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ABSTRACT

A July 1963-December 1965 survey of children aged 6 to 11 reported data on 21 body measurements. The examination of the children had two emphases. The first concerned factors related to healthy growth and development as determined by a physician, nurse, dentist, and psychologist. The second concerned a variety of somatic and physiologic measurements performed by specially trained technicians. The main purpose of collecting information on bocy measurements was to define a normal pattern of growth and development in children in the United States in the middle 1960s. (Included in the text are charts and descriptions of the survey results for each of the 21 body measurements. Also included as an appendix are more detailed tables of statistics.) (Author/JA)

Series 11 reports present findings from the National Health Examination Survey, which obtains data through direct examination, tests, and measurements of samples of the U.S. population. Reports 1 through 38 relate to the adult program, Cycle I of the Health Examination Survey. The present report is one of a number of reports of findings from the children and youth programs, Cycles II and III of the Health Examination Survey. These reports are being published in Series 11 but are numbered consecutively beginning with 101. It is hoped this will guide users to the data in which they are interested.

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Data from the
NATIONAL HEALTH SURVEY

Series 11
Number 123

Selected Body Measurements of Children 6-11 Years

United States

Presents and discusses data on 21 anthropometric dimensions of children 6-11 years of age in the United States, 1963-65. The measurements provide information on child growth and development as well as guidelines for those applying "human engineering" principles to design of children's furniture, clothing, and equipment.

DHEW Publication No. (HSM) 73-1605

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

Health Services and Mental Health Administration
National Center for Health Statistics
Rockville, Md. January 1973

NATIONAL CENTER FOR HEALTH STATISTICS

DIVISION OF HEALTH EXAMINATION STATISTICS

COOPERATION OF THE BUREAU OF THE CENSUS

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.

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SELECTED BODY MEASUREMENTS OF CHILDREN 6-11 YEARS

Robert M. Malina, Ph.D., Peter V. V. Hamill, M.D., M.P.H.,
and Stanley Lemeshow, M.S.P.H.[a]

INTRODUCTION

This report of data on 21 body measurements selected from the survey of U.S. children 6-11 years of age (Cycle II) of the Health Examination Survey is the fourth in a series of reports presenting analyses and discussions of data on heights, weights, and 28 other body measurements performed in Cycle II. The first two reports[1,2] analyzed height and weight measures by age, sex, race, geographic region, and various socioeconomic indicators; the third report presented data on skinfold thicknesses.[3]

The Health Examination Survey (HES), conducted by the National Center for Health Statistics, collects and analyzes health-related data on the American people through direct examination of selected subjects. It operates in a succession of separate programs, each referred to as a "cycle," and each cycle lasts from 2 to 4 years.[4]

Cycle I of HES, conducted from 1959 to 1962, obtained information on the prevalence of certain chronic diseases and the distribution of a number of anthropometric and sensory characteristics in the civilian, noninstitutionalized population of the continental United States aged 18-79 years. The general plan and operation of the survey and Cycle I are described in two previous reports.[4,5] and most of the results are published in other PHS Publication 1000-Series 11 reports.

Cycle II of the Health Examination Survey, conducted from July 1963 to December 1965, involved selection and examination of a probability sample of noninstitutionalized children in the United States aged 6-11 years. This program succeeded in examining 96 percent of the 7,417 children selected for the sample. The examination had two emphases. The first concerned factors related to healthy growth and development as determined by a physician, a nurse, a dentist, and a psychologist; the second concerned a variety of somatic and physiologic measurements performed by specially trained technicians. The detailed plan and operation of Cycle II and the response results are described in PHS Publication 1000-Series 1-No. 5.[6] A comparable examination of data collection for Cycle III, youths aged 12-17, was completed in 1970, and the plan and operation are described in PHS Publication 1000-Series 1-No. 8.[7]

The main purpose of the numerous body measurements collected in Cycle II was to define a normal pattern of growth and development in children in the United States in the middle 1960's (and to describe some of the modifying factors). However, the opportunity to obtain data on this uniquely representative sample of U.S. children for more utilitarian purposes as well was not disregarded. In Cycle I (adults aged 18-79), 18 body measurements were obtained not only as medical and anthropologic correlates to the rest

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of the examination, but also as data for use in the consideration of anthropometric factors in equipment and safety design and manufacture (furniture, clothing, etc.). These results have already been published.[8,9] Similar equipment and design data for children are extremely limited in availability and in terms of sampling. All too frequently children are simply viewed as miniature adults, which they obviously are not. Accordingly, the 21 anthropometric dimensions in this report were included in the group of body measurements partly for their descriptive value in the growth and development battery and partly for their use in "human engineering" or "human factors" work. Some of the measures have limited value in describing growth and development because they comprise multiple layers of tissue, multiple organ systems, and/or multiple loci of growth (e.g., waist and chest size, thigh clearance, all girths, seat breadth). However, many of these dimensions were selected primarily to achieve continuity with those measurements taken on adults in Cycle I of the HES, and thus to provide some information for those concerned with the child's body in relation to furniture, clothing, and equipment design.

The 21 dimensions reported here are: height (stature), weight, sitting height, popliteal height, knee height, buttock-popliteal length, buttock-knee length, acromion-olecranon length, elbow-wrist length, foot length, foot breadth, hand length, hand breadth, chest breadth, chest depth, elbow-elbow breadth, seat breadth, thigh clearance, chest girth, waist girth, and hip girth. Each is defined, illustrated, and described in detail in the section "Measuring Procedures and Definitions" in appendix II.

This report, which is essentially descriptive rather than analytic, presents the distributions and/or ranges of "normality" for the selected anthropometric dimensions during middle childhood. Emphasis is placed upon sex differences in the measured dimensions and, more specifically, upon the variations characteristic of each age and sex group for children 6-11 years. (The data are analyzed for the total population of children independent of race. The rather striking differences in limb and body proportions associated with race will be presented in a subsequent, more analytic report currently in preparation.[10])

While the data demonstrate, in general, a linear increase with age for most of the dimensions similar to that shown for height and weight in earlier reports,[1,2] the present report is not intended as a biologic analysis of the physical growth of the child, as is the case in most of the other reports of this series. The presentation of ranges of "normality" is directed more toward those who are interested in the applications of "human engineering" or "human factors" concepts and principles to design and manufacture of articles for children as well as other matters concerning their well-being and comfort. Various manufacturing and safety standards, for example, need to be designed with the perspectives of normal variation in the anthropometry of the growing child in mind, rather than those of the adult.

METHOD

At each of 40 preselected locations throughout the United States,[b] the children were brought to the centrally located mobile examination center for an examination which lasted about 2½ hours. Six children were examined in the morning and six in the afternoon. They were transported to and from school and/or home.

When they entered the examination center, the children's oral temperatures were taken and a cursory screening for acute illness was made; if illness was detected in a child, he was sent home and reexamined at a later date. The examinees changed into shorts, cotton sweat socks, and a light, sleeveless top and proceeded to different stages of the examination, each one following a different route. There were six different stations where examinations were conducted simultaneously and the stations were exchanged, somewhat like musical chairs, so that by the end of 2½ hours each child had essentially the same examinations by the same examiners but in a different sequence. At three of these stations

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[b] See appendix I for sample design.

were examinations by a pediatrician, a dentist, and a psychologist and at the other three stations, highly trained technicians performed a number of other examinations—chest and hand-wrist X-rays, hearing and vision tests, respiratory function tests and electrocardiography, a bicycle exercise test, a battery of body measurements, and a grip strength test.

Included in the anthropometric battery besides the 21 measurements reported here were skinfolds taken at three anatomical sites; girths of the calf, upper arm, and lower arm; biacromial diameter (shoulder span); and bicristal diameter (i.e., the two iliac crests, which span the bony part of the hips with the overlying soft tissue firmly compressed in the process of measurement). All lateral measurements were performed on the subject's right side and recorded by an observer. Details on equipment and measuring technique and a sample of the recording form listing all of the measurements are in appendix II.

Periodic quality control observation and training sessions were conducted by the supervisory medical staff and outside consultants to insure continued proficiency and obtain replicate data for the purpose of quantifying observer error. The results are presented in detail in appendix II.

In all of the reports from the HES, age is expressed as the years attained at the last birthday, and the grouping for this report follows this convention. The mean age of each category, therefore, approximates the midpoint of the whole year; e.g., the 8-year-old male group consists of a 1-year cohort whose mean age is 8.51 years, while the corresponding female sample averages 8.49 years. The age reported by the parent, which was used in all cases, was validated by birth certificate in 95 percent of the subjects.

"Race" was recorded as "white," "Negro," and "other races." White children comprised 85.69 percent of the total, Negro children 13.87 percent, and children of other races only 0.45 percent. The data are reported, however, for the total population of children independent of race.

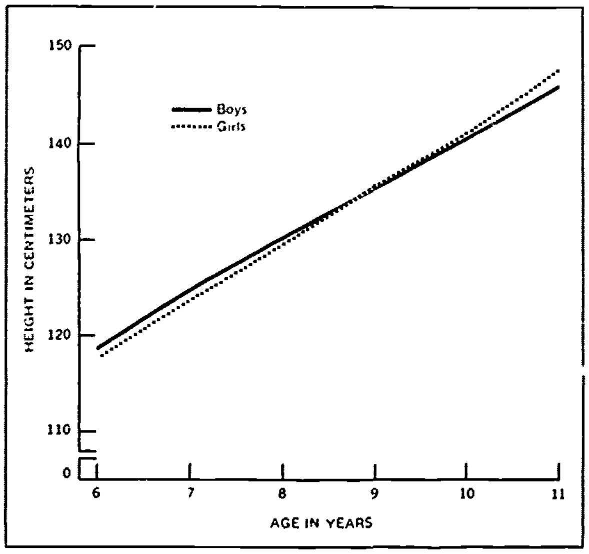

Figure 1. Mean height of U.S. children by age and sex.

FINDINGS

Height and Weight

Height and weight in the present study sample have been discussed at length in previous Series 11 reports by Hamill et al., Numbers 104 and 119.[1,2] The major findings are resummarized here to provide a more complete picture of the anthropometry of middle childhood. Height and weight are both measures of gross body size. As expected, both increase linearly with age from 6 through 11 years (figures 1 and 2, tables 1 and 2). Boys are, on the average, slightly taller and heavier than girls between 6 and 8 years of age; however, from 9 years of age to 11, girls are slightly heavier. They are also taller at 10 and 11 years of age, the mean stature for boys and girls being identical at 9 years.

Comparisons of the 5th and 95th percentiles for stature (table 1) indicate that about 90 percent of the 6-year-old boys have standing heights between 110.7 and 128.0 cm., while 90 percent of the 6-year-old girls have heights between 108.3 and 126.7 cm., indicating a negligible sex difference in the distribution of statures at this young age. At 11 years of age, the statures of

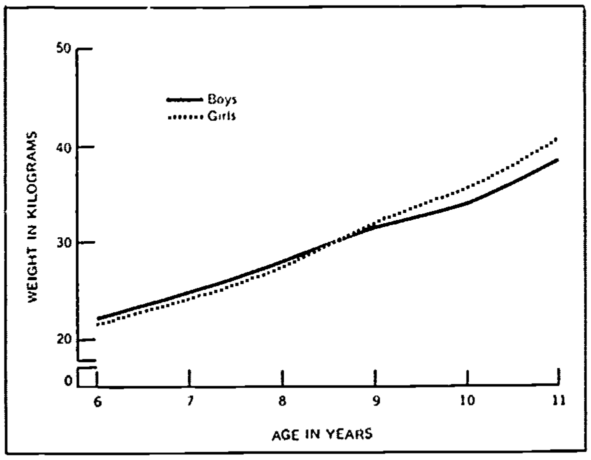

Figure 2. Mean weight of U.S. children by age and sex.

about 90 percent of the boys are between 134.6 and 157.0 cm., and those of girls are between 135.4 and 159.7 cm. The upper limits of height (95th percentile) for the 6-year-olds do not overlap the lower limits (5th percentile) for 11-year-olds. However, the upper percentile limits for 7- and 8-year-old children approach and/or overlap the lower limits for 11-year-olds.

The distribution of statures at the young ages is narrower than that for the older ages under study. At age 6, for example, the difference between the 5th and 95th percentiles is 17.3 and 18.4 cm. for boys and girls, respectively. At 11 years of age, on the other hand, the difference between the percentile extremes for stature is 22.4 cm. for males and 24.3 cm. for females; once again a wider distribution for girls is more apparent at the upper percentile limits.

Comparisons of the 5th and 95th percentiles (table 2) indicate that for about 90 percent of the 6-year-olds, boys have body weights between 17.4 and 28.0 kg., and girls weigh between 16.4 and 28.0 kg.—a very close overlap between the sexes. However, the same percentage of 11-year-old boys have weights between 28.6 and 53.0 kg., and 11-year-old girls weigh between 28.4 and 58.0 kg. Note that the upper limit (95th percentile) for the 6-year-old children (28.0 kg. in both sexes) approaches the lower limit (5th percentile) for 11-year-old children (28.6 and 28.4 kg. for boys and girls, respectively). Hence, some of the lightest 11-year-olds will have body weights comparable to the heaviest 6-year-olds—indeed a wide range of variation during middle childhood.

A closer look at the percentile extremes for body weight indicates a gradual increase in the 5th percentile between 6 and 11 years (an increase of 11.2 kg. for boys and 12.0 kg. for girls) and a rather sharp increase in the 95th-percentile values (25.0 kg. for boys and 30.0 kg. for girls). This suggests a gradual widening of the range of variation with advancing age from 6 through 11 years. Girls have a wider distribution than boys, probably reflecting the early growth acceleration of female adolescence.

Sitting Height

Standing height is a composite measurement including the head, neck, trunk, and lower extremities. By measuring an individual's sitting height while sitting erectly, the contribution of the lower extremities to stature is eliminated, leaving the height of the head, neck, and trunk. Sitting height is slightly but consistently greater in boys than girls between 6 and 9 years of age, but at 10 and 11 years girls have slightly greater sitting heights (figure 3 and table 3). In terms of its relative contribution to stature, sitting height represents about 54 percent of total height at 6 years of age (54.55 percent in boys and 54.24 percent in girls) and decreases gradually

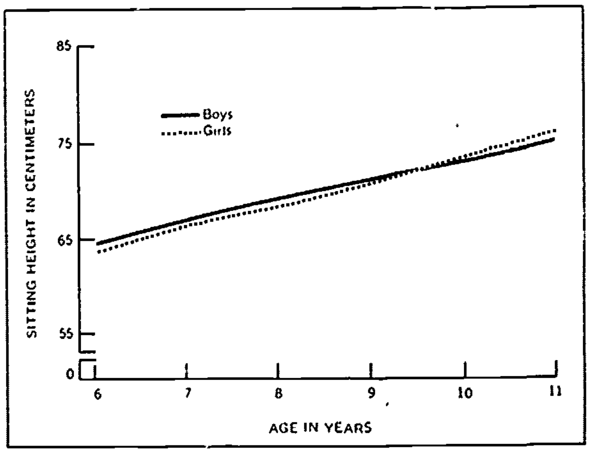

Figure 3. Mean sitting height of U.S. children by age and sex.

over middle childhood so that at 11 years of age it represents only approximately 51.7 percent of the standing height in both sexes (51.68 percent in boys and 51.69 percent in girls).

About 90 percent of the 6-year-old boys have sitting heights between 60.2 and 69.5 cm., while the measurements are between 58.8 and 68.8 cm. for 6-year-old girls. At this young age the range between the 5th and 95th percentiles is similar for both sexes—9.3 and 10.0 cm. in boys and girls, respectively. At 11 years, the oldest age studied, about 90 percent of the boys have sitting heights between 70.1 and 80.6 cm., while about 90 percent of the girls have sitting heights between 69.7 and 83.4 cm. The range between the percentile extremes is thus 10.5 cm. in boys and 13.7 cm. in girls, similar to that noted for stature, i.e., a wider distribution for girls, which is more apparent at the upper percentile limits. Note that the lower percentile limits (5th) for 11-year-old children are practically identical in both sexes and approach the upper percentile limits (95th) for 6-year-olds.

