and 1942 and were radiographed close to birthdays and half-birthdays. By a painstaking method in which radiographs were arrayed in order of maturity, within sex- and age-specific groups, one radiograph was selected as the standard for each chronological age group because it was considered most representative of the central tendency of the skeletal maturity level for the group. This selection was made from 100 radiographs for each sex at each age.

The mixed longitudinal data of Flory[16] were obtained from white Chicago youths of above average socioeconomic status who were born between 1904 and 1917. Flory had available 100 radiographs for each sex at each age; all these radiographs had been taken within 2 weeks of a birthday. From these he selected the radiographs he considered best represented the central tendencies of his groups. These selected radiographs are about 1 year retarded in maturity in comparison with the corresponding Greulich-Pyle standards (figures 1 and 3). Simmons[17] reported data from white Cleveland youths, most of whom were included among those studied by Greulich and Pyle.[10] These youths were radiographed near each birthday. The sample size varied from 68 to 198 for each year of age in each sex. Simmons excluded some girls at older ages who had surpassed the upper limits of the standards. Consequently, the means for girls at ages beyond 14 years have not been included

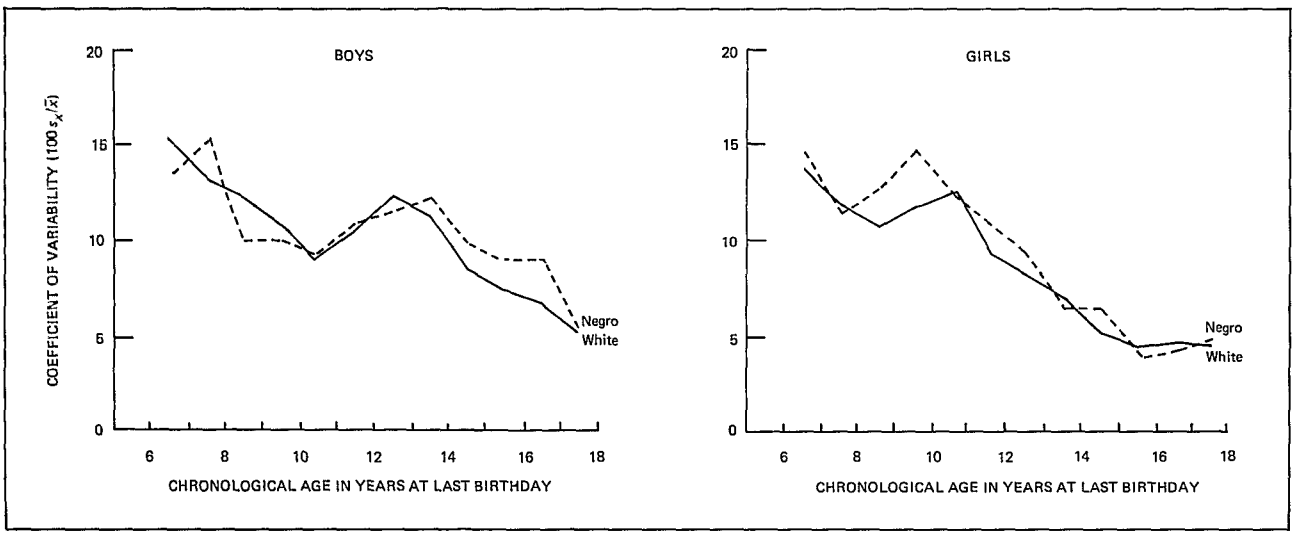

Figure 4. Relative variability in skeletal age (hand-wrist) among white and Negro boys and girls age 6-17 years by chronological age in years: United States, 1963-1970

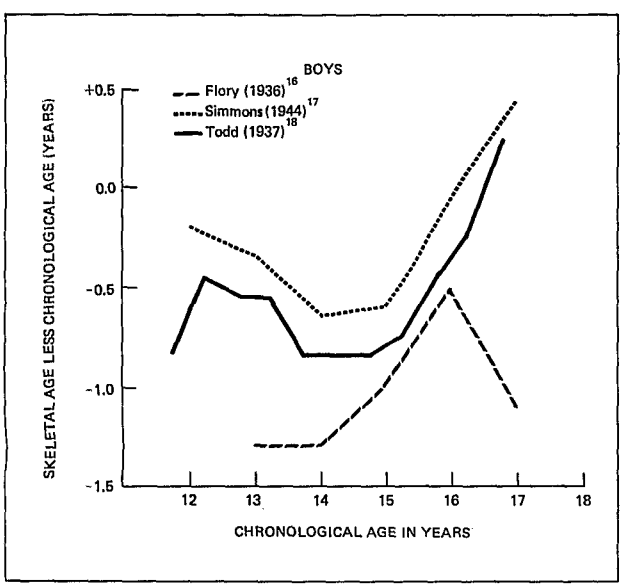

Figure 5. Differences between skeletal and chronological ages of boys 12-17 years in studies of Flory (1936),[16] Simmons (1944),[17] and Todd (1937).[18]

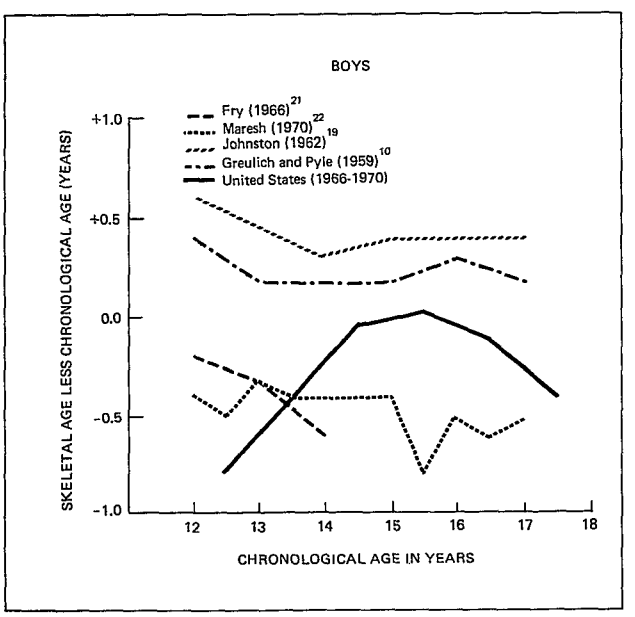

Figure 6. Differences between skeletal and chronological ages of boys 12-17 years in studies of Fry (1966),[21] Maresh (1970),[22] Johnston (1962),[19] Greulich and Pyle (1959),[10] and U.S. youths (1966-1970)

in figure 3 because the proportion excluded is unknown. The means reported by Simmons, after adjustment for the use of Todd standards, were within 0.5 year (skeletal age) of the Greulich-Pyle standards at most ages.

In 1937 Todd[18] published standards derived from a group of white Cleveland youths of all socioeconomic levels. These youths were born between 1915 and 1936 and radiographed near each birthday and half-birthday. The standard plates were chosen to represent the central tendencies for skeletal maturity level within age- and sex-specific groups. The sample size within each group varied from 42 to 161. The standards of

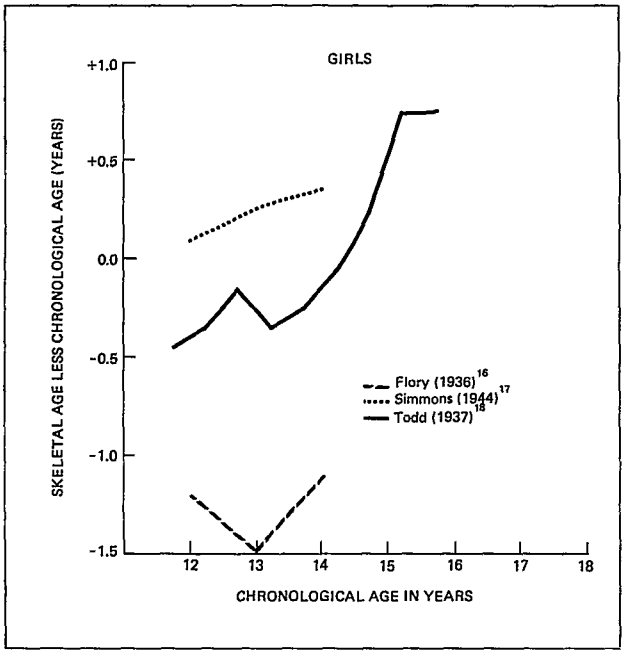

Figure 7. Differences between skeletal and chronological ages of girls 12-17 years in studies of Flory (1936),[16] Simmons (1944),[17] and Todd (1937)[18]

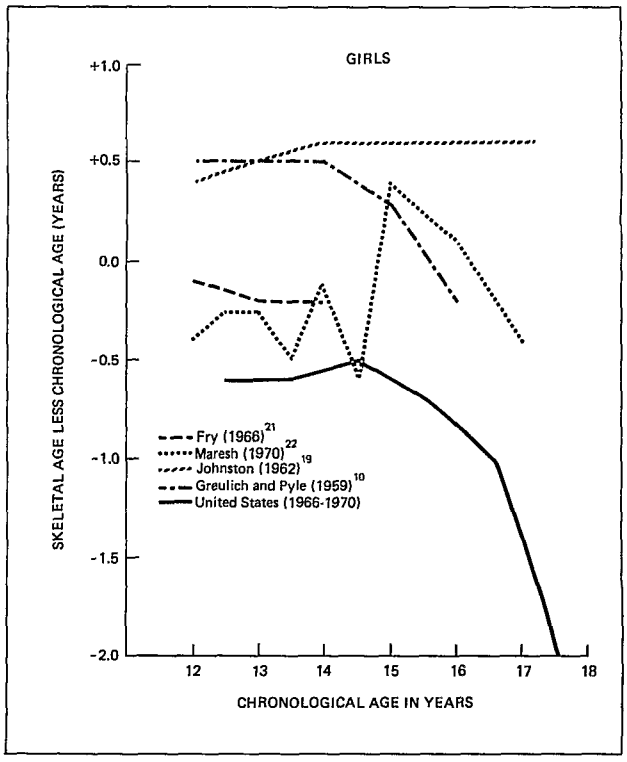

Figure 8. Differences between skeletal and chronological ages of girls 12-17 years in studies of Fry (1966),[21] Maresh (1970),[22] Johnston (1962),[19] Greulich and Pyle (1959),[10] and U.S. youths (1966-1970)

Todd were about 0.5 year lower than those of Greulich and Pyle at 12-14 years; the differences were much smaller at later ages. It is tempting to ascribe the differences between the skeletal maturity levels reported by Todd,[18] Simmons,[17] and Greulich and Pyle[10] to variations in socioeconomic status among the groups of youths studied by these workers. This leaves unexplained the relative lack of differences at later ages. This may be due, in part, to the systematic exclusion of youths who were too mature to be assessed.

Greulich and Pyle[10] reported data from the Harvard Growth Study. The group of white Boston youths included was of middle socioeconomic status, born between 1930 and 1939, and examined near each birthday. The size of the groups varied from 63 to 67 for each age in each sex. The mean skeletal ages (Greulich-Pyle) were very close to the mean chronological ages. Johnston[19] reported mixed longitudinal data from middle-class Philadelphia white youths born between 1937 and 1955. The major ethnic strains in this group were Italian and British.[20] These youths were radiographed at random chronological ages and the group size varied from 23 to 50 for each annual interval in each sex. All the mean skeletal ages for each sex were about 0.5 year in advance of the Greulich-Pyle standards.

Cross-sectional skeletal age data from some white Nebraska youths of middle socioeconomic level have been reported.[21] These children were born between 1952 and 1954 and were radiographed at random ages. The group included 25 youths of each sex within each annual interval. The means were below the Greulich-Pyle standards in the boys but not in the girls. In each sex the differences between the mean levels reported by Fry and those of the Greulich-Pyle standards did not exceed 0.6 year. Maresh[22] reported mixed longitudinal data from a group of middle class white Denver youths. These youths were born between 1915 and 1955, but most of the radiographs were taken after 1947 and close to birthdays and half-birthdays. The group size

ranged from 21 to 43 for each 6-month interval in each sex. The median skeletal ages for these youths were between 0.5 and 1.0 year below the Greulich-Pyle standards from 12 through 17 years. Data have been reported by Malina and Johnston,[23] who used Todd assessments of about 20 white Philadelphia youths of each sex for each annual interval from 12 to 16 years. After adjustment to a Greulich-Pyle baseline, their data for boys show an advancement in skeletal age of about 1 year except at 15-16 years, when the advancement is 1.6 years. The girls, however, are retarded by about 0.5 year.

These previous studies of groups of white U.S. youths indicate that sex differences in mean levels were small. This does not mean that girls did not mature more rapidly than boys but that the differences between the mean skeletal ages for the two sexes were slight *when assessments were made against sex-appropriate standards.*

The present national survey data for white boys, as noted earlier, are markedly below the HES reference standards at 12, 13, and 17 years but not at the intervening ages. These reference standards[9] were derived from and closely match those of the Greulich-Pyle Atlas.[10] The levels and patterns of change across age for white boys from the national survey are not in agreement with those reported from earlier smaller groups of U.S. white boys.[10, 16-19, 21-23]

The mean skeletal maturity levels of white girls from the national survey (female equivalent values) are best considered in two different age periods (12-14 and 15-17 years). From 12 to 14 years the mean levels are about 0.5 year lower than the Greulich-Pyle standards; these findings are similar to those reported by Todd,[18] Fry,[21] and Maresh.[22] However, at later ages (15-17 years), the mean female equivalent values for white girls from the national survey fall markedly behind the Greulich and Pyle standards until the difference is about 18 months at 17 years. It must be emphasized that *all* the national survey radiographs were assessed against a single set of male standards. Consequently, the present findings probably reflect *both* real differences in level between white girls in the national survey and the Greulich-Pyle standards *and* systematic sampling bias in the sex-associated differences in skeletal maturity levels used to transform the values assigned to the girls against the male standards when obtaining female equivalent values.

At 17 years (mean chronological age = 17.5 years) the mean skeletal age for white boys is 17.1 years and the corresponding mean skeletal age for girls (female equivalent values) is 15.5 years. The latter value was obtained after transforming the mean observed value of 17.6 years which had been obtained using the male standards. The *actual* difference between the mean values assigned to the boys and girls at 17 years, when both were assessed against the male standards, was only 0.5 year. At younger ages the actual sex difference on the male standards was considerably larger; for example, at 12 years the difference was 2.8 years. This decreasing actual sex difference, at ages after 14 years, leads to misleading female equivalent values because the sex differences used to obtain the latter were too large at these older ages. However, the errors introduced by this transformation are systematic and constant across all racial, socioeconomic, and other groupings. This subject is discussed in detail in an earlier report[1] and is considered in the "Discussion" section of this report.

Practically no previous data are available concerning the skeletal maturity status of groups of white U.S. youths of more specific ancestry, nor were such data recorded during the Health Examination Survey. Todd[24] reported insignificant differences in maturity status between 315 U.S. children and youths, both of whose parents were born in Italy (usually southern Italy or Sicily) and 201 children and youths, both of whose parents were born in the United States, most of whom were not of Italian ancestry. These children and youths, who were age 5-13 years, were examined cross-sectionally. From this study Todd concluded that the data showed no evidence of race-linked differences although, of course, there were few children in each age- and sex-specific group. Furthermore, he did not control for possible socioeconomic differences.

Comparison with foreign studies.—The available data have been collated concerning the skeletal maturity levels of youths in countries that have contributed substantially, by emigration, to the U.S. population. In order, these

countries are Germany, Italy, Great Britain (excluding Ireland), Ireland, Austria-Hungary, Canada, and the U.S.S.R.[25] Unfortunately, relevant reports are available only for England and Poland.

A major source of information concerning skeletal maturity levels of British youths is the differences between Greulich-Pyle and Tanner-Whitehouse[26,27] assessments of the same radiographs.[21,28-30] These data are relevant irrespective of the specific groups studied. It is important to note the Tanner-Whitehouse standardizing sample consisted of cross-sectional and serial radiographs of British youths, most of whom were from Scotland. The number of subjects per year for each sex in the Tanner-Whitehouse standardizing sample is about 150, but the sample did not include youths over 16 years. This led to problems at the upper end of the scale[27,28] which apparently have been remedied to some extent by enlarging the standardizing sample, redefining the criteria for grades, and eliminating some grades. This revised system of Tanner and Whitehouse is referred to as "TW-II."[27]

The reported findings summarized in table B concern studies made using the original Tanner-Whitehouse Method (TW-I). Problems in standardization and rating criteria at the upper end of the TW-I scale are presumably responsible, in large part, for the irregularity of the findings, especially in older girls.

All the reported comparisons show lower mean values for Greulich-Pyle skeletal ages than for Tanner-Whitehouse skeletal ages in boys. In girls the data are less regular. In the older girls studied by Fry[21] and by Andersen,[28] Greulich-Pyle skeletal ages tended to be higher than the corresponding Tanner-Whitehouse values. Theoretically, these variations could be due to differences between the two in the methods of weighting the bone-specific skeletal ages (or scores). It has been shown, however, that this is not an important factor.[29] There is no doubt that the reported differences almost entirely reflect variations between the standardizing samples used by Greulich and Pyle[10] and by Tanner et al.[26] To a lesser extent, they may be due to systematic bias in assessment. Consequently, the differences in table B can be interpreted as showing the variations in skeletal maturity status between the group of white youths in Cleveland and several pooled groups in Britain. As mentioned earlier, inferences from these data concerning the comparative rates of maturation of youths in the United States and several pooled groups in the United Kingdom (U.K.) can be no

Table B. Mean differences in skeletal age (years) between Greulich-Pyle and Tanner-Whitehouse assessments (GP – TW) of the same radiographs

Chronological age and sex	Fry, 1966[21]	Andersen, 1968[28]	Roche et al., 1971[29]	Clark, 1974[30]
	Mean difference			
Boys				
12.0 years	-0.9	-0.3	-0.5	-1.0
13.0 years	-0.7	-0.7	-0.4	---
14.0 years	-0.4	-0.7	-0.1	---
15.0 years	---	-0.4	---	---
16.0 years	---	-0.5	---	---
17.0 years	---	-0.4	---	---
Girls				
12.0 years	0.0	-0.5	-0.7	---
13.0 years	+1.1	0.0	-0.5	---
14.0 years	+0.5	+0.2	-0.5	---
15.0 years	---	+1.1	---	---
16.0 years	---	+1.7	---	---
17.0 years	---	---	---	---

NOTE: Fry—Nebraska, white youths; Andersen—Danish youths in Copenhagen; Roche et al.—Australian youths of British ancestry; Clark—Saskatchewan youths.

more than tentative because neither the Greulich-Pyle nor the Tanner-Whitehouse scale is based on a representative national sample.

When the levels of skeletal maturity in U.S. and U.K. youths are compared by considering the reports of investigators who applied both the Greulich-Pyle and Tanner-Whitehouse methods to the same youths, the groups studied are irrelevant except in regard to sample size, which will, of course, affect the reliability of the estimates. Fry[21] studied 25 youths of each sex at each annual interval; this study has been described earlier. The group studied by Andersen[28] included about 50 Copenhagen youths of each sex at each annual interval. Mixed longitudinal data from 23-51 Australian youths at each year of age have been reported by Roche and his coworkers.[29] Clark[30] assessed 12 youths at 12 years. All the means reported by Andersen indicate slight retardation (0.2 to 0.7 year) of the British standardizing group in comparison with Greulich-Pyle standards, except in girls at 14-16 years (0.2 to 1.7 years advanced). The differences reported by others[21,28-30] are similar for boys. However, Fry[21] and Andersen,[28] unlike Roche et al.,[29] found the Greulich-Pyle skeletal ages were more advanced than those of Tanner-Whitehouse in girls age 14 years or older. In general, these studies indicate that the standardizing sample of boys of Tanner et al.[27] was about 0.5 year behind the Greulich-Pyle standardizing sample in mean skeletal maturity level, but the differences among these reports preclude any generalization for girls. Paradoxically, when a group is given a higher mean rating on the Tanner-Whitehouse scale than on the Greulich-Pyle scale, this shows that the standardizing group used to construct the Tanner-Whitehouse scale matured more slowly than the group used to construct the Greulich-Pyle scale.

Further evidence concerning the skeletal maturity levels of British children is available from the mixed longitudinal data of Roche[31] obtained from essentially the same group of Australian children of British ancestry as that studied by Roche et al.[29] The size of this group ranged from 42 to 51 for each sex at each year of age. The mean Greulich-Pyle skeletal ages in these Australian youths were very close to the mean chronological ages, within 0.2 year. This suggests that youths of British ancestry born and living in Australia mature slightly more rapidly than British youths living in Great Britain.

Kopczyńska[32] reported cross-sectional data from about 6,000 Polish youths age 12 to 16 years living in Warsaw. The mean skeletal ages (Greulich-Pyle) tended to be less than the mean chronological ages, especially in the boys.

Other comparisons.—The literature allows only tenuous comparisons between reported skeletal maturity levels of groups of white and Negro youths in the United States. Todd[24] using cross-sectional radiographs of 149 Negro children and youths (age range not reported) tentatively concluded there were no modal differences in skeletal maturity level between Negro and white boys but that Negro girls tended to be more advanced than white girls.

Malina[33-36] and Malina et al.[36] made Tanner-Whitehouse assessments of some middle to upper-middle socioeconomic class white youths (N = 35) and some lower socioeconomic class Negro youths (N = 168) in Philadelphia, age 12 to 14 years. Both groups of youths were slightly in advance of the Tanner-Whitehouse standards except at 12 years in girls, when the difference was very small. The differences between the means for the two groups (white and Negro) were small, but the Negroes were slightly more advanced (0.1 year, boys; 0.4 year, girls) despite the lower socioeconomic status of the Negro groups. These findings suggest that, at the same socioeconomic level, the skeletal maturity status of Negro youths may be slightly in advance of that of white youths.

Cross-sectional data have been reported from 139 rural Jamaican youths age 12 to 16 years living about 15 miles north of Kingston.[37] At all ages, the mean Tanner-Whitehouse skeletal ages were less than the mean chronological ages. These differences tended to increase with age becoming comparatively large in girls between 14 and 16 years (table C). These Jamaican youths were retarded skeletally in comparison with the Negro youths in Philadelphia studied by Malina.[33,34,36] Michaut-Barthod[38] reported Greulich-Pyle skeletal ages for Dakar youths of Ovoloff ethnic origin. The group size ranged from 18 to 60 for each sex within 6-month age groups. These youths were markedly behind the

Table C. Modal differences between skeletal age and chronological age (S.A. – C.A. in years) in some Negro youths in other countries

Chronological age and sex	Marshall et al., 1970[37]	Michaud-Barthod, 1972[38]
	Modal difference	
Boys		
11.5 years	−0.2	---
12.0 years	---	−1.3
12.5 years	−0.7	−1.3
13.0 years	---	−1.4
13.5 years	−0.7	−1.2
14.0 years	---	−1.1
14.5 years	−0.8	−1.2
15.0 years	---	−1.1
15.5 years	−0.8	---
Girls		
11.5 years	−0.6	---
12.0 years	---	−1.7
12.5 years	−0.4	−1.3
13.0 years	---	−1.8
13.5 years	−0.5	−1.4
14.0 years	---	−1.6
14.5 years	−1.1	−1.6
15.0 years	---	−1.8
15.5 years	−1.7	---

NOTE: Marshall et al.—rural Jamaican youths (Tanner-Whitehouse Scale): Michaud-Barthod—Ovoloff youths in Dakar (Greulich-Pyle Scale).

Table D. Modal Greulich-Pyle skeletal age levels (S.A. – C.A. in years) in southern Chinese youths

Chronological age and sex	Low et al., 1964[39]
Boys	Modal skeletal age
12.0 years	−1.1
13.0 years	−1.5
14.0 years	−0.2
15.0 years	+0.2
16.0 years	+0.7
17.0 years	+0.6
Girls	
12.0 years	+0.1
13.0 years	+0.3
14.0 years	+0.4
15.0 years	+0.4
16.0 years	+0.5
17.0 years	+0.1

Greulich-Pyle standards. The mean differences between the chronological and skeletal ages ranged from 1.1 to 1.8 years, tending to be greater in girls. When adjustments are made for the differences in rating scales used, it becomes clear that skeletal maturation was markedly delayed in the Dakar youths compared with those in Jamaica. But as noted earlier, skeletal maturation was also delayed in the Jamaican Negro youths compared with those in Philadelphia.

Cross-sectional data from 3,624 southern Chinese youths in Hong Kong who were born between 1944 and 1950 have been reported [39] (table D). Greulich-Pyle assessments showed a marked tendency to skeletal retardation in these Chinese boys at 12 and 13 years, but later the mean differences between chronological and skeletal ages were small. This tendency to lesser delay in skeletal maturity in the boys as adolescence proceeded may reflect genetic differences between the groups studied by Low et al.[39] and Greulich and Pyle[10] in age-associated rates of skeletal maturation. From 12 to 15 years, however, it might also reflect the demonstrated differences between the Greulich-Pyle skeletal maturity levels and those present in the national probability sample of U.S. white and Negro boys. The Chinese girls studied by Low et al.[39] tended to be very slightly advanced skeletally in comparison with the Greulich-Pyle standards at all ages from 12 through 17 years. This is different from the findings of the present survey of U.S. white and Negro girls who were behind the Greulich-Pyle standards during the same age range.

Greulich[40] reported cross-sectional data from a "representative sample" of American born youths of Japanese ancestry living in the San Francisco area of California (table E). This sample included 20 to 41 youths of each sex at each annual interval who had been born between 1939 and 1944. The mean skeletal ages[41] of these Japanese-American youths were advanced over their mean chronological ages for all age groups in each sex. In the boys, these differences were small except at 16 years, but in the girls they were large from 13 through 16 years. Sutow[42] reported cross-sectional data from Japanese youths in Hiroshima who were born between 1936 and 1941 and examined within 1 month of a birthday. These youths constituted the normal control group when irradiation effects were being studied in Hiroshima youths. The group sizes varied from 56 to 107 for each sex at each age. Standards were selected from

Table E. Modal skeletal age levels (S.A. – C.A. in years) of American youths of Japanese ancestry[40] and Japanese youths in Japan[42,43]

Chronological age and sex	Greulich, 1957[40]	Sutow, 1953[42]	Sugiura and Nakazawa, 1968[43]
	Modal skeletal age		
Boys			
12.0 years	+0.4	−1.0	---
12.5 years	---	---	−0.5
13.0 years	+0.6	−0.6	---
13.5 years	---	---	0.0
14.0 years	+0.6	−1.2	---
14.5 years	---	---	0.0
15.0 years	+0.5	−1.0	---
15.5 years	---	---	0.0
16.0 years	+1.2	−1.5	---
16.5 years	---	---	+0.5
17.0 years	+0.5	−1.0	---
Girls			
12.0 years	+0.6	−1.2	---
12.5 years	---	---	−0.5
13.0 years	+1.4	−2.0	---
13.5 years	---	---	0.0
14.0 years	+1.0	−1.5	---
14.5 years	---	---	−0.5
15.0 years	+1.0	−1.5	---
15.5 years	---	---	−0.5
16.0 years	+1.1	−1.5	---
16.5 years	---	---	−0.5
17.0 years	+0.6	−2.0	---
17.5 years	---	---	−0.5

these radiographs by a procedure similar to that used by Greulich and Pyle[44] and these standards were assessed against the Greulich-Pyle Atlas by Sutow.[42] These assessments show that, by comparison with the Greulich-Pyle standards, the modal levels of skeletal maturity were low in these youths, particularly in the girls, in whom the mean retardation exceeded 1 year at each annual age interval.

These data of Greulich and Sutow show marked differences between the skeletal maturity levels of American youths of Japanese ancestry and Japanese youths in Japan, with the former being the more advanced. It must be stressed that these data were derived from youths born between 1936 and 1944; the current differences may be smaller.

That such a secular change has, in fact, occurred is shown by recent findings. The skeletal maturity standards of Sugiura and Nakazawa[43] indicate that Japanese youths living in Nagoya have median skeletal ages that are now very close to the Greulich-Pyle standards. Similarly, Ashizawa[45] reported Tanner-Whitehouse skeletal ages for Japanese youths living in Tokyo. The means for the boys were about 1 year in advance of the Tanner-Whitehouse standards, but the corresponding differences for the girls were very small. If transformed to a Greulich-Pyle[10] baseline, this would imply that the boys were about 0.5 year in advance of the Greulich-Pyle standards and that the girls were about 0.5 year behind them. Kimura[46] reported mean Tanner-Whitehouse skeletal ages for 137 Japanese youths age 12-17 years. These were about 0.5 year in advance of the mean chronological ages in each sex, implying that the mean levels would have been close to those of the Greulich-Pyle standards.

As suggested by Greulich,[40] it is reasonable to conclude that the differences between the skeletal maturity levels of youths of Japanese ancestry in California and those living in Japan in the 1950s are likely to be environmentally determined although the possibility of selective migration cannot be excluded. The more recent findings of Sugiura and Nakazawa,[43] Ashizawa,[45] and Kimura[46] suggest that these earlier differences have been greatly reduced, if not eliminated. This rapid change supports the view that the differences reported earlier were largely environmentally determined. They are also in agreement with changes in rates of growth and sexual maturation occurring in Japan in recent decades that have been reported in other studies.[47-49]

One can infer, however, that genetic factors are also involved in differences between mean skeletal maturity levels of Japanese youths and U.S. white youths from data provided by Kimura.[50,51] He reported that skeletal ages were less advanced in a group of male Japanese youths than in a group of hybrid Japanese-American youths. The members of both groups had been reared and cared for in the same Japanese orphanage environment.

Variability of skeletal ages.—The standard deviations of the various reported skeletal ages for groups of U.S. white youths can be used as a gauge of variability to compare earlier findings with those in the national survey (table F). There is considerable agreement among the studies of white youths, although the groups

Table F. Standard deviations (years) of skeletal age for United States youths

Age and sex	Flory, 1936[16]	Bayley, 1962[52]	Johnston, 1962[19]	Fry, 1966[21]	Malina,[1] 1970[53]	Malina,[2] 1970[53]	United States	
							White	Negro
Boys	Standard deviation							
12 years	1.0	0.9	0.7	1.4	1.1	1.2	1.4	1.3
13 years	0.8	0.9	0.9	1.5	---	0.9	1.5	1.6
14 years	1.1	1.0	1.0	0.9	---	---	1.2	1.4
15 years	1.1	1.1	1.0	---	---	---	1.2	1.3
16 years	1.1	1.2	0.9	---	---	---	1.1	1.4
17 years	1.1	1.2	1.1	---	---	---	0.9	0.9
Girls (female scale or equivalent)								
12 years	1.1	1.1	1.1	1.4	0.9	1.1	1.0	1.1
13 years	1.1	1.2	1.2	1.2	---	1.1	0.9	0.8
14 years	0.9	1.3	0.9	1.3	---	---	0.7	0.9
15 years	0.8	1.1	1.2	---	---	---	0.7	0.6
16 years	0.7	0.9	0.9	---	---	---	0.7	0.7
17 years	0.6	0.7	0.5	---	---	---	0.7	0.8

NOTE: Flory, Bayley, Johnston, Fry—white youths; Malina[1]—white Philadelphia youths; Malina[2]—Negro Philadelphia youths.

studied differed in socioeconomic variability and in their range of chronological ages. There is, however, a slight tendency for the standard deviations from the national survey to be larger than those reported by others for boys 12-15 years; a similar tendency is not present in the data for girls.

At all ages, the national survey data for both white and Negro youths indicate that skeletal maturity levels are less variable, judged by the standard deviations, in girls than boys. The white-Negro differences in variability are negligible (table F). Within the other reported studies, a tendency to a similar sex difference was present only at the older ages.[16,19,52] These sex differences at the older ages may only reflect the truncated distributions caused by many girls reaching the maximum values that can be assigned.

When the variability of skeletal ages is compared between the white and Negro groups in the national survey, in terms of the coefficient of variation (figure 4), it is clear that Negro boys tend to be considerably more variable than white boys except at 12 years. The pattern of differences between the white and Negro youths is less consistent in the girls; the mean skeletal ages are more variable in the white girls at 13, 15, and 16 years but less variable at 12, 14, and 17 years. This lack of a consistent pattern in the findings for boys and girls in the coefficient of variation might reflect the comparatively small samples of Negro youths. Long ago, Todd[24] considered, after analysis of data from a smaller group, that skeletal maturity was more variable in American Negroes than whites. The present findings provide limited support for his view.

Reported standard deviations for the group of Australian youths studied by Roche[31] are smaller than those for the national survey youths; however, those reported by Low et al.[39] for Chinese girls are larger (table G). Much of these differences could reflect variations between these studies in the scheduling of examinations. The Australian youths were seen very close to birthdays and half-birthdays, the Chinese children and the U.S. survey children were examined at random chronological ages. The latter procedure would have increased the measures of variability. Furthermore, there was a much wider range of socioeconomic status in the group of Chinese youths than in the Australian youths and possibly even the national survey youths. This also would tend to increase the variability. The variability of skeletal ages in the groups studied by Andersen[28] and Marshall and his associates[37] is similar to that found in the national survey. As in the national survey, variability tended to be less in older girls in the groups studied by Low and his coworkers[39] and Andersen.[28] The data of Marshall and his associates[37] show a tendency to less variability

Table G. Standard deviations (years) of skeletal age in groups of youths outside the United States

Chronological age and sex	Roche 1967[31]	Andersen 1968[28]	Low et al., 1964[39]	Marshall et al., 1970[37]
	Standard deviation			
Boys				
12.0 years	0.7	---	1.3	---
12.5 years	---	0.9	---	1.2
13.0 years	0.7	---	1.5	---
13.5 years	---	0.8	---	1.6
14.0 years	---	---	1.3	---
14.5 years	---	1.0	---	0.8
15.0 years	---	---	1.0	---
15.5 years	---	1.1	---	1.1
16.0 years	---	---	1.4	---
16.5 years	---	1.0	---	---
17.0 years	---	---	1.6	---
17.5 years	---	1.0	---	---
Girls				
12.0 years	0.8	---	1.3	---
12.5 years	---	0.9	---	0.7
13.0 years	0.8	---	1.3	---
13.5 years	---	1.1	---	0.5
14.0 years	---	---	1.1	---
14.5 years	---	1.1	---	0.6
15.0 years	---	---	1.3	---
15.5 years	---	1.1	---	0.6
16.0 years	---	---	1.0	---
16.5 years	---	0.8	---	---
17.0 years	---	---	0.8	---
17.5 years	---	0.7	---	---

NOTE: Roche—British youths in Australia; Andersen—Danish youths; Low et al.—Chinese youths; Marshall et al.—Negro youths in Jamaica.

in Negro Jamaicans than in U.S. Negro youths. This may reflect a relatively homogeneous and low socioeconomic level in Jamaica.