Popliteal Height

This dimension is, on the average, slightly greater in boys from 6 through 10 years of age and slightly greater in girls at 11 years. Average sex differences at 8 through 11 years, however, are so small as to be negligible (figure 4 and table 4). The overlap in the distribution of this dimension between the sexes is marked during middle childhood. At 6 years the popliteal heights of approximately 90 percent of the boys are between 26.3 and 32.6 cm., while those of the same percentage of girls are between 26.0 and 32.1 cm. Similarly, at 11 years of age, about 90 percent of the boys have popliteal heights between 33.7 and 41.3 cm., and those of girls are between 33.3 and 41.7 cm. Note that the upper percentile limits at 6 years of age and the lower percentile limits at 11 years do not overlap, but the difference between them is narrow (1.1 cm. in boys and 1.2 cm. in girls). Thus, some 11-year-old children will have popliteal heights similar to 6-, 7-, and 8-year-old children.

There is a slight increase in the distribution of popliteal heights with age. At 6 years of age the difference between the 5th and 95th percentiles is only 6.3 cm. in boys and 6.1 cm in girls, but by 11 years the difference is 7.6 and 8.4 cm. in boys and girls, respectively.

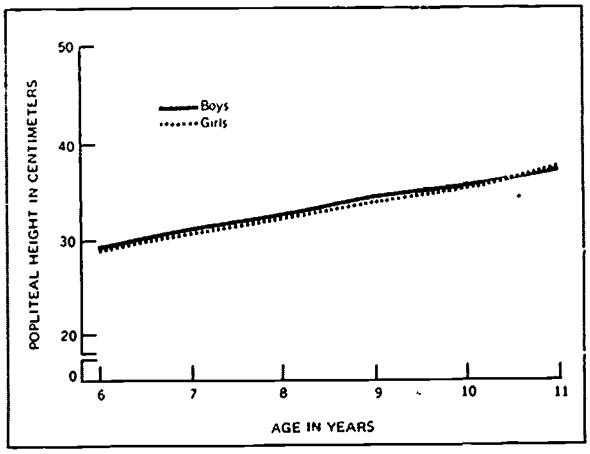

Figure 4. Mean popliteal height of U.S. children by age and sex.

Knee Height

Knee height is slightly greater, on the average, in boys at 6 and 7 years of age but slightly greater in girls at 10 and 11 years. At 8 and 9 years of age sex differences in this measurement are negligible (figure 5 and table 5). As was the case with popliteal height, the overlap in the distribution of knee height between sexes is considerable during middle childhood. Approximately 90 percent of 6-year-old boys have knee heights ranging between 32.9 and 39.7 cm., and those of girls of that age range between 32.4 and 39.7 cm. At 11 years, the knee heights of approximately 90 percent of the boys are between 41.7 and 50.9 cm., while girls measure between 42.1 and 51.2 cm. The 95th percentile for 6-year-olds and the 5th percentile for 11-year-olds do not overlap, but the difference between them is relatively small (2.0 cm. for boys and 2.4 cm. for girls), suggesting some overlapping distributions during adjacent ages of middle childhood.

There is a slight increase in the distribution of knee heights with age. In the youngest age group, the difference between the 5th and 95th percentiles is only 6.8 and 7.3 cm. in boys and girls, respectively. In the oldest age group, this

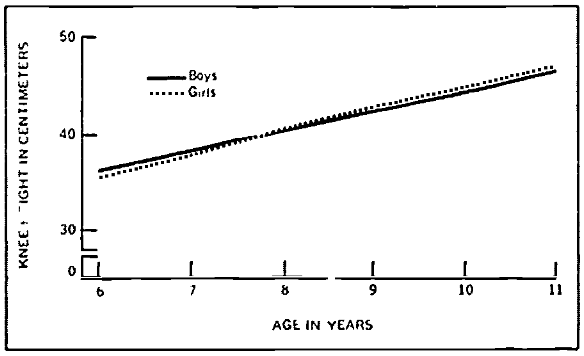

Figure 5. Mean knee height of U.S. children by age and and sex.

difference is only slightly greater and is practically identical in both sexes (9.2 cm. for boys and 9.1 cm. in girls).

Buttock-Popliteal Length

This measurement is longer in girls at all ages, the difference between means gradually increasing from 0.6 cm. at age 6 to 1.4 cm. at age 11 (figure 6 and table 6). There is considerable overlap between the sexes in buttock-popliteal length at the early ages studied. At 6 years of age, about 90 percent of the boys have buttock-popliteal lengths ranging between 28.6 and 37.4 cm., while the girls measure between 28.8 and 38.6 cm. The dimensions of the same percentage of 11-year-old boys range between 36.9 and 48.3 cm. and those of girls fall between 38.1 and 50.5 cm. The upper percentiles at 6 years of age and the lower percentiles at 11 years of age overlap slightly within each sex (0.5 cm. in both sexes). Thus, within each sex group a few 6-year-old children will have buttock-popliteal lengths as long as several 11-year-old children.

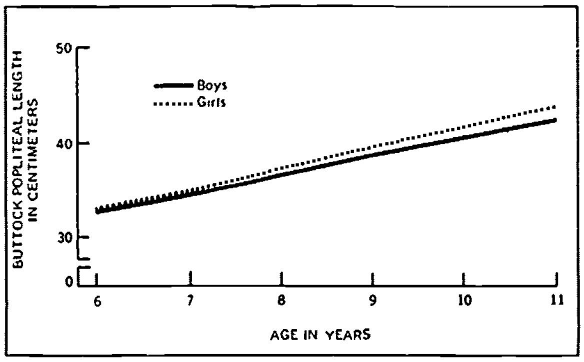

Figure 6. Mean buttock-popliteal length of U.S. children by age and sex.

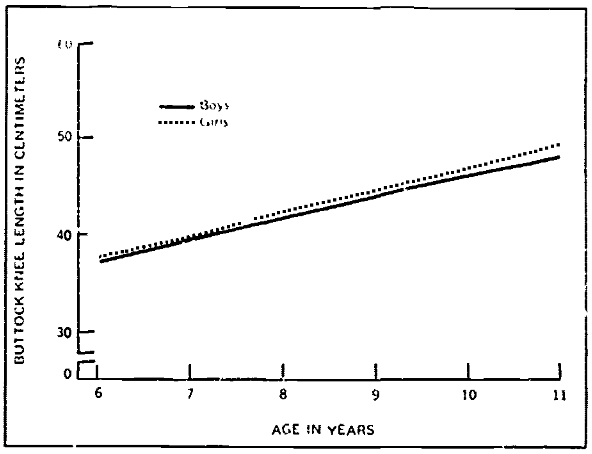

Figure 7. Mean buttock-knee length of U.S. children by age and sex.

The distribution of buttock-popliteal lengths broadens with age. At age 6, the difference encompassed by the 5th and 95th percentiles is 8.8 cm. for boys and 9.8 cm. for girls, while the range at age 11 is 11.4 cm. in boys and 12.4 cm. in girls. This indicates slightly greater variation among girls at all ages.

Buttock-Knee Length

On the average, this dimension is longer in girls over the age span studied. The difference between the means for each sex is small at 6 and 7 years (0.4 and 0.1 cm.) but increases with age so that the difference is 1.4 cm. at 11 years (figure 7 and table 7). There is considerable overlap between boys and girls in the distribution of buttock-knee lengths in the youngest age group. The measurements for about 90 percent of the boys range between 31.5 and 41.6 cm.; those for girls range between 32.2 and 41.9 cm. The distribution of buttock-knee length in each sex diverges slightly with increasing age, so that at 11 years of age about 90 percent of the boys and girls measure between 42.2 and 53.7

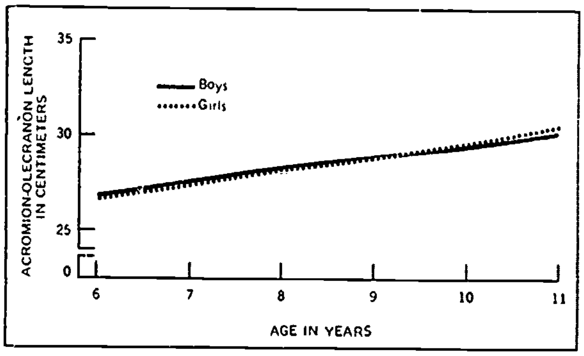

Figure 8. Mean acromion-olecranon length of U.S. children by age and sex.

cm. and 43.7 and 55.9 cm., respectively. The 95th percentile at 6 years of age and the 5th percentile at 11 years do not overlap, but the difference between them is smaller for boys (0.6 cm.) than for girls (1.8 cm.). The distribution of buttock-knee lengths becomes slightly wider with age. In 6-year-old children the difference between the percentile extremes is 10.1 and 9.7 cm. in boys and girls, respectively. The percentile range at 11 years is 11.5 cm. in boys and 12.2 in girls, suggesting slightly greater variation in this dimension with age in girls.

Acromion-Olecranon Length

On the average, boys have slightly longer upper arms at 6, 7, and 8 years of age but girls' upper arms are slightly longer at 10 and 11 years. Sex differences at 9 years of age are negligible (figure 8 and table 8). Overlapping of the distribution of acromion-olecranon lengths for boys and girls is considerable over the age span under study. About 90 percent of the 6-year-old boys have dimensions ranging between 21.6 and 26.1 cm., while about 90 percent of those of the 6-year-old girls fall between 21.2 and 25.8 cm. The same percentage of children at the oldest age studied have values ranging from 27.2 to 33.1 cm. for boys and 27.5 to 33.7 cm. for girls. At both the youngest and oldest ages under study, the range between the 5th and 95th percentiles is relatively narrow and is similar in both sexes (6 years: 4.5 cm. in boys, 4.6 cm. in girls; 11 years: 5.9 cm. in boys, 6.2 cm. in girls). The upper percentiles for 6-year-old children do not overlap the lower percentiles for 11-year-olds; however, the difference between them is relatively small in both sexes (1.1 cm. for boys and 1.7 cm. for girls), indicating overlap in acromion-olecranon lengths over the span of middle childhood.

Elbow-Wrist Length

This dimension is, on the average, longer in boys fro[illegible] 10 years of age, but it is longer [illegible] at 11 years (figure 9 and table 9). As in the case of upper arm length, elbow-wrist length shows considerable overlap in its distribution between the sexes. Forearm lengths for about 90 percent of the 6-year-olds are between 16.6 and 20.2 cm. for boys, 16.1 and 19.7 cm. for girls. At 11 years of age, the measurements for about 90 percent of the boys range be-

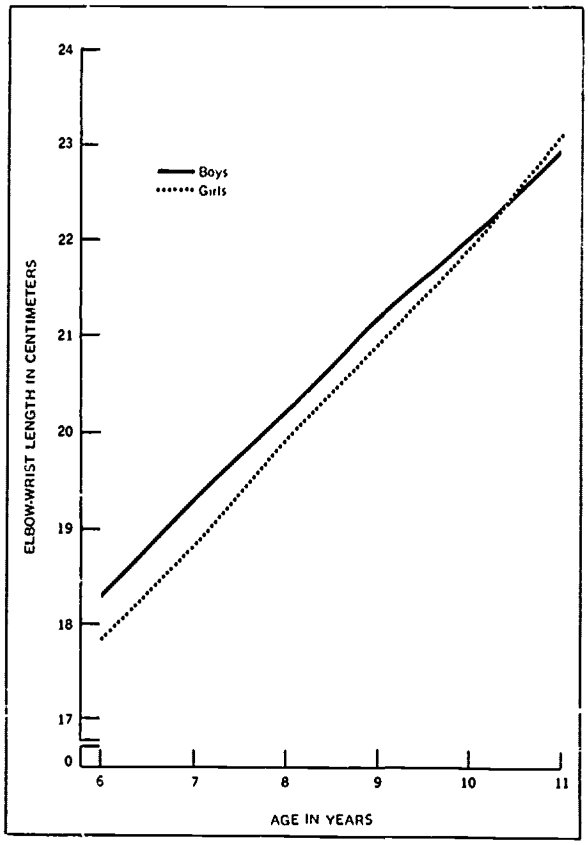

Figure 9. Mean elbow-wrist length of U.S. children by age and sex.

tween 20.6 and 25.4 cm. and those for about 90 percent of the girls fall between 20.6 and 25.8 cm. In both 6-and 11-year-old children, the span between the 5th and 95th percentiles is relatively narrow and is similar for boys and girls (6 years: 3.6 [illegible] in both sexes; 11 years: 4.8 cm. in boys, 5.2 [illegible] girls). Although the 95th percentile at age 6 and the 5th percentile at age 11 do not overlap, the difference between them is negligible in both sexes (0.4 cm. for boys and 0.9 cm. for girls).

Foot Length and Breadth

On the average, boys are consistently larger than girls in both foot length and breadth at all ages studied (figures 10 and 11, tables 10 and 11). The distribution of these two foot dimensions with age is similar for both sexes.

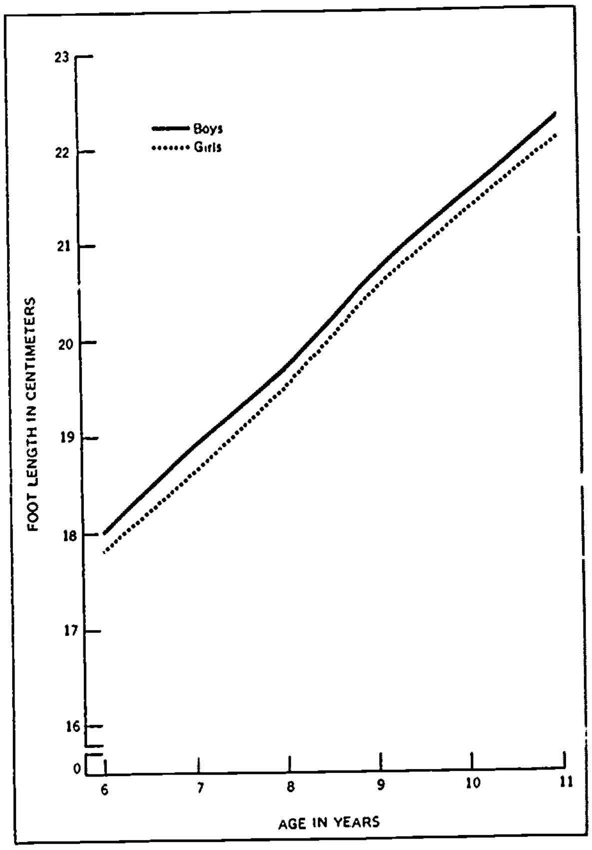

Figure 10. Mean foot length of U.S. children by age and sex.

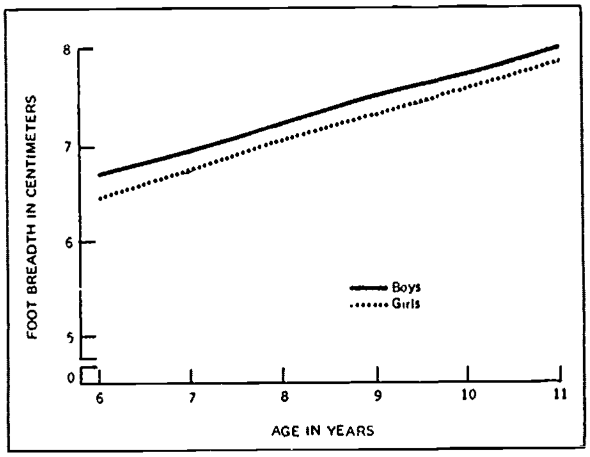

Figure 11. Mean foot breadth of U.S. children by age and sex.

In the youngest age group, the range in foot length for about 90 percent of the children is 16.2 to 19.9 cm. for boys, 15.8 to 19.8 cm. for girls. For about 90 percent of the 11-year-old children, boys measure between 20.1 and 24.7 cm., while girls measure between 20.0 and 24.5 cm. in foot length. At both 6 and 11 years of age, the range between the 5th and 95th percentiles is narrow and is quite similar in boys and girls (6 years: 3.7 for boys, 4.0 for girls; 11 years: 4.6 cm. in boys, 4.5 cm. in girls). Although the 95th percentile of 6-year-olds and the 5th percentile of 11-year-olds do not quite overlap each other, the difference between them is negligible in both sexes (0.2 cm.).

For about 90 percent of the 6-year-olds, boys have foot breadths between 5.7 and 7.8 cm., and an equal percentage of girls fall between 5.3 and 7.6 cm. At 11 years of age, the range is between 7.0 and 9.2 cm. for boys and between 6.6 and 8.9 cm. for girls. At both of these ages, the difference between the 5th and 95th percentiles is small and is almost identical in both sexes (6 years: 2.1 cm. in boys, 2.3 cm. in girls; 11 years: 2.2 cm. in boys, 2.3 cm. in girls). The 95th percentile at age 6 and the 5th percentile at age 11 overlap in both sexes, the overlap being 0.8 cm. in boys and 1.0 cm. in girls.

Hand Length and Breadth

In contrast to the two foot measurements, in which boys are, on the average, larger in both

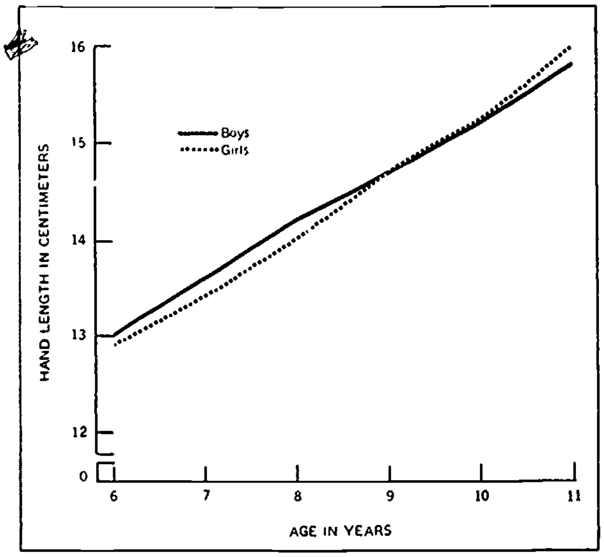

Figure 12. Mean hand length of U.S. children by age and sex.

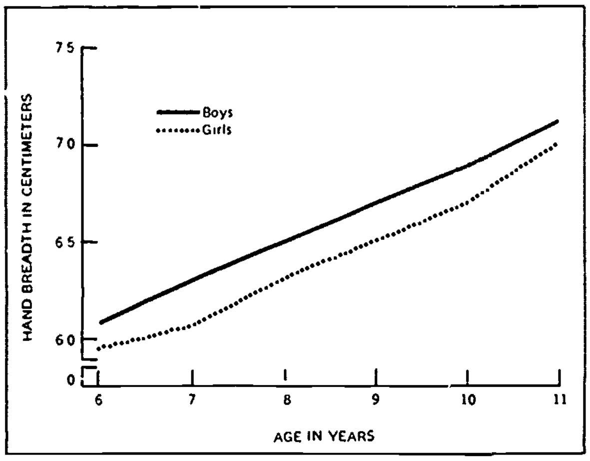

Figure 13. Mean hand breadth of U.S. children by age and sex.

dimensions, they are larger only in hand breadth over the entire age range studied. Hand length is, on the average, greater in boys from 6 to 8 years, identical in both sexes at 9 and 10 years, and larger in girls at 11 years of age (figures 12 and 13, tables 12 and 13). The distribution of both hand dimensions shows considerable overlapping in both sexes. For about 90 percent of the 6-year-old age group, hand lengths for boys range between 11.9 and 14.5 cm. and for girls between 11.4 and 14.5 cm. For about 90 percent of the 11-year-old age group, the dimensions for boys fall between 14.2 and 17.4 cm. and for girls between 14.3 and 17.8 cm. At both ages the span between the 5th and 95th percentiles is small and is similar in boys and girls (6 years: 2.6 cm. in boys, 3.1 cm. in girls; 11 years: 3.2 cm. in boys, 3.5 cm. in girls). There is slight overlap between the 95th percentile at 6 years and the 5th percentile at 11 years in both sexes—0.3 cm. in boys and 0.2 cm. in girls.

For hand breadth, the values for about 90 percent of 6-year-olds range between 5.1 and 6.9 cm. for boys, 5.1 and 6.8 cm. for girls. At 11 years, those for about 90 percent of both boys and girls range between 6.1 and 7.9 cm. At both the youngest and oldest ages studied, the range between the 5th and 95th percentiles is small and is essentially identical in both sexes (1.8 cm.). However, the 95th percentile at 6 years overlaps considerably (relative to the size of the dimensions) the 5th percentile at 11 years in both sexes, the overlap being 0.8 cm. in boys (6.9 compared to 6.1 cm.) and 0.7 in girls (6.8 compared to 6.1 cm.).

Chest Breadth and Depth (4th Intercostal Space)

Boys are, on the average, consistently larger than girls in the two chest measures at all ages (figures 14 and 15, tables 14 and 15). As with other dimensions discussed, overlapping distributions are characteristic. The chest breadths of about 90 percent of the 6-year-old boys range between 16.4 and 20.5 cm., while those for the same percentage of girls at this age fall between 16.1 and 19.8 cm. For about 90 percent of the 11-year-olds, boys have chest breadths between 19.8 and 24.9 cm., and girls measure between 19.1 and 25.3 cm. In both sexes the range between the 5th and 95th percentiles at 6 years of age is rather narrow (4.1 cm. in boys and 3.7 cm. in girls) and increases slightly with age so that the range between the percentile limits at 11 years is 5.1 cm. for boys and 6.2 cm. for girls. It should be noted that there is overlap in both sexes between the 95th percentile for 6-

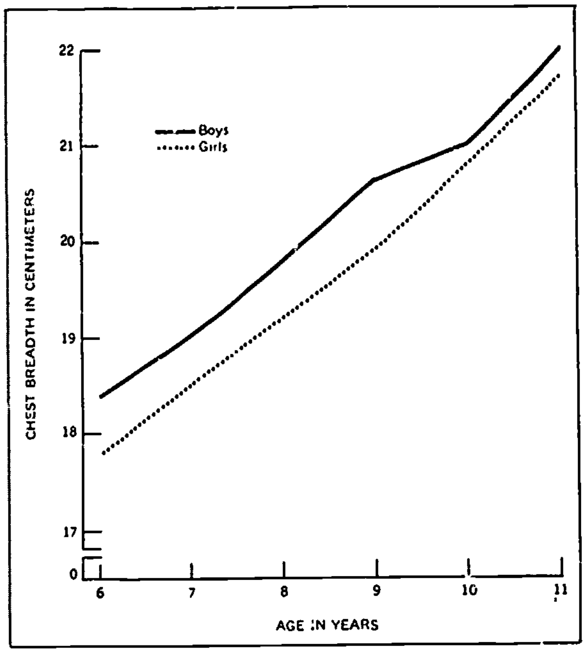

Figure 14. Mean chest breadth of U.S. children by age and sex.

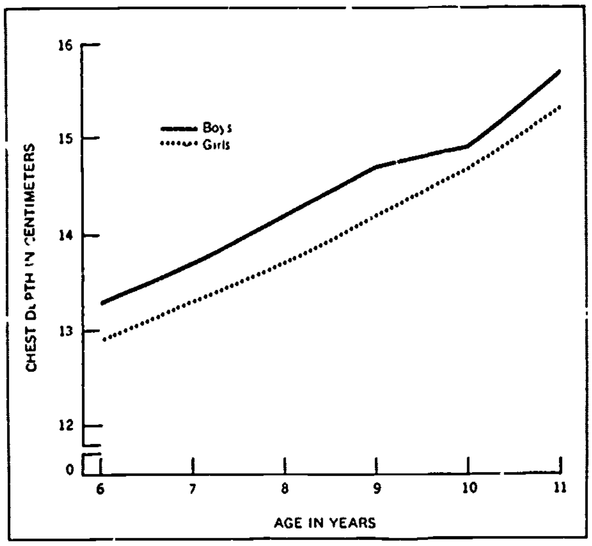

Figure 15. Mean chest depth of U.S. children by age and sex.

year-olds and the 5th percentile for 11-year-olds—0.7 cm. for both sexes.

The chest depths of about 90 percent of the 6-year-olds range from 11.5 to 15.4 cm. for boys and from 11.2 to 14.8 cm. for girls. In 11-year-old children, the chest depths of about 90 percent of the boys measure between 13.4 and 18.6 cm., and those of girls between 13.0 and 18.7 cm. In the youngest age group, the range between the upper and lower percentile limits is small in both sexes (3.9 cm. in boys and 3.6 cm. in girls). A slightly wider differential is apparent at 11 years of age in both sexes (5.2 cm. in boys and 5.7 cm. in girls). The 95th percentile for 6 years and the 5th percentile for 11 years overlap for chest depth by 2.0 cm. in boys and 1.8 cm. in girls, a slightly greater overlap than that for chest breadth.

Elbow-Elbow Breadth

This measurement is, on the average, consistently greater in boys between 6 and 11 years of age than in the corresponding girls (figure 16 and table 16). The difference between means

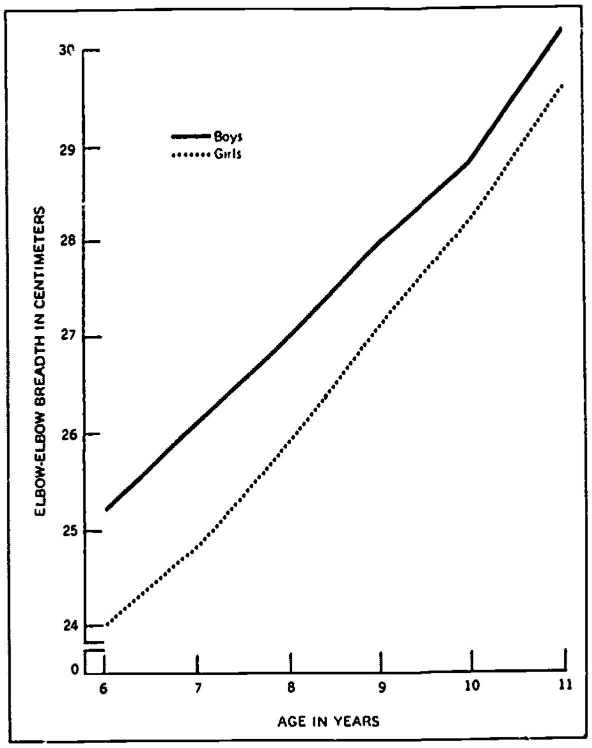

Figure 16. Mean elbow-elbow breadth of U.S. children by age and sex.

is largest at 6 and 7 years of age (1.2 and 1.3 cm., respectively) but becomes progressively less with increasing age so that at 11 years the difference between means is only 0.6 cm. About 90 percent of the 6-year-old boys have elbow-elbow breadths between 21.7 and 28.8 cm., while an equal percentage of girls have values between 21.0 and 28.1 cm. At this young age, the range between the 5th and 95th percentiles is 7.1 cm. for both sexes. With increasing age the distribution of elbow-elbow breadths widens. At 11 years, about 90 percent of the boys have measurements between 25.6 and 37.3 cm., and those of girls fall between 24.5 and 37.4 cm. The range between the percentile extremes is thus 11.7 cm. for boys and 12.9 cm. for girls at this age. There is considerable overlap between the upper percentiles at 6 years of age and the lower percentiles at 11 years in both sexes, the overlap being 3.2 and 3.6 cm. in boys and girls, respectively.

Seat Breadth

Seat breadth is consistently larger, on the average, in girls from 6 through 11 years of age than it is for boys (figure 17 and table 17). The difference between means of boys and girls is negligible (less than 0.1 cm.) at 6 years of age and gradually enlarges so that the difference at 11 years is 1.3 cm. Seat breadths for about 90 percent of 6-year-old boys range between 18.1 and 23.5 cm., and those for girls of this age range between 18.1 and 23.7 cm. With increasing age, the distribution of seat breadths in each sex widens. Thus the dimensions for about 90 percent of the 11-year-olds range from 22.3 to 33.8 cm. for girls and 22.1 to 30.6 cm. for boys. The sex difference in the percentile distribution for seat breadth is most apparent at the upper percentile limits at 11 years of age; the girls' distribution is skewed much more than the boys'. The range between the 5th and 95th percentiles in 11-year-old children is 8.5 cm. for boys compared to 11.5 cm. in girls. The overlapping between the 95th percentile at 6 years and the 5th percentile at 11 years in both sexes (1.4 cm.) should be noted.

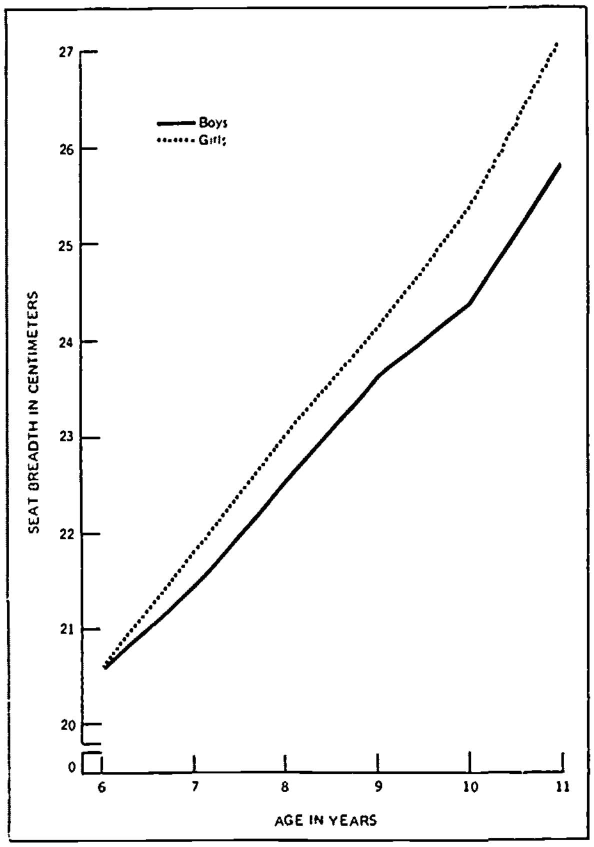

Figure 17. Mean seat breadth of U.S. children by age and sex.