Geographic Region

Analysis of the national survey data by geographic region shows that for all racial groups combined, youths in the South are slightly more advanced skeletally and those in the Midwest are less advanced in this aspect of development, on the average, than those in either the Northeast or West Regions of the United States (table 2). This regional differential is present among both boys and girls over the total age span 12-17 years but is not consistent at the individual years of chronological age and may be confounded by unequal racial distributions (figure 9). It is emphasized, however, that these regional differences are small. The total regional differences for either sex do not exceed the 95-percent confidence limits for such estimates from this study. The four regions into which the United States was arbitrarily divided for sampling and administrative reasons in this national survey are so large geographically and so heterogeneous that any real differences among smaller regions that may exist in the skeletal maturity of youths within this country would probably be masked.

Mean skeletal ages (hand-wrist) of boys age 12-17 years (mean chronological age of 15.0 years or 180 months) range from 14.7 years (175.9 months) in the South to 14.5 years (174.0 months) in the Midwest. However, for girls (assessed against the male standards) the values range from 16.5 years (197.5 months) in the South to 16.3 years (196.0 months) in the Midwest.

Among boys, the mean skeletal ages for those in the South exceed those in the other three regions of the country only at chronological ages 12 and 16 years; at ages 12, 14, 15, and 16 years the mean skeletal ages of those in the

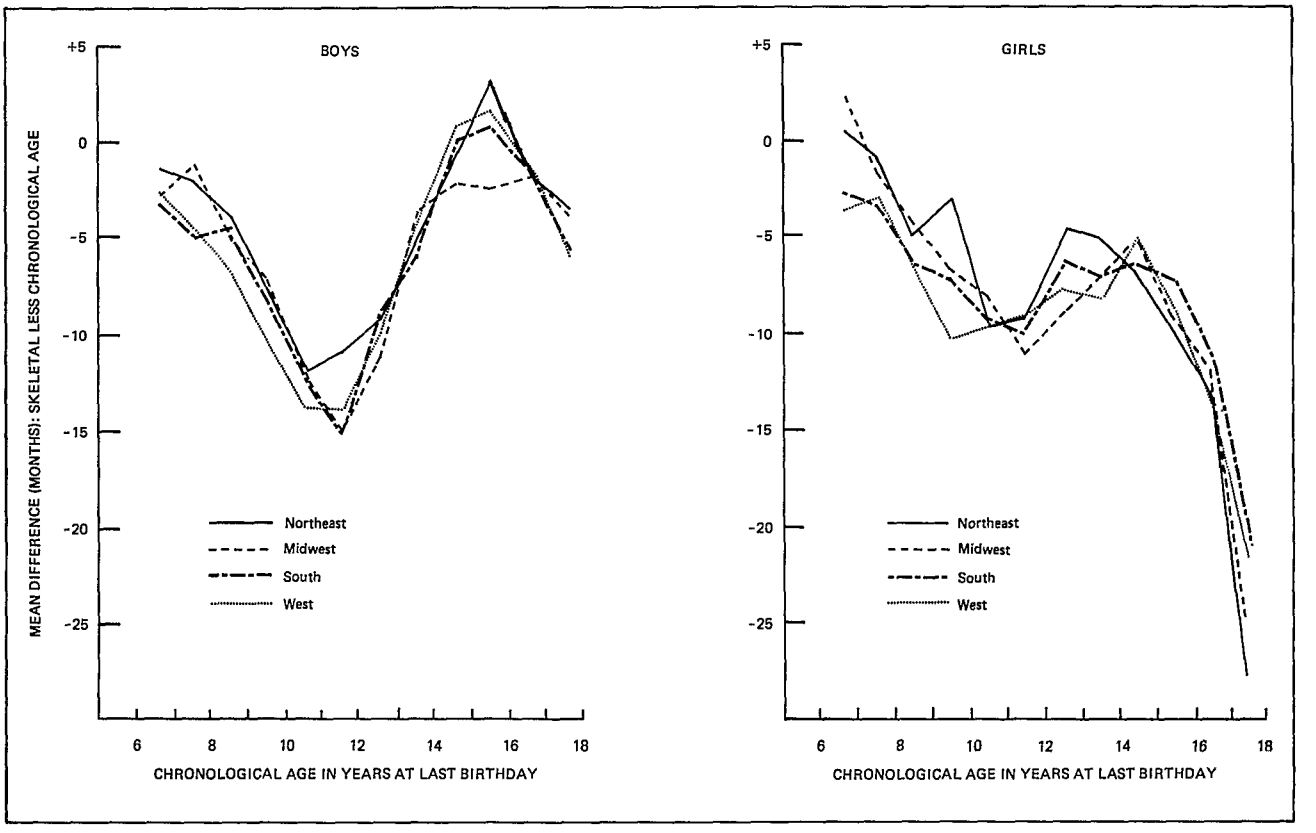

Figure 9. Mean difference in months between skeletal age (hand-wrist) and chronological age for boys and girls age 6-17 years by region and chronological age in years: United States, 1963-1970

Midwest are lower than elsewhere in the United States.

For girls at chronological ages 15-17 years, the mean skeletal ages of those in the South exceed those in the other three regions; however, only at age 12 years are girls in the Midwest less skeletally mature, on the average, than girls living elsewhere in this country.

If the age-specific mean skeletal ages for boys in the four regions combined applied in each individual region, boys in the South would be expected to be the most skeletally mature (on the basis of the chronological age distribution) and those in the Northeast, rather than the Midwest, would be expected to be the least skeletally mature, on the average. When the expected skeletal ages (on the basis of chronological ages) are determined for girls, those in the Midwest would be expected to be the least skeletally mature, and those in the South and West would be most advanced, on the average. The negligible difference between the actual and expected mean values in each region indicates that differences in the chronological age distribution of boys or girls among the regions probably account for much of the actual but small mean regional differences in skeletal maturity among youths in the United States (figure 10).

The variability of skeletal maturity, as measured by the standard deviation (table 2) or interquartile range (table 8), tends to decrease with increasing chronological age among youths (boys and girls) in each region.

The regional pattern of skeletal maturity among youths age 12-17 years is more consistent and different from that found among children age 6-11 years in the preceding national survey.[3] Boys age 6-11 years in the Northeast are the most skeletally mature and those in the South the least advanced in this respect. Among girls age 6-11 years, the mean values are highest in the Midwest and lowest in the West, though, as

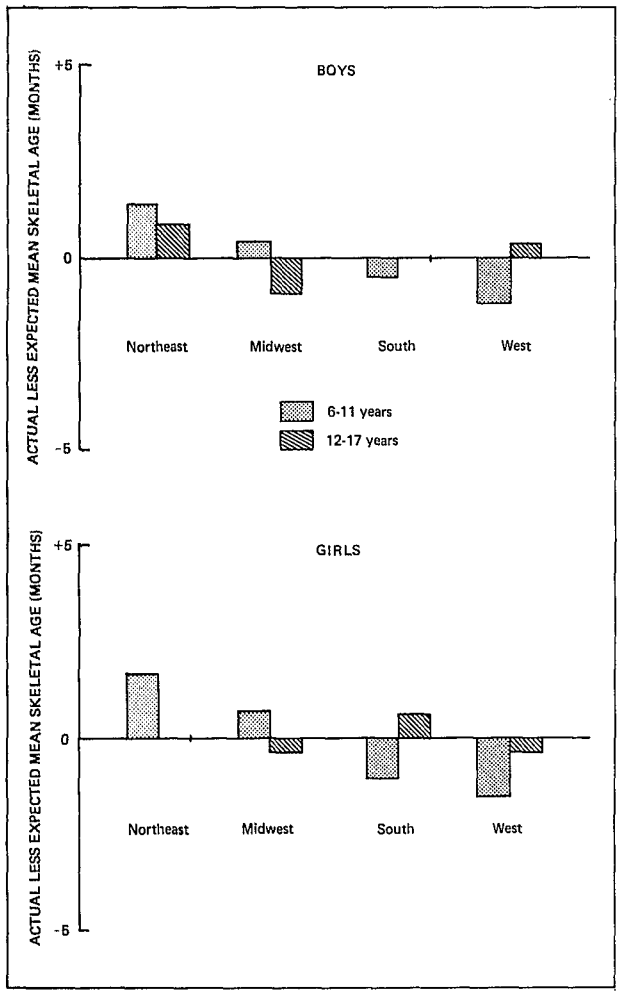

Figure 10. Difference between actual and expected mean skeletal age (hand-wrist) for boys and girls 6-17 years of chronological age by region: United States, 1963-1970

in the youth survey, all these mean values are within the 95-percent confidence limit for such estimates (not statistically significant).

When white youths only are considered, boys age 12-17 years in the South are slightly more advanced skeletally and those in the Midwest slightly less advanced in this respect, on the average, than boys living elsewhere in the Nation. Among girls age 12-17 years, those in the South are also slightly more advanced and girls in the Midwest slightly less mature skeletally than girls living elsewhere in the United States (table 3 and figure 11). The mean values for white boys age 12-17 years (mean chronological age of 15.0 years or 180 months) range from 14.8 years (177.3 months) in the South in 14.5 years (174.2 months) in the Midwest and for white girls from 16.5 years (197.5 months) in the South to 16.3 years (195.9 months) in the Midwest. All these values are for assessments against the male standards.

The regional pattern for skeletal maturity among Negro youths differs somewhat from that among white youths. Negro boys age 12-17 years in the West tend to be more skeletally mature and those in the South less skeletally mature, on the average, than Negro boys living in the other regions. Negro girls in the Midwest are more skeletally mature and those in the West less skeletally mature than Negro girls living elsewhere in the Nation. The mean skeletal age values for Negro boys age 12-17 years (mean chronological age of 15.0 years or 180 months) range from 14.6 years or 174.9 months for those in the West to 14.3 years or 172.0 months for those in the South; among Negro girls in the same age range the values range from 16.5 years or 197.8 months in the Midwest to 16.4 years or 196.2 months in the West.

Urban-Rural

There is no consistent pattern of urban-rural differences in skeletal maturity among either boys or girls in the youths' age range in the United States (table 4). This finding is similar to that for children 6-11 years old in the previous national survey.[3] Unlike the situation in some other countries, this implies a relative lack of differences between urban and rural areas of the United States in the genetic and environmental factors that influence the rate of skeletal maturation and physical growth in general.[5,4]

The mean skeletal age (hand-wrist) for boys age 12-17 years (mean chronological age of 15.0 years or 180 months) in either urban or rural areas is 14.6 years or 174.9 months. For girls the mean values (male standards) in both the urban and rural areas are 16.4 years (196.6 months, urban; 196.5 months, rural).

For both boys and girls in urban areas, the mean values are slightly higher for those living in the largest (3 million or more) urbanized areas. For those living in rural areas, there are no consistent differences dependent on whether they

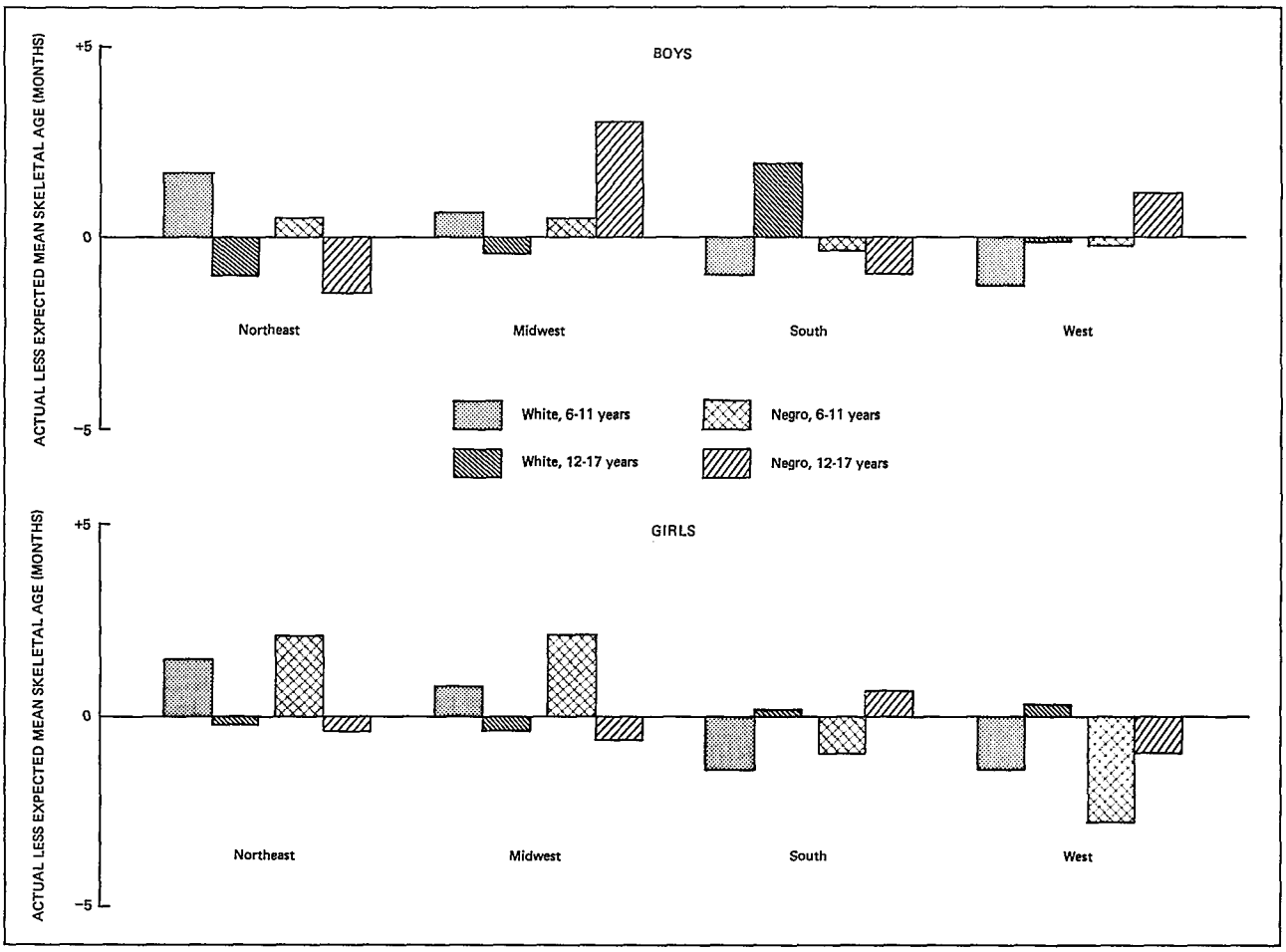

Figure 11. Difference between actual and expected mean skeletal age (hand-wrist) for white and Negro boys and girls 6-17 years of chronological age by region: United States, 1963-1970

live on farms or dependent on the size of the nonfarm community in which they live.

Family Income

There is no consistent relationship between the skeletal maturity levels of youths age 12-17 years in the United States and the size of their family income (table 5 and figure 12). However, those from the higher income levels of $10,000 and over per year appear to have slightly, but not significantly, higher mean values than those with lesser incomes.

Among boys age 12-17 years (mean chronological age 15.0 years or 180 months), the mean skeletal age (hand-wrist) for those with annual family incomes of $10,000 and over is 14.6 years or 175.5 months compared with 14.5 years (174.5 and 174.6 months) in the two broad income groups below $10,000 ($5,000-$9,999; under $5,000). If only those in extremes of the income distribution are considered, the mean skeletal age (hand-wrist) of boys in families with $15,000 or more annual income is nearly identical with that for the entire group with $10,000 and over income (175.8 months compared with 175.5 months), while among those with annual family income of less than $3,000 the mean skeletal age is slightly higher than for all those in the bracket under $5,000 (175.6 months compared with 174.5 months). The difference (all ages combined) between those with annual family incomes greater than $15,000 (175.8 months) and those with annual family incomes less than $3,000 (175.6 months) is trivial.

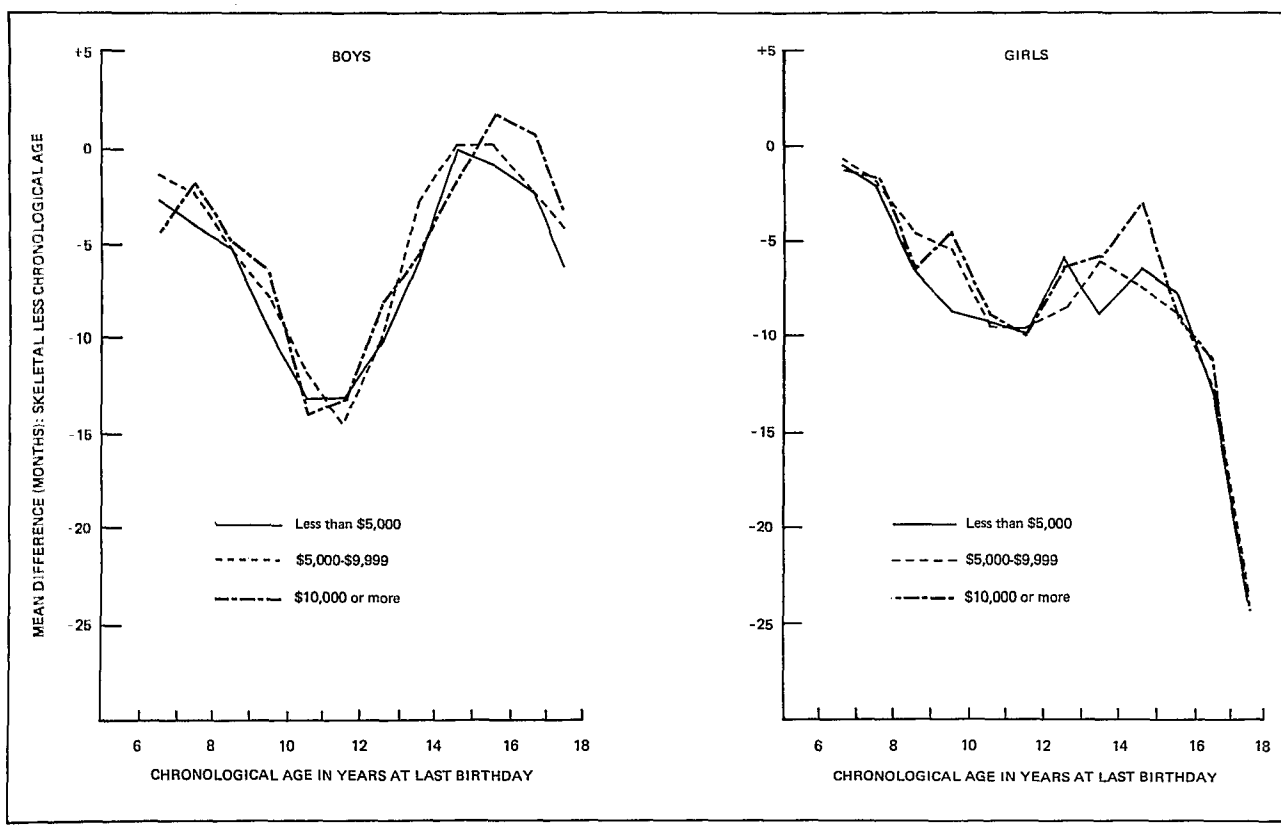

Figure 12. Mean difference in months between skeletal age (hand-wrist) and chronological age for boys and girls age 6-17 years by annual family income and chronological age in years: United States, 1963-1970

A nearly similar pattern of association exists between family income and the skeletal maturity of girls age 12-17 years (mean chronological age 15.0 years or 180 months). The mean skeletal age is greatest among those with an annual family income of $10,000 or more (16.5 years or 198.1 months) and about the same (16.3 years) in the two broad lower income groups. At the extremes of the income ranges, the mean skeletal maturity level of those with a yearly family income of $15,000 or more is 197.9 months or just slightly less than the mean of 198.1 months for all those with a yearly family income of $10,000 or more. As for boys, at the lowest income level ($3,000 a year or less) the mean skeletal age of girls (male standard) is 197.0 months, which is slightly greater than for all girls in families with annual incomes under $5,000. Despite this lack of a clear-cut association with income when all ages are combined, it is clear that in the girls, but not the boys, those with annual family incomes in excess of $15,000 were considerably more mature than those in lower income groups at age 14-17 years.

When the effect of differences in the chronological age distribution among the various income level groups is removed, boys age 12-17 years in the highest income level families ($10,000 a year and over) are slightly more advanced skeletally than expected and those in the lowest income level group (under $5,000) are less advanced than expected in this respect; the differences are slightly more marked than among younger boys age 6-11 years, but not large enough to possibly reflect more than the effect of sampling variability (figure 13). The pattern of deviation in skeletal maturity from that expected among girls 12-17 years across income differs somewhat from that shown for boys and younger girls, but the differences again are negligible.

Because of a possible confounding effect of racial differences on the preceding analysis of income-related variations, the national survey

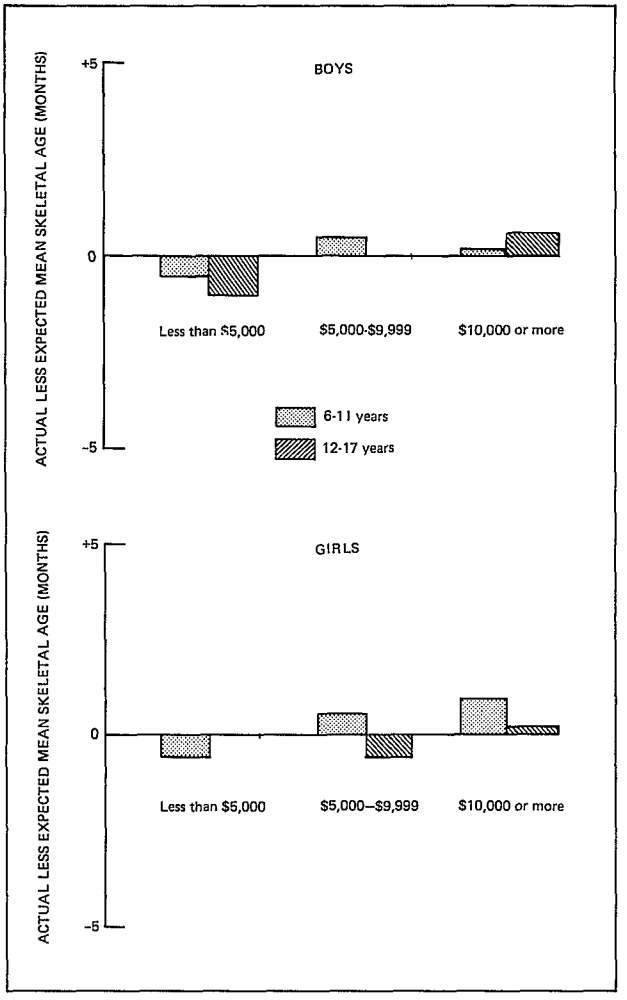

Figure 13. Difference between actual and expected mean skeletal age (hand-wrist) for boys and girls 6-17 years of chronological age by annual family income: United States, 1963-1970

data have been considered separately for whites and Negroes. Among white boys age 12-17 years there is even less association between skeletal maturity level and family income than that noted for boys of all races combined (table 6). The mean skeletal age values are identical for those with $10,000 or more and those with under $5,000 annual family income (175.4 months) and nearly identical (175.5 months) with those in the family income bracket of $15,000 and over. Furthermore, boys in the lowest income level families, less than $3,000 reported annual income, have slightly higher mean levels (176.4 months) than the others. White girls appear to show an association between skeletal maturity and family income similar to that for girls of all races combined—slightly higher means for those in the upper income levels.

Both Negro boys and girls age 12-17 years in the higher income level families ($10,000 or more per year) are slightly more advanced skeletally than those in families with income levels below $5,000. Mean skeletal age for Negro boys (mean chronological age 15.0 years or 180 months) in families with incomes of $10,000 or more is 14.6 years or 175.8 months compared with 14.4 years or 172.6 months for those in families with incomes of under $5,000. For Negro girls there is a large difference between the mean skeletal ages (male standard values) for those in families with $10,000 and over annual income (17.2 years, 206.6 months) and the corresponding ages for those in the bracket under $5,000 (16.4 years, 196.7 months). At the extremes of family income considered, the mean skeletal age for Negro boys was markedly higher (15.6 years, 187.8 months) for those in families with incomes of $15,000 or more than for the entire group in families with incomes of $10,000 or more (14.6 years, 175.8 months). However, the mean skeletal age was also slightly higher among those with family incomes less than $3,000 (14.5 years, 174.2 months) than for the entire group with family incomes less than $5,000 (14.4 years, 172.6 months). Among Negro girls, the pattern of differences between mean skeletal ages and family income were even less consistent. To some extent, the inconsistencies in each sex might reflect the effect of small samples sizes at the extremes of the distribution of family incomes.

The mean skeletal ages of Negro boys were slightly lower than those for white boys age 12-17 years in families with less than $10,000 annual income (less than $3,000; $3,000-$5,000; $5,000-$9,999) but essentially the same at income levels of $10,000 and over. Although the difference is large for those with family incomes exceeding $15,000, the Negro sample is small, and consequently this estimate is unreliable. Negro girls, in the age range 12-17 years, were slightly more mature skeletally than white girls across all three broad income groups (under $5,000; $5,000-$9,999; $10,000 and

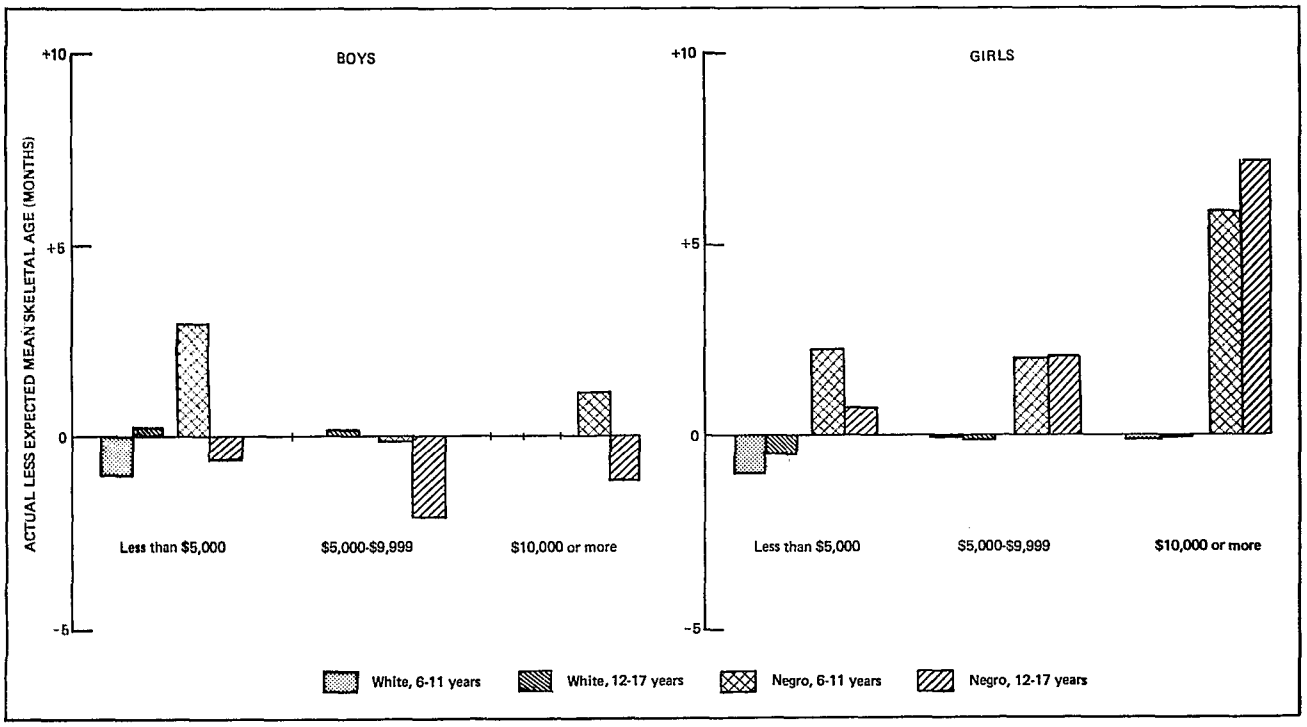

Figure 14. Difference between actual and expected mean skeletal age (hand-wrist) for white and Negro boys and girls 6-17 years of chronological age by annual family income: United States, 1963-1970

over). The opposite was true in both of the extreme groups (under $3,000 and $15,000 or more), but the small sample sizes reduce the reliability of these findings.

When the effect of differences in the chronological age distribution between the two largest racial groups within income level groups is removed, Negro boys 12-17 years of age are less mature than expected skeletally and Negro girls more mature than expected in this respect across income levels, although the deviations from the expected are not large enough to be statistically significant (figure 14).

Parental Education

The association between skeletal maturity and parental education among white and Negro youths—both boys and girls—is even less clear than that with family income (table 7). Those youths whose first parent (the father if he was still present in the household) had completed 13 years or more of formal schooling were very slightly more advanced skeletally than those in the same race-sex group with lesser parental education. This differential was slightly more evident among boys than among girls. The differences noted are much too small to be statistically significant.

BONE-SPECIFIC SKELETAL AGE FINDINGS

In the Greulich-Pyle method of assessment, the skeletal maturity of the hand-wrist assigned to an individual youth is based usually on the average of the ages assigned those of the youth's 31 hand-wrist bones that are radio-opaque but not classified as adult. While some investigators use the median and others assign an age to the whole area without recording separate skeletal ages, the common practice of using the average has been followed in this report as in the previous ones.[1-3] Although, in general, there is good concordance among the bone-specific skeletal ages for an individual, the differences are real and may be important.

The order of onset of ossification and the rates of maturation of individual bones vary considerably among individual children and youths. It is probable that there are similar individual differences in the order of epiphyseal fusion, but few findings have been reported. As a result of these variations, there are differences between the skeletal ages assigned to individual bones in a single radiograph. For youths in the age range of concern in this study, 12-17 years, nearly all the 31 hand-wrist bones have become radio-opaque, but their maturation is incomplete. There are only 2 hand-wrist bones in which the onset of ossification is normally delayed until age 12 years or later—these are the adductor and flexor sesamoids in boys and the flexor sesamoids in girls.

Several factors may be responsible for the differences that occur commonly among the skeletal ages assigned to individual bones within a single hand-wrist radiograph. The selection of standards by Greulich and Pyle[10] may have been imperfect. That is, bones each assigned the same skeletal age in a standard might, in fact, individually differ in actual skeletal age. This would not explain the largely random nature of the variations noted. Errors occur during the assessment of radiographs. These might be systematic; for example, an assessor or group of assessors might systematically assess a particular bone higher than the real level. The variations due to the assessors might, of course, be random, in which case, when the direction of the errors are taken into account they would balance each other when group data are considered, but they could cause or increase the variation among bone-specific skeletal ages in a single radiograph. Reported data indicate that the comparability and replicability of bone-specific skeletal ages are lower for the carpals than for the other hand-wrist bones.[55,56] This could increase the variability of the skeletal ages recorded for these bones.

Differences in skeletal maturity levels among the bones of a single hand-wrist might result from variability within individuals that is random in a population. Thus it is possible that while the population means for all bones could be at the same level of maturity in children of a particular age, there could still be variations in level within individual children. Alternatively, when differences are noted among the skeletal ages assigned to a radiograph, they could reflect real genetically or environmentally determined population differences. That is, a particular bone or group of bones may systematically be less mature or more mature than the other hand-wrist bones in a defined population.

Race

For each of the 31 hand-wrist bones the mean skeletal age of white boys exceeds that for Negro boys age 12-17 years in the United States. The racial differences in the mean values are, almost without exception, small enough to be within the 95-percent confidence limits for estimates in this study. This pattern of white boys being more skeletally mature than Negro boys for each bone is generally consistent at each single year of age, except at age 13 years where 30 of the 31 bones (all but the capitate) are more skeletally mature in Negro than in white boys. Minor exceptions at other individual ages are detailed in table 9—the pisiform at age 17, the adductor sesamoid at ages 12 and 17, the flexor sesamoid at ages 14 and 17, and middle phalanx IV at age 17.

In contrast to the findings among boys divided on the basis of race, Negro girls of 12-17 years generally are more advanced skeletally for each individual bone than are white girls. Mean skeletal ages for Negro girls slightly exceed those for white girls age 12-17 years in 25 of the 31 hand-wrist bones, the exceptions being the capitate, trapezoid, metacarpal V, pisiform, and distal phalanges IV and V. Across the age range in the present study the pattern of racial differences in bone-specific skeletal maturity among girls is nearly as consistent as that in boys, but the reverse in direction, and the exception among girls occurs at age 14 years. At each year of chronological age except 14 years, the mean skeletal age for 20 or more of the 31 bones in Negro girls exceeds that in white girls. At age 14 years, white girls are more advanced skeletally than Negro girls are for 27 of the 31 hand-wrist bones.

Previous studies.—There are few reports with which the present findings can be compared. In

the national survey of children (Cycle II),[3] it was shown that, within a sex, there are statistically significant differences between whites and Negroes (Negroes more mature) in the skeletal ages assigned to the radius, ulna, carpals, and metacarpals in each sex, and to distal phalanges III-V in boys. In the national survey data for age 12-17 years, the sex differences (female equivalent ages for the girls) were small,[1] as they had been during the 6-11-year period in the earlier national survey.[2]

Malina and his group[36,53] reported Tanner-Whitehouse skeletal age scores for individual bones in a group of white and Negro Philadelphia youths age 12 and 13 years. These bone-specific scores cannot be converted to skeletal ages, but they can be used to compare the maturation levels in white and Negro youths of the same sex. In the boys, most bones were more mature in Negro than in white youths at both 12 and 13 years, but the reverse was noted for the scaphoid, trapezium, trapezoid, metacarpal I, proximal phalanx V, and distal phalanges III and V. Without exception, all the hand-wrist bones tended to be more advanced in Negro girls than in white girls at both 12 and 13 years. However, in each sex almost all the mean differences between matching bone-specific scores in these two racial groups were small.

Geographic Region

There is no consistent pattern of regional differences in the levels of skeletal maturity among the 31 hand-wrist bones (table 10). Among boys the most frequent regional patterns in mean bone-specific skeletal ages were either slightly higher mean levels in the South and lower levels in the Northeast than elsewhere (12 of the 31 bones) or slightly higher levels in the West and lower levels in the Midwest than elsewhere (8 of the 31 bones). For girls the two more frequent patterns were slightly higher mean values for those in the Northeast and lower values in the West than elsewhere (14 of the 31 bones); and slightly higher mean values in the Northeast and lower in the Midwest than elsewhere (9 of the 31 bones). Within bones, there is no consistency between the sexes in these small regional differences.

Family Income

There is a clear lack of any strong relationship between skeletal age (hand-wrist) of youths and family income in the levels of skeletal maturity for the 31 individual bones (table 11). Among boys age 12-17 years, the highest mean skeletal ages for 20 of the 31 bones were among those boys in the highest annual income level families ($10,000 or more). However, the lowest mean values for these bones were as nearly common among boys in the lowest annual income bracket of under $5,000 (12 bones) as among the middle income group of $5,000-$9,999 (17 bones).

Similarly, among girls age 12-17 years, the highest mean values for 27 of the 31 hand-wrist bones were found among those in the bracket of $10,000 and over but the lowest mean skeletal ages were much more likely to occur among girls in the middle income group (21 of the 31 bones) than in the lower income level (5 of the 31 bones).