Thigh Clearance

Thigh clearance is, on the average, slightly but consistently greater in girls from 6 through 11 years of age (figure 18 and table 18). Overlapping between the sexes is, however, considerable. In the 6-year-old age group, the measurements for about 90 percent of the boys fall between 7.4 and 11.0 cm., while those for girls are between 7.4 and 11.5 cm. Similarly, among about 90 percent of 11-year-olds, boys measure between 9.3 and 14.7 cm. in thigh clearance and girls between 9.4 and 14.9 cm. The percentile range for thigh clearance measures is almost identical for both boys and girls in the youngest and oldest age groups. The overlapping of the 95th percentile at age 6 and the 5th per-

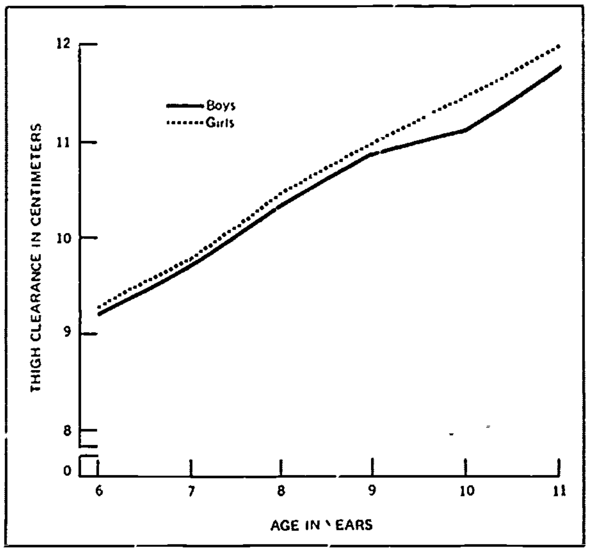

Figure 18. Mean thigh clearance of U.S. children by age and sex.

centile at age 11 in both sexes should be noted (1.7 cm. in boys and 2.1 cm. in girls).

Chest Girth

As with chest breadth and depth, chest girth is, on the average, consistently larger in boys from 6 through 11 years of age. The difference, however, is negligible at 10 and 11 years of age (figure 19 and table 19). At 6 years of age, chest girths for about 90 percent of the boys fall between 54.1 and 64.4 cm., while those for the same percentage of girls fall between 51.7 and 63.2 cm., a slightly wider percentile distribution for girls (11.5 compared to 10.3 cm.). With increasing age the percentile distributions broaden in both sexes (but more so in girls) so that at 11 years of age, the measures for about 90 percent of the girls range from 60.4 to 83.4 cm., and those for boys range from 63.3 to 83.1 cm. Thus, the span between the percentile extremes at age 11 is 19.8 cm. for boys and 23.0 cm. for girls. Overlapping is apparent between the 95th percentile at 6 years of age and the 5th percentile at 11 years, the overlap being more marked for girls (2.8 cm.) than for boys (1.1 cm.).

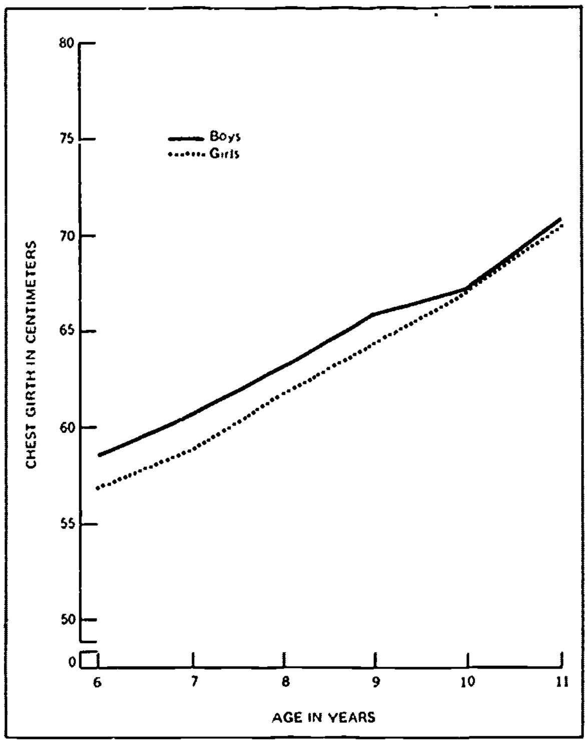

Figure 19. Mean chest girth of U.S. children by age and sex.

Waist Girth

Generally, this measurement is larger in boys in the whole age range, with the difference between means rather consistent throughout (figure 20 and table 20). About 90 percent of the youngest age group have waist girth measurements of 47.4 to 60.3 cm. for boys and 45.5 to 58.8 cm. for girls. This is a rather similar range of percentile distributions for both sexes (12.9 cm. in boys and 13.3 cm. in girls). With advancing age during middle childhood, the difference between percentile extremes increases in both sexes (but more so in boys) so that at 11 years of age, about 90 percent of the girls fall between 52.1 and 72.7 cm. in waist girth. The span between the percentile extremes in the oldest age group is 22.7 cm. for boys compared to 20.6 cm. for girls. Overlapping between the upper percentile limits at 6 years of age and the lower percentile limits at 11 years of age is con-

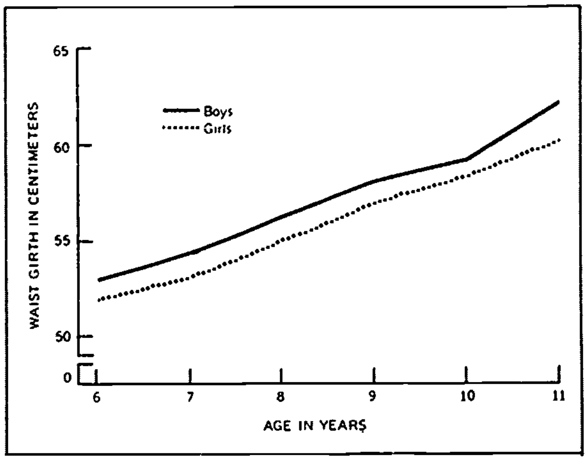

Figure 20. Mean waist girth of U.S. children by age and sex.

siderable in both sexes (6.2 cm. in boys and 6.7 cm. in girls).

Hip Girth

In contrast to the other girth measures, hip girth is consistently larger, on the average, in girls from 6 through 11 years. The difference between means is small at the youngest ages studied but increases with advancing age (figure 21 and table 21). About 90 percent of the 6-year-old boys measure between 51.3 and 66.3 cm., while an equal percentage of girls measure between 50.7 and 67.4 cm. in this circumference. The range encompassed by the percentile extremes in this young age group is larger in girls (16.7 cm.) than in boys (15.0 cm.). This range widens with age so that by 11 years of age, it is considerably broader in girls (28.0 cm.) than boys (25.1 cm.) At age 11, about 90 percent of the girls have hip girths between 64.4 and 92.4 cm., and about 90 percent of the boys are from 62.6 to 87.7 cm. in hip girth. As with waist girth, there is some overlapping between the upper percentiles at 6 years of age and the lower percentiles at 11 years (3.7 cm. in boys and 3.0 cm. in girls).

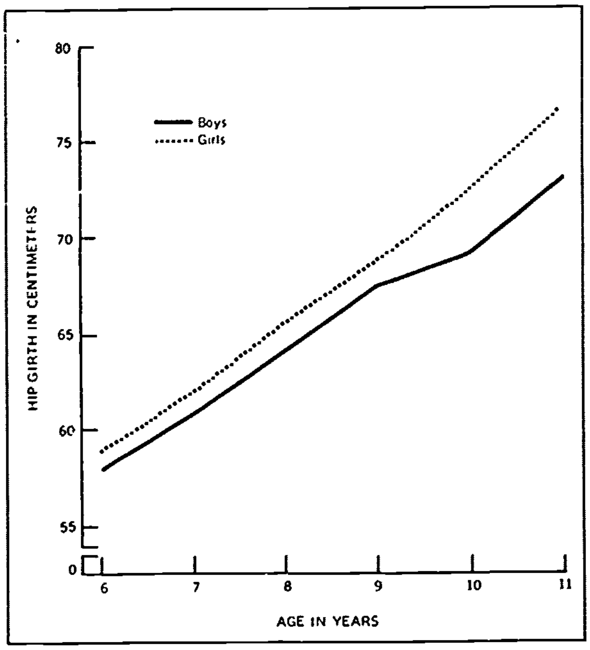

Figure 21. Mean hip girth of U.S. children by age and sex.

DISCUSSION

As expected, all the anthropometric dimensions discussed in the preceding pages increase almost linearly with age from 6 through 11 years. Thus, as children grow and grow up during middle childhood, body size and proportions change with advancing age. Children not only get larger in the various dimensions studied, but their proportions also change. For example, at 6 years of age the sitting height contributes about 54 percent to stature, while at 11 years it contributes only about 51 percent. Knee height at 6 years of age is about 30 percent of standing height, but at 11 years of age it represents about 32 percent of stature.

The pattern of sex differences in the dimensions studied is of interest. The eight measurements in which boys are, on the average, larger than girls from 6 through 11 years of age include chest breadth, chest depth, chest girth, elbow-elbow breadth, waist girth, hand breadth, foot breadth, and foot length. Three of the measurements are of hands and feet, and the other five are measurements of the breadth and girth of the torso. (Note that elbow-elbow breadth includes the breadth of the elbows and the breadth of the torso, for the elbows are held tightly against the trunk in making this measurement.)

Girls are, on the average, larger than boys over the age span studied in five dimensions: buttock-popliteal length, buttock-knee length, seat breadth, thigh clearance, and hip girth. All five of these measures involve the buttock and thigh areas, and larger measurements in girls during middle childhood are probably related to greater amounts of soft tissue, especially subcutaneous fat, in this area of the female physique.

The pattern of sex differences in the remaining measurements involves larger male averages at 6, 7, and sometimes 8 years of age; small and/or negligible differences at 8 and 9 years of age; and larger female averages at 10 and 11 years of age. Except for body weight (which itself is highly determined by stature), the dimensions showing this general pattern of sex differences are all linear measurements: stature, sitting height, popliteal height, knee height, acromion-olecranon length, elbow-wrist length, and hand length. Larger measurements for girls generally appear at about 10 years of age, probably reflecting the initial stages of the earlier female adolescent growth spurt.

Data for most of the 21 dimensions used in the present study of middle childhood are also available for adults from Cycle I of the Health Examination Survey[8,9] and from *The Human Body in Equipment Design.*[11] In contrast to the pattern of sex differences just described for ages 6-11 years, adult males are larger than females in all except two of the 21 dimensions. These two are seat breadth and hip girth, both of which are also consistently larger in the girls during middle childhood. Thus, we have a sex difference becoming evident during childhood and persisting into adulthood. It would be interesting to note whether these two dimensions show larger values for females during infancy and early childhood. Parizkova,[12] for example, reported significantly larger skinfolds over the hips of newborn girls than newborn boys. Perhaps sex differences in the patterning of subcutaneous tissue, i.e., in selective site deposition, underlie the sex difference in seat breadth and hip girth. Larger dimensions for girls in about one-third of the other measurements are apparently only temporary, reflecting the early growth acceleration characteristic of female adolescence, which is eventually overcome by the longer growth period and greater magnitude of the adolescent spurt in males.

Although each dimension increases with age and there are sex differences in mean values, there is considerable overlapping between sexes and between adjacent ages in the distributions of values for each dimension. In the presentation of findings, emphasis was placed upon comparisons of the percentile extremes at 6 and 11 years of age, which indicate some overlapping in many dimensions between the upper (95th) percentile limits at 6 years of age and the lower (5th) percentile limits at 11 years of age. Even when the upper and lower percentile limits at the youngest and oldest ages did not actually overlap each other, the difference between them was generally rather small. This indicates that some 6-year-old children will have overall body size equivalent to some 11-year-old children. It also indicates that some 6-year-olds will have specific body segment lengths, girths, etc. equivalent in size to those of some 11-year-old children. This does not, however, imply that body proportions of the two extreme age categories are identical. As indicated earlier, for example, sitting height as a percentage of standing height decreases from approximately 54 percent in 6-year-old children to approximately 51 percent in 11-year-old children. Similar age-related variations in the proportional relationships are also apparent for other body dimensions. It should be kept in mind that the span included in comparisons of the youngest and oldest groups under study is 5 years. When comparisons are made between adjacent age groups from 6 through 11 years, the overlap in distribution of measurement values is considerable for both sexes.

Although middle childhood is characteristically described as a period of slow, steady growth, there is considerable variation within the specific age groups, between different age groups, and between sexes. Problems for those who design and manufacture children's equipment, furniture, and clothing are obvious. Take for example the problem of seat design for elementary schoolchildren. A seat has to be wide enough and long enough to accommodate larger children, yet must not be so long as to be of potential discomfort to the short child. Similarly, regarding the height of the seat surface from the floor, in the U.S. Air Force report by Kroemer and Robinette, they indicate that: ". . . the height of the seat should be slightly less than the distance from the floor to the popliteal area of the seated individual."[13] Adjustable seats are a possible solution, but it is clear that having uniformly sized seats for all children unquestionably penalizes or offers potential discomfort for some, both the unusually small and the unusually large. The postural and comfort implications are well described in the U.S. Air Force report by Kroemer and Robinette:

> Pressure from the edge of the seat is distinctly uncomfortable because the soft undersides of the thighs are not qualified for sustained compression. If the seat is too high, such pressure is always present, even if the front edge of the seat surface is well rounded or upholstered. To avoid such compression, people tend to sit on the front portion of a high seat. While this leads to the desirable angle of more than 90 degrees between the thighs and the trunk, it also causes an unstable and fatiguing posture, requiring static contraction of muscles to be maintained.
>
> Compression of the thighs will certainly be eliminated if a low seat is used. However, if an individual sits on a chair that is too low, a more acute angle between his thighs and the trunk is likely to occur. This acute angle causes an unfavorable relative position of pelvis and spinal column, and also causes pressure on the abdominal organs. Tall, heavy, and elderly people often find it difficult to get up from a low chair.[13]

Similar problems relate to the height of desks or work surfaces for schoolchildren. Again to quote the review of Kroemer and Robinette on the problem:

> In contrast to the theoretical recommendation that the height of the chair should correspond to the individual's leg dimensions, surveys showed that in practice the seat height is adjusted to the height of the desk. In other words, chairs are really being adjusted to the height of the working surface; comfort of hands, arms, shoulders, and eyes plays a more important role than comfort of the legs. This frequently causes rather undesirable positions of the trunk and legs and may greatly contribute to the pains and aches reported from sedentary workers.
>
> This finding leads to a simple conclusion. Chair and desk (or table) must be regarded as a unit. The height of the desk must be derived from the height of the chair. The height of the chair must correspond to the length of the lower leg. (This axiom implies that a footrest normally should not be necessary.)[1]

The last mentioned axiom brings to mind the not too uncommon observation of children who have to be fitted with a block-type footrest during their first 2 or 3 years of school (i.e., 6, 7, and 8 years of age) because their legs are so short.

The preceding discussion suggests the utility of the present data as reference standards and guidelines for furniture design. To use adult standards for children would indeed be myopic, for:

> A child's body dimensions, proportions, and biomechanical properties are so markedly different from that of an adult that a child cannot, for design purposes, be considered simply as a scaled-down adult.[15]

The data presented in this report represent *static* anthropometric dimensions, i.e., measurements made on the body in a fixed, standardized position specific to each measurement. Hence, the observations are limited to these defined static postures. The child, however, is not a static being; rather, movement is the rule during childhood, thus implying the need for the study of *functional* or *dynamic* anthropometry of the growing child. Dynamic anthropometric dimensions, e.g., functional arm and leg reach, are those made while the body is in positions required for specific work tasks or is in motion. (See Damon, Stoudt, and McFarland[11] for a more detailed discussion.) Needless to say, dynamic dimensions are more difficult to measure and will vary with the task at hand.

One can ask whether the work space of a child in school is designed to fit the functional anthropometry of the child in terms of both safety and comfort standards and how work space requirements change with age during childhood. Of necessity, data on children in a variety of working positions—seated, standing, supine, prone, etc.—are required. Similar questions can likewise be applied to the child's work and play space at home.

Data essential to answer some of the questions raised above are lacking. Although the static anthropometric dimensions described in the present report offer some notion of the size variation during middle childhood and can be used widely in meeting the standard and design needs of various industrial and governmental concerns, they do not fully describe the essential functional parameters of the growing child. In this sense they are of limited value to "human factors" or "human engineering" problems concerning the child as a dynamic being (child restraint systems, "child-proof" lid design of medication containers, work or study space design, design of play equipment and toys, etc.).

In summary, there is a lack of complete data on the static and, especially, the dynamic anthropometry of the growing child. What, for example, are the essential, functional anthropometric parameters of a child during middle childhood? Once identified, how can they be accurately measured? Such data would extend not only to adolescents but also, most importantly, to infants, who have the least capability of making personal adaptations to the environment which is presented to them. In addition, such anthropometric observations must be complemented with detailed studies of the biomechanical and performance capabilities of the growing child.

SUMMARY

Age trends, sex differences, and ranges of variation for 21 anthropometric dimensions are reported for a probability sample of 7,417 U.S. children 6 through 11 years of age. The 21 dimensions include weight, height, sitting height, popliteal height, knee height, buttock-popliteal length, buttock-knee length, acromion-olecranon length, elbow-wrist length, foot length, foot breadth, hand length, hand breadth, chest breadth, chest depth, elbow-elbow breadth, seat breadth, thigh clearance, chest girth, waist girth, and hip girth.

All dimensions increase almost linearly with age from 6 through 11 years. Although there is considerable overlap, sex differences are apparent, but vary with the dimensions examined. For example, in eight dimensions (three of the hands and feet and five relating to the breadth and girth of the torso) boys are generally larger throughout the age range. Girls are generally larger through the age range in five measurements, all of which involve the buttock and thigh areas. In the remaining measurements, the pattern of sex differences indicates larger male values at 6, 7, and sometimes 8 years of age, small and/or negligible sex differences at 8 and 9 years, and larger female values at 10 and 11 years of age. The pattern indicated in the last measurements probably reflects the initial stages of the earlier female adolescent growth spurt.

The discussion of results is directed toward the specific application of anthropometric information to the human engineering of middle childhood, e.g., in the design of clothing, furniture, and equipment for children. The normal variation in the anthropometry of the growing child must be considered in various manufacturing and safety standards.

REFERENCES

[1] National Center for Health Statistics: Height and weight of children, United States. *Vital and Health Statistics*. PHS Pub. No. 1000-Series 11-No. 104. Public Health Service. Washington. U.S. Government Printing Office, Sept. 1970.

[2] National Center for Health Statistics: Height and weight of children: socioeconomic status, United States. *Vital and Health Statistics*. Series 11-No. 119. DHEW Pub. No. (HSM) 73-1601. Washington. U.S. Government Printing Office, Oct. 1972.

[3] National Center for Health Statistics: Skinfold thickness of children 6-11 years, United States. *Vital and Health Statistics*. Series 11-No. 120. DHEW Pub. No. (HSM) 73-1602. Washington. U.S. Government Printing Office, Oct. 1972.

[4] National Center for Health Statistics: Plan and initial program of the Health Examination Survey. *Vital and Health Statistics*. PHS Pub. No. 1000-Series 1-No. 4. Public Health Service. Washington. U.S. Government Printing Office, July 1965.

[5] National Center for Health Statistics: Cycle I of the Health Examination Survey, sample and response, United States, 1960-1962. *Vital and Health Statistics*. PHS Pub. No. 1000-Series 11-No. 1. Public Health Service. Washington. U.S. Government Printing Office, Apr. 1964.

[6] National Center for Health Statistics: Plan, operation, and response results of a program of children's examinations. *Vital and Health Statistics*. PHS Pub. No. 1000-Series 1-No. 5. Public Health Service. Washington. U.S. Government Printing Office, Oct. 1967.

[7] National Center for Health Statistics: Plan and operation of a Health Examination Survey of U.S. youths 12-17 years of age. *Vital and Health Statistics*. PHS Pub. No. 1000-Series 1-No. 8. Public Health Service. Washington. U.S. Government Printing Office, Sept. 1969.

[8] National Center for Health Statistics: Weight, height, and selected body dimensions of adults, United States, 1960-1962. *Vital and Health Statistics*. PHS Pub. No. 1000-Series 11-No. 8. Public Health Service. Washington. U.S. Government Printing Office, June 1965.

[9] National Center for Health Statistics: Skinfolds, body girths, biacromial diameter, and selected anthropometric indices of adults, United States, 1960-1962. *Vital and Health Statistics*. PHS Pub. No. 1000-Series 11-No. 35. Public Health Service. Washington. U.S. Government Printing Office, Feb. 1970.

[10] National Center for Health Statistics: Body weight, stature, and sitting height: white and Negro children 6-11 years, United States. *Vital and Health Statistics*. Series 11. Health Services and Mental Health Administration, DHEW, Rockville, Md. To be published.

[11] Damon, A., Stoudt, H. W., and McFarland, R. A.: *The Human Body in Equipment Design*. Cambridge, Mass. Harvard University Press, 1966.

[12] Parizkova, J.: Impact of age, diet, and exercise on man's body composition. *Ann. New York Acad. Sci.* 110:661-674, 1963.

[13] U.S. Air Force: Ergonomics in the design of office furniture: a review of European literature, by K. H. Kroemer and J. C. Robinette. AMRL-TR-68-80. Wright-Patterson Air Force Base, Ohio, July 1968. p. 7.

[14] Ibid., p. 15.

[15] Burdi, A. R., Huelke, D. F., Snyder, R. G., and Lowrey, G. H.: Infants and children in the adult world of automobile safety design: pediatric and anatomical considerations for design of child restraints. *J. Biomechanics* 2:267-280, 1969.

[16] National Center for Health Statistics: Replication: an approach to the analysis of data from complex surveys. *Vital and Health Statistics*. PHS Pub. No. 1000-Series 2-No. 14. Public Health Service. Washington. U.S. Government Printing Office, Apr. 1966.

[17] Hertzberg, H. T. E.: The Conference on Standardization of Anthropometric Techniques and Terminology. *Am. J. Phys. Anthropol.* 28(1):1-16, Jan. 1968.

[18] National Center for Health Statistics: Quality control in a National Health Examination Survey. *Vital and Health Statistics*. Series 2-No. 44. DHEW Pub. No. (HSM) 72-1023. Washington. U.S. Government Printing Office, Feb. 1972.

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LIST OF DETAILED TABLES

Table 1. Height of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	118.6	5.17	0.236	110.7	111.8	115.1	118.5	122.0	125.7	128.0
7 years-------	632	2,074	124.5	5.52	0.356	115.6	117.8	120.8	124.4	128.0	131.8	134.4
8 years-------	618	2,026	130.0	5.67	0.263	120.3	123.3	126.3	130.0	133.7	137.3	139.3
9 years-------	603	2,012	135.5	6.72	0.442	124.6	127.0	131.4	135.6	140.1	143.5	145.4
10 years------	576	1,963	140.2	6.81	0.373	129.3	131.4	136.2	140.6	144.6	148.5	151.3
11 years------	628	1,924	145.7	6.88	0.273	134.6	137.2	141.2	145.8	150.4	154.3	157.0
Girls												
6 years-------	536	2,016	117.8	5.52	0.269	108.3	110.6	114.4	117.7	121.6	125.0	126.7
7 years-------	609	2,010	123.5	5.87	0.175	113.7	116.3	119.7	123.6	127.4	130.7	132.7
8 years-------	613	1,960	129.4	6.26	0.331	119.1	121.4	125.5	129.6	133.4	137.2	139.3
9 years-------	581	1,945	135.5	7.00	0.312	124.4	127.1	130.8	135.4	140.1	144.8	147.4
10 years------	584	1,904	140.9	7.37	0.307	129.5	132.0	135.9	141.0	145.7	150.2	153.4
11 years------	564	1,868	147.6	7.85	0.243	135.4	138.9	143.0	147.4	152.8	158.0	159.7

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 2. Weight of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In kilograms									
6 years-------	575	2,082	22.0	3.37	0.148	17.4	18.2	19.8	21.6	23.7	26.0	28.0
7 years-------	632	2,074	24.7	3.97	0.185	19.4	20.4	22.2	24.1	26.6	29.5	31.5
8 years-------	618	2,026	27.8	4.86	0.225	21.5	22.6	24.5	27.1	29.8	33.9	36.4
9 years-------	603	2,012	31.2	6.79	0.430	23.2	24.5	26.8	29.7	33.9	38.5	43.5
10 years------	576	1,963	33.7	6.48	0.297	25.5	26.7	29.4	32.6	36.5	42.0	45.0
11 years------	628	1,924	38.3	8.09	0.360	28.6	30.1	33.1	36.6	41.7	48.6	53.0
Girls												
6 years-------	536	2,016	21.6	3.68	0.229	16.4	17.6	19.2	21.1	23.2	25.8	28.0
7 years-------	609	2,010	24.2	4.16	0.206	18.7	19.5	21.3	23.5	26.4	29.7	31.5
8 years-------	613	1,960	27.5	5.36	0.233	20.5	21.7	23.8	26.7	30.0	34.5	38.2
9 years-------	581	1,945	31.4	6.80	0.371	22.9	24.3	26.6	29.8	34.6	41.8	45.6
10 years------	584	1,904	35.2	8.18	0.411	24.9	26.2	29.2	34.2	39.5	45.6	49.9
11 years------	564	1,868	40.0	9.17	0.401	28.4	29.8	33.4	38.2	45.0	52.1	58.0

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 3. Sitting height of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	64.7	2.73	0.101	60.2	61.1	62.8	64.7	66.5	68.3	69.5
7 years-------	632	2,074	67.0	2.78	0.145	62.4	63.5	65.1	67.1	68.7	70.6	71.7
8 years-------	618	2,026	69.2	2.98	0.114	64.5	65.5	67.3	69.3	71.3	73.2	74.1
9 years-------	603	2,012	71.3	3.32	0.191	65.9	66.8	69.2	71.4	73.6	75.5	76.6
10 years------	576	1,963	73.0	3.25	0.184	67.4	69.0	71.0	73.1	75.2	77.2	78.5
11 years------	628	1,924	75.3	3.22	0.129	70.1	71.3	73.3	75.2	77.5	79.5	80.6
Girls												
6 years-------	536	2,016	63.9	3.01	0.153	58.8	60.1	62.1	64.1	65.8	67.9	68.8
7 years-------	609	2,010	66.2	3.05	0.116	61.2	62.3	64.1	66.3	68.2	70.3	71.3
8 years-------	613	1,960	68.5	3.08	0.111	63.1	64.4	66.5	68.6	70.7	72.4	73.3
9 years-------	581	1,945	71.0	3.32	0.152	65.5	66.7	68.7	70.8	73.3	75.3	76.4
10 years------	584	1,904	73.3	3.50	0.136	67.8	68.8	70.7	73.4	75.6	77.6	79.1
11 years------	564	1,868	76.3	4.00	0.133	69.7	71.6	73.8	76.1	78.7	81.4	83.4

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 4. Popliteal height of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	29.2	1.84	0.060	26.3	26.9	28.0	29.3	30.5	31.6	32.6
7 years-------	632	2,074	31.1	1.98	0.131	28.1	28.6	29.7	31.1	32.4	33.7	34.6
8 years-------	618	2,026	32.6	2.00	0.112	29.2	30.1	31.3	32.7	33.9	35.2	35.8
9 years-------	603	2,012	34.3	2.20	0.107	30.8	31.5	32.9	34.3	35.7	37.2	38.0
10 years------	576	1,963	35.9	2.24	0.120	32.2	33.0	34.4	35.9	37.4	39.0	39.7
11 years------	628	1,924	37.4	2.32	0.103	33.7	34.5	35.7	37.3	39.1	40.4	41.3
Girls												
6 years-------	536	2,016	29.0	1.84	0.065	26.0	26.5	27.7	29.0	30.2	31.4	32.1
7 years-------	609	2,010	30.6	1.99	0.079	27.4	28.2	29.3	30.6	32.0	33.3	34.0
8 years-------	613	1,960	32.4	2.09	0.115	29.1	29.6	31.1	32.5	33.7	34.9	35.8
9 years-------	581	1,945	34.2	2.36	0.111	30.3	31.3	32.6	34.2	35.7	37.6	38.4
10 years------	584	1,904	35.7	2.51	0.142	31.8	32.6	34.1	35.6	37.4	39.1	39.8
11 years------	564	1,868	37.5	2.62	0.137	33.3	34.2	35.7	37.5	39.3	40.7	41.7

NOTE: n = sample size; N = estimated number of children in population in thousands: $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 5. Knee height of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	36.1	2.03	0.079	32.9	33.5	34.6	35.9	37.4	38.8	39.7
7 years-------	632	2,074	38.2	2.17	0.112	34.8	35.5	36.7	38.2	39.6	41.3	42.2
8 years-------	618	2,026	40.2	2.25	0.109	36.3	37.3	38.6	40.2	41.7	42.9	43.8
9 years-------	603	2,012	42.4	2.65	0.140	38.1	39.1	40.7	42.4	43.8	45.6	46.7
10 years------	576	1,963	44.2	2.64	0.114	39.7	40.7	42.4	44.3	45.9	47.5	48.6
11 years------	628	1,924	46.3	2.73	0.104	41.7	42.8	44.4	46.3	48.2	49.8	50.9
Girls												
6 years-------	536	2,016	35.9	2.18	0.103	32.4	33.1	34.5	35.9	37.3	38.7	39.7
7 years-------	609	2,010	37.9	2.22	0.074	34.3	35.2	36.5	37.8	39.5	40.7	41.6
8 years-------	613	1,960	40.2	2.40	0.091	36.3	37.2	38.5	40.1	41.8	43.3	44.3
9 years-------	581	1,945	42.5	2.79	0.131	38.2	39.1	40.5	42.3	44.4	46.1	47.3
10 years------	584	1,904	44.4	2.88	0.118	39.6	40.7	42.4	44.4	46.4	47.8	49.3
11 years------	564	1,868	46.6	2.83	0.113	42.1	43.0	44.8	46.6	48.3	50.3	51.2

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 6. Buttock-popliteal length of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	32.3	2.71	0.246	28.6	29.3	30.4	31.9	33.7	35.7	37.4
7 years-------	632	2,074	34.2	2.66	0.257	30.4	31.2	32.4	33.8	35.7	38.0	38.9
8 years-------	618	2,026	36.2	2.93	0.278	32.3	33.1	34.3	35.8	37.8	40.1	42.2
9 years-------	603	2,012	38.4	3.32	0.386	34.1	34.7	36.3	38.2	39.9	42.7	45.0
10 years------	576	1,963	40.1	[illegible]	0.299	35.3	36.2	37.8	39.7	41.9	44.3	46.5
11 years------	628	1,924	42.0	3.42	0.284	36.9	38.2	39.7	41.7	43.7	46.4	48.3
Girls												
6 years-------	536	2,016	32.9	2.90	0.231	28.8	29.7	31.1	32.6	34.4	37.0	38.6
7 years-------	609	2,010	34.8	2.96	0.281	30.6	31.6	32.8	34.6	36.5	38.5	40.3
8 years-------	613	1,960	37.0	3.04	0.272	32.7	33.5	35.1	36.6	38.6	41.1	43.1
9 years-------	581	1,945	39.3	3.40	0.272	34.3	35.4	37.2	38.9	41.2	43.8	45.2
10 years------	584	1,904	41.4	3.64	0.322	35.8	37.0	39.1	41.2	43.6	45.8	47.7
11 years------	564	1,868	43.4	4.24	0.309	38.1	39.2	40.9	43.1	45.7	48.7	50.5