Range of Bone-Specific Skeletal Ages

Commonly, and indeed almost universally, there are differences among the maturity levels of the hand-wrist bones within a single radiograph.[57] If this were not the case the range would, of course, be equal to zero. While it has been claimed that these ranges are greater in children who are skeletally retarded,[58] curiously there have been few studies of the ranges and, until recently,[1,2] reference data were not available.

It has been claimed[58,59] that a wide range of bone-specific skeletal ages within a hand-wrist reduces the reliability of assessments. This does occur when overall assessments are made, but there has been some doubt as to whether this factor still operates when bone-specific assessments are made.[60] This variation among skeletal ages of hand-wrist bones gives rise to problems of interpretation. Using the atlas method of Greulich and Pyle, the same mean skeletal age may be assigned to two hand-wrist radiographs, although in one the carpals may be more mature than the other bones are and in the second radiograph the carpals may be less mature than the

other bones are. In fact, there is always uncertainty about the skeletal age equivalents of all radiographs in which unusual patterns of skeletal maturity levels are present due to the lack of adequate standardizing samples with the same patterns.[61]

Many earlier workers have claimed that illness or malnutrition has differential effects on the ages of onset of ossification or rates of later maturation among individual bones.[10,62-70] If this were established, and if there were no "catchup" maturation, the range of bone-specific skeletal ages within a hand-wrist radiograph would be a sensitive indicator of past environmental effects.

Findings from the present national survey with respect to the consistency and variability of the range of bone-specific skeletal ages, within individual radiographs, have been analyzed across racial, regional, and family income level subgroups among youths in the United States of chronological age 12-17 years. As do the comparable findings among U.S. children age 6-11 years from the preceding national survey,[3] these provide reference data that can be used to assess the possible effects of such factors as illness or malnutrition on skeletal maturation. Medians and quartile points in the distributions of the range of bone-specific skeletal ages within individual hand-wrists by race, geographic region, and family income are included in tables 12-14.

Race.—Among white youths age 12-17 years, the median range in these bone-specific skeletal ages decreases with advancing chronological age somewhat more rapidly in girls than boys (table 12). The median values for boys exceed those for girls at each chronological age. Toward the end of the range, this would be expected, because girls characteristically reach adult levels earlier than do boys and as a consequence there would be fewer bones in the girls to which skeletal ages could be assigned. For white boys the median range decreases from 15.9 months at age 12 years to 4.9 months at age 17 years; while for white girls the decrease is from 14.4 months at age 12 years to 1.7 months at age 17 years. Although the median values are higher for the boys, the variability in these skeletal age ranges, as measured by the difference between the 25th and 75th percentiles in their distributions, is generally less among white boys than among white girls. Exceptions occur at age 12, where the values are nearly identical (8.1 months for white boys and 8.0 months for white girls) and at age 16, where values for white girls are the less variable (11.2 months for white boys and 9.6 months for white girls). The younger white boys age 12-15 years show less variability (P_{75} - P_{25} of 8-9 months) than the older white boys of 16 and 17 years (P_{75} - P_{25} of about 11 months); among white girls the variability increases from a minimum at age 12 (P_{75} - P_{25} of 8 months) to a maximum at age 15 years (P_{75} - P_{25} of 15.4 months).

As among white youths, the median ranges of bone-specific skeletal ages within individual hand-wrists for Negro youths decrease with advancing chronological age and somewhat more rapidly in Negro girls than boys. The median values for Negro boys exceed those for Negro girls throughout the age range 12-17 years. For Negro boys the median range of bone-specific skeletal ages within the hand-wrist decreases from 15.0 months at age 12 years to 8.4 months at age 17 years; among Negro girls the decrease is from medians of about 12 months at 12 and 13 years (11.6 months and 12.5 months, respectively) to 2.7 months at age 17 years. The variability in these skeletal age ranges, as measured by the difference between the 25th and 75th percentile in their distributions, is less among Negro boys than among girls at age 12-16 years and is somewhat less among younger (age 12-15 years) than among older (age 16-17 years) Negro boys. The pattern of variability across chronological age among Negro girls is slightly less consistent than that for Negro boys.

There is no consistent racial difference between white and Negro youths in these ranges of skeletal maturity. Median ranges for white and Negro boys differ by only negligible amounts (1 month or less except at age 17 years) across the age range and not consistently in one direction; among girls the median values for white girls at ages 12-15 years are slightly greater than those for Negro girls. When variability is judged from the difference between 75th and 25th percentiles, both white and Negro boys at ages 12-15 years are less variable in skeletal maturity than their older counterparts; the pattern of variability is less consistent among both white and Negro girls. There are no marked dif-

ferences in the variability of these ranges when youths are separated on the basis of race within a sex.

Geographic region.—No significant pattern of geographical regional differences is evident in the range of bone-specific skeletal ages within the hand-wrists of youths in the United States (table 13). Among boys, the geographic regional median values in these ranges decrease consistently with advancing chronological age from 15-16 months at age 12 years to 4-6 months at age 17; among girls the medians decrease from 13-15 months at 12 years to 1-4 months at age 17 years. Although the differences between regions are generally small, there is a slight tendency for the median ranges to be larger in the West for boys and in the Northeast for older girls. Furthermore, there is a slight tendency for the variability of these ranges in the girls to be greater in the Northeast; but a similar tendency is not apparent in the data for the boys.

Socioeconomic factors.—Possible socioeconomic influences on the range of bone-specific skeletal ages within individuals in the youths' age range were analyzed in relation to family income. There is no consistent pattern of income-level differences in the ranges of bone-specific skeletal ages for boys or girls age 12-17 years (table 14). Within each of three broad income groups, there is a fairly consistent and similar pattern of decrease in these ranges with advancing age. Among boys, the decrease in the median values is from 15-16 months at age 12 years to 4-7 months at age 17 years; among girls the decrease is from 13-15 months at age 12 to 1-5 months at age 17 years. Among girls, but not boys, the median ranges tend to be slightly larger for those with family incomes of $5,000-$9,999 per year than for the groups with either larger or smaller incomes. This result would be puzzling were it not that the differences between these income groups of girls in their median ranges of bone-specific skeletal ages were generally small.

ONSET OF OSSIFICATION FINDINGS

During the age range of youths, 12-17 years, ossification usually begins in two hand-wrist bones—the adductor and flexor sesamoids in boys and the flexor sesamoid in girls.

Race

Among white boys in the United States, the median age of onset of ossification in the adductor sesamoid is 12.4 years, somewhat earlier than that for Negro boys (12.7 years). The median age of onset for the flexor sesamoid is more than a year later but shows about the same racial difference, and in the same direction, 14.2 years in white boys and 14.5 years in Negro boys (table 15). The median age of onset of ossification for the flexor sesamoid in girls is about 1 year earlier than in boys and is about the same in white as Negro girls—13.0 years and 13.1 years, respectively.

Geographic Region

Across all four regions into which the United States was divided for the purposes of this survey, the median age of onset of ossification for the adductor sesamoid in boys is 12.5 years. For the flexor sesamoid the median age of onset in boys ranges from a low of 13.3 years in the Midwest to 14.4 years in the South and West. Among girls there is essentially no geographic regional difference in the median age of onset of ossification—13.1 years in the Northeast and 13.0 years in each of the other three regions.

Family Income

Among boys (table 15), the median age of onset of ossification for the adductor sesamoid is negligibly lower for those in the middle income bracket of $5,000-$9,999 per year (12.4 years) than in either the lower or higher income level groups (12.5 years for both those with less than $5,000 and those with $10,000 or more family incomes). The onset of ossification for the flexor sesamoid is delayed in boys from the family income group of under $5,000 per year (14.4 years); it is about 1 year later than the median age for the onset of ossification of this bone in boys in the yearly income levels of $5,000 or more. The median age of onset for the flexor sesamoid in girls shows a consistent but negligible association with family income. The median age for those girls in families with less

than $5,000 annual income is 13.1 years and is 12.9 years at the income level of $10,000 or more per year.

Previous studies.—Reported modal ages for the onset of ossification in the adductor sesamoid in United States boys and the flexor sesamoid in both boys and girls are included in table H. The data in this table are based on two types of modal ages: the median or mean age at onset of ossification and the age when the center was ossified in 50 percent of the youths. The latter estimate was obtained after plotting the percents, at successive chronological ages, on probability paper. The youths included in these samples were predominantly of northwestern European ancestry and of middle, or slightly above middle, socioeconomic status.

The report of Harding[71] was based on mixed longitudinal data from white youths in Boston born between 1930 and 1939 and examined near each birthday. The sample size varied from 40 to 60 at each age in each sex.

The data of Greulich and Pyle[10] and Pyle et al.[73] were obtained from serial radiographs, by interpolation, on the thesis that onset of ossification occurred between the age at which the center was first visible radiographically and the age at which the last radiograph was taken in which the center was not visible radiographically. The interpolated ages were not necessarily midway between the ages at which these two annual radiographs were taken. However, it is reasonable to assume that the recorded ages were systematically 0.5 year earlier than would have been recorded had these authors applied the more familiar method of recording the age at which the center was first observed. Consequently, to make these findings more comparable, in methodology, with those reported by others, 0.5 year has been added to each modal age reported by Greulich and Pyle[10] and Pyle et al.[73] before it was included in table H. Greulich and Pyle[10] analyzed data from serial radiographs of 100 boys and 100 girls in the Brush Foundation study. These were white youths of upper socioeconomic class living in Cleveland, Ohio, who had been born between 1917 and 1930. Data from the serial study at the Department of Maternal and Child Health at Harvard University were reported by Pyle et al.[73] These youths (16 boys, 14 girls with relevant data) were white and middle-class socioeconomically, and were living in or near Boston, Massachusetts, having been born between 1930 and 1939. The youths whose data were reported by Pyle et al.[73] were included also in the group studied by Harding.[71]

The data of Buehl and Pyle[64] were obtained from a subset of Brush Foundation youths (30 boys). It is not clear whether these authors interpolated ages at ossification in the manner of Greulich and Pyle[10] and Pyle et al.;[73] consequently the reported ages have not been adjusted.

Mixed longitudinal data derived from middle socioeconomic class white youths in southwestern Ohio who were born between 1929 and 1960 were reported by Garn et al.[72] These youths were radiographed within 1 month of each birthday and half-birthday. The sample size was about 180 for each sex in each 6-month interval.

Table H. Modal ages (years) for onset of ossification in selected bones in U.S. white youths

Bone and sex	Modal age from previous studies					United States, 1966-1970
Boys						
Adductor sesamoid	12.1[64]	12.6[73]	12.7[71]	12.8[72]	13.2[10]	12.5
Flexor sesamoid	13.5[10]					14.2
Girls						
Adductor sesamoid	10.5[64]	10.7[72]	10.8[10]	11.0[73]	11.2[74]	10.7
Flexor sesamoid	11.0[10]					13.0

Hansman[74] studied about 50 white boys and 50 white girls of middle socioeconomic status who were enrolled in the program of the Child Research Council, Denver, Colorado. These youths were born between 1915 and 1954.

There is very close agreement between the ages reported by Pyle et al.,[73] Harding,[71] and Garn et al.[72] for the onset of ossification of the adductor sesamoid in boys. It is surprising, however, that both the earliest and the latest ages have been reported from the Brush Foundation.[64,73] In part, this may be methodological. As noted earlier, Buehl and Pyle may have interpolated, in which case 0.5 year should be added to the ages reported by them. The median age for white boys in the national survey is at about the midpoint of the range of modal ages reported by others. In both boys and girls, the flexor sesamoid began to ossify just slightly later in the national survey youths than in the group of youths studied by Greulich and Pyle.[10] These authors have provided the only other set of data on age of onset of ossification for the flexor sesamoid of youths in the United States.

In reviewing data for youths of European ancestry living outside the United States, emphasis will be placed on those countries from which large numbers of immigrants have come to the United States. Joseph[75] reported data concerning the onset of ossification in the adductor sesamoid for English youths living in London, but the sample size and the method of reporting do not allow useful comparisons between his conclusions and those of the present national survey. Sempé[76] reported median ages for the onset of ossification of the adductor sesamoid and flexor sesamoid in French youths (91 boys, 89 girls) generally of middle socioeconomic status living in Paris (table J). These youths were born in 1953 and radiographed close to birthdays and half-birthdays. Rudzinski[77] reported modal ages for the onset of ossification of the adductor and flexor sesamoids based on mixed longitudinal data from 6-month radiographs of 91 Polish boys in Warsaw. These ages for youths in Paris or Warsaw are slightly later than the estimates for U.S. white youths in the present national survey (table J), with the exception of the flexor sesamoid in girls. It is stressed, however, that all these differences are small.

Table J. Modal ages (years) for onset of ossification in youths of European ancestry living in Europe

Bone and sex	Modal age	
	Sempé, 1970[76]	Rudzinski, 1970[77]
Boys		
Adductor sesamoid	13.0	13.0
Flexor sesamoid	14.0	13.5
Girls		
Flexor sesamoid	12.0	---

NOTE: Sempé—French youths in Paris; Rudzinski—Polish youths in Warsaw.

Comparisons can be made between reported modal ages for the onset of ossification in some hand-wrist centers in Negro youths living in the United States and Negro youths living in Africa. The differences are not easily interpreted because it is impossible to identify groups of Negro youths in the United States or Africa that belong to the same relatively homogeneous genetic pool. The data considered for Negro youths in Africa relate to the part of Africa from which large numbers of slaves were transported to the United States,[78,79] but, almost certainly, the present U.S. Negro population is unrepresentative of the original slaves and the slaves were unrepresentative of the African populations from which they were taken.

Michaut-Barthod[80] reported data from 628 radiographs of Ovoloff youths of low socioeconomic status living in Dakar (Senegal). Most of these youths were radiographed three times near birthdays or half-birthdays. About 40 radiographs were available for each sex at each 6-month interval. Although all the youths were more than 11 years of age at the time of their first radiograph, the data are useful for comparative purposes. Masse and Hunt[81] reported cross-sectional data from children of Ovoloff ethnic origin living in Dakar. The sample included 45 to 95 children of each sex in both age groups. The data of Michaut-Barthod[80] and Masse and Hunt[81] make it clear that the onset of ossification tends to occur considerably earlier in U.S.

Negro girls than in African Negro girls they studied, but the corresponding differences are smaller for boys.

Sutow[42] reported data from normal Japanese youths of all socioeconomic levels in Hiroshima. The sample size for each sex varied from 67 to 104 for each year of age. The ages at onset of ossification that he reported (boys: pisiform 12.3 years, adductor sesamoid, 14.0; girls: adductor sesamoid, 11.8 years) are considerably later than those found in Cycles II[2] and III[1] of the Health Examination Survey. As pointed out earlier in this report, it is likely that the current ages of onset of ossification in Japanese youths are much closer to those of youths in the United States.

EPIPHYSEAL FUSION

The national survey data were used to estimate median ages at epiphyseal fusion by interpolating between prevalence data for annual age groups. This allowed reasonably accurate estimates for all relevant bones except the radius in each sex and the ulna in the boys. The order of median ages was closely similar in each sex and in both white and Negro youths. Fusion tends to occur earlier in white boys than in Negro boys (table 16). For about half the bones (metacarpal I, proximal phalanges I-V, and middle phalanges II-V) these bone-specific differences are statistically significant at the 5-percent level. The bone-specific racial differences in median ages at epiphyseal fusion are less consistent in the girls. About half these median ages are earlier in white girls than in Negro girls; and nearly half are earlier in Negro than in white girls. Fusion occurs significantly (5-percent level) earlier in white girls than in Negro girls for metacarpal I, proximal phalanges I-V, and middle phalanges II-V. An opposite tendency, also significant at the 5-percent level, is present, however, for the ulna; metacarpals II-V; and distal phalanges I, II, and IV.

Table K. Modal ages for epiphyseal fusion in the hand-wrist of U.S. white youths

Hand-wrist bone	Boys	Girls	United States, 1966-1970	
			Boys	Girls
	Modal age			
Radius	18.0[74]	15.8[74]	---	---
Ulna	17.8[74]	15.9[74]	---	16.2
Metacarpal I	16.3[74,82]	14.1[74,82]	15.8	13.8
Metacarpal II	16.4,[82] 16.5[74]	14.5,[74] 14.6[82]	16.5	14.8
Metacarpal III	16.4,[82] 16.5[74]	14.5,[74] 14.6[82]	16.6	14.8
Metacarpal IV	16.4[74,82]	14.4,[74] 14.6[82]	16.6	14.9
Metacarpal V	16.5[74,82]	14.4,[74] 15.0[82]	16.6	15.0
Proximal phalanx I	16.2,[73,74] 16.3[82]	14.2,[74] 14.3,[73] 14.4[82]	16.3	14.0
Proximal phalanx II	16.3,[82] 16.4[74]	14.2[74,82]	15.9	14.0
Proximal phalanx III	16.2,[73] 16.3[74,82]	14.2,[74] 14.5[82]	16.1	14.1
Proximal phalanx IV	16.2,[82] 16.5[74]	14.2[74,82]	16.1	14.1
Proximal phalanx V	16.2[74,82]	14.2[74,82]	15.8	14.0
Middle phalanx II	16.4[74,82]	14.2[74,82]	16.1	13.9
Middle phalanx III	16.4,[82] 16.5[74]	14.4,[74] 14.5[82]	16.3	14.1
Middle phalanx IV	16.4[74,82]	14.3,[74] 14.5[82]	16.3	14.1
Middle phalanx V	16.3,[74] 16.4[82]	14.2,[74] 14.3[82]	16.3	14.0
Distal phalanx I	15.7,[82] 15.9[74]	13.5,[82] 13.6[74]	15.7	13.5
Distal phalanx II	15.7,[73] 15.8,[74] 16.0[82]	12.5,[64] 13.6,[74,82] 13.7[73]	15.8	13.5
Distal phalanx III	16.0[74,82]	13.6[74,82]	15.8	13.5
Distal phalanx IV	15.8,[74] 16.0[82]	13.6[74,82]	15.6	13.4
Distal phalanx V	15.9,[74] 16.0[82]	13.6[74,82]	15.7	13.4

Previous Studies

Data from other studies of white youths living in the United States are included in table K. There are no previously reported data for Negro youths in the United States. Hansman[74] reported data on Denver, Colorado, youths of above average socioeconomic status who were radiographed at 6-month intervals. These youths (about 30 of each sex) were born between 1915 and 1941.

Data from a small group (N = about 12 for each bone in each sex) of Boston youths have been reported by Pyle et al.[73] These middle class youths who were born between 1930 and 1939 were radiographed annually. In interpreting these data, it is important to recall that the relatively late-maturing males are underrepresented because the study was discontinued before all had matured.

Buehl and Pyle[64] reported data from 30 boys and 30 girls of upper socioeconomic status enrolled in The Brush Foundation Study, Cleveland, Ohio, who were examined serially. Findings from 107 youths in southwestern Ohio who were slightly above average socioeconomically have been reported by Garn et al.[82] In all these studies, as in the national survey, epiphyseal fusion was considered to be present when the epiphyseal cartilage had been completely replaced, even if a radio-opaque line persisted at the junction.

In general, the national survey estimates are close to those reported for these smaller, less representative groups; the match is particularly close for girls. The median ages for boys from the national survey are earlier than those in the previous reports for metacarpal I, proximal phalanges II and V, middle phalanx II, and distal phalanges IV and V. In girls, the national survey ages are earlier than those reported previously for middle phalanges III and IV and later for metacarpal IV.

There are few sets of satisfactory data reported for youths living abroad. Ages at which epiphyseal fusion occurred, using cross-sectional data from 1,613 Japanese children and adolescents, have been reported by Russell et al.[83] Although the subjects had been *in utero* in Hiroshima or Nagasaki at the time of the atomic bombing, there was no evidence that the age of closure was related to the estimated radiation exposure dose. The ages reported by Russell et al.[83] indicate that fusion occurred about 7 months later than in U.S. youths (table L). These findings are in general agreement with those of other workers who have studied groups of Japanese youths.[42,43,84]

Table L. Reported ages of epiphyseal fusion in Japanese youths

Hand-wrist bone	Russell et al., 1973[83]		Sutow, 1953[42]	
	Boys	Girls	Boys	Girls
Radius	18.75	17.75	18.8	17.5
Ulna	18.25	17.25	18.7	17.3
Metacarpal I	16.25	14.75	---	---
Metacarpal II	16.75	15.50	---	---
Metacarpal III	16.75	15.25	---	---
Metacarpal IV	17.0	15.5	---	---
Metacarpal V	17.0	15.75	---	---
Proximal phalanx I	16.75	15.25	---	---
Proximal phalanx II	16.75	15.0	---	---
Proximal phalanx III	16.75	15.0	---	---
Proximal phalanx IV	16.75	15.25		
Proximal phalanx V	16.75	15.0	---	---
Middle phalanx II	16.75	15.25	---	---
Middle phalanx III	17.0	15.5	---	---
Middle phalanx IV	17.0	15.5	---	---
Middle phalanx V	16.75	15.0	---	---
Distal phalanx I	16.0	14.5	---	---
Distal phalanx II	16.25	14.5	16.3	14.5
Distal phalanx III	16.25	14.5	---	---
Distal phalanx IV	16.5	14.75	---	---
Distal phalanx V	16.5	14.5	---	---

Median ages at fusion in the third proximal, middle, and distal phalanges of Danish boys are very similar to those estimated from the United States National Survey.[85]

DISCUSSION

There is no doubt that youths of different racial groups vary in body size and in levels of skeletal maturation and sexual maturity at corresponding chronological ages.[86-91] The factors that control the rate of skeletal maturation must act by influencing the formation or resorption of bone. The possible factors are related to genes, nutrition, illness, and climate, *inter alia*, but few studies have been designed so as to sep-

arate the possible effects of these factors. Consequently, knowledge is almost entirely lacking concerning the effects of relatively precise environmental factors (e.g., protein intake, temperature), on rates of skeletal maturation in youths or of specific groups of genes (e.g., autosomal, sex-linked).

This discussion will relate to the factors considered in this report (race, geographic region, size and type of community, family income, parental education) that could have been associated with real population differences in skeletal maturity levels. The findings from the present survey will be discussed in relation to the findings from the corresponding study of children age 6-11 years[3] and in relation to reports based on findings from smaller less representative groups. In interpreting these findings, it should be recalled that the national surveys are the only source for national estimates of skeletal maturity levels. The sampling technique employed ensured that a truly representative sample was chosen for each survey. Of the children chosen, 96 percent were examined; the corresponding figure for the youths is 90 percent. Consequently, these national surveys can provide reasonably reliable estimates for the entire U.S. population of children and youths.

Race

It is difficult to interpret racial comparisons because, almost always, the groups compared differ not only genetically but in environmental factors, particularly in nutrition and the incidence of disease. The importance of genetic factors is clear from studies of the timing and pattern of onset of ossification and the occurrence of skeletal variants (e.g., pseudoepiphyses) in pairs or triads of individuals sharing similar environments but different proportions of genes.[65,92-111] These studies indicate that the extent of the differences within pairs or triads are approximately inversely related to the percentage of genes shared in common.

Skeletal age (hand-wrist).—The two national surveys show that Negro boys tend to be more mature skeletally than white boys at 6-9, 11, and 13 years, but the reverse is true at the other ages. White girls, however, are less mature skeletally than Negro girls throughout the whole age range except at age 16-17 years. There are no consistent white-Negro differences in the variability of skeletal age. These findings indicate possible changes with age in racial differences (white-Negro) relating to skeletal maturation in boys and girls, but the patterns vary between the two sexes. Soon after birth, centers of ossification are more numerous in newly born Negroes than in whites; this is true for Negroes living in Africa as well as for those living in the United States. This acceleration in Negroes occurs despite their generally less favorable socioeconomic circumstances.[111-115] This advancement of Negroes in onset of ossification has been reported up to about 7 years of age.[116,117] However, as noted earlier in the national surveys, Negro youths were more advanced in skeletal maturation than white youths only until age 13 years (and then not at all ages) in boys and until 16-17 years in girls. Age-related patterns of racial differences in skeletal maturity have been noted by Lee et al.[118] These workers reported that Chinese children in Hong Kong were advanced in onset of ossification over U.S. children when early-appearing hand-wrist centers were considered, but an opposite tendency was present for late-appearing centers.

In the national survey data there are only slight differences between the mean values for skeletal age in Negro and white youths within each sex. The small size of these differences and their inconsistency across age and sex are in agreement with reports by Todd[24] and Malina[33-35] and Malina et al.[36] that white-Negro differences are inconsequential during the age range 12-17 years. The substantial acceleration of skeletal maturation in U.S. Negroes compared with those in Jamaica or Dakar[37,38] presumably reflects environmental effects.

Previous studies of groups of white U.S. boys[10,16-19,21-23] are not in complete agreement with the national survey findings that the mean skeletal ages of U.S. white boys are considerably less than the mean chronological ages at 9-12 years. While Flory,[16] Todd,[18] and Maresh[22] reported low mean skeletal ages during this age range, the patterns of change with age in their data differed from those in the national sample. It must be stressed that these earlier studies were of less representative groups of youths in the United States, and most of the

studies were not based on bone-specific skeletal ages. A further factor to be considered is the level of reliability of assessments of skeletal maturity.

The national survey data for white girls (female equivalent values) are generally similar to those for boys with two exceptions: the retardation of the mean skeletal ages from 9 to 12 years is less marked, and there is a marked and rapid retardation after 15 years. The data of Flory[16] indicate an even greater skeletal retardation of girls at 9-12 years, but the early literature contains no hint of the change in relative level after 15 years that is so marked in the national survey data. As discussed earlier,[1] this is almost certainly due to the fact that all the national survey radiographs were assessed, without identification by sex, against a single set of male standards. Later the values for girls were transformed to female equivalent values using a set of sex-associated differences in skeletal age provided by Dr. S. Idell Pyle. These sex differences were derived by Dr. Pyle after a painstaking study of radiographs.[9] However, to take the extreme example, the means of the skeletal ages assigned to boys and girls age 17 years on the male standards differed by only 5.9 months, whereas the difference of 22 months as reported by Pyle et al.[9] was used in the transformation. The actual sex difference on the male standards was greater than reported in the HES Standard[9] at the earlier ages. Its marked reduction at later ages was due only slightly to the exclusion of girls in whom all the hand-wrist bones had become adult.

The previous literature for U.S. youths would lead one to expect that epiphyseal fusion would be complete throughout the hand-wrist of a typical girl age 17.5 years, but that fusion would not have occurred at the distal ends of the radius and ulna in a typical boy of the same age.[73,74,82] Also, these earlier studies lead to the expectation that in a majority of the girls age 17.5 years it would be impossible to assess the hand-wrist because all the bones of this area would be adult. In the national survey data this occurred in 22 percent of the girls. If a skeletal age of 19.1 years were assigned to each of these girls (19.1 years is the highest maximum value for any bone on the male standards) this would have very little effect on the sex-associated differences in skeletal maturity, as calculated previously. This matter is discussed more fully in the earlier report.[1]

There is no evidence of a secular trend in skeletal maturation rate when the data for white U.S. children and youths are compared with reported findings from earlier studies. This is true whether the comparison is with the sets of data in figures 1-4[10,16-19,21,22] or with data reported still earlier from New England children and youths, 24 percent of whom were of Italian ancestry.[119,120]

It is not easy to interpret the apparent absence of secular trends when data from the national surveys are compared with data from less representative groups—sampling variations may mask real differences or alternatively any differences found may be due to sampling variations. These methodological problems can be overcome only by repeated national surveys, but it is interesting to note some findings from long-term serial studies of unrepresentative groups in the United States.

In the group of southwestern Ohio children and youths studied at the Fels Research Institute, real secular trends are not apparent over a period of 36 years, when skeletal age is regressed against year of birth (table M).[121] Similarly, in the same group, the mean relative differences for RWT (Roche, Wainer, and Thissen) skeletal ages between parent-offspring pairs, within sex, are small and inconsistent in direction (table N). RWT skeletal ages are obtained from the knee, but there is no reason to believe that this area is any less representative of the whole skeleton than is the hand-wrist.[61] These findings show that little if any secular trend has occurred during recent decades in a group of children and

Table M. Correlation coefficients between skeletal age (Greulich-Pyle) and year of birth in the Fels Longitudinal Study (Roche, unpublished data)

Chronological age	Boys		Girls	
	N	*r*	*N*	*r*
3 years	112	−0.016	118	+0.187
6 years	120	−0.088	105	+0.162
9 years	91	+0.179	82	+0.185
12 years	73	−0.011	73	+0.105

NOTES: None of these coefficients is significant at the 5-percent level.

N = number of subjects; *r* = simple correlation coefficient.

Table N. Mean relative differences between parent-offspring pairs in skeletal age (RWT, knee in years)

Chronological age	Difference					
	Father-son			Mother-daughter		
	N	Mean	s_x	*N*	Mean	s_x
6 years	25	−.33	1.16	33	−.16	1.17
7 years	24	−.15	1.36	35	+.21	1.10
8 years	23	+.40	1.14	32	+.23	1.40
9 years	25	+.29	1.32	29	+.08	1.35
10 years	21	+.12	1.45	19	−.35	1.28
11 years	17	+.16	1.32	20	−.95	1.52
12 years	14	+.24	1.89	21	−.14	1.00
13 years	8	+.04	1.36	17	−.15	0.98
14 years	9	+.17	0.75	17	−.32	1.15
15 years	8	−.93	0.59	19	−.62	1.71
16 years	8	−.02	0.51	10	−.57	1.48

NOTE: + = parent more mature; *N* = number; s_x = standard deviation.

youths of middle socioeconomic status when effects of sampling variability are largely removed. These findings are in close agreement with those of Maresh[122] who reported data from a middle socioeconomic group in Denver, Colorado. Taken together, these studies suggest that secular trends in skeletal maturation rates are absent or very slight in white U.S. children and youths of middle socioeconomic status. Of course, due to the method of group selection, these findings cannot be extended to all socioeconomic levels and geographic regions as the national survey data can for youths in the United States.

The tentative conclusion that secular changes in the rates of skeletal maturation may no longer be occurring in the U.S. population should be considered in relation to secular changes in body size. After a close analysis of data recorded in national probability samples between 1962 and 1974,[90,123,124] it was concluded there was no evidence of a secular trend in either stature or weight during this period except for a slight change at the lower percentiles. Thus the data for body size are in agreement with the tentative conclusion that has been reached in regard to skeletal maturation.

Variability.—The national survey findings concerning possible white-Negro differences in the variability of skeletal age are inconsistent suggesting that, if such differences do occur, they must be small. In each of these racial groups skeletal age was more variable for the boys than for the girls. This is in agreement with earlier reports.[16,19,38,39,52] Presumably it is due, at least in part, to truncation of the distributions for girls as they approach the upper limit of the skeletal maturity scale.

Bone-specific skeletal ages.—The national survey data show that, among boys 12-17 years, the mean skeletal age of each hand-wrist bone is more advanced in the whites than in the Negroes, although the individual differences are not large enough to be statistically significant. There is an opposite tendency among girls but this also is not statistically significant. The directions of these differences within each sex, at 12-13 years, match those reported by Malina et al.[36] and by Malina.[53] As would be expected from the findings for mean skeletal ages, the white-Negro differences in bone-specific skeletal ages are, however, in the reverse direction to those found in the national survey of children.[3] In the earlier survey, most of the individual hand-wrist bones were less mature in the whites than in the Negroes.

In the national survey data, there are no consistent white-Negro differences in the mean ranges of bone-specific skeletal ages or in the variability of these ranges within individual hand-wrist radiographs. In both Negro and white groups, the means of the bone-specific skeletal ages are less variable in boys than girls, but the range of bone-specific skeletal ages is greater in boys than in girls.

Onset of ossification.—Only for the adductor and flexor sesamoids in boys and the flexor sesamoid in girls do the modal ages of onset of ossification occur during the age range of the present survey (12-17 years). White boys are very slightly advanced over Negro boys in median ages for the onset of ossification in these bones (0.3 year); the corresponding difference for the flexor sesamoid in girls is trivial (0.1 year). These findings are consistent with the small, statistically nonsignificant white-Negro differences in mean skeletal age and bone-specific skeletal ages. The national survey data are close to those reported for other groups of white youths in the United States except for the flexor sesamoid in boys. The only previous estimate for this bone[10] is considerably earlier. There are no pre-

vious estimates for Negro youths in the United States.

Epiphyseal fusion.—The national survey data allow estimates for the median ages at epiphyseal fusion for all hand-wrist bones that develop epiphyses except the radius in both boys and girls and the ulna in boys only. In the latter bones, the median ages are too late for them to be estimated accurately from the present data. There is no evidence of a racial difference in the sequence of fusion, but fusion tends to occur earlier in white boys than in Negro boys. This would be expected from the racial differences in skeletal maturity levels for boys. Both in girls and in boys there is a consistent pattern of statistically significant differences in ages at epiphyseal fusion between white and Negro youths (metacarpal I, proximal phalanges I-V, and middle phalanges II-V); these ages are earlier in whites than in Negroes. There is a significant racial difference in the opposite direction in girls for the ulna, metacarpals II-V, and distal phalanges I, II, and IV. This is in agreement with the finding that white girls are less advanced skeletally than Negro girls at 12-15 years although the reverse is true at 16-17 years. The estimated ages at fusion for white boys and girls are very similar to those reported by others for smaller groups of U.S. youths;[64,73,74,82] there are no comparable data for Negroes in the United States.

Geographic Region

Very few studies of regional factors allow the separation of genetic and specific environmental effects. Regional differences, within the United States, in the incidence of illness, based on the same regions considered here, will be provided in later NCHS reports. Regional differences in nutritional status have been reported from the Ten-State Nutritional Survey,[125] and anthropometric differences have been reported in a previous NCHS report.[124]

An earlier report[3] provides estimates of regional differences in the skeletal ages of U.S. children 6-11 years. After removal of the effects of age differences and varying racial distributions among regions, there was a tendency for U.S. children in the Northeast and Midwest Regions to be slightly advanced in skeletal maturity compared with those in the other regions. However, most of these regional differences relating to children age 6-11 years could have been due to chance.

The data for U.S. youths (boys and girls) from the present survey reveal only small regional differences after age-related and race-related effects are removed. Those in the South are slightly more advanced skeletally and those in the Midwest slightly less advanced than those in the Northeast and West, but these differences were not statistically significant. Sampling variability could have been responsible for the variation between this pattern for youths and that reported previously for children.[3] If the skeletal maturity of U.S. youths indeed differs by geographic region, this was obscured by the large heterogeneous regions into which the United States was divided when the national survey data were analyzed.

If real differences between geographic regions had been found, it could have been postulated that climatic factors were responsible. Despite suggestions, there is no convincing evidence that tropical climates retard skeletal maturation,[126,127] although it does appear that warm climates retard age of menarche.[128] There are severe difficulties in interpreting the reported data because there has not been control of many confounding variables in the study design or the statistical analysis. While heat promotes calcification experimentally,[129,130] this is doubtfully relevant. Studies of experimental animals in extreme environmental temperatures[118,131-133] suggest that heat accelerates skeletal maturation, but large ambient temperature differences between the control and experimental groups are needed to produce this effect.