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 7. Buttock-knee length of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	37.2	2.89	0.258	31.5	33.6	35.7	37.4	39.1	40.8	41.6
7 years-------	632	2,074	39.7	3.08	0.286	33.7	36.1	38.1	39.9	41.6	43.4	44.6
8 years-------	618	2,026	41.7	3.26	0.287	35.7	37.6	40.2	41.8	43.8	45.4	46.5
9 years-------	603	2,012	44.0	3.49	0.308	37.7	39.7	41.9	44.2	46.2	47.9	49.5
10 years------	576	1,963	46.0	3.55	0.286	39.8	41.5	44.2	46.3	48.2	50.1	51.0
11 years------	628	1,924	48.2	3.51	0.276	42.2	44.1	46.2	48.3	50.5	52.5	53.7
Girls												
6 years-------	536	2,016	37.6	3.01	0.260	32.2	33.5	36.1	37.9	39.6	41.2	41.9
7 years-------	609	2,010	39.8	3.14	0.266	34.2	35.7	38.2	40.1	41.9	43.5	44.4
8 years-------	613	1,960	42.4	3.20	0.209	37.1	38.6	40.5	42.5	44.5	46.4	47.6
9 years-------	581	1,945	44.8	3.60	0.285	38.6	40.4	42.6	44.7	47.3	49.4	50.5
10 years------	584	1,904	47.0	3.73	0.322	40.5	42.3	44.7	47.3	49.5	51.4	52.7
11 years------	564	1,868	49.6	3.70	0.270	43.7	45.2	47.3	49.5	52.1	54.8	55.9

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 8. Acromion-olecranon length of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	23.7	1.32	0.072	21.6	22.1	22.7	23.7	24.7	25.6	26.1
7 years-------	632	2,074	25.0	1.40	0.076	22.6	23.2	24.1	25.1	25.9	26.8	27.6
8 years-------	618	2,026	26.3	1.38	0.073	24.0	24.5	25.4	26.4	27.3	28.1	28.7
9 years-------	603	2,012	27.6	1.59	0.098	25.1	25.5	26.4	27.5	28.6	29.7	30.4
10 years------	576	1,963	28.6	1.70	0.067	25.7	26.4	27.5	28.6	29.8	30.7	31.4
11 years------	628	1,924	30.0	1.82	0.074	27.2	27.8	28.8	30.1	31.2	32.4	33.1
Girls												
6 years-------	536	2,016	23.5	1.42	0.074	21.2	21.6	22.5	23.6	24.5	25.4	25.8
7 years-------	609	2,010	24.7	1.44	0.045	22.4	23.0	23.7	24.7	25.7	26.6	27.1
8 years-------	613	1,960	26.2	1.59	0.075	23.5	24.2	25.2	26.2	27.3	28.4	29.1
9 years-------	581	1,945	27.6	1.64	0.076	24.9	25.5	26.5	27.5	28.7	29.9	30.6
10 years------	584	1,904	28.9	1.90	0.092	26.0	26.6	27.7	29.0	30.2	31.4	31.9
11 years------	564	1,868	30.5	1.91	0.087	27.5	28.2	29.2	30.5	32.0	33.1	33.7

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 9. Elbow-wrist length of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
			In centimeters									
Boys												
6 years-------	575	2,082	18.3	1.02	0.037	16.6	17.1	17.5	18.3	18.9	19.7	20.2
7 years-------	632	2,074	19.3	1.15	0.064	17.4	18.0	18.5	19.3	20.1	20.8	21.4
8 years-------	618	2,026	20.2	1.20	0.064	18.2	18.6	19.4	20.2	20.9	21.8	22.3
9 years-------	603	2,012	21.2	1.29	0.064	19.1	19.5	20.3	21.2	22.0	22.8	23.5
10 years------	576	1,963	22.0	1.26	0.071	19.8	20.3	21.1	22.0	22.8	23.7	24.2
11 years------	628	1,924	22.9	1.41	0.049	20.6	21.2	22.1	23.0	23.9	24.8	25.4
Girls												
6 years-------	536	2,016	17.8	1.07	0.044	16.1	16.3	17.1	17.8	18.6	19.4	19.7
7 years-------	609	2,010	18.8	1.20	0.038	17.0	17.3	18.1	18.7	19.6	20.5	20.8
8 years-------	613	1,960	19.9	1.22	0.044	17.8	18.2	19.0	19.8	20.7	21.5	21.9
9 years-------	581	1,945	20.9	1.32	0.058	19.0	19.2	20.0	20.8	21.8	22.8	23.4
10 years------	584	1,904	21.9	1.45	0.051	19.6	20.1	20.8	21.8	22.9	23.8	24.5
11 years------	564	1,868	23.1	1.53	0.066	20.6	21.2	22.1	23.0	24.2	25.1	25.8

NOTE: n = sample size; N = estimated number of children in population in thou ands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 10. Foot length of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
			In centimeters									
Boys												
6 years-------	575	2,082	18.0	1.04	0.045	16.2	16.6	17.3	18.0	18.7	19.5	19.9
7 years-------	632	2,074	18.9	1.07	0.064	17.1	17.4	18.2	18.8	19.7	20.5	20.8
8 years-------	618	2,026	19.7	1.21	0.068	17.8	18.2	18.8	19.7	20.6	21.4	21.8
9 years-------	603	2,012	20.7	1.25	0.063	18.5	19.1	20.0	20.7	21.6	22.5	22.8
10 years------	576	1,963	21.5	1.31	0.058	19.3	19.8	20.5	21.5	22.5	23.3	23.8
11 years------	628	1,924	22.3	1.34	0.068	20.1	20.5	21.4	22.4	23.3	24.1	24.7
Girls												
6 years-------	536	2,016	17.8	1.10	0.065	15.8	16.3	17.1	17.7	18.6	19.4	19.8
7 years-------	609	2,010	18.6	1.09	0.038	16.7	17.2	17.8	18.6	19.5	20.1	20.6
8 years-------	613	1,960	19.5	1.18	0.055	17.5	18.1	18.6	19.5	20.4	21.2	21.7
9 years-------	581	1,945	20.5	1.27	0.055	18.2	18.7	19.6	20.4	21.3	22.3	22.8
10 years------	584	1,904	21.3	1.36	0.060	19.1	19.5	20.4	21.3	22.3	22.9	23.6
11 years------	564	1,868	22.1	1.33	0.063	20.0	20.3	21.2	22.1	23.1	23.8	24.5

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 11. Foot breadth of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
			In centimeters									
Boys												
6 years-------	575	2,082	6.7	0.58	0.060	5.7	6.1	6.3	6.6	7.2	7.7	7.8
7 years-------	632	2,074	7.0	0.54	0.053	6.1	6.1	6.4	7.0	7.5	7.8	7.9
8 years-------	618	2,026	7.2	0.56	0.039	6.1	6.3	6.7	7.3	7.6	7.9	8.3
9 years-------	603	,012	7.5	0.56	0.040	6.3	6.6	7.1	7.5	7.8	8.5	8.7
10 years------	576	1,963	7.7	0.57	0.038	6.5	7.0	7.3	7.6	8.2	8.6	8.8
11 years------	628	1,924	8.0	0.61	0.036	7.0	7.1	7.4	7.9	8.5	8.8	9.2
Girls												
6 years-------	536	2,016	6.5	0.51	0.045	5.3	5.7	6.2	6.5	6.8	7.4	7.6
7 years-------	609	2,010	6.7	0.51	0.040	6.0	6.1	6.3	6.7	7.2	7.7	7.8
8 years-------	613	1,960	7.0	0.55	0.043	6.1	6.2	6.5	7.1	7.5	7.8	7.9
9 years-------	581	1,945	7.3	0.58	0.034	6.1	6.3	6.8	7.3	7.7	8.2	8.6
10 years------	584	1,904	7.5	0.58	0.035	6.3	6.6	7.2	7.5	7.9	8.6	8.8
11 years------	564	1,868	7.8	0.60	0.033	6.6	7.1	7.3	7.8	8.4	8.8	8.9

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 12. Hand length of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
			In centimeters									
Boys												
6 years-------	575	2,082	13.0	0.71	0.027	11.9	12.1	12.5	13.2	13.6	14.0	14.5
7 years-------	632	2,074	13.6	0.75	0.043	12.2	12.5	13.1	13.6	14.2	14.7	14.9
8 years-------	618	2,026	14.2	0.83	0.035	12.6	13.1	13.6	14.3	14.8	15.4	15.7
9 years-------	603	2,012	14.7	0.81	0.029	13.2	13.6	14.2	14.6	15.3	15.8	16.2
10 years------	576	1,963	15.2	0.85	0.040	13.8	14.1	14.5	15.2	15.7	16.4	16.7
11 years------	628	1,924	15.8	0.89	0.026	14.2	14.5	15.2	15.7	16.4	16.8	17.4
Girls												
6 years-------	536	2,016	12.9	0.78	0.038	11.4	11.9	12.3	12.8	13.5	14.0	14.5
7 years-------	609	2,010	13.4	0.80	0.035	12.1	12.3	13.0	13.4	13.9	14.6	14.8
8 years-------	613	1,960	14.0	0.81	0.045	12.5	13.0	13.4	13.9	14.6	15.2	15.6
9 years-------	581	1,945	14.7	0.87	0.036	13.2	13.4	14.1	14.6	15.3	15.9	16.4
10 years------	584	1,904	15.2	0.93	0.037	13.6	14.1	14.5	15.3	15.8	16.6	16.8
11 years------	564	1,868	16.0	0.97	0.037	14.3	14.7	15.3	15.9	16.7	17.4	17.8

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 13. Hand breadth of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	6.1	0.39	0.025	5.1	5.3	5.7	6.2	6.6	6.8	6.9
7 years-------	632	2,074	6.3	0.42	0.035	5.2	5.4	6.1	6.4	6.7	6.8	6.9
8 years-------	618	2,026	6.5	0.44	0.024	5.4	5.8	6.2	6.5	6.8	7.2	7.4
9 years-------	603	2,012	6.7	0.45	0.024	6.0	6.1	6.3	6.7	7.2	7.6	7.8
10 years------	576	1,963	6.9	0.46	0.032	6.1	6.1	6.4	6.8	7.4	7.7	7.8
11 years------	628	1,924	7.1	0.46	0.027	6.1	6.3	6.7	7.3	7.6	7.8	7.9
Girls												
6 years-------	536	2,016	5.9	0.38	0.029	5.1	5.1	5.4	5.8	6.4	6.7	6.8
7 years-------	609	2,010	6.1	0.40	0.018	5.1	5.3	5.7	6.2	6.6	6.8	6.8
8 years-------	613	1,960	6.3	0.42	0.027	5.2	5.4	6.1	6.4	6.7	6.9	7.1
9 years-------	581	1,945	6.5	0.46	0.024	5.6	6.0	6.2	6.5	6.8	7.3	7.6
10 years------	584	1,904	6.7	0.45	0.029	6.0	6.1	6.3	6.6	7.2	7.6	7.8
11 years------	564	1,868	7.0	0.48	0.028	6.1	6.2	6.5	7.1	7.5	7.8	7.9

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 14. Chest breadth of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	18.4	1.15	0.081	16.4	17.0	17.6	18.4	19.2	19.9	20.5
7 years-------	632	2,074	19.0	1.20	0.084	17.1	17.5	18.2	19.1	19.7	20.6	21.1
8 years-------	618	2,026	19.8	1.31	0.095	18.0	18.3	19.0	19.7	20.7	21.5	22.0
9 years-------	603	2,012	20.6	1.57	0.090	18.3	18.7	19.5	20.5	21.5	22.5	23.2
10 years------	576	1,963	21.0	1.39	0.066	19.0	19.3	20.1	20.9	21.9	22.8	23.5
11 years------	628	1,924	22.0	1.58	0.092	19.8	20.2	21.1	21.8	23.0	24.3	24.9
Girls												
6 years-------	536	2,016	17.8	2.21	0.077	16.1	16.3	17.1	17.8	18.6	19.4	19.8
7 years-------	609	2,010	18.5	1.34	0.088	16.5	17.1	17.7	18.5	19.3	19.9	20.7
8 years-------	613	1,960	19.2	1.29	0.062	17.3	17.6	18.3	19.2	20.1	21.0	21.6
9 years-------	581	1,945	19.9	1.57	0.081	18.0	18.2	18.9	19.8	20.7	21.9	22.8
10 years------	584	1,904	20.8	1.79	0.104	18.3	18.7	19.6	20.7	21.8	23.1	24.1
11 years------	564	1,868	21.7	1.81	0.083	19.1	19.6	20.5	21.6	22.8	24.2	25.3

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 15. Chest depth of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	13.3	1.19	0.112	11.5	12.0	12.5	13.3	14.1	14.8	15.4
7 years-------	632	2,074	13.7	1.26	0.114	11.9	12.2	13.0	13.6	14.5	15.3	15.9
8 years-------	618	2,026	14.2	1.40	0.091	12.2	12.5	13.3	14.2	14.8	15.8	16.7
9 years-------	603	2,012	14.7	1.51	0.088	12.5	13.1	13.7	14.6	15.6	16.6	17.5
10 years------	576	1,963	14.9	1.47	0.115	13.0	13.3	14.1	14.8	15.7	16.7	17.5
11 years------	628	1,924	15.7	1.56	0.096	13.4	14.0	14.7	15.6	16.6	17.7	18.6
Girls												
6 years-------	536	2,016	12.9	1.14	0.079	11.2	11.5	12.2	12.8	13.6	14.4	14.8
7 years-------	609	2,010	13.3	1.28	0.090	11.4	11.8	12.4	13.2	14.0	14.8	15.5
8 years-------	613	1,960	13.7	1.31	0.069	11.8	12.2	12.7	13.6	14.6	15.5	16.3
9 years-------	581	1,945	14.2	1.61	0.077	12.1	12.4	13.2	14.0	15.1	16.5	17.3
10 years------	584	1,904	14.7	1.70	0.108	12.3	12.8	13.5	14.5	15.7	16.9	17.9
11 years------	564	1,868	15.3	1.83	0.110	13.0	13.3	14.1	15.2	16.6	17.8	18.7

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 16. Elbow-elbow breadth of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	25.2	2.30	0.130	21.7	22.5	23.7	25.3	26.8	28.0	28.8
7 years-------	632	2,074	26.1	2.51	0.161	22.3	23.1	24.5	26.2	27.6	29.2	30.2
8 years-------	618	2,026	27.0	2.85	0.145	23.1	23.8	25.3	26.8	28.6	30.1	31.6
9 years-------	603	2,012	28.0	3.56	0.225	23.5	24.4	25.9	27.5	29.5	32.1	34.7
10 years------	576	1,963	28.8	3.10	0.147	24.3	25.3	27.0	28.5	30.5	32.6	34.4
11 years------	628	1,924	30.2	3.54	0.195	25.6	26.5	27.9	29.7	32.1	34.9	37.3
Girls												
6 years-------	536	2,016	24.0	2.37	0.122	21.0	21.4	22.5	24.0	25.4	26.9	28.1
7 years-------	609	2,010	24.8	2.53	0.136	21.3	22.0	23.1	24.6	26.4	28.3	29.5
8 years-------	613	1,960	25.9	3.04	0.176	21.4	22.3	24.1	25.7	27.7	29.7	31.6
9 years-------	581	1,945	27.1	3.47	0.200	23.0	23.5	24.8	26.5	28.8	31.7	34.2
10 years------	584	1,904	28.2	3.78	0.201	23.4	24.2	25.7	27.7	30.4	33.4	36.1
11 years------	564	1,868	29.6	3.91	0.230	24.5	25.3	26.8	29.2	32.1	35.2	37.4

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 17. Seat breadth of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	20.6	1.70	0.119	18.1	18.6	19.5	20.5	21.5	22.6	23.5
7 years-------	632	2,074	21.4	1.75	0.115	19.1	19.4	20.3	21.3	22.4	23.6	24.5
8 years-------	618	2,026	22.5	2.19	0.141	19.6	20.2	21.2	22.3	23.5	24.9	26.3
9 years-------	603	2,012	23.6	2.63	0.165	20.3	21.0	22.1	23.3	24.7	26.8	28.8
10 years------	576	1,963	24.4	2.47	0.153	21.1	21.7	22.7	24.1	25.6	27.5	28.9
11 years------	628	1,924	25.8	2.68	0.161	22.1	22.7	23.9	25.5	27.3	29.3	30.6
Girls												
6 years-------	536	2,016	20.6	1.84	0.137	18.1	18.5	19.4	20.5	21.7	22.8	23.7
7 years-------	609	2,010	21.8	2.08	0.138	18.7	19.4	20.4	21.6	22.9	24.6	25.7
8 years-------	613	1,960	23.0	2.27	0.114	19.7	20.3	21.4	22.8	24.4	25.9	26.9
9 years-------	581	1,945	24.1	2.62	0.137	20.6	21.3	22.4	23.6	25.7	28.0	29.2
10 years------	584	1,904	25.4	3.00	0.175	21.3	22.1	23.4	25.2	27.3	29.5	31.2
11 years------	564	1,868	27.1	3.30	0.166	22.3	23.2	24.9	26.6	28.8	31.6	33.8

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 18. Thigh clearance of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Boys			In centimeters									
6 years-------	575	2,082	9.2	1.10	0.093	7.4	7.7	8.3	9.1	9.9	10.7	11.0
7 years-------	632	2,074	9.7	1.20	0.098	7.9	8.2	8.8	9.6	10.5	11.4	11.7
8 years-------	618	2,026	10.3	1.24	0.104	8.3	8.8	9.4	10.3	11.2	11.9	12.6
9 years-------	603	2,012	10.8	1.63	0.131	8.4	9.1	9.8	10.7	11.7	12.9	13.9
10 years------	576	1,963	11.1	1.44	0.126	9.0	9.3	10.1	11.1	11.9	13.1	13.7
11 years------	628	1,924	11.8	1.64	0.143	9.3	9.8	10.6	11.6	12.8	13.9	14.7
Girls												
6 years-------	536	2,016	9.3	1.18	0.097	7.4	7.8	8.4	9.2	10.0	10.8	11.5
7 years-------	609	2,010	9.8	1.26	0.099	8.0	8.2	8.8	9.6	10.5	11.5	12.2
8 years-------	613	1,960	10.4	1.39	0.091	8.2	8.7	9.4	10.	11.3	12.4	12.9
9 years-------	581	1,945	11.0	1.58	0.123	8.5	9.1	9.8	10.7	11.8	13.3	13.8
10 years------	584	1,904	11.5	1.84	0.141	9.0	9.4	10.3	11.4	12.6	13.6	14.3
11 years------	564	1,868	12.0	1.70	0.133	9.4	10.1	10.7	11.9	13.1	14.3	14.9

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 19. Chest girth of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
			In centimeters									
Boys												
6 years-------	575	2,082	58.6	3.46	0.162	54.1	54.9	56.3	58.4	60.6	63.1	64.4
7 years-------	632	2,074	60.7	3.94	0.223	55.5	56.5	58.3	60.4	62.7	65.5	67.6
8 years-------	618	2,026	63.1	4.68	0.258	57.4	58.5	60.2	62.5	65.3	68.6	71.3
9 years-------	603	2,012	66.0	5.80	0.366	58.9	60.1	62.3	65.3	68.5	72.4	76.7
10 years------	576	1,963	67.4	5.21	0.279	60.5	61.7	64.1	66.9	69.8	73.7	76.0
11 years------	628	1,924	70.9	6.14	0.253	63.3	65.1	66.9	67.9	73.6	79.9	83.1
Girls												
6 years-------	536	2,016	56.9	3.82	0.191	51.7	52.7	54.5	56.6	58.9	61.0	63.2
7 years-------	609	2,010	58.8	4.20	0.230	53.2	54.3	56.0	58.3	61.2	64.3	66.9
8 years-------	613	1,960	61.7	5.19	0.170	55.2	56.2	58.1	61.2	64.4	67.8	71.8
9 years-------	581	1,945	64.5	5.90	0.292	57.2	58.1	60.5	63.5	67.8	72.5	76.4
10 years------	584	1,904	67.1	6.71	0.353	58.6	60.1	62.4	66.3	70.8	76.6	80.2
11 years------	564	1,868	70.5	7.11	0.349	60.4	62.4	65.5	69.4	75.2	80.4	83.4

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 20. Waist girth of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
			In centimeters									
Boys												
6 years-------	575	2,082	52.9	4.21	0.185	47.4	48.4	50.2	52.4	54.9	58.2	60.3
7 years-------	632	2,074	54.3	4.47	0.250	47.9	49.5	51.8	54.1	56.5	59.5	61.3
8 years-------	618	2,026	56.2	5.43	0.269	50.0	50.6	53.0	55.7	58.6	62.3	65.5
9 years-------	603	2,012	58.1	6.19	0.390	51.1	52.1	54.3	57.1	60.3	65.8	70.8
10 years------	576	1,963	59.2	5.89	0.272	52.3	53.3	55.3	58.2	61.8	66.8	69.8
11 years------	628	1,924	62.1	7.08	0.238	54.1	55.4	57.6	60.5	64.8	70.9	76.8
Girls												
6 years-------	536	2,016	51.8	4.41	0.229	45.5	46.8	49.2	51.7	53.9	56.7	58.8
7 years-------	609	2,010	53.0	4.49	0.281	47.2	48.3	50.1	52.5	55.4	58.9	61.5
8 years-------	613	1,960	54.9	5.36	0.204	47.8	49.4	51.5	54.0	57.5	61.7	65.8
9 years-------	581	1,945	57.0	5.77	0.286	50.1	51.1	53.4	56.1	59.5	65.1	68.3
10 years------	584	1,904	58.3	6.33	0.380	50.4	51.6	54.3	57.3	61.4	65.8	71.6
11 years------	564	1,868	60.2	6.82	0.362	52.1	53.2	55.5	59.2	63.5	68.9	72.7

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

Table 21. Hip girth of children by sex and age at last birthday: sample sizes, mean, standard deviation, standard error of the mean, and selected percentiles, United States, 1963-65

Sex and age	n	N	$\bar{X}$	s	$s_{\bar{x}}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
			In centimeters									
Boys												
6 years-------	575	2,082	58.0	4.76	0.311	51.3	52.3	54.8	57.6	60.7	64.3	66.3
7 years-------	632	2,074	60.7	5.10	0.289	53.5	55.1	57.5	60.2	63.3	67.3	69.4
8 years-------	618	2,026	64.0	5.80	0.385	56.3	57.6	60.3	63.5	67.1	71.2	74.5
9 years-------	603	2,012	67.4	7.15	0.501	58.0	59.4	62.5	65.8	70.2	75.8	80.5
10 years------	576	1,963	69.2	6.47	0.459	60.1	62.2	64.8	68.3	72.8	78.1	80.8
11 years------	628	1,924	73.1	7.39	0.427	62.6	65.2	68.2	72.2	77.1	82.7	87.7
Girls												
6 years-------	536	2,016	58.9	5.14	0.305	50.7	52.7	55.4	58.5	62.1	65.3	67.4
7 years-------	609	2,010	61.9	5.66	0.322	54.2	55.7	57.9	61.2	65.5	69.4	72.3
8 years-------	613	1,960	65.5	6.28	0.318	55.9	57.6	61.3	65.2	69.2	73.5	76.9
9 years-------	581	1,945	68.8	7.17	0.442	58.8	60.7	63.5	67.8	73.5	79.0	81.5
10 years------	584	1,904	72.4	8.01	0.516	61.1	63.1	66.8	71.8	76.9	82.9	86.5
11 years------	564	1,868	76.6	8.59	0.556	64.4	66.4	70.8	75.6	82.1	87.8	92.4

NOTE: n = sample size; N = estimated number of children in population in thousands; $\bar{X}$ = mean; s = standard deviation; $s_{\bar{x}}$ = standard error of the mean.

APPENDIX I

STATISTICAL NOTES

The Survey Design

The sampling plan of the second cycle of the HES followed a highly stratified, multistage probability design in which a sample of the U.S. population (including Alaska and Hawaii) from the ages of 6 through 11 years inclusive was selected. Excluded were those children confined to an institution or residing upon any of the reservation lands set up for the American Indians.

In the first stage of this design, the nearly 2,000 primary sampling units (PSU's), geographic units into which the United States was divided, were grouped into 357 strata for the use of the Health Interview Survey and the Current Population Survey of the U.S. Bureau of the Census and were then further grouped into 40 superstrata for use in Cycle II of the HES.

The average size of each Cycle II stratum was 4.5 million persons, and all strata fell between the limits of 3.5 and 5.5 million. Grouping into 40 strata was done in a way that maximized homogeneity of the PSU's included in each stratum, particularly with regard to the degree of urbanization, geographic proximity, and degree of industrialization. The 40 strata were classified into four broad geographic regions (each with 10 strata) of approximately equal population and cross-classified into four broad population density groups (each having 10 strata). Each of the resultant 16 cells contained either two or three strata. A single stratum might include only one PSU (or only part of a PSU as, for example, New York City, which represented two strata) or several score PSU's.

To take account of the possible effect that the rate of population change between the 1950 and the 1960 Census might have had on health, the 10 strata within each region were further classified into four classes ranging from those with no increase to those with the greatest relative increase. Each such class contained two or three strata.

One PSU was then selected from each of the 40 strata. A controlled selection technique was used in which the probability of selection of a particular PSU was proportional to its 1960 population. In the controlled selection an attempt was also made to maximize the spread of the PSU's among the States. While not every one of the 64 cells in the 4x4x4 grid contributes a PSU to the sample of 40 PSU's, the controlled selection technique ensured the sample's matching the marginal distributions in all three dimensions and being closely representative of all cross-classifications.

Generally, within a particular PSU, 20 ED's (census enumeration districts) were selected with the probability of selection of a particular ED proportional to its population in the age groups 5-9 years in the 1960 Census, which by 1963 roughly approximated the population in the target age group for Cycle II. A similar method was used for selecting one segment (clusters of households) in each ED. Each of the resultant 20 segments was either a bounded area or a cluster of households (or addresses). All of the children in the age range properly resident at the address visited were EC's (eligible children). Operational considerations made it necessary to reduce the number of prospective examinees at any one location to a maximum of 200. The EC's to be excluded for this reason from the SC (sample child) group were determined by systematic subsampling. If one of the sample children had a twin who was not a sample child, this other twin was brought in for examination, and while the results were recorded for use in a special substudy of twins, this twin was not included in the 7,119 children under the present analysis.

The total sample included 7,417 children 6-11 years of age of whom 96 percent were finally examined. These 7,119 examined children represented the roughly 24 million children in the United States who met the general criteria for inclusion in the sampling universe as of mid-1964.

All data presented in this publication are based on "weighted" observations. That is, data recorded for each sample child are inflated in the estimation process to characterize the larger universe of which the sample child is representative. The weights used in this inflation process are a product of the reciprocal of the probability of selecting the child, 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 for single years of age 6-11.

In the second cycle of the HES the sample was the result of three stages of selection—the single PSU from each stratum, the 20 segments from each sample PSU, and the sample children from the eligible children. The probability of selecting an individual child is the product of the probabilities of selection at each stage.

Since the strata are roughly equal in population size and a nearly equal number of sample children 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 child 6-11 years old had about the same probability of being drawn into the sample.

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 children in a sample PSU having the same age (in years) and sex as children not examined in that sample PSU.

The poststratified ratio adjustment used in the second cycle achieved most of the gains in precision which would have been attained if the sample had been drawn from a population stratified by age, color, and sex and made the final sample estimates of population agree exactly with independent controls prepared by the U.S. Bureau of the Census for the noninstitutional population of the United States as of August 1, 1964 (approximate midsurvey point) by color and sex for each single year of age 6-11. The weights of every responding sample child in each of the 24 age, color, and sex classes are adjusted upward or downward so that the weighted total within the class equals the independent population control.

A more detailed description of the sampling plan and estimation procedures is included in earlier reports of the *Vital and Health Statistics* series.[5,6] Series 11, No. 1[5] describes the techniques used in Cycle I, which are similar to those of Cycle II.

Parameter and Variance Estimation

As each of the 7,119 sample children has an assigned statistical weight, all estimates of population parameters presented in HES publications are computed taking this weight into consideration. Thus, $\overline{X}$, the estimate of a population mean, "μ," is computed as follows: $\overline{X} = \sum_{i=1}^{n} W_i X_i / \sum W_i$, where X_i is the observation or measurement taken on the i^{th} person and W_i is the statistical weight assigned to that person.

The HES has an extremely complex sampling plan, and obviously the estimation procedure is, by the very nature of the sample, complex as well. A method is required for estimating the reliability of findings which "reflects both the losses from clustering sample cases at two stages and the gains from stratification, ratio estimation, and poststratification."[16]

The method for estimating variances in the HES is the half-sample replication technique. The method was developed at the U.S. Bureau of the Census prior to 1957 and has at times been given limited use in the estimation of the reliability of results from the Current Population Survey. This half-sample replication technique is particularly well suited to the HES because the sample, although complex in design, is relatively small (7,119 cases) and is based on but 40 strata. This feature permitted the development of a variance estimation computer program which produces tables containing desired estimates of aggregates, means, or distributions, together with a table identical in format but with the estimated variances instead of the estimated statistics. The computations required by the method are simple, and the internal storage requirements are well within the limitation of the IBM 360-50 computer system utilized at the National Center for Health Statistics.

Variance estimates computed for this report were based on 20 balanced half-sample replications. A half sample was formed by choosing one sample PSU from each of 20 pairs of sample PSU's. The composition of the 20 half samples was determined by an orthogonal plan. To compute the variance of any statistic, this statistic is computed for each of the 20 half samples. Using the mean as an example, this is denoted $\overline{X}_i$. Then, the weighted mean of the entire, undivided sample $(\overline{\overline{X}})$ is computed. The variance of the mean is the mean square deviation of each of the 20 half-sample means about the overall mean. Symbolically,

$$Var.(\overline{X}) = \frac{\sum_{i=1}^{20} \left(\overline{X} - \overline{\overline{X}}\right)^2}{20}$$

and the standard error of the mean is the square root of this. In a similar manner, the standard error of any statistic may be computed.

A detailed description of this replication process by Philip J. McCarthy, Ph.D., has been published.[16]

Standards of Reliability and Precision

All means, variances, and percentages appearing in this report met defined standards before they were considered acceptably precise and reliable.

The rule for reporting means and percentiles consisted of two basic criteria. The first criterion was that a sample size of at least five was required. If this first criterion was met, then the second criterion, that the coefficient of variation [i.e., the standard error of the mean divided by the mean $(s_{\overline{x}}/\overline{X})$] was to be less than 25 percent, must have been demonstrated. Thus, if either the sample size was too small, or the variation with respect to the mean was too large, the estimate was considered neither precise nor reliable

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NOTE: The list of references follows the text.

enough to meet the standards established for publication.

Hypothesis Testing

Although this report is primarily descriptive, it is often desirable to make statistical comparisons between two groups such as males and females or 6-year-olds and 7-year-olds. Classically, if a statistician wishes to test the difference between two means (or, put differently, to test whether two samples could have been drawn from the same population), he could do so by setting up a normal deviate in which he would utilize the means and standard errors of the means as computed from the samples. The statistic

$$z = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{s^2_{\bar{x}_1} + s^2_{\bar{x}_2}}}$$

is then compared to a table of normal deviates to determine whether or not there is, in fact, a difference between the two groups. (Note that the above makes the assumption that the two groups are independent and that $s^2_{\bar{x}} \longrightarrow \sigma^2_{\bar{x}}$.)

While the technique may appeal to many, in the analyses of this report this technique is not used for two basic reasons:

(1) Use of the z statistic makes necessary the assumption of normality. As is clearly shown by the percentile distributions of the variables considered in this report, this assumption is badly violated.