If significant differences had been found between the skeletal maturity of groups of youths separated by geographic region, it would have been difficult to associate these differences with climate. The fact that significant differences were not found may reflect the diversity of these large regions and, perhaps, migration between them. If the aim had been to demonstrate the existence of regional differences, a more appropriate sampling (e.g., of those living at high altitudes, in the desert, or in the arctic region) would have been employed. However interesting, such a study would be less important

in relation to public health within the United States than the present estimates for very large groups.

Bone-specific skeletal ages.—The differences between the mean bone-specific skeletal ages for groups separated on the basis of geographic region are inconsistent. This would be expected from the lack of statistically significant differences between the mean skeletal ages for groups of youths in the four large geographic regions of the United States. The mixed pattern of advancement and retardation among the bone-specific skeletal ages for each region is inconsistent for the two sexes. This indicates a lack of major differences among the regions in their general levels of factors, as an example, nutrition, known to affect the rate of skeletal maturation. Similarly, there are only small differences among the geographic regions in the median ranges of bone-specific skeletal ages within single radiographs. There is, however, a slight tendency for the median ranges to be larger for boys in the West and for older girls in the Northeast.

Onset of ossification.—There were almost no regional differences in the mean ages of onset of ossification for either the adductor sesamoid or the flexor sesamoid except that the flexor sesamoid in boys ossified somewhat earlier in the Midwest.

Urban-Rural

There are no consistent urban-rural differences in mean skeletal ages either for youths in the present national survey or for children in the previous survey.[3] However, among youths but not among children, there is a slight tendency for skeletal maturation to be advanced in those living in large urban areas (population exceeding 3 million). Presumably, the absence of real differences between urban and rural areas reflects the heterogeneous nature of the environment within these groupings and the lack of major urban-rural environmental differences in the United States, as in the case in Australia.[134] This situation differs sharply from that in some other countries where there are major socioeconomic differences between urban and rural areas and associated differences in rates of skeletal maturation and physical growth.[135-142]

Socioeconomic Factors

Skeletal maturation.—The importance of socioeconomic factors in controlling the rate of skeletal maturation, as distinct from age at onset of ossification, has been stressed by several workers.[18,135,143-145] Particularly important data have been reported by Low et al.[39] who recorded Greulich-Pyle skeletal ages for a large group of Hong Kong youths separated into high (N = 3,659), middle (N = 5,227), and low (N = 5,591) socioeconomic groups (table O). This grouping was made using a combination of parents' education, parents' occupation, total family income, and housing.[87] Skeletal maturity level is associated positively with socioeconomic status in these data, but the mean differences are small despite the very wide ranges of socioeconomic status among the groups compared. These comparatively small differences are in agreement with the observations of Grande Covián and Rof Carballo.[146]

Kopczyńska[32] reported data from upper and lower socioeconomic class Polish youths (total N = 3,988) that show a significant association in the expected direction between socioeconomic status and the level of skeletal maturity. Because her data were analyzed on the basis of the percentages of subgroups in whom the chronological age exceeded the skeletal age,

Table O. Mean skeletal ages for southern Chinese youths in Hong Kong at various socioeconomic levels (Low et al., 1964)[39]

Chronological age and sex	Socioeconomic status		
	High	Middle	Low
Boys	Mean skeletal age		
12.0 years	11.5	11.1	11.1
13.0 years	12.8	12.5	12.5
14.0 years	13.9	13.8	13.9
15.0 years	15.3	15.1	15.0
16.0 years	16.6	16.4	16.2
17.0 years	17.7	17.6	17.3
Girls			
12.0 years	12.3	12.1	11.8
13.0 years	13.6	13.3	13.0
14.0 years	14.6	14.5	14.2
15.0 years	15.5	15.4	15.3
16.0 years	16.3	16.3	16.2
17.0 years	17.0	17.0	17.0

direct comparisons cannot be made between these data and those of Low et al.[39] with regard to the magnitude of socioeconomic effects.

Neyzi et al.[147] using data from 2,000 urban Turkish youths of moderately different socioeconomic levels found only slight associations with skeletal maturity levels. The differences were significant only when extreme socioeconomic groups were compared and, even then, only in the girls. These relatively small or absent socioeconomic effects on the rate of skeletal maturation in youths support the contention of Acheson[148] that the slowing of skeletal maturation with an adverse environment has been demonstrated with certainty only in the prepubertal period.

The differences among socioeconomic groups reported by Low et al.[39] for Chinese youths were slightly greater in girls than in boys up to age 15 years. Later, there was a slight sex difference in the reverse direction that may have been due, in part, to some of the girls reaching the upper limit of the skeletal maturity scale. This greater effect in girls is in agreement with the findings of Neyzi et al.[147] In Polish youths, however, the apparent effect of socioeconomic status on skeletal maturity level is greater in boys than girls.[32,149]

Deschamps and Benchemsi[150] reported findings from 4,526 French children and youths examined at ages from 6 to 18 years. The hand-wrist skeletal ages (Greulich-Pyle) of these children were significantly related to the occupation of the father (especially in boys), the level of education of the mother (girls only), the quality of housing (both sexes), and the number of children in the family. Their data were not analyzed within age groups, but the authors report that the differences in skeletal maturity levels with environmental factors were more marked in adolescents, which is in conflict with the report of Frisancho et al.[151] Although many of the differences reported by Deschamps and Benchemsi[150] were statistically significant, the mean differences were rather small (3-6 months of skeletal age), which is in general agreement with other reports from Belgium[152,153] and France.[154]

These variations between studies in sex differences could reflect variations among races in the sensitivity of skeletal maturation to socioeconomic influences, or differences among races between the care of boys and girls classified as being at the same socioeconomic level. These reports draw attention to the slender and inconsistent evidence on which claims are made that skeletal maturation is less affected by environmental factors in girls than in boys.

Andersen, in her analysis of data from Copenhagen children,[28] reported a marked association between skeletal maturity level and the father's occupation and a lesser association with family income. There were no real differences in skeletal maturity levels in relation to employment of the mothers, but crowding of apartments seems to be associated with skeletal retardation in lower socioeconomic groups.

When such skeletal retardation occurs, it is probable that adverse environmental circumstances do not affect all bones equally. Differential effects have been described within the hand-wrist only.[155] If they occur throughout the skeleton, they could lead to differences in body proportions between upper and lower socioeconomic groups. That such differences in proportions are affected by environmental influences may be inferred from data relating to the ratio

$$\frac{\text{sitting height}}{\text{stature}}$$

in Japanese youths, American-born Japanese youths, and American children.[40] This inference is supported also by the marked secular trend in this ratio. Similarly, a secular trend toward a more linear build has been noted in Yugoslavia with improved socioeconomic conditions.[156]

In the present national survey, socioeconomic status was categorized by family income (within wide groupings) and by years of parental education. In the survey data, mean skeletal age is not related consistently to family income. Although there is a slight tendency for it to be slightly more advanced in those with family incomes exceeding $10,000 per year, the lowest income group (less than $3,000 per year) were not the least advanced in either sex. This lack of a clear-cut relationship is not due to a confounding effect of race. Within racial groups, there is no consistent relationship between family income and skeletal maturity. However, within family income groups, white boys tend to be

more mature skeletally than Negro boys for those in families of moderate or lower income levels under $10,000 while white girls tend to be less mature in this respect than Negro girls irrespective of family income level. Similarly, there are no statistically significant differences in skeletal maturity between groups separated according to the length of parental education.

There is also no strong interrelationship between bone-specific skeletal ages and family income. While more advanced ages tend to occur in the upper family income groups, the lowest ages are almost equally distributed between the middle and lower family income groups. The differences among the ranges of bone-specific skeletal ages, within single radiographs, for groups of youths separated by family income are very small and the pattern of differences is inconsistent.

Onset of ossification.—The modal ages reported from previous studies concerning the onset of ossification for youths in the United States of northwestern European ancestry were derived from middle or slightly superior socioeconomic groups (table B). Those studied by Harding[71] were from average middle class families. Findings from youths described as being from a good class of English-speaking people were reported by Baldwin et al.[157] The data of Hansman[74] were derived from upper-middle socioeconomic class youths studied by the Child Research Council, Denver.[158] The youths studied by Flory[16] were also above average in economic and in social status. The youths from whom Garn et al.[72] obtained data were generally of upper-middle socioeconomic status, but not quite as high as the sample of Hansman.[74]

It is difficult to interpret the variations among ages at the onset of ossification reported by these workers in relation to socioeconomic status. Youths in the groups studied by Hansman[74] and Flory[16] appear to have been of slightly higher socioeconomic status than youths in the groups studied by others. If such a difference in socioeconomic status were present, it is not reflected in the data for age at onset of ossification (table H).

The failure of these studies to show socioeconomic effects on age at onset of ossification may be due to the fact that they were not designed for this purpose or, perhaps, such effects are slight. It has been suggested that socioeconomic status has more effect on the onset of ossification in infancy and childhood than in adolescence.[151]

The median ages at onset of ossification, estimated from the national survey data for youths, for the adductor sesamoid in boys and the flexor sesamoid in girls are not related consistently to family income. However, the onset of ossification of the flexor sesamoid in boys is markedly delayed in the lowest family income group. In general, these findings are in agreement with earlier reports that the onset of ossification is rather insensitive to environmental effects, but it is not completely insensitive. This is clear from the rather large differences between corresponding ages for Negroes in the United States and Africa.[80,81]

Epiphyseal fusion.—There are no previous studies of the influence of socioeconomic factors on age at epiphyseal fusion, however, it can be concluded from the data of Low et al.[39] that such differences are probably small. Reported data concerning the age at which growth in stature ceases are not helpful because elongation of the trunk continues after the cessation of elongation in the limbs.[159] Furthermore, serial data from individuals studied until at least age 25 years are not available for low socioeconomic groups. Such data are necessary, however, to determine when growth in stature has ceased in an individual.[160]

The national survey data show the absence of a close interrelationship between socioeconomic status judged by broad groupings of either family income or parental education and various aspects of skeletal maturation (mean skeletal age, bone-specific skeletal ages and their ranges, onset of ossification, and epiphyseal fusion). It is important, however, to stress that these findings relate to only a limited range of socioeconomic status; real effects may be present at lower levels than those studied. If such effects were present, they might reflect the influence of differences in illness experience and diet. The literature concerning these factors will be reviewed briefly.

Illness

Onset of ossification.—The influence of illness on age at onset of ossification in children has

been reviewed recently.[2] There have not been corresponding reports for youths, perhaps because so few centers begin to ossify between 12 and 17 years in the areas of the skeleton that are usually radiographed for skeletal age assessments. The evidence indicates that the usual illnesses of childhood have little or no effect, but when effects occur they may differ among bones. There is little doubt that very severe illnesses retard the onset of ossification in children, but all the previous reports for children have come from either the Brush Foundation Study or the Fels Research Institute. These reports relate to "normal" volunteers in whom severe illnesses were uncommon. Additionally, the timing of radiographic examinations was scheduled according to chronological age; it was not planned to maximize the possibility of demonstrating the effects of illnesses. In a schedule designed for this purpose, examinations would be made before, during, and after each illness.

It has been claimed that unusual orders of onset of ossification are due to illnesses near the time of ossification of particular centers; as a result ossification of these centers is delayed.[10,18,62,64] The report of Garn and Rohmann[161] for children, and that of Hansman and Maresh[66] for children and youths do not support this view. If illnesses had such an effect, they would be associated with increases in the ranges of bone-specific skeletal ages within radiographs. This subject has not been studied adequately; reports based on very few individuals have led to conflicting conclusions.[148,162,163] In a large-scale study, it has been shown that the median order of onset of ossification in the hand-wrist is the same in Guatemalan boys as in boys in southwestern Ohio and that the variability of sequence was similar in both groups, although illnesses were much more common in the Guatemalans.[164]

Skeletal maturation.—In youths, skeletal maturation is retarded by severe illnesses but it accelerates during the catchup growth that may follow the illness.[165] The nature of the illness may be important. Bashe and Ratner[166,167] assessed 1,054 hand-wrist radiographs of children and youths hospitalized because of tuberculosis. About half of these patients were Negro and all were of low socioeconomic status, despite which many were skeletally advanced. In these patients there was no apparent relationship between skeletal maturity level, or the ranges of bone-specific skeletal ages within individuals, and either the severity or the duration of the disease.

Epiphyseal fusion.—Reports are not available concerning the influence of generalized illnesses on age at epiphyseal fusion.

Diet

There is no doubt that undernutrition retards the onset of ossification and skeletal maturation and, presumably, it retards epiphyseal fusion. Many studies are difficult to interpret because of confounding variables and the lack of reliable information concerning specific dietary factors. Commonly of course, undernutrition is associated with a high incidence of disease, poor housing, and racial differences.

Onset of ossification.—There is convincing evidence that malnutrition retards the onset of ossification, but during adolescence these effects tend to be small[151] or absent.[168] Dreizen et al.,[169] using serial radiographs, studied the onset of ossification in 541 undernourished white urban children and youths in Alabama. There was a marked delay that tended to be greater in girls than in boys (table P).

In general, in the data of Dreizen et al.,[169] the standard deviation levels for ages at onset of ossification in the late ossifying bones (adductor and flexor sesamoids) were higher than those for bones that ossify during childhood. This is in contrast to the claim of Frisancho et al.[151]

Skeletal maturation.—Undernutrition retards skeletal maturation and dietary supplementation accelerates it in youths.[145,146,155,170-175] These effects are less marked in girls than in boys.[155] Skeletal maturation is slow also in youths with inflammatory bowel disease;[176]

Table P. Retardation (years) in age of onset of ossification of hand-wrist centers in malnourished white youths (data of Dreizen et al., 1958)[169]

Hand-wrist bones	Boys	Girls
Adductor sesamoid	−0.1	−0.7
Flexor sesamoid	−0.7	−1.1

this may be a result of the associated malnutrition.

Few have studied the effects of specific nutrients, but an increased rate of maturation in skeletally retarded youths occurs after the milk intake is increased.[171,177] Mack and Urbach[172] showed that restriction of calories, in association with a protein intake at the recommended level, resulted in retardation of skeletal maturation. Others consider that the level of protein intake may be a more important factor than the level of caloric intake.[89] Both workers may be reporting correctly; the difference between the reports could reflect differences between the groups studied in their deficiencies of specific nutrients or groups of nutrients; the bulk of the evidence shows that skeletal maturation is retarded in undernourished youths whether the main lack is in calories or proteins.[151,173,178]

Malnutrition apparently has a differential retarding effect across bones. Dreizen et al.[179] reported that the carpals and the bones of the fifth finger were more retarded than other hand-wrist bones in undernourished Alabama children and youths of British ancestry. An attempt was not made, however, to establish whether there were corresponding real differences in bone-specific skeletal ages in well-nourished children within the same population group. It is well to be cautious when assessing their conclusions. The differences reported by Dreizen et al.[179] could reflect variations between these workers and Greulich and Pyle in the ways in which bone-specific skeletal ages were assessed.

Massé and Hunt[81] have claimed that skeletal retardation due to malnutrition is less marked in the carpals than in the short bones of the hand-wrist. Whichever of these conflicting views is correct, acceptance of Todd's attitude[18] that one should use the most advanced centers as a guide to actual maturity would lead to the employment of the centers that are least sensitive to environmental influences. This would be inappropriate in many circumstances.

In general, overnutrition has effects in experimental animals that are the opposite to the effects of undernutrition.[180,181] The changes in overfed animals resemble those in overweight or obese youths,[182-191] although a significant association between overnutrition and accelerated skeletal maturation was not found by Hortling et al.[183] except in obese adolescents who were also short.

Within age groups, the level of skeletal maturity is correlated positively with weight and subcutaneous fat thickness,[15,186,192] but this relationship is not close. The acceleration of skeletal maturation is more marked in those who have been obese for a long time[190] or in whom lean body mass is increased.[193] It has been reported that the effect of overnutrition on the rate of skeletal maturation is equal in both sexes;[191] others consider the effect more marked in girls than boys.[190] Furthermore, it has been claimed that the acceleration of skeletal maturation in obese youths is more marked in the late than in the early ossifying carpals.[191] Probably, however, this reflects only the greater variability of the ages at onset of ossification in the carpals that are late to ossify.

Epiphyseal fusion.—Data from malnourished children and youths who received a milk supplement have been reported by Spies et al.[174] With supplementation, skeletal maturation was accelerated in the children, but in the youths there was no reduction in the delay of epiphyseal fusion.[145] It has been claimed that malnutrition delays epiphyseal fusion to similar extents in each sex and in each bone.[145] It is difficult to determine the accuracy of this claim because satisfactory reference data for the sequence of epiphyseal fusion and the distribution of ages at epiphyseal fusion have not been available.

SUMMARY

In this report, data for the skeletal maturity of the right hand-wrist in noninstitutionalized youths age 12-17 years are analyzed and described in respect to race, geographic region, size and type of community, family income, and parental education. The original data were obtained from radiographs taken during the Health Examination Survey of 1966-1970. For this survey, a representative sample of 7,514 youths was chosen from the entire U.S. population within the age range 12-17 years. Examinations were made of 90 percent (6,768) of the youths who had been chosen.

The radiographs were assessed, bone by bone, by specially trained medical students who did not know either the age or the sex of any youth whose radiograph was assessed. This removed several sources of bias. The assessments were all made against male standards, thus providing a unique opportunity to establish the true extent of the sex-associated differences in rates of skeletal maturation. Later, the ages assigned to the girls were adjusted to female equivalent values, using a set of sex-associated differences in skeletal maturity reported by Pyle et al.[9] In this summary, reference will be made not only to the data from the present survey but also to the data from the corresponding survey of children 6-11 years.[2,3]

Negro boys tend to be more mature skeletally than white boys at 6-9, 11, and 13 years, but not at other ages within the range 6-17 years. Negro girls, however, are more mature skeletally than white girls at all ages except 8, 16, and 17 years. It must be stressed that the differences between the means are small, which is in agreement with several earlier reports. The mean skeletal ages for both white and Negro boys are markedly less than the mean chronological ages at 9-12 years, showing, as reported earlier, that the Greulich-Pyle Atlas standards during this age range are set much too high for the total U.S. population. There is a similar pattern in the girls, but the differences between the mean skeletal and mean chronological ages are smaller. While the levels of skeletal maturity for whites in the United States are close to those reported for northern European children, levels of skeletal maturity for Negroes in the United States are substantially accelerated compared with groups of Negroes in Africa and Jamaica.

In the girls, whether white or Negro, the skeletal ages (female equivalent values) are markedly retarded (less than chronological age) after 15 years. Almost certainly, this is due to the use of inappropriate sex differences to transform to female equivalent values the skeletal ages obtained against the male standards. A survey of earlier literature had led to the expectation that almost all hand-wrist bones would be adult in a typical girl at 17.5 years; actually, only 22 percent of the girls age 17.0-17.9 years had all their hand-wrist bones mature. Even if the maximum value of the male set of standards were assigned to each excluded girl, this would have influenced only slightly the mean skeletal ages (female equivalent values) for the girls. The large retardation of female equivalent values at older ages is, almost certainly, due largely to the inaccuracy of the sex-associated differences used to obtain the female equivalent values.

There is no evidence that the bones of U.S. children and youths are now maturing more rapidly than in recent decades. There is evidence that any such changes have been absent or slight in white U.S. children of middle socioeconomic status; conclusions for the total population await the analysis of data from repeated national surveys.

Mean skeletal ages tend to be more advanced in Negro boys than in white boys at most ages up to 10 years but not, in general, later. The mean skeletal ages tend to be more advanced in Negro than in white girls at all ages except 8, 16, and 17 years. The mean hand-wrist skeletal ages are more variable in boys than in girls, but there are no consistent differences in variability between white and Negro youths. There are statistically significant differences in bone-specific skeletal ages between white and Negro groups of boys when each bone is considered separately, but there is a general tendency for each bone to be more mature in white than Negro boys from 12 to 17 years. The slight tendencies noted are in the reverse direction to those reported earlier from the national survey of children. Similarly, the white-Negro differences in both the mean ranges of bone-specific skeletal ages within single hand-wrists and in the variability of these ranges are too small to be statistically significant. In the girls, there is an opposite tendency that is not significant for the majority of the individual bones to be more mature in Negro than in white girls from 7 to 17 years.

The white-Negro differences in both the mean ranges of bone-specific skeletal ages within single hand-wrists and in the variability of these ranges are too small to be statistically significant. Also, there are no consistent white-Negro differences in the ages at onset of ossification of the adductor and flexor sesamoids.

Epiphyseal fusion, judged from the median ages, occurs in the same sequence in both white and Negro youths. Fusion occurs significantly earlier in white than in Negro youths of both

sexes in metacarpal I, proximal phalanges I-V, and middle phalanges II-V. Among girls there are also significant racial differences in the opposite direction for the ulna; metacarpals II-V; and distal phalanges I, II, and IV.

After adjusting for effects associated with chronological age and racial distribution, U.S. children age 6-11 years in the Northeast and Midwest Regions tend to be somewhat advanced skeletally, although much of the observed difference could have been due to chance.[3] Among youths in the United States age 12-17 years, the differences in skeletal maturity between regions are small also. Youths in the South tend to be more advanced and those in the Midwest less advanced than youths in the other two regions.

There are inconsistencies between variations by geographic region in mean skeletal ages and those in age at onset of ossification. In part, this may reflect the few hand-wrist bones in which ossification had not occurred by age 12 years. If there are real regional differences in the United States, it is probable that they occur only among much smaller regions than those analyzed. When each region is considered as a whole, there are only minor differences among the four large heterogeneous regions into which the United States was divided for the purpose of this national survey.

The earlier literature indicates that socioeconomic factors exert a definite influence on the rate of skeletal maturation, but these effects are small unless extreme groups are compared. The present national survey data are consistent with these earlier findings.

Within both white and Negro groups of youths, mean skeletal age is not related consistently to family income. Nevertheless, except at the extremes of family income where the estimates are less reliable because of small sample size, white boys tend to be more mature skeletally than Negro boys and white girls less mature in this respect than Negro girls within corresponding family income groups. In the national survey data, there is a similar pattern of inconsistent differences associated with family income for bone-specific skeletal ages, the range of these ages within individual radiographs, and onset of ossification. However, the data relating to onset of ossification are somewhat more consistent, especially in girls, but the differences between family income groups are small.

In the present report, numerous references have been made to earlier studies of smaller and less representative groups of youths in this country and abroad. These other studies have provided much important information, but the data from the present national survey together with those from the previous survey of youths[1,3] provide, for the first time, estimates that are applicable to the total U.S. population in the age range 6-17 years.

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LIST OF DETAILED TABLES

Table 1. Mean, standard deviation, and standard error of the mean skeletal age (hand-wrist) of youths by race, chronological age at last birthday, and sex: United States, 1966-1970

Standard of reference, sex, and chronological age at last birthday	White			Negro			Other races	
	$\bar{x}$	s_x	$s_{\bar{x}}$	$\bar{x}$	s_x	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
	Skeletal age in months							
Male standard								
Boys:								
12 years	140.4	17.17	0.62	138.7	16.04	2.84	149.3	105.58
13 years	156.8	17.77	0.93	160.6	19.69	3.10	164.5	52.37
14 years	173.7	14.84	0.74	172.7	17.04	2.03	170.7	54.06
15 years	187.1	13.91	0.73	181.7	15.91	1.09	197.3	5.02
16 years	197.0	13.12	0.78	192.7	16.93	2.93	188.9	74.35
17 years	205.8	10.97	0.52	202.4	11.37	1.65	209.1	1.05
Girls:								
12 years	174.3	14.36	0.71	178.4	16.72	2.40	184.5	9.43
13 years	186.5	13.12	0.72	187.5	12.10	1.09	187.2	132.41
14 years	197.9	10.46	0.63	198.7	12.82	1.70	198.8	140.57
15 years	205.3	9.28	0.57	207.6	8.35	0.81	204.6	64.71
16 years	211.5	10.00	0.52	210.2	9.36	0.96	206.6	146.06
17 years	211.7	9.82	0.64	210.5	10.34	2.14	220.0	155.56
Actual Values:								
Boys 12-17 years	175.2	---	0.40	172.6	---	1.17	182.7	6.32
Girls 12-17 years	196.5	---	0.38	197.1	---	0.85	198.4	3.80
Expected values:								
Boys 12-17 years	175.0	---	0.40	174.2	---	1.18	179.2	6.29
Girls 12-17 years	196.7	---	0.38	196.1	---	0.84	196.0	3.78
Female equivalent								
Girls:								
12 years	142.3	11.72	0.58	146.4	13.72	1.97	152.5	7.79
13 years	154.8	10.89	0.60	156.5	10.10	0.91	156.2	110.50
14 years	167.9	8.87	0.53	169.1	10.91	1.45	168.3	119.00
15 years	177.3	8.01	0.49	179.9	7.24	0.70	175.9	55.63
16 years	185.8	8.78	0.46	184.2	8.20	0.84	178.6	126.26
17 years	186.0	8.63	0.56	184.5	9.06	1.88	197.0	139.30

NOTE: $\bar{x}$ = mean skeletal age (hand-wrist); s_x = standard deviation of skeletal age; and $s_{\bar{x}}$ = standard error of mean. Expected values remove the effect of differences in the chronological age distribution with respect to skeletal age over the 12-17-year age span by indirect adjustment.

Table 2. Mean, standard deviation, and standard error of the mean skeletal age (hand-wrist) of youths by geographic region, chronological age at last birthday, and sex: United States, 1966-1970

Standard of reference, sex, and chronological age at last birthday	Northeast			Midwest			South			West		
	$\bar{x}$	s_x	$s_{\bar{x}}$	$\bar{x}$	s_x	$s_{\bar{x}}$	$\bar{x}$	s_x	$s_{\bar{x}}$	$\bar{x}$	s_x	$s_{\bar{x}}$
	Skeletal age in months											
Male standard												
Boys:												
12 years	141.0	16.93	1.14	139.0	17.59	1.28	141.1	16.03	1.62	140.2	17.20	1.38
13 years	157.6	20.02	2.60	157.9	17.45	1.62	156.1	18.34	1.32	157.8	16.32	1.16
14 years	173.6	15.00	1.02	172.0	14.91	1.61	174.2	15.80	1.87	174.7	14.66	1.16
15 years	189.1	13.82	1.45	183.6	14.48	1.14	186.7	14.88	1.02	187.6	13.20	1.41
16 years	196.2	13.25	1.33	196.2	13.26	1.52	196.6	14.28	1.04	196.4	14.37	1.36
17 years	206.6	10.35	1.42	206.3	9.66	0.53	204.4	11.65	0.72	204.3	11.95	1.40
Girls:												
12 years	177.4	14.13	1.46	173.3	14.85	1.38	175.7	14.30	1.35	173.9	15.58	2.39
13 years	187.9	13.02	0.95	186.7	13.19	1.78	186.7	12.87	1.03	185.4	12.64	0.87
14 years	197.3	10.78	1.23	198.5	11.42	1.34	197.6	11.16	0.81	198.5	9.69	1.47
15 years	204.8	9.25	0.82	205.2	9.37	1.56	206.9	9.46	0.74	205.4	8.45	1.02
16 years	210.8	8.66	0.94	211.8	9.80	0.97	212.0	11.95	1.22	210.5	9.17	1.15
17 years	209.2	10.06	1.27	211.1	9.85	1.66	213.0	9.22	1.40	212.9	9.32	1.20
Actual values:												
Boys 12-17 years	174.7	---	0.84	174.0	---	0.69	175.9	---	0.91	175.3	---	0.83
Girls 12-17 years	196.4	---	0.72	196.0	---	0.66	197.5	---	0.96	196.6	---	0.86
Expected values:												
Boys 12-17 years	173.9	---	0.83	174.9	---	0.70	175.9	---	0.91	175.0	---	0.83
Girls 12-17 years	196.4	---	0.72	196.3	---	0.67	196.9	---	0.95	196.9	---	0.87
Female equivalent												
Girls:												
12 years	145.4	11.58	1.20	141.3	12.11	1.13	143.7	11.70	1.10	141.9	12.71	1.95
13 years	156.9	10.87	0.79	155.0	10.95	1.48	155.0	10.68	0.86	153.4	10.46	0.72
14 years	167.3	9.14	1.04	168.8	9.71	1.14	167.6	9.47	0.69	168.8	8.24	1.25
15 years	176.2	7.96	0.71	177.2	8.09	1.35	178.9	8.18	0.64	177.4	7.30	0.88
16 years	184.8	7.59	0.82	186.2	8.62	0.85	187.0	10.54	1.08	184.5	8.04	1.01
17 years	182.3	8.77	1.11	185.2	8.64	1.46	189.0	8.18	1.24	188.4	8.25	1.06

NOTE: $\bar{x}$ = mean skeletal age (hand-wrist); s_x = standard deviation of skeletal age; and $s_{\bar{x}}$ = standard error of mean. Expected values remove the effect of differences in the chronological age distribution with respect to skeletal age over the 12-17-year age span by indirect adjustment.

Table 3. Mean and standard error of the mean skeletal age (hand-wrist) of white and Negro youths by geographic region, chronological age at last birthday, and sex: United States, 1966-1970

Standard reference, sex, and chronological age at last birthday	Northeast				Midwest				South				West			
	White		Negro		White		Negro		White		Negro		White		Negro	
	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
	Skeletal age in months															
Male standard																
Boys:																
12 years	141.1	1.24	140.7	1.56	139.6	1.22	131.1	2.66	142.0	1.19	139.1	5.85	139.9	1.76	142.4	7.66
13 years	157.4	2.63	158.8	7.86	157.2	1.60	164.5	13.84	154.5	1.19	159.4	4.34	157.4	1.55	166.5	12.96
14 years	173.4	0.82	174.9	3.05	172.9	1.43	162.9	4.52	174.0	2.13	174.9	3.50	174.7	1.17	174.8	4.44
15 years	189.6	1.63	184.5	8.39	184.2	1.18	176.1	3.35	188.5	1.08	181.4	1.10	187.3	1.58	186.7	41.90
16 years	196.6	1.44	196.0	3.40	196.9	2.08	190.4	2.82	196.8	1.14	196.1	1.76	197.4	1.27	176.0	57.46
17 years	207.3	1.24	200.0	8.88	206.2	0.61	206.8	4.51	206.1	0.92	199.1	2.14	203.8	1.44	208.3	46.75
Girls:																
12 years	177.0	1.33	179.4	4.88	173.1	1.50	174.9	9.84	174.9	1.33	177.8	3.74	172.8	2.22	182.7	57.88
13 years	187.8	1.20	188.5	2.56	186.6	1.98	187.5	2.44	186.8	1.13	186.6	1.85	185.2	0.93	188.7	2.74
14 years	196.8	1.27	200.5	3.68	198.2	1.46	203.1	2.99	198.0	0.50	196.4	2.31	198.4	1.56	199.9	1.20
15 years	204.8	1.07	204.9	2.36	204.6	1.73	211.2	2.18	206.6	0.69	207.9	1.40	205.4	1.09	206.1	2.75
16 years	211.1	0.99	207.9	0.69	211.7	1.00	213.4	1.92	212.4	1.51	211.1	1.33	210.9	1.22	204.0	4.97
17 years	209.3	1.13	208.6	4.54	211.1	1.74	211.1	2.93	213.3	1.30	212.3	4.06	213.1	0.97	209.2	47.65
Actual values:																
Boys 12-17 years	175.0	0.99	172.3	0.96	174.2	0.64	172.4	3.16	177.3	0.92	172.0	2.18	175.1	0.82	174.9	6.64
Girls 12-17 years	196.4	0.86	196.4	1.53	195.9	0.71	197.8	1.66	197.5	0.88	197.5	1.63	196.5	0.94	196.2	1.87
Expected values:																
Boys 12-17 years	176.0	1.00	173.7	0.97	174.6	0.64	169.4	3.11	175.4	0.91	172.9	2.19	175.2	0.82	173.7	6.59
Girls 12-17 years	196.6	0.86	196.8	1.53	196.2	0.71	198.4	1.67	197.3	0.88	196.8	1.62	196.2	0.94	197.1	1.88
Female equivalent																
Girls:																
12 years	145.0	1.09	147.4	4.01	141.1	1.22	142.9	8.04	142.9	1.09	145.8	3.07	140.8	1.81	150.7	47.74
13 years	156.8	1.00	157.5	2.14	155.2	1.65	156.5	2.04	155.6	0.94	155.2	1.54	153.2	0.77	157.7	2.29
14 years	166.8	1.08	171.5	3.15	168.4	1.24	174.1	2.56	168.0	0.42	166.4	1.96	168.8	1.33	170.9	1.03
15 years	176.6	0.92	176.8	2.04	176.2	1.49	185.4	1.91	178.6	0.60	180.8	1.22	177.4	0.94	178.1	2.38
16 years	185.2	0.87	180.8	0.60	186.4	0.88	189.4	1.70	187.8	1.34	185.2	1.17	184.9	1.07	175.0	4.26
17 years	182.6	0.99	181.6	3.95	185.2	1.53	185.2	2.57	189.3	1.15	187.6	3.59	189.1	0.86	182.4	41.55

NOTE: $\bar{x}$ = mean skeletal age (hand-wrist) and $s_{\bar{x}}$ = standard error of mean. Expected values remove the effect of differences in the chronological age distribution with respect to skeletal age over the 12-17-year age span by indirect adjustment.

Table 4. Mean skeletal age (hand-wrist) of youths by population size in urban areas and land use in rural areas of residence, chronological age at last birthday, and sex, with selected standard errors: United States, 1966-1970

Standard of reference, sex, and chronological age at last birthday	Urban total	Urbanized areas				Urban outside urbanized areas			Rural total	Rural—farm		Rural—nonfarm	
		3 million or more	1.0-2.9 million	250,000-999,999	Less than 250,000	25,000 or more	10,000-24,999	2,500-9,999		10 acres or more	Less than 10 acres	10 acres or more	Less than 10 acres
Male standard	Mean skeletal age in months												
Boys:													
12 years	140.2	140.2	139.7	141.8	138.6	137.6	138.8	141.3	140.4	137.0	—	134.1	141.5
13 years	157.9	159.0	155.7	156.7	160.3	163.0	160.4	155.3	156.4	153.2	161.8	152.6	157.4
14 years	173.4	173.4	172.8	174.0	175.5	172.1	169.6	173.9	173.9	174.9	190.3	173.3	173.6
15 years	187.1	188.4	185.1	190.8	186.3	186.2	182.6	185.9	185.3	183.5	163.0	184.2	186.2
16 years	196.4	196.1	194.8	197.5	197.1	199.1	197.4	196.1	196.3	200.4	191.2	197.7	195.2
17 years	205.6	206.9	206.5	205.3	205.6	208.3	202.5	201.3	204.9	203.6	—	204.7	205.3
Girls:													
12 years	175.0	178.5	173.2	173.9	173.9	170.5	171.4	172.0	175.1	173.0	189.2	175.6	175.3
13 years	186.7	187.5	184.9	186.2	188.0	190.4	186.6	186.2	186.5	180.6	197.5	187.1	188.3
14 years	198.2	199.6	194.8	198.7	198.8	196.7	199.4	199.1	197.7	197.2	204.7	196.0	197.9
15 years	205.8	207.5	203.4	206.1	206.2	204.1	204.8	206.4	205.2	203.8	193.6	210.7	205.2
16 years	210.7	212.3	207.6	212.0	211.6	210.3	208.8	210.7	212.4	211.7	—	211.2	212.5
17 years	212.0	209.6	211.2	215.6	213.6	212.8	209.0	213.3	210.6	208.1	212.0	208.4	211.5
Actual values:													
Boys 12-17 years	174.9	175.5	171.9	176.7	175.1	174.9	177.2	174.9	174.9	176.0	183.8	177.1	174.4
Girls 12-17 years	196.6	197.4	195.2	198.0	197.4	197.1	193.3	195.3	196.5	193.5	199.0	194.8	197.6
Expected values:													
Boys 12-17 years	174.7	174.8	172.8	175.6	174.3	174.0	178.7	175.9	175.3	177.0	186.7	179.1	174.4
Girls 12-17 years	196.6	196.0	197.3	197.4	196.8	197.7	194.3	195.6	196.6	196.1	193.1	194.8	197.1
Female equivalent													
Girls:													
12 years	143.0	146.5	141.2	141.9	141.9	138.5	139.4	140.0	143.1	141.0	158.2	143.6	143.3
13 years	155.0	156.5	152.9	154.3	157.0	159.4	154.9	154.3	154.8	148.6	167.5	156.1	157.3
14 years	168.4	170.6	164.2	169.0	169.2	166.7	170.4	170.1	167.7	167.2	176.0	166.0	167.9
15 years	177.8	179.8	174.4	178.1	178.2	175.2	176.2	178.4	177.2	174.8	162.6	184.7	177.2
16 years	184.7	187.4	179.9	187.0	185.9	184.3	181.8	184.7	187.6	186.0	—	185.3	187.8
17 years	187.0	182.9	185.3	191.6	189.6	188.2	182.0	189.3	184.6	181.1	187.0	181.4	185.8
Male standard	Standard error of the mean												
Boys:													
12 years	0.75	2.15	1.84	2.03	7.46	3.27	3.40	1.78	0.82	2.08	—	3.04	1.12
17 years	0.81	1.72	1.67	1.91	3.31	1.40	45.64	2.37	0.85	2.83	—	3.52	1.02
Girls:													
12 years	0.94	1.51	1.59	4.39	2.03	7.65	4.40	3.04	1.24	3.67	95.17	4.88	1.08
17 years	0.77	1.18	2.46	0.98	5.66	3.04	80.94	1.72	0.95	2.13	149.91	2.56	1.09
Boys 12-17 years	0.52	1.29	1.39	1.56	2.61	3.91	2.85	2.04	0.67	1.59	9.01	3.49	0.85
Girls 12-17 years	0.44	0.61	1.17	2.11	2.50	2.33	6.04	0.99	0.38	1.27	8.14	1.57	0.45

Table 5. Mean, standard deviation, and standard error of the mean skeletal age (hand-wrist) of youths by annual family income, chronological age at last birthday, and sex: United States, 1966-1970

Standard of reference, sex, and chronological age at last birthday	Less than $5,000			$5,000-$9,999			$10,000 or more			Less than $3,000		$15,000 or more	
	$\bar{x}$	s_x	$s_{\bar{x}}$	$\bar{x}$	s_x	$s_{\bar{x}}$	$\bar{x}$	s_x	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
Male standard	Skeletal age in months												
Boys:													
12 years	139.5	16.34	2.35	139.7	17.59	0.96	141.6	16.31	1.34	138.8	2.51	141.3	2.28
13 years	156.2	19.27	2.61	159.2	17.66	0.78	156.5	17.70	1.50	154.4	3.66	155.8	2.42
14 years	174.0	15.90	2.03	174.3	15.57	0.86	172.1	14.15	1.23	175.7	2.26	173.9	1.49
15 years	185.1	15.42	1.46	186.3	14.15	0.97	187.9	13.48	1.00	183.6	2.17	189.3	1.81
16 years	195.6	13.91	0.98	195.6	14.32	1.21	198.7	12.20	1.94	193.3	1.25	199.9	2.64
17 years	203.9	11.18	1.07	205.7	9.75	0.66	206.8	11.78	1.13	204.7	1.80	205.7	2.51
Girls:													
12 years	176.3	16.31	1.97	173.5	15.65	1.12	175.7	12.29	0.90	178.1	2.37	173.2	1.39
13 years	185.3	12.37	0.98	187.0	13.49	0.99	187.3	12.71	1.25	185.5	1.32	185.0	2.20
14 years	197.5	11.45	1.08	196.6	11.74	0.89	200.0	8.66	0.47	198.0	1.20	199.3	1.09
15 years	206.3	8.71	0.74	205.1	8.51	0.47	205.0	9.81	1.15	206.5	1.17	204.1	1.50
16 years	210.9	11.88	1.41	211.0	8.93	0.82	211.9	9.02	0.95	211.4	1.27	211.3	1.19
17 years	211.6	10.60	1.19	211.8	9.56	0.98	211.4	9.71	1.04	212.9	2.08	208.7	1.66
Actual values:													
Boys 12-17 years	174.5	27.28	1.28	174.6	27.25	0.56	175.5	26.84	0.87	175.6	2.06	175.8	1.40
Girls 12-17 years	195.8	18.04	0.72	195.5	18.04	0.61	198.1	17.02	0.78	197.0	0.69	197.9	1.00
Expected values:													
Boys 12-17 years	175.5	---	1.29	174.6	---	0.56	174.9	---	0.86	177.1	2.08	174.8	1.39
Girls 12-17 years	195.8	---	0.72	196.1	---	0.62	197.9	---	0.78	196.2	0.68	199.0	1.02
Female equivalent													
Girls:													
12 years	144.2	13.34	1.61	141.5	12.76	0.91	143.7	10.05	0.74	146.1	1.94	141.2	1.13
13 years	153.3	10.23	0.81	156.0	11.25	0.83	156.3	10.61	1.04	153.5	1.09	153.0	1.82
14 years	167.5	9.71	0.92	166.6	9.95	0.75	171.0	7.40	0.40	168.0	1.02	170.3	0.93
15 years	178.3	7.53	0.64	177.1	7.35	0.41	177.0	8.47	0.99	178.5	1.01	175.1	1.29
16 years	184.9	10.42	1.24	185.0	7.83	0.72	186.8	7.95	0.84	185.8	1.12	185.6	1.05
17 years	186.2	9.33	1.05	186.6	8.42	0.86	185.8	8.53	0.91	188.8	1.84	181.7	1.45

NOTE: $\bar{x}$ = mean skeletal age (hand-wrist); s_x = standard deviation of skeletal age; and $s_{\bar{x}}$ = standard error of mean. Expected values remove the effect of differences in the chronological age distribution with respect to skeletal age over the 12-17-year age span by indirect adjustment.

Table 6. Mean and standard error of the mean skeletal age (hand-wrist) of white and Negro youths by annual family income, chronological age at last birthday, and sex: United States, 1966-1970

Standard of reference, sex, and chronological age at last birthday	Less than $5,000				$5,000-$9,999			
	White		Negro		White		Negro	
	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
	Skeletal age in months							
Male standard								
Boys:								
12 years	139.9	2.32	138.5	4.53	139.8	0.96	138.4	3.10
13 years	154.7	2.57	158.8	4.94	158.4	0.93	164.1	3.46
14 years	173.5	2.51	175.1	3.42	175.0	0.88	168.6	2.65
15 years	186.2	1.89	182.3	2.05	186.8	1.02	180.7	3.66
16 years	196.4	1.20	193.5	1.91	196.4	1.19	190.1	7.03
17 years	205.0	1.19	201.3	1.89	205.7	0.70	206.0	2.32
Girls:								
12 years	175.1	2.83	179.4	2.80	173.2	1.07	176.0	4.48
13 years	185.1	1.19	185.8	1.97	186.7	1.11	189.8	2.51
14 years	196.8	1.24	199.0	1.65	196.4	0.90	199.1	3.44
15 years	206.1	0.90	207.0	0.82	204.9	0.63	207.1	2.07
16 years	211.3	2.07	210.2	0.79	210.9	0.93	212.2	3.50
17 years	212.3	1.45	210.4	3.10	211.7	1.12	212.3	2.45
Actual values:								
Boys 12-17 years	175.4	1.52	172.6	1.64	174.9	0.64	171.4	1.57
Girls 12-17 years	195.3	0.95	196.7	0.96	195.4	0.70	196.8	1.56
Expected values:								
Boys 12-17 years	175.1	1.51	173.3	1.65	174.7	0.64	173.6	1.59
Girls 12-17 years	195.7	0.96	196.0	0.95	195.6	0.70	194.7	1.54
Female equivalent								
Girls:								
12 years	143.1	2.32	147.4	2.30	141.2	0.87	144.0	3.67
13 years	153.1	0.98	153.8	1.63	155.4	0.92	158.1	2.09
14 years	166.8	1.05	170.0	1.41	166.4	0.76	170.1	2.94
15 years	178.1	0.78	179.0	0.71	176.8	0.54	179.2	1.79
16 years	185.6	1.81	184.2	0.69	184.9	0.82	187.4	3.09
17 years	187.6	1.28	184.4	2.72	186.4	0.99	187.6	2.16

NOTE: $\bar{x}$ = mean skeletal age (hand-wrist) and $s_{\bar{x}}$ = standard error of mean. Expected values remove the effect of differences in the chronological age distribution with respect to skeletal age over the 12-17-year age span by indirect adjustment.

Table 6. Mean and standard error of the mean skeletal age (hand-wrist) of white and Negro youths by annual family income, chronological age at last birthday, and sex: United States, 1966-1970—Con.

$10,000 or more				Less than $3,000				$15,000 or more			
White		Negro		White		Negro		White		Negro	
$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
Skeletal age in months											
141.5	1.36	144.2	10.04	139.4	3.45	137.8	3.39	140.8	2.33	161.2	80.69
156.4	1.56	162.5	51.95	154.4	5.69	154.5	5.07	155.9	2.44	–	–
172.4	1.19	159.6	8.72	173.6	2.14	178.4	3.69	174.2	1.48	149.6	105.79
188.1	1.06	177.2	8.27	184.1	3.07	182.8	3.24	189.1	1.90	188.7	133.41
198.6	2.01	205.9	103.16	194.2	1.61	191.8	1.75	199.7	2.75	220.0	155.56
206.6	1.19	211.8	5.51	206.8	1.70	200.9	3.10	205.5	2.66	209.0	104.68
175.1	0.93	183.9	12.38	177.8	3.26	179.0	2.53	173.1	1.47	170.1	120.30
187.1	1.28	199.0	5.12	186.5	1.80	184.0	2.67	184.4	2.22	196.7	5.92
199.9	0.53	200.8	5.41	198.0	1.68	198.1	2.68	199.1	1.18	202.9	101.65
204.8	1.18	213.9	3.55	206.5	1.64	206.5	1.24	203.9	1.53	–	–
211.9	0.96	209.8	66.49	213.3	1.20	208.2	1.94	211.5	1.16	196.0	138.59
211.5	1.01	208.3	46.72	214.5	1.49	210.5	4.56	208.7	1.67	206.8	146.22
175.4	0.85	175.8	5.22	176.4	2.90	174.2	2.53	175.5	1.47	187.8	60.28
198.0	0.79	206.6	2.29	197.4	0.93	196.1	1.42	198.1	1.03	197.0	4.74
175.4	0.85	177.1	5.24	176.1	2.89	174.8	2.54	175.6	1.47	181.2	60.20
198.1	0.79	199.4	2.25	196.9	0.92	197.2	1.44	198.2	1.03	195.4	4.72
143.1	0.76	151.9	10.23	145.8	2.67	147.0	2.08	141.1	1.20	138.1	97.67
156.1	1.07	170.0	4.37	155.0	1.50	152.0	2.21	152.4	1.83	166.7	5.02
170.9	0.45	171.8	4.63	168.0	1.43	168.2	2.28	170.1	1.01	173.9	87.12
176.6	1.02	189.9	3.15	178.5	1.42	178.5	1.07	174.9	1.31	–	–
186.8	0.85	183.6	58.19	189.3	1.06	181.2	1.69	186.0	1.02	166.0	117.38
186.0	0.89	181.3	46.72	190.5	1.32	184.5	4.00	181.7	1.45	178.8	126.42

Table 7. Mean and standard error of the mean skeletal age (hand-wrist) of white and Negro youths by education of first parent, chronological age of youth at last birthday, and sex: United States, 1966-1970

Standard of reference, sex, and chronological age at last birthday	Education of parent															
	Less than 5 years				5-8 years				9-12 years				13 years or more			
	White		Negro		White		Negro		White		Negro		White		Negro	
	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$	$\bar{x}$	$s_{\bar{x}}$
Male standard	Mean skeletal age in months															
Boys:																
12 years	140.4	0.79	138.6	3.12	138.0	0.62	136.3	3.07	138.8	0.61	137.3	2.97	138.6	0.77	137.2	3.26
13 years	156.9	0.97	161.0	3.19	154.5	1.20	159.0	3.55	155.1	1.09	159.4	3.56	155.2	1.15	159.7	3.80
14 years	174.4	0.79	173.4	2.09	174.8	0.92	173.2	2.49	174.6	0.84	172.8	2.42	175.4	0.87	173.5	2.33
15 years	187.5	0.77	183.0	1.21	188.6	0.81	183.8	1.26	188.2	0.79	182.3	1.24	188.7	0.81	183.9	1.15
16 years	197.2	0.82	192.7	2.93	197.8	0.84	192.9	2.95	197.5	0.80	192.9	2.95	197.7	0.82	192.9	2.95
17 years	206.1	0.54	203.4	1.42	206.4	0.56	203.4	1.42	206.0	0.54	202.4	1.65	206.3	0.55	203.2	1.51
Girls:																
12 years	174.4	0.78	179.6	2.36	175.1	0.93	179.5	2.85	175.0	0.88	178.8	2.75	175.2	0.96	179.8	2.57
13 years	186.7	0.77	188.4	1.39	188.2	0.89	189.7	1.19	187.9	0.82	188.7	1.07	188.3	0.88	189.4	1.06
14 years	198.3	0.58	199.2	1.75	199.0	0.62	201.3	1.42	198.6	0.66	200.6	1.44	199.1	0.61	201.2	1.41
15 years	205.5	0.57	207.6	0.81	205.8	0.51	207.6	0.81	205.6	0.52	207.6	0.81	205.7	0.51	207.6	0.81
16 years	211.7	0.51	210.7	0.92	211.7	0.50	210.7	0.92	211.5	0.52	210.2	0.96	211.6	0.50	210.4	0.90
17 years	212.0	0.68	210.9	2.15	212.0	0.68	210.9	2.15	211.7	0.64	210.5	2.14	211.8	0.67	210.9	2.15
Actual values:																
Boys 12-17 years	176.5	0.39	173.7	1.29	176.8	0.43	173.3	1.34	176.4	0.41	173.0	1.27	177.7	0.41	174.4	1.42
Girls 12-17 years	197.2	0.41	198.0	0.97	198.7	0.45	199.2	0.77	198.0	0.42	198.5	0.72	198.7	0.46	199.2	0.73
Expected values:																
Boys 12-17 years	176.3	0.38	175.2	1.30	176.6	0.43	175.0	1.35	176.1	0.41	174.9	1.28	177.4	0.41	176.2	1.43
Girls 12-17 years	197.4	0.41	196.7	0.96	198.9	0.45	197.9	0.76	198.2	0.42	197.4	0.71	198.9	0.46	197.9	0.72
Female equivalent																
Girls:																
12 years	142.4	0.64	147.6	1.94	143.1	0.76	147.5	2.34	143.0	0.72	146.8	2.26	143.2	0.78	147.8	2.11
13 years	155.0	0.64	157.4	1.16	157.2	0.74	158.7	1.00	156.9	0.68	157.7	0.89	157.3	0.74	158.4	0.89
14 years	168.4	0.49	170.2	1.50	170.0	0.53	172.3	1.22	168.9	0.56	171.6	1.23	170.1	0.52	172.2	1.20
15 years	177.5	0.49	179.9	0.70	177.8	0.44	179.9	0.70	177.6	0.45	179.9	0.70	177.7	0.44	179.9	0.70
16 years	186.0	0.45	184.7	0.81	186.0	0.44	184.7	0.81	185.8	0.46	184.2	0.84	185.9	0.44	184.4	0.79
17 years	187.0	0.60	184.9	1.88	187.0	0.60	184.9	1.88	186.0	0.56	184.5	1.88	186.2	0.59	184.9	1.88

NOTE: $\bar{x}$ = mean skeletal age (hand-wrist) and $s_{\bar{x}}$ = standard error of mean. Expected values remove the effect of differences in the chronological age distribution with respect to skeletal age over the 12-17-year age span by indirect adjustment.

Table 8. Selected percentiles in the distribution of skeletal age (hand-wrist) for youths by race, geographic region, annual family income, chronological age at last birthday, and sex: United States, 1966-1970

Race, region, annual family income, and percentile	Chronological age in years at last birthday					
	Boys					
	12 years	13 years	14 years	15 years	16 years	17 years
	Skeletal age in months					
White						
P_{75}	154.3	170.0	182.1	198.4	206.3	213.1
P_{50}	140.0	158.3	174.1	186.4	199.1	207.1
P_{25}	127.3	144.8	165.6	177.2	189.5	199.6
Negro						
P_{75}	154.4	172.8	183.7	195.4	205.2	210.6
P_{50}	134.7	163.5	172.7	179.8	197.3	203.1
P_{25}	126.1	151.0	161.7	170.2	181.9	195.7
Northeast						
P_{75}	154.1	172.8	182.8	200.5	205.5	216.0
P_{50}	142.0	159.4	173.6	191.8	198.8	206.5
P_{25}	127.8	143.6	163.4	178.4	189.2	199.5
Midwest						
P_{75}	153.0	169.4	180.8	195.7	205.0	213.2
P_{50}	137.3	159.8	172.8	182.0	198.9	206.7
P_{25}	123.9	146.1	161.5	175.0	188.1	199.9
South						
P_{75}	155.1	171.0	182.8	198.1	207.3	212.9
P_{50}	141.0	157.1	175.1	185.6	199.1	207.1
P_{25}	128.7	144.9	167.0	176.5	187.9	197.9
West						
P_{75}	155.0	169.3	181.3	198.2	206.0	211.0
P_{50}	138.6	158.5	175.1	187.6	199.1	206.9
P_{25}	127.1	146.5	166.6	178.5	189.5	198.7
Less than $5,000						
P_{75}	154.2	171.0	181.9	198.3	207.0	211.6
P_{50}	138.8	157.6	173.5	182.4	198.5	205.6
P_{25}	126.1	144.1	166.8	174.5	186.5	197.1
$5,000-$9,999						
P_{75}	153.9	171.6	183.5	197.1	206.0	212.7
P_{50}	137.7	159.7	174.4	185.9	198.6	206.6
P_{25}	127.0	147.2	166.1	177.3	188.5	199.8
$10,000 or more						
P_{75}	155.2	169.0	180.7	200.0	206.2	213.8
P_{50}	142.1	159.7	173.9	188.3	200.7	207.8
P_{25}	127.7	144.4	160.9	178.2	192.9	200.0

Table 8. Selected percentiles in the distribution of skeletal age (hand-wrist) for youths by race, geographic region, annual family income, chronological age at last birthday, and sex: United States, 1966-1970—Con.

Race, region, annual family income, and percentile	Chronological age in years at last birthday					
	Girls (female equivalent)					
	12 years	13 years	14 years	15 years	16 years	17 years
	Skeletal age in months					
White						
P_{75}	152.1	166.8	176.4	186.2	197.4	198.2
P_{50}	142.7	156.2	170.2	177.9	187.4	189.0
P_{25}	134.4	145.1	162.3	169.0	179.0	177.3
Negro						
P_{75}	159.6	166.4	180.0	187.8	196.3	197.3
P_{50}	146.8	156.9	171.2	181.1	185.9	187.4
P_{25}	138.8	146.9	165.0	173.0	173.7	172.9
Northeast						
P_{75}	153.9	167.3	177.4	185.3	196.3	193.9
P_{50}	144.3	157.4	169.2	177.5	185.3	185.6
P_{25}	137.9	145.7	161.7	167.9	175.4	173.0
Midwest						
P_{75}	149.6	167.5	178.5	187.0	198.4	200.0
P_{50}	140.7	157.4	171.5	177.5	187.6	187.2
P_{25}	134.4	145.3	162.4	168.3	178.4	175.2
South						
P_{75}	155.4	166.9	176.0	190.1	200.1	200.2
P_{50}	145.3	155.2	170.2	179.2	188.2	189.7
P_{25}	134.5	144.8	162.6	172.4	179.6	184.5
West						
P_{75}	152.3	165.7	175.9	186.2	192.7	199.1
P_{50}	142.6	153.2	169.4	177.4	189.4	191.2
P_{25}	134.1	145.1	162.6	168.9	179.6	178.5
Less than $5,000						
P_{75}	156.2	163.5	176.4	188.2	197.2	198.2
P_{50}	145.4	152.1	168.9	178.0	187.3	189.6
P_{25}	135.0	145.4	162.3	171.7	179.6	178.6
$5,000-$9,999						
P_{75}	151.7	167.4	175.9	185.9	195.2	199.5
P_{50}	142.3	157.0	167.9	177.4	186.4	189.2
P_{25}	134.3	144.5	161.2	168.8	175.9	177.5
$10,000 or more						
P_{75}	152.1	167.2	177.8	185.4	197.6	197.6
P_{50}	142.8	157.5	172.1	178.4	187.2	188.2
P_{25}	135.7	145.8	163.8	167.8	179.0	174.7

Table 8. Selected percentiles in the distribution of skeletal age (hand-wrist) for youths by race, geographic region, annual family income, chronological age at last birthday, and sex: United States, 1966-1970—Con.

Race, region, annual family income, and percentile	Chronological age in years at last birthday					
	Girls (male standard)					
	12 years	13 years	14 years	15 years	16 years	17 years
	Skeletal age in months					
White						
P_{75}	184.1	196.8	204.9	211.8	220.3	220.8
P_{50}	174.7	187.2	199.2	205.9	212.3	213.0
P_{25}	165.9	177.1	193.3	198.7	207.0	205.3
Negro						
P_{75}	190.6	196.4	207.5	212.8	219.3	220.2
P_{50}	178.8	187.9	200.2	208.1	211.6	212.3
P_{25}	170.8	178.9	195.0	202.0	202.7	201.9
Northeast						
P_{75}	185.9	197.3	205.4	211.2	219.3	217.9
P_{50}	176.3	188.4	198.8	205.9	211.2	211.4
P_{25}	169.9	177.7	192.7	197.9	204.3	202.0
Midwest						
P_{75}	181.6	197.5	206.5	212.0	220.9	222.0
P_{50}	172.7	188.4	200.5	205.5	212.4	212.1
P_{25}	165.7	177.3	193.4	198.2	206.4	204.1
South						
P_{75}	186.9	196.9	204.7	214.1	222.1	222.2
P_{50}	177.3	186.8	199.2	207.1	212.8	213.7
P_{25}	166.0	176.8	193.6	201.4	207.4	210.5
West						
P_{75}	184.3	195.7	204.6	211.8	216.7	221.1
P_{50}	174.6	185.2	198.9	205.4	213.4	215.2
P_{25}	165.2	177.1	193.6	198.6	207.4	206.5
Less than $5,000						
P_{75}	187.2	194.5	204.9	212.8	220.1	220.8
P_{50}	177.4	184.1	198.6	206.0	212.2	213.6
P_{25}	167.0	177.4	193.3	200.7	207.4	206.6
$5,000-$9,999						
P_{75}	183.7	197.4	204.6	211.6	218.8	221.5
P_{50}	174.3	188.0	197.9	205.4	211.9	213.2
P_{25}	165.6	176.5	192.2	198.5	204.6	205.5
$10,000 or more						
P_{75}	184.1	197.2	205.8	211.3	220.4	220.4
P_{50}	174.8	188.5	201.1	206.4	212.1	212.8
P_{25}	167.7	177.8	194.8	197.8	207.0	203.7

Table 9. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of white and Negro youths by chronological age in years at last birthday and sex, with selected standard errors: United States, 1966-1970

Standard of reference, sex, and chronological age at last birthday	Radius		Ulna		Capitate		Hamate		Triquetral	
	White	Negro	White	Negro	White	Negro	White	Negro	White	Negro
Male standard	Mean skeletal age in months									
Boys:										
12 years	139.9	139.0	140.0	139.5	141.0	140.1	142.1	141.4	140.8	139.5
13 years	156.7	160.3	156.1	160.6	155.7	155.3	156.3	157.1	154.8	156.2
14 years	173.7	171.8	173.2	172.3	168.2	164.2	168.8	165.4	167.8	164.0
15 years	186.9	181.9	186.3	181.1	175.6	171.4	176.1	173.1	175.2	171.7
16 years	198.0	192.8	195.0	190.6	178.6	167.1	179.6	170.3	178.6	167.5
17 years	207.5	204.0	202.2	199.3	184.9	184.6	185.3	184.9	185.7	185.1
Girls:										
12 years	173.2	177.9	172.8	177.7	168.2	168.2	169.1	169.1	167.3	168.4
13 years	185.7	186.5	185.2	186.6	175.9	175.2	176.5	176.2	174.9	174.8
14 years	197.8	199.2	196.6	196.2	182.0	178.1	181.8	179.0	181.8	178.0
15 years	208.5	209.5	203.7	203.8	188.0	–	188.7	–	188.4	–
16 years	214.2	213.9	206.6	205.2	185.4	192.0	183.2	192.0	183.1	192.0
17 years	217.0	217.7	208.4	208.2	191.6	192.0	191.5	192.0	191.6	192.0
Actual values:										
Boys 12-17 years	175.4	172.4	172.5	170.6	157.8	156.0	158.4	157.4	157.3	156.1
Girls 12-17 years	197.6	198.4	191.2	192.0	173.3	173.1	173.8	174.0	172.4	172.8
Expected values:										
Boys 12-17 years	175.2	174.2	172.4	171.7	157.5	158.1	158.2	158.9	157.0	157.8
Girls 12-17 years	197.8	197.1	191.4	190.8	173.2	173.6	173.8	174.2	172.5	172.8
Female equivalent										
Girls:										
12 years	141.2	145.4	140.8	145.7	136.2	136.2	137.1	137.1	136.2	136.5
13 years	153.7	154.5	153.2	154.6	143.9	143.2	144.5	144.2	141.9	141.8
14 years	167.8	169.2	166.9	166.3	150.0	146.1	149.8	147.0	149.8	145.0
15 years	181.8	183.5	174.0	174.2	157.0	–	157.7	–	156.4	–
16 years	190.2	189.9	179.6	177.3	153.4	162.0	151.2	162.0	151.1	162.0
17 years	194.0	194.7	181.4	181.2	161.6	162.0	161.5	162.0	161.6	162.0
Male standard	Standard error of the mean									
Boys:										
12 years	0.66	2.95	0.64	2.87	0.70	2.75	0.65	2.75	0.73	2.70
17 years	0.51	1.81	0.64	0.98	1.84	41.73	1.75	41.79	1.72	41.81
Girls:										
12 years	0.73	2.60	0.80	2.48	0.66	2.01	0.63	2.17	0.66	2.21
17 years	0.41	0.92	0.37	0.81	60.59	96.00	85.66	96.00	60.59	135.76
Boys 12-17 years	0.42	1.15	0.52	1.36	0.81	2.47	0.82	2.48	0.82	2.47
Girls 12-17 years	0.37	1.01	0.39	0.72	0.50	1.26	0.49	1.49	0.51	1.49

Table 9. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of white and Negro youths by chronological age in years at last birthday and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Lunate		Scaphoid		Trapezium		Trapezoid		Metacarpal I	
	White	Negro	White	Negro	White	Negro	White	Negro	White	Negro
Male standard	Mean skeletal age in months									
Boys:										
12 years	140.6	139.3	139.2	137.6	138.3	137.6	139.0	137.4	138.8	137.3
13 years	155.0	157.0	154.1	156.1	154.2	155.7	154.7	155.6	155.0	158.0
14 years	167.7	164.6	167.4	163.4	167.7	162.8	168.0	163.2	169.6	167.6
15 years	175.0	171.5	175.5	171.3	175.3	171.3	175.5	170.8	176.9	172.9
16 years	178.1	167.0	178.3	167.3	178.5	167.1	178.2	166.0	179.8	174.7
17 years	185.4	185.0	186.3	183.9	185.2	185.1	185.3	185.1	183.4	182.4
Girls:										
12 years	167.3	168.9	166.6	167.4	166.7	167.1	167.0	165.6	170.0	172.0
13 years	174.7	175.5	174.6	175.2	175.1	174.2	175.0	174.5	177.2	178.8
14 years	181.3	177.5	181.0	178.4	181.0	178.3	181.2	179.7	181.3	179.0
15 years	187.9	–	187.6	–	188.6	–	188.4	–	185.1	186.0
16 years	187.7	192.0	187.3	190.6	188.5	191.3	188.4	191.3	185.5	186.0
17 years	191.2	–	190.4	192.0	192.0	192.0	192.0	192.0	185.8	186.0
Actual values:										
Boys 12-17 years	157.1	156.4	156.6	155.0	156.3	154.9	156.6	154.7	160.2	159.4
Girls 12-17 years	172.3	173.0	172.0	173.0	172.3	172.5	172.3	172.3	175.3	176.5
Expected values:										
Boys 12-17 years	157.0	157.8	156.3	156.8	156.0	156.6	156.3	156.9	160.0	160.4
Girls 12-17 years	172.4	172.5	172.0	172.8	172.2	172.9	172.2	173.2	175.5	175.5
Female equivalent										
Girls:										
12 years	136.2	137.0	134.6	135.4	134.8	135.1	135.0	134.3	138.0	140.0
13 years	141.7	142.5	142.6	143.2	142.1	141.1	142.0	141.5	145.2	146.8
14 years	149.3	144.5	149.0	146.4	149.0	146.3	149.2	147.0	149.4	147.0
15 years	156.4	–	156.2	–	156.6	–	156.4	–	154.1	155.0
16 years	156.0	161.0	155.6	159.6	156.5	159.4	156.4	160.0	154.5	155.0
17 years	160.2	–	159.4	161.0	161.0	161.0	161.0	161.0	154.8	155.0
Male standard	Standard error of the mean									
Boys:										
12 years	0.70	2.56	0.59	2.87	0.59	2.83	0.61	2.97	0.59	2.62
17 years	1.78	41.81	1.77	41.66	1.77	41.81	1.77	41.81	0.43	1.95
Girls:										
12 years	0.60	1.90	0.60	2.23	0.61	2.25	0.59	2.04	0.68	1.61
17 years	60.47	–	42.59	135.76	42.93	135.76	42.93	135.76	0.17	58.81
Boys 12-17 years	0.74	2.26	0.76	2.31	0.77	2.37	0.79	2.44	0.37	1.81
Girls 12-17 years	0.50	1.21	0.47	1.38	0.41	1.41	0.38	1.52	0.42	0.97

Table 9. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of white and Negro youths by chronological age in years at last birthday and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Metacarpal II		Metacarpal III		Metacarpal IV		Metacarpal V		Pisiform	
	White	Negro	White	Negro	White	Negro	White	Negro	White	Negro
Male standard	Mean skeletal age in months									
Boys:										
12 years	138.6	137.6	139.4	137.9	139.2	137.9	139.7	138.3	141.4	139.5
13 years	154.9	159.4	155.5	160.1	155.4	160.6	155.8	160.2	155.6	157.6
14 years	171.6	169.9	171.8	170.2	171.9	170.5	172.1	171.3	167.7	163.8
15 years	182.7	177.2	182.2	177.3	182.1	177.4	182.8	178.6	174.8	171.6
16 years	188.5	183.4	188.2	182.0	188.0	182.2	190.0	184.0	179.1	164.6
17 years	196.0	195.2	194.2	194.2	193.7	192.0	196.6	192.8	185.3	186.9
Girls:										
12 years	171.4	173.6	171.9	175.0	171.6	174.1	171.9	175.4	167.1	166.7
13 years	183.2	184.5	182.7	183.8	182.4	184.5	183.3	184.2	174.8	174.7
14 years	194.2	193.5	192.8	191.5	192.8	190.5	194.6	192.3	182.5	178.9
15 years	198.4	201.4	196.4	199.6	196.7	200.5	199.1	201.3	187.0	–
16 years	203.2	204.2	200.2	200.3	200.3	200.6	203.1	202.7	187.3	192.0
17 years	204.5	198.6	200.4	200.0	200.7	198.6	205.1	204.8	192.0	192.0
Actual values:										
Boys 12-17 years	165.3	164.7	165.1	164.7	165.0	164.5	166.4	165.8	158.0	157.5
Girls 12-17 years	184.5	184.9	183.5	184.3	183.5	184.1	185.6	185.2	172.9	172.2
Expected values:										
Boys 12-17 years	165.2	165.7	165.0	165.7	164.9	165.4	166.2	166.9	157.8	159.4
Girls 12-17 years	184.6	183.8	183.7	183.0	183.7	182.9	185.8	184.3	172.8	172.8
Female equivalent										
Girls:										
12 years	139.4	141.6	139.9	142.5	139.6	142.1	139.9	143.4	135.6	135.4
13 years	151.2	152.5	150.7	151.8	150.4	152.5	151.3	152.2	141.8	141.7
14 years	164.2	163.5	161.8	160.5	162.2	159.5	163.2	161.2	150.5	146.9
15 years	168.4	171.4	166.4	169.6	166.7	170.5	169.1	171.3	155.0	–
16 years	174.2	175.2	170.2	170.3	170.3	170.6	173.2	172.7	155.3	160.0
17 years	175.5	168.6	170.4	170.0	170.7	168.6	176.1	175.7	160.0	160.0
Male standard	Standard error of the mean									
Boys:										
12 years	0.62	3.01	0.62	2.95	0.66	2.93	0.67	2.95	0.69	2.49
17 years	1.08	2.52	0.91	2.20	0.91	2.14	1.10	1.96	1.98	42.75
Girls:										
12 years	0.79	1.89	0.74	1.84	0.74	1.73	0.72	2.06	0.60	2.29
17 years	1.42	99.28	1.35	63.29	1.19	99.28	0.97	102.45	–	135.76
Boys 12-17 years	0.47	1.46	0.39	1.30	0.37	1.29	0.41	1.17	0.53	1.57
Girls 12-17 years	0.43	1.07	0.44	0.94	0.45	0.94	0.36	0.94	0.47	1.48

Table 9. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of white and Negro youths by chronological age in years at last birthday and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Adductor sesamoid		Flexor sesamoid		Proximal phalanx I		Proximal phalanx II		Proximal phalanx III	
	White	Negro	White	Negro	White	Negro	White	Negro	White	Negro
Male standard	Mean skeletal age in months									
Boys:										
12 years	159.7	159.9	165.4	163.9	140.8	139.4	141.0	138.2	141.0	138.3
13 years	164.7	167.0	168.4	169.1	157.0	160.7	157.5	160.6	157.8	161.0
14 years	170.4	169.9	172.0	172.5	172.9	171.3	172.5	170.5	172.6	170.8
15 years	175.5	172.2	176.0	172.4	183.7	175.8	183.2	176.3	183.4	176.8
16 years	178.6	169.0	178.7	167.6	189.1	183.6	188.4	180.3	187.9	180.6
17 years	183.4	184.4	185.0	186.9	198.8	196.4	195.9	194.2	196.1	194.3
Girls:										
12 years	169.4	172.3	171.6	174.6	174.5	177.3	174.9	176.3	175.1	177.1
13 years	174.3	175.0	175.9	175.2	184.5	186.9	183.4	185.9	183.6	185.9
14 years	179.4	174.8	180.6	176.5	195.7	193.7	193.1	192.1	193.7	192.7
15 years	180.1	178.8	180.5	192.0	202.8	206.7	198.6	202.2	199.0	202.6
16 years	180.8	184.8	184.0	184.8	206.5	206.5	201.8	202.6	202.4	202.6
17 years	184.8	186.3	186.3	190.5	207.7	208.6	202.9	204.0	203.3	204.0
Actual values:										
Boys 12-17 years	168.8	168.4	172.3	170.8	165.8	165.0	165.2	163.7	165.4	164.0
Girls 12-17 years	173.6	174.5	175.5	176.4	185.6	187.0	183.7	186.0	184.3	186.3
Expected values:										
Boys 12-17 years	168.7	169.2	172.0	172.3	165.6	166.5	164.9	165.8	165.1	165.9
Girls 12-17 years	173.7	173.6	175.6	175.8	185.9	185.6	184.0	184.8	184.5	185.0
Female equivalent										
Girls:										
12 years	137.4	140.3	139.6	142.6	141.5	144.3	141.9	143.3	144.0	145.1
13 years	142.3	143.0	143.9	143.2	152.5	154.9	150.7	152.9	151.6	153.9
14 years	147.4	142.8	148.6	144.5	165.7	163.7	163.0	161.2	163.7	162.7
15 years	148.1	146.8	148.5	161.0	173.8	178.7	168.6	172.2	169.0	173.6
16 years	148.8	152.8	152.0	152.8	178.5	178.5	171.8	172.6	173.4	173.6
17 years	152.8	154.3	154.3	159.5	179.7	180.9	172.9	174.0	174.3	176.0
Male standard	Standard error of the mean									
Boys:										
12 years	0.55	1.14	0.67	2.17	0.64	3.29	0.66	3.00	0.63	2.90
17 years	1.36	58.91	2.13	59.94	1.22	2.96	1.17	1.87	1.18	1.85
Girls:										
12 years	0.63	1.54	0.55	1.71	0.69	1.89	0.67	1.80	0.67	1.95
17 years	2.07	72.21	2.05	95.27	1.21	46.66	1.16	45.61	0.86	79.00
Boys 12-17 years	0.37	1.23	0.42	1.59	0.46	1.60	0.48	1.73	0.46	1.70
Girls 12-17 years	0.35	1.32	0.43	1.06	0.50	1.00	0.44	1.11	0.41	1.19

Table 9. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of white and Negro youths by chronological age in years at last birthday and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Proximal phalanx IV		Proximal phalanx V		Middle phalanx II		Middle phalanx III		Middle phalanx IV	
	White	Negro	White	Negro	White	Negro	White	Negro	White	Negro
Male standard	Mean skeletal age in months									
Boys:										
12 years	141.0	138.4	141.2	138.8	141.9	139.8	141.8	140.1	141.1	139.1
13 years	157.6	161.1	157.5	161.6	157.5	160.9	157.6	161.0	157.1	160.8
14 years	172.9	170.6	172.5	171.1	172.6	170.3	172.8	170.4	172.8	169.5
15 years	183.4	176.6	183.3	177.0	182.6	176.1	183.1	176.8	182.8	176.2
16 years	188.4	180.4	188.0	181.3	188.2	181.9	188.0	183.6	187.9	183.0
17 years	195.5	193.3	195.7	192.4	195.2	193.8	195.6	194.9	195.0	195.6
Girls:										
12 years	175.4	177.8	175.7	177.4	175.1	176.8	175.3	176.8	174.9	177.1
13 years	184.0	186.3	183.9	186.4	184.1	185.2	184.4	185.2	184.4	185.6
14 years	193.6	192.3	193.4	193.2	192.8	191.0	193.5	192.1	193.2	192.3
15 years	198.7	203.0	199.6	202.8	199.2	200.3	198.9	200.3	198.7	200.1
16 years	202.4	202.8	202.2	202.8	202.3	202.4	201.7	202.2	202.4	202.0
17 years	203.0	204.0	203.4	204.0	202.9	204.0	203.0	204.0	203.0	204.0
Actual values:										
Boys 12-17 years	165.3	163.5	165.1	164.0	165.5	164.4	165.8	165.3	165.4	164.7
Girls 12-17 years	184.5	186.8	184.6	186.7	183.9	185.2	184.4	185.7	184.2	186.1
Expected values:										
Boys 12-17 years	165.0	165.5	164.9	165.6	165.3	166.1	165.6	166.7	165.2	166.3
Girls 12-17 years	184.8	185.4	184.8	185.3	184.0	184.6	184.5	185.1	184.4	185.2
Female equivalent										
Girls:										
12 years	144.2	145.8	143.7	145.4	143.1	144.8	142.4	144.7	141.9	145.1
13 years	152.0	154.3	151.9	154.4	152.1	153.2	152.4	153.2	152.4	153.6
14 years	163.6	162.3	162.4	162.2	162.6	160.0	162.5	161.1	162.2	161.3
15 years	168.7	174.0	169.4	173.4	170.1	170.6	169.4	171.3	169.4	171.1
16 years	173.4	173.8	173.1	173.4	172.4	172.6	172.7	173.0	173.4	173.0
17 years	174.0	176.0	173.7	174.0	173.4	175.0	174.0	175.0	174.0	175.0
Male standard	Standard error of the mean									
Boys:										
12 years	0.68	3.09	0.69	3.07	0.65	2.88	0.63	2.85	0.66	2.95
17 years	1.22	1.89	1.25	1.95	1.01	2.19	0.85	1.91	0.93	2.16
Girls:										
12 years	0.67	1.85	0.65	1.71	0.70	1.80	0.64	1.61	0.69	1.63
17 years	0.80	45.61	0.70	45.61	0.68	102.00	0.66	102.00	0.67	79.00
Boys 12-17 years	0.46	1.94	0.46	2.02	0.50	1.89	0.49	1.85	0.47	1.78
Girls 12-17 years	0.40	1.13	0.44	1.12	0.39	0.99	0.41	0.96	0.42	1.02

Table 9. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of white and Negro youths by chronological age in years at last birthday and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Middle phalanx V		Distal phalanx I		Distal phalanx II		Distal phalanx III		Distal phalanx IV		Distal phalanx V	
	White	Negro	White	Negro	White	Negro	White	Negro	White	Negro	White	Negro
Male standard	Mean skeletal age in months											
Boys:												
12 years	141.4	139.8	140.0	138.7	140.3	137.6	140.3	137.7	140.6	137.9	140.5	138.0
13 years	157.3	160.4	155.7	156.4	156.0	157.6	155.7	157.8	155.9	157.5	156.0	157.3
14 years	172.6	169.3	168.7	165.7	169.2	165.0	169.0	165.5	169.2	166.0	169.0	166.0
15 years	182.9	176.4	176.7	170.0	176.6	169.8	176.2	170.0	175.8	169.9	175.6	170.2
16 years	187.8	183.2	180.9	173.4	180.5	172.6	180.0	172.5	179.0	173.0	179.3	173.4
17 years	194.8	193.8	184.8	183.4	185.2	181.0	184.8	181.3	183.8	181.8	183.6	181.1
Girls:												
12 years	175.1	176.3	170.9	169.9	171.0	170.4	170.6	170.6	170.4	170.6	170.4	170.5
13 years	183.9	185.6	178.4	178.1	178.7	178.8	178.3	178.6	176.4	176.9	176.6	176.9
14 years	192.7	192.0	183.2	183.9	183.6	184.0	182.1	182.6	181.1	178.6	181.3	178.5
15 years	198.5	199.7	186.8	190.0	186.7	190.9	186.7	191.0	185.7	186.0	185.7	186.0
16 years	202.2	202.2	187.2	186.0	187.2	185.9	187.4	185.9	186.0	186.0	186.0	186.0
17 years	202.9	204.0	185.8	191.0	185.8	190.9	185.8	191.0	185.9	186.0	185.9	186.0
Actual values:												
Boys 12-17 years	165.4	164.4	159.7	157.8	160.2	157.5	160.6	157.7	159.6	157.8	159.6	157.9
Girls 12-17 years	183.6	185.5	176.1	176.5	176.3	176.6	175.9	176.5	175.2	174.9	175.3	175.0
Expected values:												
Boys 12-17 years	165.2	166.1	159.4	159.9	159.8	160.2	159.6	160.0	159.3	160.0	159.3	160.0
Girls 12-17 years	183.8	184.7	176.2	176.6	176.3	176.4	176.0	176.1	175.2	175.0	175.3	175.2
Female equivalent												
Girls:												
12 years	143.1	144.3	138.9	137.9	139.0	138.4	138.6	138.6	138.4	138.6	138.4	138.5
13 years	151.9	153.6	146.4	146.1	145.4	145.9	146.3	146.6	144.4	144.9	143.6	143.9
14 years	162.4	161.0	151.1	151.4	151.6	152.0	150.1	150.6	149.1	146.6	149.3	145.5
15 years	168.5	169.7	153.8	160.0	154.7	160.7	154.4	161.0	152.8	153.0	153.7	154.0
16 years	172.2	172.2	154.6	153.0	155.2	153.9	155.4	152.9	153.0	153.0	154.0	154.0
17 years	172.9	174.0	152.8	161.0	153.8	160.7	152.9	161.0	152.9	153.0	153.9	154.0
Male standard	Standard error of the mean											
Boys:												
12 years	0.64	2.85	0.66	2.91	0.65	2.80	0.64	2.81	0.66	2.90	0.66	2.97
17 years	0.99	2.38	0.92	2.32	0.79	1.90	0.85	2.03	0.60	1.76	0.64	2.11
Girls:												
12 years	0.71	1.80	0.64	2.00	0.67	2.06	0.61	1.89	0.58	1.98	0.62	2.01
17 years	0.72	79.00	0.84	75.07	0.90	75.07	0.85	75.07	0.07	93.00	0.10	93.00
Boys 12-17 years	0.49	1.81	0.40	1.92	0.38	1.70	0.33	1.68	0.41	1.68	0.41	1.57
Girls 12-17 years	0.40	1.04	0.34	1.38	0.36	1.44	0.36	1.43	0.43	1.28	0.44	1.31

Table 10. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of youths by geographic region, chronological age in years at last birthday, and sex, with selected standard errors: United States, 1966-1970

Standard of reference, sex, and chronological age at last birthday	Radius				Ulna				Capitate			
	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West
Male standard	Mean skeletal age in months											
Boys:												
12 years	140.4	139.2	140.3	139.6	140.2	139.2	141.5	139.3	141.2	140.1	141.7	140.7
13 years	157.2	157.8	156.4	157.2	157.2	157.0	155.8	156.9	155.1	156.3	154.2	157.3
14 years	173.1	172.2	173.8	174.9	172.9	171.8	173.6	173.9	168.5	167.2	166.7	168.5
15 years	189.0	183.1	186.7	187.7	188.5	182.9	185.4	187.1	176.8	173.2	174.3	176.2
16 years	198.4	196.4	197.2	197.8	195.2	194.0	194.0	194.6	177.9	177.7	174.2	177.1
17 years	209.4	207.6	205.5	206.2	202.7	202.3	201.0	201.6	180.4	191.2	185.6	184.4
Girls:												
12 years	176.7	172.3	174.5	172.6	176.7	171.8	174.2	171.5	170.2	167.9	168.6	166.7
13 years	186.6	186.3	186.0	184.3	185.6	185.5	186.0	184.4	177.6	175.5	175.0	175.4
14 years	197.8	197.4	197.9	198.9	196.8	196.4	196.5	196.7	182.1	181.3	178.6	184.1
15 years	207.4	208.4	210.1	208.3	203.2	203.6	204.6	203.4	184.9	190.9	184.2	187.2
16 years	215.6	213.8	214.2	213.4	207.6	206.7	205.6	205.6	192.0	192.0	189.7	183.7
17 years	216.6	217.3	216.9	217.5	208.6	208.8	207.2	208.6	191.2	192.0	—	192.0
Actual values:												
Boys 12-17 years	174.8	174.2	176.0	175.5	171.6	171.8	173.4	172.5	157.4	157.1	157.2	158.5
Girls 12-17 years	198.0	197.1	198.5	197.6	191.9	190.9	191.8	191.0	175.2	172.9	172.7	172.5
Expected values:												
Boys 12-17 years	173.9	175.1	176.2	175.1	170.8	172.6	173.4	172.2	157.2	157.5	157.8	157.8
Girls 12-17 years	197.3	197.4	198.1	198.1	191.0	191.2	191.4	191.7	173.6	173.0	173.1	173.3
Female equivalent												
Girls:												
12 years	144.4	140.3	142.5	140.6	144.7	139.8	142.2	139.5	138.2	135.9	136.2	135.4
13 years	154.6	154.3	154.0	152.3	153.6	153.5	154.0	152.4	145.6	143.5	143.0	143.4
14 years	167.8	167.4	167.9	168.9	167.6	166.8	167.0	167.4	150.1	149.3	146.6	152.1
15 years	180.4	181.8	184.1	181.6	173.4	174.2	175.6	173.8	152.9	160.8	152.2	156.2
16 years	192.6	189.8	190.4	189.4	180.6	179.7	178.2	178.2	162.0	162.0	158.7	161.7
17 years	193.6	194.3	193.9	194.3	181.6	181.8	180.2	181.6	161.2	162.0	·	162.0
Male standard	Standard error of the mean											
Boys:												
12 years	1.19	1.48	1.88	1.35	1.13	1.53	1.69	1.24	1.33	1.34	1.56	1.56
17 years	0.78	0.87	0.92	1.56	0.48	1.34	0.47	1.25	41.01	95.62	2.42	41.34
Girls:												
12 years	1.40	1.65	1.43	2.78	1.58	1.75	1.49	2.70	2.08	1.53	0.98	1.92
17 years	0.77	0.47	0.77	0.73	0.91	0.48	0.83	0.67	0.83	135.76	—	96.00
Boys 12-17 years	0.94	0.74	0.93	0.93	1.01	1.04	1.03	0.98	1.86	1.74	1.41	1.35
Girls 12-17 years	0.81	0.67	0.97	0.89	0.68	0.75	0.57	0.51	0.68	1.19	0.72	1.43

Table 10. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of youths by geographic region, chronological age in years at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Hamate				Triquetral				Lunate				Scaphoid			
	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West
Male standard	Mean skeletal age in months															
Boys:																
12 years	142.0	141.0	143.0	142.4	141.3	139.7	141.4	140.4	140.0	139.6	141.5	140.7	139.2	138.6	139.5	138.8
13 years	156.0	156.8	154.9	158.1	155.3	155.5	153.6	155.7	154.5	155.2	154.4	157.1	154.1	154.3	153.2	156.1
14 years	168.8	167.6	167.1	169.8	167.9	166.3	166.3	168.8	168.1	166.6	166.2	168.5	167.9	165.8	165.5	168.7
15 years	177.2	173.6	175.2	177.4	176.7	172.1	174.5	176.1	176.1	172.6	173.9	175.8	176.8	172.8	173.8	176.8
16 years	178.1	178.7	174.1	179.9	177.8	177.7	173.2	177.9	176.7	177.7	173.8	176.8	176.8	176.8	175.0	177.2
17 years	181.0	192.0	186.1	184.5	183.4	192.0	186.1	184.6	183.4	190.8	186.2	184.2	182.5	192.0	184.8	187.1
Girls:																
12 years	170.8	168.3	169.7	168.2	169.2	167.3	167.4	166.5	168.7	167.4	167.9	166.2	168.2	166.2	167.0	165.8
13 years	177.8	176.5	175.2	176.3	176.4	174.3	174.5	174.7	176.2	174.3	175.0	173.9	176.5	174.1	174.3	174.0
14 years	182.2	181.8	178.4	184.0	181.2	181.8	178.5	184.0	181.4	180.7	178.0	183.1	181.2	179.7	178.6	183.4
15 years	184.7	190.9	192.0	188.0	184.4	190.8	192.0	188.4	184.4	191.5	192.0	183.0	184.4	191.5	184.2	183.9
16 years	192.0	192.0	189.7	180.5	192.0	192.0	188.9	180.6	192.0	192.0	188.1	187.3	—	192.0	187.5	187.7
17 years	191.2	192.0	—	192.0	190.9	192.0	—	192.0	189.8	192.0	—	—	190.0	192.0	—	—
Actual values:																
Boys 12-17 years	157.8	157.7	157.7	159.7	157.5	156.4	156.7	158.1	156.8	156.4	156.9	158.3	156.4	155.6	155.8	157.7
Girls 12-17 years	175.6	173.4	173.2	173.4	174.0	172.1	172.0	172.1	173.8	172.3	172.2	171.6	173.8	171.6	171.8	171.5
Expected values:																
Boys 12-17 years	157.8	158.3	158.4	158.6	156.8	157.0	157.3	157.4	156.8	157.0	157.2	157.3	156.0	156.3	156.5	156.7
Girls 12-17 years	174.3	173.7	173.7	173.8	172.8	172.3	172.5	172.5	172.7	172.3	172.3	172.4	172.6	171.9	172.1	172.0
Female equivalent																
Girls:																
12 years	138.8	136.3	137.7	136.2	136.7	136.1	136.1	135.5	136.8	136.2	136.4	135.2	136.2	134.2	135.0	133.9
13 years	145.8	144.5	143.2	144.3	143.4	141.3	141.5	141.7	143.2	141.3	142.0	140.9	144.5	142.1	142.3	142.0
14 years	150.2	149.8	146.4	152.0	149.2	149.8	145.5	152.0	149.4	148.7	145.0	151.1	149.2	147.7	146.6	151.4
15 years	152.7	160.8	162.0	157.0	152.4	160.8	162.0	156.4	152.4	160.5	161.0	151.0	152.4	160.5	152.2	151.9
16 years	162.0	162.0	158.7	148.5	162.0	162.0	156.9	148.6	161.0	161.0	157.1	155.6	—	161.0	156.0	156.4
17 years	161.2	162.0	—	162.0	160.9	162.0	—	162.0	158.8	161.0	—	—	159.0	161.0	—	—
Male standard	Standard error of the mean															
Boys:																
12 years	1.26	1.29	1.54	1.34	1.29	1.33	1.55	1.63	1.18	1.15	1.38	1.73	1.13	1.39	1.66	1.29
17 years	40.99	96.00	2.28	41.33	41.46	96.00	2.31	41.36	41.46	95.38	2.35	41.30	41.55	135.76	2.80	41.90
Girls:																
12 years	1.77	1.17	1.29	1.88	1.90	1.52	1.35	1.68	1.60	1.42	1.16	1.54	1.66	0.93	1.37	2.00
17 years	0.83	135.76	—	135.76	95.44	96.00	—	135.76	94.90	96.00	—	—	1.52	96.00	—	—
Boys 12-17 years	1.89	1.74	1.46	1.36	1.89	1.75	1.44	1.38	1.68	1.57	1.25	1.35	1.75	1.51	1.35	1.56
Girls 12-17 years	0.69	0.94	0.97	1.46	0.71	1.12	0.92	1.43	0.60	1.21	0.72	1.40	0.87	0.90	0.97	1.51

Table 10. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of youths by geographic region, chronological age in years at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Trapezium				Trapezoid				Metacarpal I				Metacarpal II			
	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West
Male standard	Mean skeletal age in months															
Boys:																
12 years	138.4	137.5	138.4	138.6	139.2	138.4	138.4	139.1	138.6	137.7	139.8	138.6	139.5	136.8	139.8	138.3
13 years	153.6	155.1	153.0	155.8	154.1	156.0	153.2	155.8	154.4	156.1	155.0	155.9	155.3	156.1	154.7	156.0
14 years	168.0	166.5	165.6	168.3	167.8	166.8	166.1	168.7	169.1	168.2	169.8	170.4	170.8	170.6	172.2	172.2
15 years	176.7	172.5	174.1	176.1	176.6	172.9	173.9	176.3	177.2	175.7	176.4	176.8	183.6	180.8	181.3	183.3
16 years	176.0	178.0	173.8	178.1	175.8	177.1	174.0	177.7	178.4	179.4	179.4	177.8	188.7	188.8	187.1	185.7
17 years	181.6	192.0	185.3	185.5	181.6	192.0	185.2	185.7	184.4	184.4	182.1	182.6	199.2	196.0	192.6	196.9
Girls:																
12 years	168.5	166.7	166.4	165.5	168.9	166.8	166.2	165.8	171.9	168.7	172.0	169.1	173.4	170.0	172.4	171.7
13 years	176.2	174.5	174.5	174.8	176.4	174.4	174.8	174.6	177.6	176.7	178.4	177.2	184.7	182.7	182.3	183.8
14 years	181.1	180.0	179.4	182.3	181.1	180.2	179.7	183.2	181.0	181.2	179.1	182.6	192.7	194.6	195.1	193.8
15 years	184.7	191.5	184.4	188.5	184.4	191.4	177.0	189.6	184.2	185.6	185.4	185.4	197.6	199.2	199.1	199.0
16 years	192.0	192.0	189.2	187.8	192.0	192.0	189.8	187.3	186.0	184.5	186.0	186.0	204.7	204.3	201.4	202.1
17 years	192.0	192.0	—	—	192.0	192.0	—	—	186.0	185.7	186.0	186.0	203.1	204.6	204.5	204.3
Actual values:																
Boys 12-17 years	155.8	155.6	155.5	157.4	156.1	156.1	155.7	157.5	158.9	160.3	161.5	159.6	164.5	165.2	166.2	165.0
Girls 12-17 years	174.0	171.9	171.7	171.7	174.2	171.8	171.8	171.8	176.4	174.5	176.1	175.2	184.8	183.8	184.7	185.0
Expected values:																
Boys 12-17 years	155.6	156.0	156.5	156.4	155.9	156.2	156.7	156.6	159.1	160.6	161.2	159.2	164.0	165.8	166.3	164.7
Girls 12-17 years	172.8	172.0	172.2	172.2	172.9	172.0	172.4	172.2	175.6	175.4	175.2	175.6	184.2	184.4	184.6	185.0
Female equivalent																
Girls:																
12 years	136.5	134.8	134.7	134.2	136.4	134.9	134.6	134.4	140.8	136.8	140.0	137.1	141.4	138.0	140.4	139.7
13 years	143.2	141.2	141.2	141.4	143.4	141.4	141.8	141.6	145.6	144.7	146.4	145.2	152.7	150.7	150.3	151.8
14 years	149.1	148.0	147.4	150.2	149.1	148.2	147.4	151.2	149.0	149.4	147.1	151.6	162.4	164.6	165.1	163.8
15 years	152.7	160.0	152.4	156.5	152.4	160.4	144.0	157.6	153.2	154.6	154.4	154.4	167.6	169.2	169.1	169.0
16 years	161.0	161.0	157.2	155.8	161.0	161.0	157.8	155.3	155.0	153.5	155.0	155.0	175.7	175.3	171.4	172.2
17 years	161.0	161.0	—	—	161.0	161.0	—	—	155.0	154.7	155.0	155.0	174.1	175.6	175.5	175.3
Male standard	Standard error of the mean															
Boys:																
12 years	1.48	1.12	1.50	1.42	1.27	1.31	1.65	1.40	1.09	1.28	1.60	1.29	1.25	1.24	1.81	1.54
17 years	40.99	135.76	2.53	41.57	40.99	135.76	2.58	41.57	0.91	1.04	0.88	1.26	1.72	1.35	1.42	2.09
Girls:																
12 years	1.41	1.10	1.54	1.66	1.61	0.99	1.21	1.61	1.55	1.29	1.27	2.03	1.69	1.48	1.06	2.73
17 years	—	96.00	—	—	—	96.00	—	—	93.00	0.29	—	58.81	2.19	3.91	1.50	2.65
Boys 12-17 years	1.90	1.53	1.32	1.30	1.91	1.58	1.39	1.35	1.17	0.57	1.03	0.88	0.81	0.83	0.75	1.31
Girls 12-17 years	0.78	1.13	0.96	1.18	0.87	0.94	0.93	1.13	1.06	0.79	0.58	0.59	1.05	0.98	0.82	0.91

Table 10. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of youths by geographic region, chronological age in years at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Metacarpal III				Metacarpal IV				Metacarpal V				Pisiform			
	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West
Male standard	Mean skeletal age in months															
Boys:																
12 years	140.2	137.6	140.5	139.0	140.2	137.5	140.0	139.0	140.4	138.1	140.6	139.4	142.4	139.9	140.7	141.8
13 years	155.9	156.6	155.3	156.6	155.8	156.6	155.5	156.4	156.3	156.9	155.8	156.8	156.2	157.3	154.9	154.8
14 years	171.4	171.0	171.8	172.3	171.5	171.1	171.7	172.6	171.6	171.0	172.3	173.2	166.5	166.5	167.4	168.8
15 years	183.2	179.7	181.1	183.3	183.6	179.6	181.5	182.7	184.3	180.8	181.9	182.9	174.8	170.5	175.7	176.6
16 years	187.7	188.6	186.6	185.4	186.8	187.9	187.0	186.2	190.1	189.3	188.4	188.4	176.2	177.7	175.9	177.0
17 years	196.0	195.5	191.7	194.5	195.7	195.4	190.0	193.3	199.2	198.2	192.8	194.5	183.4	—	185.4	185.7
Girls:																
12 years	173.6	170.6	173.6	172.2	173.8	170.2	173.0	171.5	174.5	170.6	173.5	171.8	168.6	166.3	166.5	167.2
13 years	184.4	182.1	182.6	182.6	183.8	182.3	182.4	182.5	185.1	183.0	182.5	183.3	175.7	173.8	174.6	175.2
14 years	191.9	192.9	192.8	193.0	191.4	192.5	192.5	193.4	193.2	194.2	194.9	194.7	182.7	181.7	179.0	184.4
15 years	196.2	196.7	196.6	197.2	197.2	197.6	196.2	197.3	199.6	199.8	198.7	199.2	183.7	187.4	188.6	185.6
16 years	201.3	199.1	198.3	201.2	202.0	198.9	199.4	200.6	203.8	203.2	201.6	202.9	192.0	180.0	189.1	184.0
17 years	201.6	199.8	201.4	200.0	201.8	200.1	200.9	200.1	203.8	205.0	207.0	204.9	192.0	192.0	192.0	192.0
Actual values:																
Boys 12-17 years	164.2	165.1	166.0	164.9	164.3	164.9	165.8	164.7	165.9	166.4	167.1	166.0	157.7	157.2	158.5	158.7
Girls 12-17 years	184.3	182.4	183.9	184.0	184.5	182.6	183.6	184.0	186.6	184.5	185.5	186.0	174.5	171.7	172.1	173.2
Expected values:																
Boys 12-17 years	163.7	165.6	166.1	164.6	163.7	165.5	166.0	164.4	165.2	167.0	167.3	165.8	157.4	157.7	158.7	158.2
Girls 12-17 years	183.6	183.3	183.5	184.0	183.6	183.4	183.4	184.0	185.7	185.2	185.4	186.1	173.4	172.4	172.9	172.8
Female equivalent																
Girls:																
12 years	141.6	138.6	141.6	140.2	141.8	138.2	141.0	139.5	142.5	138.6	141.5	139.8	136.6	135.2	135.2	135.6
13 years	152.4	150.1	150.6	150.6	151.8	150.3	150.4	150.5	153.1	151.0	150.5	151.3	142.7	140.9	141.6	142.2
14 years	160.9	161.9	161.8	162.0	160.4	162.0	162.0	163.4	161.6	162.2	162.9	162.7	150.7	149.7	147.0	152.4
15 years	166.2	166.7	166.6	167.2	167.2	167.6	166.2	167.3	169.6	169.8	168.4	169.2	151.7	155.4	156.6	153.6
16 years	171.3	169.1	168.3	171.2	172.0	168.9	169.4	170.6	174.6	173.4	171.6	172.9	160.0	148.0	157.1	152.0
17 years	171.6	169.8	171.4	170.0	171.8	170.1	170.9	170.1	174.6	176.0	179.0	175.9	160.0	160.0	160.0	160.0
Male standard	Standard error of the mean															
Boys:																
12 years	1.28	1.19	1.67	1.62	1.26	1.36	1.72	1.68	1.27	1.29	1.76	1.70	1.14	1.35	1.25	2.10
17 years	1.81	0.85	1.20	2.36	1.78	0.80	1.01	2.32	2.06	1.04	1.35	1.62	4.36	—	4.30	41.60
Girls:																
12 years	1.64	1.45	1.15	2.55	1.58	1.40	1.07	2.84	1.93	1.38	0.88	2.43	1.40	1.11	1.39	1.74
17 years	2.39	3.52	1.86	1.93	2.17	2.69	1.64	2.12	1.92	2.28	1.07	1.71	—	96.00	135.76	74.36
Boys 12-17 years	0.90	0.67	0.83	1.01	0.98	0.71	0.81	1.02	0.83	0.88	0.68	1.01	1.13	1.04	0.98	1.02
Girls 12-17 years	1.05	0.98	0.66	0.95	1.11	0.93	0.72	0.96	1.04	0.82	0.88	0.92	0.74	1.04	0.77	1.19

Table 10. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of youths by geographic region, chronological age in years at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Adductor sesamoid				Flexor sesamoid				Proximal phalanx I				Proximal phalanx II			
	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West
Male standard	Mean skeletal age in months															
Boys:																
12 years	159.2	159.9	159.1	160.4	164.3	166.2	164.3	165.9	141.3	139.1	141.7	140.7	141.8	139.3	141.3	140.4
13 years	166.8	165.3	164.0	163.8	171.7	168.0	168.5	166.5	157.4	158.5	155.8	158.0	158.1	158.5	156.6	158.4
14 years	170.1	170.4	170.0	170.8	171.7	171.1	172.8	172.5	172.8	171.8	172.8	173.3	172.3	170.9	172.3	173.7
15 years	175.8	173.6	175.4	175.8	175.4	174.3	175.6	176.8	185.9	180.9	181.6	183.8	184.8	180.5	181.5	183.7
16 years	177.7	176.7	174.6	179.0	177.0	176.6	175.6	179.2	188.0	188.8	187.4	188.1	187.8	187.6	186.6	186.4
17 years	181.8	192.0	182.1	184.3	184.7	192.0	184.2	186.1	199.5	200.2	193.3	200.2	198.4	197.4	190.6	196.6
Girls:																
12 years	169.6	168.9	171.4	169.6	172.0	170.6	173.4	172.7	176.0	173.6	176.4	174.2	176.5	174.2	175.7	174.3
13 years	175.7	173.2	175.9	173.4	176.7	175.9	175.1	175.5	186.2	186.1	184.5	182.5	185.2	183.5	184.1	182.7
14 years	177.7	181.1	177.5	179.8	179.4	183.0	179.0	179.4	194.9	194.6	195.3	197.4	193.2	191.3	193.4	194.5
15 years	178.9	177.4	185.4	180.5	180.5	179.5	184.1	182.0	203.4	202.6	201.7	204.8	198.9	198.9	198.1	200.2
16 years	180.7	184.0	181.8	178.3	185.8	185.6	187.0	178.9	207.6	207.2	204.2	205.7	204.0	200.5	201.1	200.7
17 years	178.8	186.9	187.3	185.2	187.0	186.2	192.0	189.8	209.5	207.2	205.3	208.5	204.0	202.5	202.0	204.0
Actual values:																
Boys 12-17 years	168.8	168.4	168.4	169.3	172.2	171.1	172.5	172.7	165.2	165.6	166.1	165.9	164.8	164.7	165.4	165.2
Girls 12-17 years	173.6	173.3	175.0	173.4	176.0	175.2	175.8	175.8	187.2	185.7	185.5	185.1	185.6	183.4	184.2	183.2
Expected values:																
Boys 12-17 years	168.3	168.5	169.0	169.0	171.7	171.7	172.5	172.4	164.5	166.1	166.8	165.3	163.9	165.4	166.0	164.6
Girls 12-17 years	173.6	173.8	173.7	173.7	175.9	175.6	175.4	175.8	186.3	186.0	185.3	185.6	184.5	184.2	183.9	183.6
Female equivalent																
Girls:																
12 years	137.6	136.9	139.4	137.6	140.0	138.6	141.4	140.7	143.0	140.6	143.4	141.2	143.5	141.2	142.7	141.3
13 years	143.7	141.2	143.9	141.4	144.7	143.9	143.1	143.5	154.2	154.1	152.5	150.5	152.4	150.8	151.1	150.4
14 years	145.7	149.1	145.5	147.8	147.4	151.0	147.0	147.4	164.9	164.6	165.3	167.4	163.1	159.6	163.2	163.8
15 years	146.9	145.4	153.4	148.5	148.5	147.5	152.1	150.0	174.4	173.6	172.7	176.6	168.9	168.9	168.1	170.2
16 years	148.7	152.0	149.8	146.3	153.8	153.6	155.0	146.9	179.6	179.2	175.4	177.7	174.0	170.5	171.1	170.7
17 years	146.8	154.9	155.6	153.2	155.0	154.2	161.0	158.8	182.5	179.2	177.3	181.0	174.0	172.5	172.0	174.0
Male standard	Standard error of the mean															
Boys:																
12 years	1.20	1.45	0.74	0.96	1.02	1.49	0.78	1.54	1.07	1.35	2.01	1.62	1.11	1.56	1.67	1.38
17 years	70.58	96.00	2.76	2.17	92.77	135.76	3.22	2.81	2.36	3.83	1.29	2.05	2.19	1.66	1.91	2.09
Girls:																
12 years	0.89	0.90	1.23	1.34	1.07	0.87	0.68	1.35	1.72	1.23	1.12	2.55	1.29	1.09	1.11	2.68
17 years	11.53	72.43	59.34	71.77	59.65	72.20	135.76	73.50	0.82	3.13	1.55	1.11	—	2.96	1.49	—
Boys 12-17 years	0.53	0.96	0.45	0.61	0.58	0.92	0.52	1.05	0.81	0.99	0.96	1.16	0.86	0.85	1.04	0.97
Girls 12-17 years	0.38	0.68	0.74	0.80	0.85	0.81	0.89	0.69	1.58	1.04	0.58	1.12	1.28	1.17	0.46	0.90

Table 10. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of youths by geographic region, chronological age in years at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Proximal phalanx III				Proximal phalanx IV				Proximal phalanx V				Middle phalanx II			
	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West
Male standard	Mean skeletal age in months															
Boys:																
12 years	141.9	139.6	141.3	140.8	141.6	139.3	141.6	140.4	142.0	139.6	141.8	140.6	142.6	140.1	141.9	142.1
13 years	158.2	158.8	157.0	158.8	158.3	158.6	156.9	158.3	158.2	158.7	157.1	158.2	158.8	158.5	156.4	158.3
14 years	172.3	171.3	172.6	173.4	172.4	171.2	172.9	173.9	172.4	171.3	172.4	173.4	172.1	171.3	172.3	173.6
15 years	185.1	181.1	181.5	183.6	185.1	180.9	181.1	184.0	185.3	181.2	180.8	183.6	182.8	180.1	181.9	183.3
16 years	186.8	187.7	186.0	186.1	187.4	187.5	186.2	187.3	187.5	187.5	186.4	185.9	186.8	188.2	185.6	187.8
17 years	197.9	197.0	191.3	197.4	197.5	198.0	190.7	195.4	196.5	198.6	190.7	195.9	196.6	197.0	191.3	195.6
Girls:																
12 years	176.8	174.6	176.0	174.3	177.4	175.0	176.5	174.5	177.5	175.1	176.6	174.7	177.0	174.3	176.2	174.2
13 years	184.7	183.8	184.2	183.4	185.5	183.8	184.8	183.4	185.5	184.6	184.2	182.9	185.3	184.7	184.4	182.7
14 years	193.6	192.3	194.5	194.1	193.4	192.3	194.2	194.1	193.3	191.8	194.0	194.8	193.4	191.4	192.9	193.0
15 years	199.4	199.1	198.9	200.4	199.5	198.6	198.8	200.1	198.8	198.9	201.5	201.0	198.7	199.8	199.2	200.0
16 years	204.0	201.5	201.0	203.0	204.0	201.7	201.3	203.2	204.0	200.9	201.4	203.0	203.6	201.0	201.3	203.1
17 years	204.0	202.4	204.0	204.0	203.7	202.8	201.7	204.0	204.0	202.7	204.0	204.0	204.0	201.3	201.3	204.0
Actual values:																
Boys 12-17 years	164.6	165.1	165.6	165.4	164.6	164.8	165.5	165.3	164.6	165.0	165.3	165.0	164.5	165.3	165.8	165.8
Girls 12-17 years	186.0	183.9	185.0	183.8	186.5	184.2	185.2	183.8	186.4	184.2	185.3	184.0	185.9	183.0	184.8	182.9
Expected values:																
Boys 12-17 years	164.0	165.7	166.2	164.8	163.8	165.4	166.0	164.7	163.8	165.5	165.9	164.7	163.9	165.9	166.4	165.0
Girls 12-17 years	185.2	184.6	184.5	184.2	185.4	184.9	184.8	184.4	185.4	184.8	184.8	184.6	184.8	183.6	184.5	183.7
Female equivalent																
Girls:																
12 years	144.9	143.6	144.5	143.3	145.4	144.0	144.8	143.5	145.5	143.1	144.6	142.7	145.0	142.3	144.2	142.2
13 years	152.7	151.8	152.2	151.4	153.5	151.8	152.8	151.4	153.5	152.6	152.2	150.9	153.3	152.7	152.4	150.7
14 years	163.6	162.3	164.5	164.1	163.4	162.3	164.2	164.1	162.3	160.6	163.0	163.8	163.4	160.4	162.8	163.0
15 years	169.8	169.1	168.9	171.4	170.0	168.6	168.8	171.1	168.6	168.8	172.5	172.0	169.4	170.4	170.1	170.5
16 years	176.0	172.5	172.0	174.0	176.0	172.7	172.3	174.4	174.0	171.8	172.4	173.5	174.6	171.0	171.3	174.1
17 years	176.0	173.4	176.0	176.0	175.4	173.8	172.7	176.0	174.0	173.4	174.0	174.0	175.0	171.3	171.3	175.0
Male standard	Standard error of the mean															
Boys:																
12 years	1.11	1.51	1.65	1.24	1.11	1.53	1.74	1.35	1.20	1.54	1.71	1.40	1.28	1.38	1.81	1.17
17 years	2.85	1.41	1.84	2.52	2.86	2.37	1.91	1.96	2.95	1.80	2.03	2.08	1.86	2.35	1.08	1.64
Girls:																
12 years	1.60	1.05	1.10	2.59	1.18	1.07	1.16	2.60	1.14	1.21	1.04	2.47	1.05	1.07	1.39	2.54
17 years	—	3.10	—	—	0.25	1.64	1.71	—	—	1.95	—	—	—	2.61	1.91	—
Boys 12-17 years	0.96	0.84	0.99	1.14	1.02	0.87	0.94	1.16	0.92	0.86	1.01	1.29	0.77	1.17	1.01	1.06
Girls 12-17 years	1.12	1.07	0.45	0.79	1.09	0.93	0.47	0.93	1.28	1.18	0.53	1.05	1.21	0.73	0.55	1.37

Table 10. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of youths by geographic region, chronological age in years at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Middle phalanx III				Middle phalanx IV				Middle phalanx V				Distal phalanx I			
	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West	North-east	Mid-west	South	West
Male standard	Mean skeletal age in months															
Boys:																
12 years	142.4	140.2	141.7	142.1	141.7	139.7	141.5	141.0	142.1	139.8	141.8	141.4	141.0	138.4	140.7	139.6
13 years	158.8	158.5	156.6	158.4	158.3	158.0	156.0	158.1	158.5	158.0	155.9	158.3	155.7	156.6	154.2	156.5
14 years	172.4	171.4	172.6	173.5	172.3	171.4	172.2	173.5	172.3	171.2	172.0	173.3	168.4	166.8	168.5	169.8
15 years	183.9	180.0	182.2	184.2	183.2	180.0	182.0	183.9	183.1	180.1	181.6	184.3	177.6	173.8	175.7	176.7
16 years	187.0	188.0	186.4	187.4	187.6	187.9	185.8	186.9	187.0	187.5	185.7	187.9	181.4	179.2	177.6	179.8
17 years	197.8	197.3	192.1	195.5	197.8	196.6	192.1	195.0	197.3	197.0	190.2	194.9	186.8	186.6	184.6	186.8
Girls:																
12 years	177.0	174.5	176.5	174.4	176.8	174.2	176.1	174.2	176.8	174.0	175.7	175.0	171.8	170.5	171.2	170.1
13 years	185.8	184.5	184.8	183.1	186.3	184.0	184.8	183.5	185.4	184.8	184.5	181.7	181.0	177.5	178.7	176.4
14 years	194.0	191.6	193.8	194.1	193.8	191.9	193.2	193.8	192.2	190.9	193.2	194.2	183.9	181.5	183.4	184.8
15 years	198.4	199.5	198.9	199.2	198.6	199.2	198.6	199.0	198.5	199.1	198.1	198.8	189.2	191.0	188.8	191.0
16 years	203.4	199.7	201.3	202.9	203.4	201.4	201.1	202.9	203.1	201.2	200.7	203.2	189.4	188.0	187.2	191.0
17 years	204.0	201.3	201.6	204.0	204.0	201.7	201.3	204.0	204.0	201.7	201.3	204.0	189.9	186.0	186.0	186.0
Actual values:																
Boys 12-17 years	165.2	165.5	166.3	166.2	164.8	165.2	165.8	165.6	164.5	165.1	165.6	165.8	159.7	158.8	159.3	160.1
Girls 12-17 years	186.6	183.3	185.4	183.3	186.7	183.2	185.0	183.4	185.8	182.8	184.5	182.7	179.6	176.1	177.1	175.9
Expected values:																
Boys 12-17 years	164.6	166.2	166.9	165.4	164.1	165.8	166.4	165.0	163.8	165.8	166.4	164.9	159.0	159.6	159.6	159.5
Girls 12-17 years	185.4	184.0	184.9	184.0	185.4	184.0	184.7	184.1	184.8	183.4	184.2	183.2	178.5	176.6	177.1	176.6
Female equivalent																
Girls:																
12 years	145.0	141.5	144.5	141.4	144.8	141.2	144.1	141.2	144.8	142.0	143.7	143.0	139.8	138.5	139.2	138.1
13 years	153.8	152.5	152.8	151.1	154.3	152.0	152.8	151.5	153.4	152.8	152.5	149.7	149.0	145.5	146.7	144.4
14 years	163.0	160.6	162.8	163.1	162.8	160.9	162.2	162.8	161.4	158.9	163.2	164.2	151.4	149.5	151.2	151.9
15 years	168.8	170.5	169.8	170.2	169.2	170.2	169.2	170.0	168.5	169.1	168.1	168.8	158.4	161.0	157.8	161.0
16 years	174.4	170.7	172.3	173.9	174.4	172.4	172.1	173.9	173.1	171.2	170.7	173.2	158.8	157.0	154.6	161.0
17 years	175.0	172.3	172.6	175.0	175.0	172.7	172.3	175.0	174.0	171.7	171.3	174.0	159.8	153.0	153.0	153.0
Male standard	Standard error of the mean															
Boys:																
12 years	1.27	1.43	1.78	1.13	1.23	1.36	1.75	1.42	1.21	1.40	1.68	1.32	1.23	1.33	1.66	1.49
17 years	1.63	2.06	1.02	1.34	1.86	2.14	0.94	1.70	1.95	2.04	0.94	1.50	2.36	2.51	2.49	2.02
Girls:																
12 years	1.03	1.05	1.27	2.41	1.18	1.14	1.37	2.47	1.21	1.19	1.51	2.50	1.55	1.20	1.29	2.24
17 years	—	2.61	1.69	—	—	1.97	1.91	—	—	1.97	1.91	—	2.44	—	—	41.59
Boys 12-17 years	0.69	1.09	1.10	1.12	0.71	0.95	1.01	1.19	0.80	1.02	0.97	1.16	0.93	0.97	0.77	0.97
Girls 12-17 years	1.26	0.71	0.47	1.42	1.28	0.76	0.50	1.44	1.20	0.85	0.51	1.50	0.77	0.96	0.68	1.09

Table 10. Mean bone-specific skeletal ages for the 31 individual hand-wrist bones of youths by geographic region, chronological age in years at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Distal phalanx II				Distal phalanx III				Distal phalanx IV				Distal phalanx V			
	Northeast	Midwest	South	West	Northeast	Midwest	South	West	Northeast	Midwest	South	West	Northeast	Midwest	South	West
Male standard	Mean skeletal age in months															
Boys:																
12 years	141.1	138.5	140.4	140.1	141.2	138.4	140.4	140.0	141.6	138.8	140.7	140.2	141.8	138.6	140.8	140.0
13 years	156.5	156.8	154.9	156.7	156.4	156.1	154.9	156.7	156.0	156.8	155.1	156.6	156.1	156.8	155.0	156.8
14 years	168.9	167.6	169.1	169.5	168.9	167.1	169.2	169.2	169.0	167.6	169.7	169.0	168.8	167.1	169.7	169.2
15 years	177.9	173.8	175.3	176.8	177.6	173.6	175.0	176.4	176.2	173.8	174.2	176.3	176.4	173.5	174.3	176.1
16 years	181.2	178.4	177.3	179.8	181.1	178.6	176.4	178.8	178.7	178.1	176.9	177.8	178.5	178.3	176.9	179.0
17 years	185.8	186.2	184.5	187.2	185.7	186.0	184.3	187.0	183.9	184.3	181.1	184.1	183.7	184.3	180.9	183.4
Girls:																
12 years	172.4	170.3	171.5	170.0	172.3	169.8	171.3	169.6	172.0	169.9	170.9	169.3	172.2	169.9	171.0	169.2
13 years	181.6	177.6	179.2	176.8	181.3	176.7	179.0	176.8	177.6	175.5	176.9	176.2	178.2	175.5	176.8	176.3
14 years	184.4	181.8	183.7	185.2	184.2	181.5	183.5	185.1	181.7	180.1	179.8	181.9	181.8	180.4	179.8	182.0
15 years	189.3	191.0	188.6	190.9	189.3	191.0	188.7	190.9	185.7	185.8	185.8	185.8	185.6	185.7	185.8	185.8
16 years	189.3	188.2	187.5	191.0	189.5	188.5	187.5	191.0	186.0	186.0	186.0	186.0	186.0	186.0	186.0	186.0
17 years	190.2	186.0	186.0	186.0	190.0	186.0	186.0	186.0	186.0	185.8	186.0	186.0	186.0	185.7	186.0	186.0
Actual values:																
Boys 12-17 years	160.2	159.0	159.9	160.4	160.2	158.9	159.7	160.1	159.3	159.2	159.7	159.4	159.4	159.0	159.8	159.6
Girls 12-17 years	179.8	176.1	177.4	176.0	179.6	175.6	177.2	175.8	177.1	174.3	175.4	174.1	177.3	174.3	175.5	174.2
Expected values:																
Boys 12-17 years	159.3	159.9	160.3	159.8	159.2	159.9	160.0	159.6	158.7	159.8	159.9	159.0	158.7	159.8	159.9	159.2
Girls 12-17 years	178.4	176.9	177.2	176.8	178.1	176.6	176.9	176.6	176.0	174.9	175.2	174.6	176.0	174.9	175.4	174.8
Female equivalent																
Girls:																
12 years	140.4	138.3	139.5	138.0	140.3	137.8	139.3	137.6	140.0	137.9	138.9	137.3	139.6	137.9	139.0	137.2
13 years	149.6	145.3	146.4	144.6	149.3	144.7	147.0	144.8	145.6	143.5	144.9	144.2	145.2	142.8	143.8	143.3
14 years	152.4	149.8	151.7	153.2	152.1	149.5	151.5	152.6	149.7	148.1	147.8	149.9	149.8	148.4	147.6	150.0
15 years	157.3	161.0	156.6	160.7	158.3	161.0	157.4	160.8	152.8	152.9	152.9	152.9	153.6	153.7	153.8	153.8
16 years	157.3	156.2	155.5	161.0	158.5	157.0	155.5	161.0	153.0	153.0	153.0	153.0	154.0	154.0	154.0	154.0
17 years	158.6	154.0	154.0	154.0	159.0	153.0	153.0	153.0	153.0	152.9	153.0	153.0	154.0	153.7	154.0	154.0
Male standard	Standard error of the mean															
Boys:																
12 years	1.09	1.26	1.46	1.47	1.10	1.28	1.44	1.42	1.00	1.38	1.48	1.38	1.03	1.33	1.49	1.45
17 years	2.85	2.28	1.45	1.62	3.53	2.36	1.63	1.66	1.32	1.60	0.91	1.02	1.43	1.41	1.04	1.13
Girls:																
12 years	1.82	1.09	1.32	2.01	1.83	1.07	1.20	1.65	1.49	1.18	1.36	1.73	1.52	1.18	1.29	1.70
17 years	2.60	—	—	—	2.46	—	—	—	—	0.60	—	—	—	0.45	—	—
Boys 12-17 years	1.01	0.73	0.62	1.11	1.01	0.73	0.62	1.04	0.96	0.83	0.66	1.10	0.98	0.74	0.62	1.18
Girls 12-17 years	0.69	0.96	0.72	0.96	0.73	0.99	0.72	0.91	0.78	0.90	0.69	1.27	0.79	0.83	0.68	1.28

Table 11. Mean bone-specific skeletal ages for selected hand-wrist bones of youths by annual family income, chronological age at last birthday, and sex, with selected standard errors: United States, 1966-1970

Standard of reference, sex, and chronological age at last birthday	Triquetral			Metacarpal III			Metacarpal V			Proximal phalanx III		
	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more
Male standard	Mean skeletal age in months											
Boys:												
12 years	140.0	139.1	142.0	138.4	137.2	140.9	138.5	137.7	141.2	139.1	139.9	142.0
13 years	153.1	156.7	154.2	154.8	157.5	155.4	155.2	158.0	155.6	156.9	159.5	157.9
14 years	167.8	166.6	167.4	171.8	171.9	171.3	172.6	171.9	171.6	172.6	172.1	172.5
15 years	172.7	174.5	176.1	180.0	181.7	182.8	180.6	181.9	183.7	180.7	181.9	184.5
16 years	176.2	175.6	180.2	185.8	187.2	189.0	187.4	189.2	190.4	186.1	187.5	186.1
17 years	185.2	186.3	188.1	193.0	194.5	197.1	193.8	196.7	197.4	193.5	195.8	200.3
Girls:												
12 years	165.7	166.3	170.0	172.9	171.4	173.0	173.5	171.4	172.7	176.1	174.4	175.9
13 years	174.6	174.2	175.6	182.2	183.0	182.4	182.5	183.8	183.1	183.3	184.0	184.0
14 years	180.6	180.0	185.8	192.9	190.6	194.6	194.7	192.3	196.1	193.4	190.9	195.8
15 years	190.0	189.2	182.8	198.0	196.6	196.2	200.9	198.4	199.8	201.0	199.3	198.9
16 years	171.0	185.0	189.6	200.8	200.1	199.0	204.5	202.6	202.4	202.6	203.6	201.8
17 years	-	192.0	191.1	199.3	202.2	198.4	203.0	206.1	203.6	204.0	204.0	202.1
Actual values:												
Boys 12-17 years	156.7	156.3	157.6	165.1	164.6	165.1	166.2	166.0	166.1	164.9	164.8	165.5
Girls 12-17 years	171.4	171.8	174.8	183.5	183.2	183.8	185.3	185.1	186.1	184.6	183.9	185.5
Expected values:												
Boys 12-17 years	157.7	156.5	157.1	166.1	164.6	164.5	167.2	166.1	165.6	166.1	164.7	164.8
Girls 12-17 years	172.6	172.7	172.6	183.4	183.8	183.4	185.0	185.8	185.7	184.5	184.7	185.0
Female equivalent												
Girls:												
12 years	134.8	135.3	137.0	140.9	139.4	141.0	141.5	139.4	140.7	144.6	143.4	144.4
13 years	141.6	141.2	142.6	150.2	151.0	150.4	150.5	151.8	151.1	151.3	152.0	152.0
14 years	148.6	148.0	153.8	161.9	159.6	163.6	163.4	161.2	165.1	163.4	160.8	165.8
15 years	160.0	157.6	150.8	168.0	166.6	166.2	170.9	167.8	169.8	172.0	169.6	168.9
16 years	138.0	153.0	158.8	170.8	170.1	169.1	175.5	172.6	172.4	173.6	175.2	172.8
17 years	-	162.0	161.1	169.3	172.2	168.4	173.0	177.1	173.6	176.0	176.0	173.1
Male standard	Standard error of the mean											
Boys 12-17 years	1.15	0.50	0.78	1.21	0.53	0.82	1.22	0.53	0.82	1.21	0.53	0.82
Girls 12-17 years	0.63	0.54	0.69	0.67	0.57	0.72	0.68	0.58	0.73	0.68	0.57	0.73

Table 11. Mean bone-specific skeletal ages for selected hand-wrist bones of youths by annual family income, chronological age at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Proximal phalanx IV			Middle phalanx V			Radius			Ulna		
	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more
Male standard	Mean skeletal age in months											
Boys:												
12 years	139.2	139.5	141.8	140.6	140.0	142.3	138.9	138.8	140.5	139.5	138.5	140.7
13 years	156.8	159.4	157.4	156.8	159.2	157.4	156.0	158.5	155.9	156.0	158.0	155.3
14 years	172.5	172.4	173.0	172.1	172.2	171.7	173.9	174.1	172.2	173.5	173.8	171.7
15 years	180.9	182.0	184.2	179.9	182.2	182.7	185.0	186.1	188.2	183.7	185.7	187.7
16 years	185.3	188.5	187.3	186.5	187.4	187.6	196.1	196.2	200.2	194.0	193.4	196.6
17 years	193.1	195.2	200.0	191.9	195.9	198.4	204.9	207.2	208.7	200.5	202.5	202.9
Girls:												
12 years	176.6	174.5	176.6	175.9	174.2	176.1	175.4	173.0	173.2	174.8	172.4	172.9
13 years	184.0	184.2	183.6	183.4	183.8	184.0	184.4	186.2	185.7	184.5	185.6	185.1
14 years	193.2	191.0	194.8	192.1	192.1	192.9	197.2	196.9	199.6	195.5	195.0	199.1
15 years	201.0	198.8	198.7	198.2	199.4	198.1	208.6	208.7	208.0	203.5	204.2	203.1
16 years	202.6	203.6	201.8	201.6	202.6	202.0	214.7	214.1	214.8	206.9	205.3	206.7
17 years	201.5	204.0	202.5	202.5	204.0	202.7	216.3	218.2	215.9	205.8	209.4	208.5
Actual values:												
Boys 12-17 years	164.6	164.8	165.2	164.8	165.2	164.9	174.6	174.8	175.6	172.5	172.0	172.3
Girls 12-17 years	185.1	184.1	185.6	183.8	183.7	180.4	196.6	197.0	199.2	190.4	190.7	193.0
Expected values:												
Boys 12-17 years	165.8	164.6	164.5	166.1	165.0	164.5	175.7	174.8	175.0	173.2	171.9	172.0
Girls 12-17 years	184.8	184.8	185.3	183.9	184.2	184.0	196.8	197.1	199.2	190.6	191.1	192.6
Female equivalent												
Girls:												
12 years	144.8	143.5	144.8	143.9	142.2	144.1	143.4	141.0	141.2	142.8	140.4	140.9
13 years	152.0	152.2	151.6	151.4	151.8	152.0	152.4	154.2	153.7	152.5	153.6	153.1
14 years	163.2	161.0	164.8	161.2	161.2	162.8	167.2	166.9	169.6	165.5	165.0	170.1
15 years	172.0	168.8	168.7	168.2	169.4	168.1	182.2	182.4	181.0	174.0	175.4	173.2
16 years	173.6	175.2	172.8	171.6	172.6	172.0	191.4	190.2	191.6	179.9	177.6	179.7
17 years	172.5	176.0	173.5	172.5	174.0	172.7	193.3	195.2	192.9	178.6	182.4	181.5
Male standard	Standard error of the mean											
Boys 12-17 years	1.22	0.53	0.82	1.22	0.53	0.82	...	...	...	...	...	...
Girls 12-17 years	0.68	0.58	0.73	0.67	0.57	0.72	...	...	...	...	...	...

Table 11. Mean bone-specific skeletal ages for selected hand-wrist bones of youths by annual family income, chronological age at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Capitate			Hamate			Lunate			Scaphoid		
	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more
Male standard	Mean skeletal age in months											
Boys:												
12 years	139.9	139.1	142.7	141.4	140.7	143.1	139.9	138.7	142.1	138.4	137.6	140.2
13 years	153.7	157.5	155.1	154.6	158.4	155.5	154.1	156.2	154.7	153.1	155.4	154.0
14 years	168.2	166.8	168.1	168.7	167.9	167.9	167.4	167.0	167.6	167.2	166.5	167.3
15 years	173.0	174.9	176.1	173.5	175.6	176.8	172.3	173.9	176.1	172.7	174.7	175.9
16 years	176.3	176.1	179.6	177.7	177.1	180.4	176.0	175.6	179.7	176.6	175.6	179.4
17 years	183.8	185.9	187.6	184.7	186.2	187.9	185.1	185.5	188.2	182.7	186.3	190.5
Girls:												
12 years	166.8	167.1	169.9	168.0	167.6	171.5	166.0	166.0	169.6	165.7	165.1	169.4
13 years	175.7	175.2	176.3	175.8	175.9	177.2	175.0	174.0	175.6	174.7	173.8	175.5
14 years	180.7	180.2	186.0	181.4	180.2	183.0	179.8	179.4	185.7	179.3	179.6	185.3
15 years	190.0	188.4	184.3	190.0	189.7	183.8	190.0	189.1	183.1	190.0	188.6	182.1
16 years	179.0	184.0	190.3	171.0	184.0	190.3	192.0	184.0	188.7	190.6	184.0	188.9
17 years	192.0	192.0	191.3	192.0	192.0	191.3	–	192.0	190.2	–	192.0	189.9
Actual values:												
Boys 12-17 years	157.1	156.7	158.3	157.8	157.7	158.3	156.8	155.9	157.8	156.0	155.4	157.1
Girls 12-17 years	172.7	172.5	175.1	173.1	172.9	176.1	171.6	171.4	174.8	171.5	171.0	174.9
Expected values:												
Boys 12-17 years	158.2	156.9	157.6	158.8	157.6	158.1	157.7	156.3	157.1	157.0	155.6	156.5
Girls 12-17 years	173.5	173.4	173.4	173.9	174.0	174.2	172.3	172.6	172.9	172.1	172.2	172.7
Female equivalent												
Girls:												
12 years	135.4	135.2	137.9	136.0	135.6	139.5	135.0	135.0	137.6	133.8	133.6	137.8
13 years	143.7	143.2	144.3	143.8	143.9	145.2	142.0	141.0	142.6	142.7	141.8	143.5
14 years	148.7	148.2	154.0	149.4	148.2	151.0	147.6	147.4	153.7	147.3	147.6	153.3
15 years	159.0	157.4	152.3	159.0	158.7	151.8	159.0	158.1	151.1	159.0	157.6	150.1
16 years	147.0	152.0	159.6	139.0	152.0	159.6	161.0	152.0	157.7	159.6	152.0	157.9
17 years	162.0	162.0	161.3	162.0	162.0	161.3	–	161.0	159.2	–	161.0	158.9
Male standard	Standard error of the mean											
Boys 12-17 years	...	...	...	...	...	...	...	...	...	...	...	...
Girls 12-17 years	...	...	...	...	...	...	...	...	...	...	...	...

Table 11. Mean bone-specific skeletal ages for selected hand-wrist bones of youths by annual family income, chronological age at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Trapezium			Trapezoid			Metacarpal I			Metacarpal II		
	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more
Male standard	Mean skeletal age in months											
Boys:												
12 years	137.7	136.6	139.7	138.0	137.2	140.2	138.0	137.0	140.0	137.8	136.7	140.0
13 years	152.2	155.7	154.2	152.4	156.6	154.3	153.9	156.7	154.8	154.2	157.0	154.8
14 years	167.5	166.2	167.5	167.7	166.5	167.7	169.4	169.1	169.4	171.3	171.9	171.0
15 years	172.4	174.5	175.9	172.2	174.7	176.0	174.7	176.8	177.3	180.1	181.6	184.2
16 years	176.4	175.8	179.8	176.6	175.5	178.9	178.8	177.9	180.7	187.4	187.1	189.6
17 years	183.5	186.1	189.2	183.4	187.0	188.4	183.0	183.5	185.7	193.2	196.5	200.0
Girls:												
12 years	165.5	164.8	169.3	165.4	165.2	169.7	170.2	169.5	171.4	171.9	170.9	172.4
13 years	174.4	174.7	175.5	174.9	174.4	175.5	177.5	177.1	177.3	182.4	183.8	182.7
14 years	180.1	179.2	185.8	181.3	179.1	185.6	179.9	180.3	183.1	195.5	191.3	196.0
15 years	191.0	189.1	184.0	191.0	189.1	182.8	186.0	185.2	184.6	200.3	197.8	199.1
16 years	191.3	185.0	189.1	191.3	185.0	189.2	186.0	186.0	184.3	205.8	202.5	202.8
17 years	–	192.0	192.0	–	192.0	192.0	186.0	186.0	185.7	200.9	206.7	199.6
Actual values:												
Boys 12-17 years	155.7	155.0	156.9	155.7	155.4	157.0	160.0	159.4	160.2	165.2	164.5	165.6
Girls 12-17 years	171.5	171.2	174.8	171.9	171.2	174.8	175.5	175.2	175.9	184.6	184.1	184.7
Expected values:												
Boys 12-17 years	156.8	155.3	156.1	157.0	155.6	156.4	160.8	159.5	159.8	166.2	164.6	164.9
Girls 12-17 years	172.3	172.4	172.7	172.5	172.4	172.6	175.5	175.7	175.2	184.4	184.7	184.4
Female equivalent												
Girls:												
12 years	134.2	133.9	137.3	134.2	134.1	136.8	138.2	137.5	139.4	139.9	138.9	140.4
13 years	141.2	141.4	141.8	141.9	141.4	142.5	145.5	145.1	145.3	150.4	151.8	150.7
14 years	148.1	147.2	153.8	149.3	146.2	153.6	147.9	148.3	152.1	165.5	160.3	166.0
15 years	159.0	157.1	152.0	160.0	157.1	150.8	155.0	154.2	153.6	170.3	167.8	169.1
16 years	159.6	153.0	157.1	160.3	153.0	157.2	155.0	155.0	153.3	176.8	173.0	173.6
17 years	–	161.0	161.0	–	161.0	161.0	155.0	155.0	154.7	170.9	178.7	169.6
Male standard	Standard error of the mean											
Boys 12-17 years	...	...	...	...	...	...	...	...	...	...	...	...
Girls 12-17 years	...	...	...	...	...	...	...	...	...	...	...	...

Table 11. Mean bone-specific skeletal ages for selected hand-wrist bones of youths by annual family income, chronological age at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Metacarpal IV			Pisiform			Adductor sesamoid			Flexor sesamoid		
	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more
Male standard	Mean skeletal age in months											
Boys:												
12 years	138.4	137.2	140.7	140.5	140.5	141.0	158.4	160.6	159.3	162.9	165.2	165.6
13 years	154.7	157.6	155.3	153.5	157.5	154.8	163.9	165.6	164.8	167.9	170.0	167.1
14 years	172.2	171.8	171.3	167.8	167.0	167.4	170.2	170.5	170.1	171.6	171.9	172.0
15 years	179.6	181.7	182.3	173.1	173.7	174.7	173.4	175.6	174.4	174.0	175.8	174.9
16 years	185.7	187.4	188.5	178.3	173.2	181.0	176.1	176.3	180.8	177.3	175.8	180.5
17 years	191.8	193.3	196.6	187.2	183.8	190.4	181.3	183.9	187.0	183.2	184.9	189.8
Girls:												
12 years	172.4	171.0	172.5	166.0	166.0	169.3	170.5	169.7	169.3	174.1	172.1	170.8
13 years	181.7	182.8	182.6	174.8	173.9	175.6	175.2	173.8	173.5	175.6	175.3	176.0
14 years	192.7	190.8	194.3	181.2	180.4	184.8	177.4	177.5	183.2	179.0	179.1	184.0
15 years	198.6	196.3	197.3	180.0	189.3	181.9	181.4	184.5	176.7	183.4	184.6	177.9
16 years	201.2	200.0	199.2	192.0	188.4	189.9	184.3	184.6	175.6	191.4	184.4	179.2
17 years	200.1	202.7	199.3	192.0	192.0	192.0	162.7	187.0	186.9	186.0	188.2	189.5
Actual values:												
Boys 12-17 years	164.8	164.7	164.8	158.5	157.3	157.4	168.2	168.8	168.7	171.7	172.1	172.0
Girls 12-17 years	183.6	183.1	184.0	172.2	172.3	174.4	174.0	173.8	173.6	176.4	175.7	175.3
Expected values:												
Boys 12-17 years	165.7	164.6	164.3	159.3	157.3	157.5	169.3	168.5	168.6	172.6	171.8	172.0
Girls 12-17 years	183.5	183.7	183.5	172.9	173.1	172.6	173.6	173.8	173.9	175.6	175.9	175.7
Female equivalent												
Girls:												
12 years	140.4	139.0	140.5	135.0	135.0	137.3	138.5	137.7	137.3	142.1	140.1	138.8
13 years	149.7	150.8	150.6	141.8	140.9	142.6	143.2	141.8	141.5	143.6	143.3	144.0
14 years	162.4	159.8	164.3	149.2	148.4	152.8	145.4	145.5	151.2	147.0	147.1	152.0
15 years	168.6	166.3	167.3	148.0	157.3	149.9	149.4	152.5	144.7	151.4	152.6	145.9
16 years	171.2	170.0	169.2	160.0	156.4	157.9	152.3	152.6	143.6	160.4	152.4	147.2
17 years	170.1	173.4	169.3	160.0	160.0	160.0	132.7	155.0	154.9	154.0	157.2	158.5
Male standard	Standard error of the mean											
Boys 12-17 years	...	...	...	...	...	...	...	...	...	...	...	...
Girls 12-17 years	...	...	...	...	...	...	...	...	...	...	...	...

Table 11. Mean bone-specific skeletal ages for selected hand-wrist bones of youths by annual family income, chronological age at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Proximal phalanx I			Proximal phalanx II			Proximal phalanx V			Middle phalanx II		
	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more
Male standard	Mean skeletal age in months											
Boys:												
12 years	139.5	139.1	142.1	138.6	139.6	142.0	139.5	139.6	142.4	140.8	140.5	143.0
13 years	155.9	158.8	157.1	156.5	159.3	157.5	156.7	159.5	157.4	155.8	159.4	157.7
14 years	172.4	173.2	172.0	172.4	172.1	172.3	172.8	172.5	172.1	172.4	172.1	172.1
15 years	180.4	182.7	184.4	180.4	182.1	184.2	180.6	181.6	184.2	179.6	181.8	183.4
16 years	188.5	188.1	188.2	186.2	187.9	187.4	185.6	187.9	186.6	186.3	187.7	188.1
17 years	195.7	200.2	201.8	193.3	195.8	200.4	194.1	194.8	199.9	193.0	196.2	198.2
Girls:												
12 years	175.7	173.6	175.7	175.3	174.3	175.9	176.4	174.8	176.8	176.3	174.3	176.1
13 years	183.7	184.7	185.7	182.8	183.7	183.9	183.0	184.3	184.0	183.8	183.8	184.0
14 years	194.2	193.8	197.8	192.6	190.4	195.2	193.1	190.7	194.4	191.7	191.6	193.9
15 years	203.1	203.4	204.0	200.8	198.8	198.5	202.3	199.3	199.7	199.7	199.5	199.6
16 years	207.5	207.0	204.9	202.6	202.4	201.4	202.7	203.6	202.3	202.6	203.2	201.8
17 years	204.5	208.7	207.6	201.8	204.0	202.2	204.0	204.0	202.7	202.1	204.0	202.7
Actual values:												
Boys 12-17 years	165.7	165.4	165.5	164.6	164.7	165.2	164.9	164.5	165.0	165.0	165.2	165.3
Girls 12-17 years	185.0	185.5	187.1	183.9	183.4	185.1	184.6	184.3	185.9	184.2	183.6	184.8
Expected values:												
Boys 12-17 years	166.8	165.2	165.0	165.9	164.6	164.5	165.9	164.5	164.4	166.2	165.1	164.6
Girls 12 17 years	185.5	186.2	186.2	184.1	184.1	184.5	184.8	184.9	185.4	184.2	184.2	184.3
Female equivalent												
Girls:												
12 years	142.7	140.6	142.7	142.3	141.3	142.9	144.4	142.8	144.8	144.3	142.3	144.1
13 years	151.7	152.7	153.7	150.4	150.8	150.9	151.0	152.3	152.0	151.8	151.8	152.0
14 years	164.2	163.8	167.8	162.2	158.4	164.2	162.1	158.7	163.4	160.7	160.6	163.9
15 years	174.1	174.4	175.0	170.8	168.8	168.5	173.2	169.3	169.7	170.4	170.2	170.3
16 years	179.5	179.0	176.8	172.6	172.4	171.4	173.4	173.8	173.2	173.2	174.2	171.8
17 years	176.0	181.4	179.6	171.8	174.0	172.2	174.0	174.0	173.4	173.0	175.0	173.4
Male standard	Standard error of the mean											
Boys 12-17 years	...	...	...	...	...	...	...	...	...	...	...	...
Girls 12-17 years	...	...	...	...	...	...	...	...	...	...	...	...

Table 11. Mean bone-specific skeletal ages for selected hand-wrist bones of youths by annual family income, chronological age at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Middle phalanx III			Middle phalanx IV			Distal phalanx I			Distal phalanx II		
	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more
Male standard	Mean skeletal age in months											
Boys:												
12 years	140.9	140.5	142.6	140.1	140.0	141.9	139.4	138.5	140.9	139.0	138.7	141.3
13 years	156.0	159.3	158.0	155.4	158.8	157.6	152.9	157.4	156.1	153.6	158.0	156.1
14 years	172.5	172.3	172.3	172.6	172.3	171.8	168.8	168.0	167.9	168.3	168.5	168.8
15 years	180.1	182.9	182.7	180.0	182.2	183.1	173.3	175.3	177.5	173.5	175.6	176.9
16 years	186.8	187.3	188.3	186.6	186.9	188.2	178.4	179.8	180.7	178.0	178.8	181.7
17 years	193.5	196.8	198.2	194.0	196.1	197.6	185.5	185.2	190.6	185.4	185.3	190.5
Girls:												
12 years	176.5	174.3	176.3	176.4	174.0	176.0	170.6	169.0	173.4	170.2	169.2	173.6
13 years	184.0	183.9	184.7	184.0	183.8	185.2	178.4	177.7	179.1	178.9	178.0	179.3
14 years	193.2	192.0	194.2	193.1	190.6	191.6	181.2	182.1	186.6	181.8	182.8	186.3
15 years	199.4	199.1	199.3	198.7	199.1	199.1	191.0	189.5	190.9	191.0	189.5	190.9
16 years	202.1	201.6	201.5	201.9	203.3	202.0	186.0	189.8	190.9	186.0	187.6	191.0
17 years	201.9	204.0	202.7	202.5	204.0	202.7	189.0	187.6	180.0	190.2	187.6	186.0
Actual values:												
Boys 12-17 years	165.6	165.7	165.3	165.2	165.2	165.0	158.6	158.9	159.8	158.6	159.5	160.3
Girls 12-17 years	185.0	184.0	185.2	184.8	183.8	185.4	176.6	176.4	179.2	176.6	176.6	179.3
Expected values:												
Boys 12-17 years	166.7	165.5	164.9	166.3	165.1	164.6	159.9	159.0	159.2	160.1	159.5	159.6
Girls 12-17 years	184.8	184.8	184.5	184.7	184.6	184.6	176.9	177.5	177.3	177.0	177.7	177.4
Female equivalent												
Girls:												
12 years	144.5	141.3	144.3	144.4	141.0	144.0	138.6	137.0	141.4	138.2	137.2	141.6
13 years	152.0	151.9	152.7	152.0	151.8	153.2	146.4	145.7	147.1	145.9	145.5	146.6
14 years	162.2	161.0	163.2	162.1	159.2	160.6	149.2	150.1	153.6	149.8	150.8	154.3
15 years	170.4	170.1	170.3	169.4	170.1	170.1	161.0	159.0	160.9	161.0	157.5	160.7
16 years	173.1	172.6	172.5	172.9	174.3	173.0	153.0	159.6	160.9	154.0	155.6	161.0
17 years	172.9	175.0	173.7	173.5	175.0	173.7	158.0	155.8	148.0	158.6	155.6	154.0
Male standard	Standard error of the mean											
Boys 12-17 years	...	...	...	...	...	...	...	...	...	...	...	...
Girls 12-17 years	...	...	...	...	...	...	...	...	...	...	...	...

Table 11. Mean bone-specific skeletal ages for selected hand-wrist bones of youths by annual family income, chronological age at last birthday, and sex, with selected standard errors: United States, 1966-1970—Con.

Standard of reference, sex, and chronological age at last birthday	Distal III			Distal IV			Distal V		
	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more	Less than $5,000	$5,000-$9,999	$10,000 or more
Male standard	Mean skeletal age in months								
Boys:									
12 years	139.0	138.8	141.2	139.1	139.0	141.6	139.2	138.9	141.4
13 years	153.6	157.9	155.5	153.6	158.8	156.0	153.3	158.0	156.1
14 years	168.3	168.4	168.8	168.3	168.6	168.9	168.3	168.5	168.7
15 years	173.4	175.3	176.4	173.2	175.3	176.1	173.0	175.3	176.3
16 years	177.7	178.0	181.3	177.9	176.3	181.1	177.8	177.2	181.0
17 years	185.8	185.0	190.7	181.8	184.4	185.6	181.5	184.5	185.2
Girls:									
12 years	169.7	168.9	173.4	169.2	169.2	173.2	170.0	169.0	173.2
13 years	178.6	177.6	179.0	177.0	175.3	177.0	177.3	175.3	177.4
14 years	181.8	182.4	186.2	179.9	179.8	183.2	179.8	180.0	183.2
15 years	191.0	189.5	190.8	186.0	185.8	185.7	186.0	185.7	185.5
16 years	186.0	187.8	191.0	186.0	186.0	186.0	186.0	186.0	186.0
17 years	190.2	187.5	186.0	186.0	186.0	185.6	186.0	186.0	185.6
Actual values:									
Boys 12-17 years	158.5	159.3	160.2	158.5	159.0	159.8	158.3	159.3	159.8
Girls 12-17 years	176.4	176.2	179.0	174.6	174.6	176.8	174.9	174.5	177.0
Expected values:									
Boys 12-17 years	159.8	159.2	159.6	159.8	159.0	159.1	159.8	159.1	159.2
Girls 12-17 years	176.8	177.4	177.0	175.1	175.5	175.0	175.2	175.5	175.1
Female equivalent									
Girls:									
12 years	137.7	136.9	141.4	137.2	137.2	141.2	138.0	137.0	140.4
13 years	146.6	145.6	147.0	145.0	143.3	145.0	144.3	142.6	144.4
14 years	149.8	150.4	153.4	147.9	147.8	151.2	147.6	148.0	151.2
15 years	161.0	158.5	160.6	153.0	152.9	152.8	154.0	153.7	153.5
16 years	153.0	155.8	161.0	153.0	153.0	153.0	154.0	154.0	154.0
17 years	159.4	155.5	153.0	153.0	153.0	152.8	154.0	154.0	153.6
Male standard	Standard error of the mean								
Boys 12-17 years	...	...	...	...	...	...	...	...	...
Girls 12-17 years	...	...	...	...	...	...	...	...	...

Table 12. Selected percentiles in the distribution of the individual youth's range in bone-specific skeletal ages for the radio-opaque (not adult) bones in the hand-wrist for white and Negro youths by chronological age in years at last birthday and sex: United States, 1966-1970

Chronological age in years and sex	Percentile points					
	White			Negro		
	P_{75}	P_{50}	P_{25}	P_{75}	P_{50}	P_{25}
	Bone-specific skeletal age range in months—male standard					
Boys						
12 years	20.4	15.9	12.3	20.5	15.0	12.1
13 years	18.8	14.6	10.9	18.1	13.3	10.6
14 years	16.8	12.3	8.9	18.2	13.8	8.9
15 years	16.0	11.0	6.7	13.4	10.0	6.5
16 years	14.9	8.7	3.7	15.3	9.2	4.2
17 years	11.5	4.9	0.9	16.2	8.4	2.1
Girls						
12 years	19.0	14.4	11.0	17.9	11.6	7.8
13 years	18.9	12.8	8.7	18.7	12.5	9.1
14 years	18.5	10.8	5.0	18.5	10.0	4.0
15 years	17.0	6.8	1.6	12.9	4.6	0.8
16 years	10.1	2.1	0.5	13.9	3.2	0.7
17 years	14.5	1.7	0.5	13.8	2.7	0.6

Table 13. Selected percentiles in the distribution of the individual youth's range in bone-specific skeletal ages for the radio-opaque (not adult) bones in the hand-wrist for youths by geographic region, chronological age in years at last birthday, and sex: United States, 1966-1970

Chronological age in years and sex	Percentile points											
	Northeast			Midwest			South			West		
	P_{75}	P_{50}	P_{25}	P_{75}	P_{50}	P_{25}	P_{75}	P_{50}	P_{25}	P_{75}	P_{50}	P_{25}
	Bone-specific skeletal age range in months—male standard											
Boys												
12 years	20.4	16.0	12.1	20.4	15.7	12.3	20.3	15.0	12.3	20.3	16.1	12.3
13 years	18.8	14.2	10.6	18.6	14.4	12.0	17.7	14.2	10.1	19.1	15.5	12.1
14 years	16.9	12.1	8.8	16.2	12.4	8.6	18.2	12.6	8.8	16.7	12.5	9.4
15 years	16.7	10.6	6.1	15.6	11.3	7.5	14.1	10.1	6.5	16.4	12.0	6.4
16 years	14.7	8.8	5.0	16.0	8.6	4.1	13.2	8.5	2.7	16.4	10.3	3.9
17 years	13.0	3.9	0.7	13.7	6.5	2.2	9.7	5.2	0.9	12.9	5.1	0.9
Girls												
12 years	18.4	14.2	10.6	18.9	14.7	11.9	18.7	13.0	8.9	20.0	13.7	10.4
13 years	21.0	12.8	8.3	18.9	12.8	8.8	18.1	12.4	8.2	20.1	12.9	9.8
14 years	20.4	10.8	6.2	18.1	10.5	4.1	18.5	10.7	5.0	18.4	10.6	5.3
15 years	18.9	6.5	1.4	18.7	6.7	2.3	13.7	4.6	0.8	16.0	9.5	2.4
16 years	13.8	4.6	0.7	8.7	1.0	0.5	8.2	0.9	0.5	10.9	2.6	0.6
17 years	19.4	4.2	0.6	16.9	3.0	0.6	6.9	0.9	0.5	12.1	0.9	0.4

Table 14. Selected percentiles in the distribution of the individual youth's range in bone-specific skeletal ages for the radio-opaque (not adult) bones in the hand-wrist for youths by annual family income, chronological age in years at last birthday, and sex: United States, 1966-1970

Chronological age in years and sex	Percentile points								
	Less than $5,000			$5,000-$9,999			$10,000 or more		
	P_{75}	P_{50}	P_{25}	P_{75}	P_{50}	P_{25}	P_{75}	P_{50}	P_{25}
	Bone-specific skeletal age range in months—male standard								
Boys									
12 years	20.0	15.3	12.2	20.7	16.1	12.4	20.4	16.0	12.3
13 years	18.6	14.6	11.0	19.9	14.8	10.9	18.0	14.0	10.6
14 years	18.3	12.8	9.0	16.0	12.3	9.0	17.7	12.2	8.7
15 years	15.6	11.3	6.8	15.4	11.0	6.5	15.1	10.6	6.7
16 years	14.1	8.6	3.8	16.8	10.1	4.6	13.7	7.3	2.6
17 years	13.1	6.7	1.6	12.6	4.5	0.7	11.1	5.1	1.0
Girls									
12 years	18.4	13.6	10.0	19.3	13.0	10.3	19.1	15.0	12.2
13 years	18.3	12.6	9.6	20.8	13.7	9.0	18.5	12.4	7.9
14 years	18.5	10.4	6.0	18.6	12.5	5.3	18.3	9.8	4.8
15 years	16.1	6.8	1.0	18.6	6.9	2.3	19.9	6.5	1.0
16 years	12.9	2.3	0.5	10.9	2.5	0.5	8.9	2.3	0.5
17 years	8.3	0.8	0.4	16.9	5.3	0.6	12.6	1.3	0.5

Table 15. Median (chronological) age of onset of ossification in selected hand-wrist bones for youths 12-17 years by race, region, annual family income, and sex: United States, 1966-1970

Race, region, and annual family income	Boys		Girls
	Adductor sesamoid	Flexor sesamoid	Flexor sesamoid
	Chronological age in years		
Race			
White	12.4	14.2	13.0
Negro	12.7	14.5	13.1
Region			
Northeast	12.5	14.0	13.1
Midwest	12.5	13.3	13.0
South	12.5	14.4	13.0
West	12.5	14.4	13.0
Annual family income			
Less than $5,000	12.5	14.4	13.1
$5,000-$9,999	12.4	13.1	13.0
$10,000 or more	12.5	13.0	12.9

Table 16. Median age in months at epiphyseal fusion for selected hand-wrist bones of white and Negro boys and girls 12-17 years of chronological age at last birthday: United States, 1966-1970

Hand-wrist bone	White		Negro	
	Boys	Girls	Boys	Girls
	Median age in months			
Radius	*	*	*	*
Ulna	*	194	*	192
Metacarpal I	190	165	194	167
Metacarpal II	198	178	199	176
Metacarpal III	199	178	198	175
Metacarpal IV	199	179	198	174
Metacarpal V	199	180	199	175
Proximal phalanx I	195	168	198	170
Proximal phalanx II	191	168	194	171
Proximal phalanx III	193	169	196	171
Proximal phalanx IV	193	169	196	171
Proximal phalanx V	190	168	196	171
Middle phalanx II	193	167	197	171
Middle phalanx III	196	169	199	171
Middle phalanx IV	196	169	198	172
Middle phalanx V	195	168	198	171
Distal phalanx I	188	162	188	160
Distal phalanx II	189	162	188	160
Distal phalanx III	189	162	188	161
Distal phalanx IV	187	161	187	159
Distal phalanx V	188	161	188	161

*Estimates of median age not possible or not sufficiently reliable for publication. The radius had reached the "adult" stage for only 26 percent of boys and 53 percent of girls and the ulna in only 51 percent of boys by 17.9 years.

APPENDIXES

CONTENTS

LIST OF APPENDIX TABLES

APPENDIX I

STATISTICAL NOTES

The Survey Design

The sample design for the first three programs of Cycles I-III of the Health Examination Survey has been essentially similar in that each has been a multistage, stratified probability sample of clusters of households in land-based segments. The successive elements for this sample design are primary sampling units, census enumeration district, segment (a cluster of households), eligible persons, and finally, the sample person.

The 40 sample areas and the segments utilized in the design of Cycle III were the same as those in Cycle II. Previous reports describe in detail the sample design used for Cycle II and, in addition, discuss the problems and considerations given to other types of sampling frames, cluster versus random sampling, and whether or not to control the selection of siblings.[7,8]

Requirements and limitations placed on the design for Cycle III, similar to those for children in Cycle II, were that:

1. The target population be defined as the civilian noninstitutionalized population of the United States, including Alaska and Hawaii, between the ages of 12 and 17 years for Cycle III, with the special exclusion of children residing on reservation lands of the American Indians. The latter exclusion was due to operational problems encountered on these lands in Cycle I.
2. The time period of data collection be limited to about 3 years for each cycle and the length of the individual examination within the specially constructed mobile examination center be between 2 and 3 hours.
3. Ancillary data be collected on specially designed household, medical history and school questionnaires, and from birth certificate copies.
4. Examination objectives be primarily related to factors of physical and intellectual growth and development.
5. The sample be sufficiently large to yield reliable findings within broad geographic regions and population density groups as well as age, sex, and limited socioeconomic groups for the total sample.

The sample was drawn jointly with the U.S. Bureau of the Census starting with the 1960 decennial census list of addresses and the nearly 1,900 primary sampling units (PSU's) into which the entire United States was divided. Each PSU is either a standard metropolitan statistical area (SMSA), a county, or a group of two or three contiguous counties. These PSU's were grouped into 40 strata, each stratum having an average size of about 4.5 million persons, in such a manner as to maximize the degree of homogeneity within strata with regard to the population size of the PSU's, degree of urbanization, geographic proximity, and degree of industrialization. The 40 strata were then classified into 4 broad geographic regions of 10 strata each and then within each region, cross-classified by four population density classes and classes of rate of population change from 1950 to 1960. Using a modified Goodman-Kish controlled-selection technique, one PSU was drawn from each of the 40 strata.

NOTE: A list of references follows the text.

Further stages of sampling within PSU's required first the selection of census enumeration districts (ED's). The ED's are small well-defined areas of about 250 housing units into which the entire Nation was divided for the 1960 population census. Each ED was assigned a "measure of size" equal to the rounded whole number resulting from a "division by nine" of the number of children, age 5-9, in the ED at the time of the 1960 census. A sample of 20 ED's in the sample PSU was selected by systematic sampling with each ED having a probability of selection proportional to the population of children 5-9 years at the time of the 1960 census date. A further random selection by size of segments (smaller clusters of housing units) within each ED was then made.

Because of the 3-year time interval between Cycle II and Cycle III, the Cycle III frame had to be supplemented for new construction and to compensate for segments where housing was partially or totally demolished to make room for highway construction or urban redevelopment.

Advanced planning for the examinations at the various locations or stands provided for about 17 days of examinations which limited the number of examinees per location to approximately 200. When the number of eligible youths in the sample drawn for a particular location exceeded this number, subsampling was done by deleting from the master list of eligible youths (ordered by segment, household order within segment, and age within household) every nth name on the list starting with the yth name, y being a number between 1 and n selected randomly and n being the extent of oversampling in the original draw.

In Cycle III, as in Cycle II, twins who were deleted in the sample selection were also scheduled for examination, time permitting, as were youths deleted from the Cycle III sample who had been examined in Cycle II. The sample was selected in Cycle III, as it had been for the children in Cycle II, so as to contain the correct proportion of youths from families having only one eligible youth, two eligible youths, and so on to be representative of the total target population. However, since households were one of the elements in the sample frame, the number of related youths in the resultant sample is greater than would come from a design which sampled youths 12-17 years without regard to household. The resultant estimated mean measurements or rates should be unbiased but their sampling variability will be somewhat greater than those from more costly, time-consuming systematic sample design in which every kth youth would be selected.

The total probability sample for Cycle III included 7,514 youths representative of the approximately 22.7 million noninstitutionalized U.S. youths of 12-17 years. The sample contained youths from 25 different States and approximately 1,000 in each single year of age.

The response rate in Cycle III was 90 percent, with 6,768 youths examined out of the total sample. These examinees were closely representative of those in the samples as well as the population from which the samples were drawn with respect to age, sex, race, region, population density, and population growth in area of residence. Hence it appears unlikely that nonresponse could bias the findings appreciably.

Measures used to control the quality of the data from these surveys have been cited;[7,8,194,195] these additional measures specifically related to skeletal age are outlined earlier in this report.

Reliability

Although measurement processes in the surveys were carefully standardized and closely controlled, the correspondence between the real world and survey results cannot be expected to be exact. Survey data are imperfect for three major reasons: (1) results are subject to sampling error, (2) the actual conduct of a survey never agrees perfectly with the design, and (3) the measurement processes themselves are inexact even though standardized and controlled.

The first report on Cycle III[8] describes in detail the faithfulness with which the sampling design was carried out.

Data recorded for each sample youth are inflated in the estimation process to characterize the larger universe of which the sample youth is representative. The weights used in this inflation process are a product of the reciprocal of the probability of selecting the youth, an adjustment for nonresponse cases, and a poststratified ratio adjustment which increases precision by bringing survey results into closer alignment

with known U.S. population figures by color and sex within single years of age 12 through 17 for the youths' survey.

In the third cycle of the Health Examination Survey (as for the children in Cycle II) the samples were the result of three principal stages of selection—the single PSU from each stratum, the 20 segments from each sample PSU, and the sample youth from the eligible persons.[196,197] The probability of selecting an individual youth is the product of the probability of selection at each stage.

Since the strata are roughly equal in population size and a nearly equal number of sample youths were examined in each of the sample PSU's, the sample design is essentially self-weighting with respect to the target population; that is, each youth 12 through 17 years had about the same probability of being drawn into the respective samples.

The adjustment upward for nonresponse is intended to minimize the impact of nonresponse on final estimates by imputing to nonrespondents the characteristics of "similar" respondents. Here "similar" respondents were judged to be examined youths in a sample PSU having the same age (in years) and sex as youths not examined in that sample PSU.

The poststratified ratio adjustment used in the third cycle achieved most of the gains in precision that would have been attained if the sample had been drawn from a population stratified by age, color, and sex and makes the final sample estimates of population agree exactly with independent controls prepared by the Bureau of the Census for the U.S. noninstitutionalized population as of March 9, 1968 (approximate midsurvey point for Cycle III) by color and sex for each single year of age 12-17. The weights of every responding sample youth in each of the 24 age, color, and sex classes is adjusted upward or downward so that the weighted total within the class equals the independent population control for each survey.

In addition to youths not examined at all, there were 32 for whom there was no radiograph or else the radiograph could not be assessed. The age and sex distribution for these 32 youths as well as for the 6,736 for whom assessments were made is shown in table I. The skeletal ages for these youths without usable radiographs were not estimated. It is assumed that the distribution of their skeletal ages is similar to that for the remaining 6,736. In other words, they were treated as nonresponders.

Table I. The number of youths whose radiographs were assessed; the number not assessed refers to youths who were examined but whose radiographs were missing or of poor quality: Health Examination Survey, 1966-1970

Age	Assessed (6,736)		Not assessed (32)	
	Boys	Girls	Boys	Girls
	Number of youths			
Total	3,534	3,202	11	21
12 years	640	543	3	4
13 years	625	582	1	-
14 years	617	584	1	2
15 years	610	503	3	-
16 years	555	528	1	8
17 years	487	462	2	7

Sampling and Measurement Error

In the present report, reference has been made to efforts to minimize bias and variability of measurement techniques.

The probability design of the survey makes possible the calculation of sampling errors. The sampling error is used here to determine how imprecise the survey test results may be because they come from a sample rather than from the measurements of all elements in the universe.

The estimation of sampling errors for a study of the type of the Health Examination Survey is difficult for at least three reasons: (1) measurement error and "pure" sampling error are confounded in the data—it is not easy to find a procedure which will either completely include both or treat one or the other separately, (2) the survey design and estimation procedure are complex and accordingly require computationally involved techniques for the calculation of variances, and (3) from the survey are coming thousands of statistics, many for subclasses of the population for which there are a small number of cases. Estimates of sampling error are obtained from the sample data and are themselves subject to sampling error which may be large when the number of cases in a cell is small or

even occasionally when the number of cases is substantial.

Estimates of approximate sampling variability for selected statistics used in this report are included in the detailed tables. These estimates have been prepared by a replication technique that yields overall variability through observation of variability among random subsamples of the total sample. The method reflects both "pure" sampling variance and a part of the measurement variance.

In accordance with usual practice, the interval estimate for any statistic may be considered the range within 1 standard error of the tabulated statistic, with 68-percent confidence; or the range within 2 standard errors of the tabulated statistic, with 95-percent confidence. The latter is used as the level of significance in this report.

An approximation of the standard error of a difference $d = x - y$ of two statistics x and y is given by the formula

$$S_d = (S_x^2 + S_y^2)^{1/2}$$

where S_x and S_y are the sampling errors, respectively, of x and y. Of course, where the two groups of measures are positively or negatively correlated, this will give an overestimate or underestimate, respectively, of the actual standard error.

Expected Values

In the detailed tables both the actual and expected mean skeletal ages are shown for children in the various demographic groups. The expected mean values are obtained by assuming that the national age-specific mean values apply within the appropriate age subgroup for which the value is derived.

For example, if in an area (e.g., the Northeast), estimates from the Health Examination Survey show n_i boys in the ith age group ($i = 1,2,\ldots,6$; $\sum n_i = n$) and the estimates of mean skeletal age for all U.S. boys in the ith age group to be X_i, then the expected mean skeletal age for boys in that area is:

$$\frac{1}{n}\sum_i n_i \overline{X}_i$$

The specific area may have higher values for younger boys and lower values for older boys than in the other areas. In that case, the expected average may obliterate one or both of these differentials. These types of limitations need to be kept in mind in interpreting these data. The standard error of the difference between an actual and an expected mean value may be approximated by the standard error of the actual value.

Table II. Number of boys and girls for whom skeletal age assessments were made on each of the 31 hand-wrist bones: Health Examination Survey, 1966-1970

Bone	Radio-opaque, not adult		Adult	
	Boys	Girls	Boys	Girls
	Number			
Radius	3,445	2,977	11	5
Ulna	3,286	2,407	11	4
Capitate	2,011	759	1	1
Hamate	1,986	741	1	1
Triquetral	2,007	752	2	1
Lunate	2,000	756	3	1
Scaphoid	2,017	776	1	1
Trapezium	2,007	780	2	1
Trapezoid	1,995	768	2	1
Metacarpal I	2,448	1,128	1	1
Metacarpal II	2,759	1,590	1	1
Metacarpal III	2,738	1,560	1	1
Metacarpal IV	2,729	1,577	1	1
Metacarpal V	2,799	1,701	2	1
Proximal phalanx I	2,638	1,398	2	3
Proximal phalanx II	2,588	1,319	1	1
Proximal phalanx III	2,591	1,346	1	1
Proximal phalanx IV	2,584	1,350	1	1
Proximal phalanx V	2,576	1,327	1	1
Middle phalanx II	2,618	1,316	1	1
Middle phalanx III	2,651	1,372	1	1
Middle phalanx IV	2,648	1,377	1	1
Middle phalanx V	2,625	1,292	1	2
Distal phalanx I	2,296	968	1	3
Distal phalanx II	2,339	982	2	1
Distal phalanx III	2,335	974	2	2
Distal phalanx IV	2,298	893	1	1
Distal phalanx V	2,307	893	2	1
Pisiform	1,773	744	166	10
Adductor sesamoid	1,511	908	574	25
Flexor sesamoid	1,095	746	1,052	264

Small Numbers

In some tables, magnitudes are shown for cells for which the sample size is so small that the sampling error may be several times as great as the statistic itself. Obviously, in such instances the statistic has no meaning in itself except to indicate that the true quantity is small. Such numbers, if shown, have been included in the belief that they may help to convey an impression of the overall story of the table.

Among the 6,736 children with usable radiographs, there were a few of inadequate quality to permit assessment of all bones. In general, these would have been bones that became radiopaque recently or bones near the margin of the radiographic field. The number of youths for whom bone-specific skeletal ages were assigned and the numbers in which particular bones were adult are shown in table II.

APPENDIX II

DEMOGRAPHIC AND SOCIOECONOMIC TERMS

Age.—The age recorded for each youth was the age at last birthday on the date of examination. The age criterion for inclusion in the sample used in this survey was defined in terms of age at time of interview. Since the examination usually took place 2-4 weeks after the interview, some of those who were 17 years old at the time of interview became 18 years old by the time of examination. There were 23 such cases. In the adjustment and weighting procedures used to produce national estimates these 23 were included in the 17-year-old group.

Race.—Race was recorded as "white," "Negro," or "other." "Other" included American Indians, Chinese, Japanese, and all races other than white or Negro. Mexican persons were included with "white" unless definitely known to be American Indian or of other nonwhite race. Negroes and persons of mixed Negro and other parentage were recorded as "Negro."

Geographic region.—For purposes of stratification, the United States was divided into four broad geographic regions of approximately equal population. These regions, which correspond closely to those used by the Bureau of the Census, were as follows:

Region	*States included*
Northeast	Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, and Pennsylvania
Midwest.....	Ohio, Illinois, Indiana, Michigan, Wisconsin, Minnesota, Iowa, and Missouri
South	Delaware, Maryland, District of Columbia, West Virginia, Virginia, Kentucky, Tennessee, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Arkansas
West	Washington, Oregon, California, Nevada, New Mexico, Arizona, Texas, Oklahoma, Kansas, Nebraska, North Dakota, South Dakota, Idaho, Utah, Colorado, Montana, Wyoming, Alaska, and Hawaii

Urban-rural.—The definition of urban-rural areas was the same as that used in the 1960 Census. According to this definition, the urban population was comprised of all persons living in (a) places of 2,500 inhabitants or more incorporated as cities, boroughs, villages, and towns (except towns in New England, New York, and Wisconsin); (b) the densely settled urban fringe, whether incorporated or unincorporated of urbanized areas; (c) towns in New England and townships in New Jersey and Pennsylvania that contained no incorporated municipalities as subdivisions and had either 2,500 inhabitants or more, or a population of 2,500 to 25,000 and a density of 1,500 persons or more per square mile; (d) counties in States other than the New England States, New Jersey, and Pennsylvania that had no incorporated municipalities within their boundaries and had a density of 1,500 persons or more per square mile; and (e) unincorporated places of 2,500 inhabitants or more not included in any urban fringe. The remaining population was classified as rural.

Urban areas are further classified by population size for places within urbanized areas and other urban places outside urbanized areas.

Grade in school.—The grade that the youth attended at the time of interview was used here and later verified against school records. The grade of those youths on summer vacation was considered to be the grade that they would enter when school resumed.

Education of parent or guardian.—This was recorded as the highest grade completed in school. The only grades counted were those attended in a regular school where persons were given formal education in graded public or private schools, whether day or night school, and whether attendance was full or part time. A "regular" school is one that advances a person toward an elementary or high school diploma, or a college, university, or professional school degree. Education in vocational, trade, or business schools outside the regular school system was not counted in determining the highest grade of school completed.

Family income.—The income recorded was the total income of the past 12 months received by the head of the household and all other household members related to the head by blood, marriage, or adoption. This income was the gross cash income (excluding pay in kind) except in the case of a family with their own farm or business, in which case net income was recorded.

Parent.—A parent was the natural parent or, in the case of adoption, the legal parent of the youth.

Guardian.—A guardian was responsible for the care and supervision of the youth. He (or she) did not have to be the legal guardian to be considered the guardian for this survey. A guardianship could only exist when the parent(s) of the youth did not reside within the sample household.

Head of household.—Only one person in each household was designated as the "head." He (or she) was the person who was regarded as the "head" by the members of the household. In most cases the head was the chief breadwinner of the family, although this was not always true. In some cases the head was the parent of the chief earner, or the only adult member of the household.

APPENDIX III

RELIABILITY OF ASSESSMENTS

To provide the basis for determining the level of reliability of the bone-specified skeletal age assessments made by the nine medical students at Case Western Reserve University from hand-wrist radiographs of the 12-17-year-old youths examined in the Health Examination Survey of 1966-1970, a randomly selected sample of 1 in 23 radiographs was reassessed by the same reader and approximately 1 in 20 independently randomly selected radiographs were reassessed by another reader, as described previously. All nine readers, before starting these final assessments, had been trained by Dr. Pyle in the Greulich-Pyle method using the "HES Standard" to the point that their assessments were in close agreement with hers. In all, 351 self-replicate assessments and 301 cross-replicate assessments were made. Each reader made approximately the same number of self-replicate and cross-replicate assessments.

All nine readers maintained a high level of consistency in their own assessments throughout all 40 examination stands of the survey. The mean difference in self-replicate assessments for all nine readers was 0.1 month for all 31 bones as well as for the 28 bones from which those that were late to ossify (the pisiform, adductor sesamoid and flexor sesamoid) were excluded. Considering data for all 31 bones, the mean difference per reader between original and self-replicate assessments ranged from 0.2 to 1.7 months combining data from both sexes. For the 28 bones that ossify relatively early, the mean differences range from 0.2 to 1.6 months among the nine readers (table III).

A consistently high level of agreement in bone-specific skeletal age assessments was maintained among the nine readers but the level was, as expected, somewhat lower than that for the individual readers with themselves. The mean

Table III. Mean difference in cross- and self-replicate assessments of bone-specific skeletal ages from hand-wrists radiographs of examinees 12-17 years old at last birthday, by reader: Health Examination Survey, 1966-1970

Reader	Self-replicates		Cross-replicates		Number of films replicated	
	31 bones	28 bones	31 bones	28 bones	Self	Cross
	Mean difference					
All readers	-0.1	-0.1	-0.2	-0.1	351	301
Reader 21	1.6	1.6	0.7	0.8	36	32
Reader 22	-1.2	-1.4	-2.3	-2.1	36	30
Reader 24	-1.7	-1.6	-1.7	-1.6	21	20
Reader 25	0.5	0.4	2.6	2.4	66	56
Reader 26	-0.2	-0.2	-0.8	-0.5	44	32
Reader 27	-0.3	-0.3	-1.5	-1.7	44	43
Reader 28	0.3	0.2	1.0	1.3	44	33
Reader 29	0.2	0.3	-1.0	-0.8	30	27
Reader 30	-1.0	-1.0	-1.3	-1.0	30	28

cross-replicate difference for all 31 hand-wrist bones was 0.2 month. It ranged between 0.7 and 2.6 months for the readers. When only the 28 centers that are relatively early to ossify were considered, the overall mean difference was slightly less—0.1 month—and ranged from 0.8 to 2.4 months among the individual readers.

The aspects considered include consistency within observers (intraobserver differences), comparability between observers (interobserver differences), and differences resulting from variations in the way the Greulich-Pyle Atlas has been used. This review is restricted to reports based on samples of at least 10 radiographs and to the chronological age range 12-17 years.

Although it is impossible at present to determine the true maturity level of the bones visualized in a radiograph, it is necessary to define the reliability of assessments both within and between observers. As stated by Greulich and Pyle:[10] "Though the ability to duplicate assessments with a good degree of consistency must be possessed by a competent assessor, it alone is not enough. It is even more important that the assessments be made correctly, that is, that they be made according to the method recommended by the particular radiographic atlas on which they purport to be based." Unfortunately, the suggestion by Moore[196] that sets of duplicate radiographs that have been assessed by recognized experts be available to those who wish to measure their level of comparability has not been implemented.

Area Skeletal Age

It is not easy to compare reported findings because workers have analyzed their data in different ways. For intraobserver differences, 95-percent confidence limits of 7.2 months[197] and mean differences ranging from 1.2 to 6.6 months have been reported,[28,198-201] in addition to variable errors to 1.4 to 4.2 months.[202,203] The median intraobserver differences range from zero to 4 months.[204,205] A report of zero median differences seems surprising but it is possible because Moed and his coworkers made overall assessments to the nearest atlas standard.

Todd's[18] claim that interobserver differences less than 6 months could be achieved readily appears justified. Reported mean interobserver differences range from 1.3 to 4.2 months.[200,206,207] In addition, a root mean square of 6.2 months and confidence limits of 7.4 months have been reported.[197,201] Reported incidences of particular interobserver differences indicate that the medians were less than 3 months for the study by Hansman and Maresh[66] and less than 6 months for the study by Moed et al.[204]

Bone-Specific Skeletal Ages

Moore[196] reported interobserver differences that were less than 12 months in 94 percent of bones.

Factors Influencing Replicability

There is no indication that the level of replicability is related to the differences between chronological and skeletal ages.[199,202] However, the range of maturity between the bones of a hand-wrist influences the replicability of overall but not bone-specific assessments.[199,200] The quality of the radiographs (exposure, positioning) has no effect on replicability within the range that is common in research studies[200] but unusually poor radiographic quality does reduce replicability.[202] The method by which the Greulich-Pyle Atlas is used has an effect. Maresh[22] reported a technical error of 3.0 months between overall assessments and those obtained as the means of bone-specific skeletal ages.

NOTE: A list of references follows the text.

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