(2) Because of the many breakdowns of the HES sample, innumerable tests of this nature could be performed and, with each new test, the probability of rejecting a hypothesis incorrectly may be .05, but if 10 such tests are performed, the probability of making at least one mistake somewhere in those 10 tests is something closer to .50.

It was therefore decided to place the greatest emphasis on a relationship remaining consistent over both sexes and all ages under consideration. In other words, to say, for instance, that "girls have buttock-popliteal lengths greater than boys for all ages between 6 and 11 years" has far more meaning and interpretability than to say "the mean buttock-popliteal length for 6-year-old girls is significantly greater than the corresponding mean for 6-year-old boys," as determined by a normal deviate. In these analyses, *consistency* rather than a statement about a succession of individual probability levels is the factor considered most important in demonstrating a relationship.

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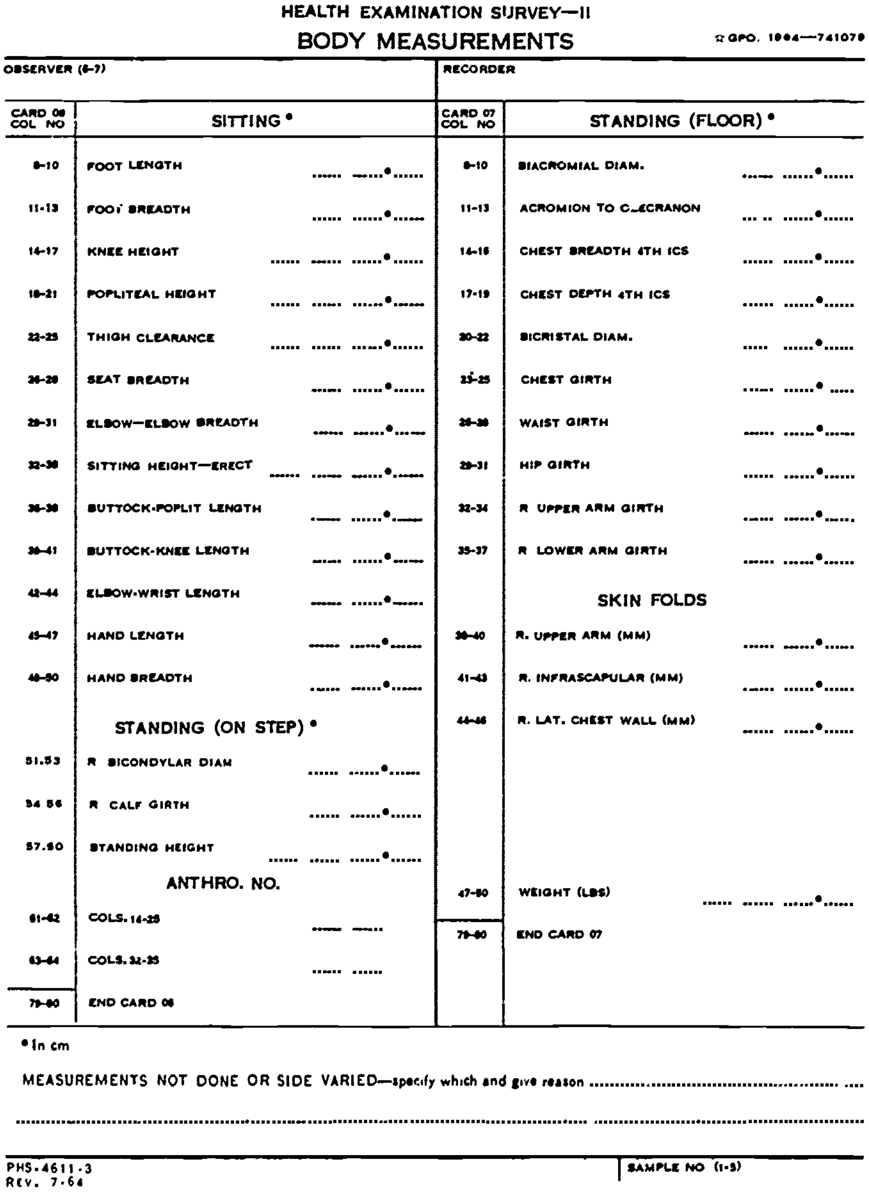
APPENDIX II

TECHNIQUES OF MEASUREMENT AND QUALITY CONTROL

Techniques of Measurement

Trained observers made all measurements, reading them to the nearest millimeter (tenth of a centimeter). All measurements were read aloud to a recorder, who repeated aloud each number back to the observer as it was recorded in the proper space on the record form. This repetition served both as a doublecheck on the measurement and to reduce recording errors.

Measurements were performed in a regular sequence to minimize the number of position changes the child was required to make. The sequence is illustrated on the measurement recording form (figure 1). It should be noted that not all the measurements taken in



HEALTH EXAMINATION SURVEY—II
BODY MEASUREMENTS
☆GPO. 1964—741070

OBSERVER (6-7)
RECORDER

CARD 06 COL NO	SITTING *	CARD 07 COL NO	STANDING (FLOOR) *
8-10	FOOT LENGTH	8-10	BIACROMIAL DIAM.
11-13	FOOT BREADTH	11-13	ACROMION TO OLECRANON
14-17	KNEE HEIGHT	14-16	CHEST BREADTH 4TH ICS
18-21	POPLITEAL HEIGHT	17-19	CHEST DEPTH 4TH ICS
22-25	THIGH CLEARANCE	20-22	BICRISTAL DIAM.
26-28	SEAT BREADTH	23-25	CHEST GIRTH
29-31	ELBOW—ELBOW BREADTH	26-28	WAIST GIRTH
32-35	SITTING HEIGHT—ERECT	29-31	HIP GIRTH
36-38	BUTTOCK-POPLIT LENGTH	32-34	R UPPER ARM GIRTH
39-41	BUTTOCK-KNEE LENGTH	35-37	R LOWER ARM GIRTH
42-44	ELBOW-WRIST LENGTH		SKIN FOLDS
45-47	HAND LENGTH	38-40	R. UPPER ARM (MM)
48-50	HAND BREADTH	41-43	R. INFRASCAPULAR (MM)
	STANDING (ON STEP) *	44-46	R. LAT. CHEST WALL (MM)
51.53	R BICONDYLAR DIAM		
54 56	R CALF GIRTH		
57.60	STANDING HEIGHT		
	ANTHRO. NO.	47-50	WEIGHT (LBS)
61-62	COLS. 14-25	79-80	END CARD 07
63-64	COLS. 32-35		
79-80	END CARD 06		

* In cm

MEASUREMENTS NOT DONE OR SIDE VARIED—specify which and give reason ....

PHS-4611-3
REV. 7-64
SAMPLE NO (1-5)

Figure 1. Body measurement recording form.

the survey are reported in the present report. The three skinfolds, for example, have been analyzed and reported already, while other specific reports are still in preparation.

All of the technicians were experienced X-ray technicians who had been trained in anatomy and the identification of specific body landmarks. In addition, X-ray technicians, both by disposition and training, tend to work well with people and are skilled in giving the examinee verbal orders along with the necessary handling to achieve proper positioning.

Each technician received more than a month of intensive training before being considered minimally proficient in making body measurements. In this training, he became skilled with the equipment, the precise locations of the body at which the measurements were to be taken, and the technique of measurement itself. The major sources of measurement error are improper positioning of subject's body, improper selection of specific body landmarks, and improper application of instrument (for instance, not perpendicular when measuring a diameter or circumference, or improperly compressing the soft tissue over bony landmarks). Incorrect reading of the instrument (usually transposition of numbers) also occurs with discouraging frequency. When these errors were mostly overcome, the new technician's data were carefully compared with those of the other three technicians and the two supervisors (P.V.V.H. and F.E.J.) before they were officially accepted as recorded data.

As was emphatically stated by Hertzberg when summarizing the Conference on Standardization of Anthropometric Techniques and Terminology in 1968,[17] every effort must be made to insure accuracy of measurement and standardization of procedure if the data are to be useful. The preceding discussion sketches the chief procedures used to reduce both systematic and variable measurement error. As discussed in the lengthy subsequent section, "Quality Control and Estimation of Residual Measurement Error," the absolute amount of systematic error can never truly be known unless one agrees on the "perfect measurer with perfect equipment perfectly applied, etc." A good estimate of the residual variable measurement error can, however, be achieved by replicate examinations for both inter- and intra-observer variability.

In the subsequent pages, the equipment, measurements, and specific procedures used in the survey are described and illustrated. Next the quality control procedures which were used to monitor the body measurements are discussed extensively.

Equipment

The measuring equipment consisted of several anthropometers, small sliding calipers, steel tapes, and a measuring table with an adjustable footrest.

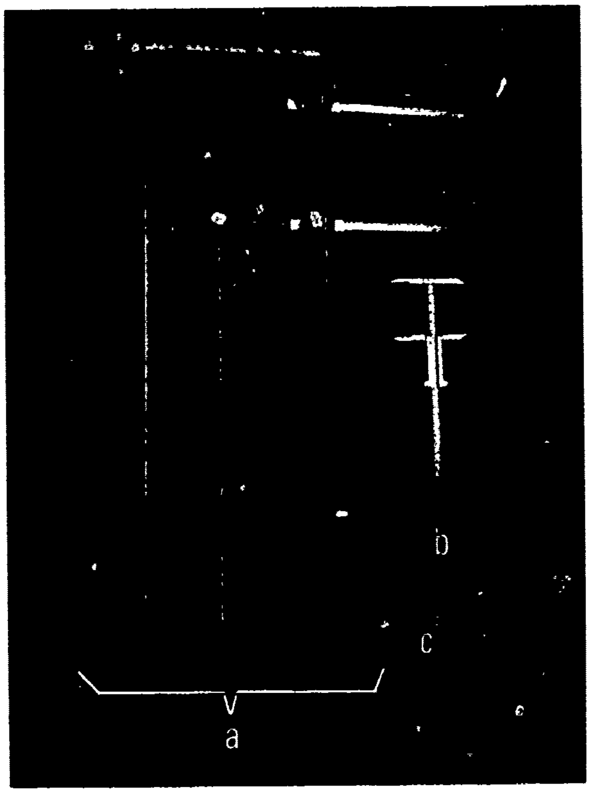


Figure 11. Anthropometric instruments used in Health Examination Survey, United States, 1963-65. A: anthropometer; B: sliding caliper; C: steel tape.

The *anthropometer* (figure 11) was used to measure various body lengths, heights, and breadths. It is a rod consisting of four sections and two crossbars, or measuring arms. One of the crossbars is fixed, while the other is movable. The anthropometer is calibrated in centimeters amd millimeters. It has two scales, one reading from the top down and the other from the bottom up. In this survey, a section of one anthropometer was fitted with a base for stabilizing purposes (to avoid tilting when making various height measurements), while another was fitted into the sliding backboard of the measuring table.

The *small sliding caliper* (figure 11) was used to measure hand length and breadth. It consists of a flat metal bar upon which a slide moves. One of the crossbars is fixed, while the other is movable. The small sliding calipers are calibrated in centimeters and millimeters.

The *steel tape* (figure 11) was used to measure various body circumferences. It is a flexible tape with a spring rewind and it is scaled in centimeters and millimeters on one side, in inches on the other.

The *measuring table* was such that it could accommodate children of varying sizes and proportions. It was equipped with an adjustable footrest in order to maintain a standardized position of the lower extrem-

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NOTE. The list of references follows the text.

ities during the measurement process. The surface of the table was also equipped with a measurement scale in centimeters and millimeters and with a sliding backboard at right angles to the scale.

Measuring Procedures and Definitions

Weight was measured on a Toledo self-balancing weight scale which mechanically printed the body weight directly onto a permanent record. It was recorded to the nearest 0.5 pounds.[1]

Height was measured as the distance from the standing surface to the top of the head. The child was in stocking feet with feet together, back and heels against the upright bar of the height scale, head in the Frankfort plane (looking directly forward), and standing erectly ("standing up tall").[1]

General position for sitting measurements. The child sat on the measuring table with the popliteal fossae at the front edge of the table. The footrest was adjusted so that the child sat with his knees and feet together, heels against the heel rests, feet at right angles to the lower legs, and lower legs at right angles to the thighs. Elbows were held at the sides with forearms at right angles, hands open, and palms facing each other, or with hands resting on knees. Arm positions were adjusted when necessary to meet the requirements of specific measurements.

General position for standing measurements. The child stood erectly with the head oriented in the Frankfort plane, i.e., looking directly ahead and feet together. Arms were held relaxed at the sides. Postural adjustments were made to meet the requirements of specific measurements.

Sitting height was measured as the vertical distance from the sitting surface to the top of the head. With the subject seated as described above, the backboard on the measuring table was brought up firmly against the buttocks. The movable arm of the anthropometer (which was inserted into the backboard) was brought down *firmly* to the midline of the top of the head.

Knee height was measured as the distance from the surface of footrest to the top of the right knee. With the subject seated so that knees and heels were together, the anthropometer with its attached base was placed on the footrest adjacent to the right foot and the movable arm was brought into *light contact* with the top of the right knee just back of the kneecap (patella).

Popliteal height was measured as the distance from the surface of the footrest to the underside of the right knee. With the subject seated as previously described, the anthropometer with its attached base was placed on the footrest adjacent to the right foot and the movable arm was brought to the level of the table surface on which the child was seated. This is the level at which the under side of the right knee (tendon of the biceps femoris muscle) comes into contact with the table surface.

Buttock-popliteal length was measured as the distance from the rearmost projection of the buttock to the back of the right knee. With the subject seated as previously described, the backboard on the measuring table was brought into *light contact* with the rearmost projection of the buttock. The distance measured was the distance from the table edge in contact with the back of the right knee (popliteal fossa) to the point at which the movable backboard, in light contact with the buttock, crossed the table scale.

Buttock-knee length was measured as the distance from the rearmost projection of the buttock to the front of the right kneecap. With the subject seated as previously described, the fixed crossbar of the anthropometer was placed in *light contact* with the rearmost projection of the buttock, and the movable crossbar was brought into *light contact* with the front surface of the right kneecap (patella).

Acromial-olecranon length was measured as the distance from the acromial process of the right scapula (outer point of the shoulder) to the olecranon process of the ulna (elbow). With the subject standing, right arm at his side and elbow bent at a 90-degree angle, the fixed crossbar of the anthropometer was placed *firmly* at the right acromial process and the movable crossbar was brought into *firm contact* with the olecranon process (tip of the elbow).

Elbow-wrist length was measured as the distance from the olecranon process (elbow) to the distal end of the styloid process of the ulna. With the subject seated as previously described but with palm facing downward, the fixed arm of the anthropometer was *firmly* placed at the olecranon process (tip of the elbow) and the movable arm was *firmly* placed at the distal end of the styloid process of the ulna.

Foot length was measured as the distance from the back of the right heel to the tip of the longest toe. With the child seated as previously described, the fixed arm of the anthropometer was *lightly* applied behind the heel with the rod parallel to the long axis of the foot. The movable bar of the anthropometer was then brought into *light contact* with the tip of the longest toe.

Foot breadth was measured as the maximum breadth of the right foot. With the child seated as previously described, the fixed bar of the anthropometer was applied *lightly* to the outer side of the foot, parallel to the long axis of the foot, and the movable bar of the anthropometer was brought into *light contact* with the most prominent part of the inner side of the foot. This is a maximum breadth measurement.

Hand length was measured as the distance from the wrist (midpoint of most distal crease or groove) to the tip of the middle finger. With the right hand fully extended, palm up and thumb straight but relaxed, the fixed end of the sliding caliper was placed at the midpoint of the distal crease at the wrist (located by having the child flex the hand at the wrist), and the movable

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NOTE: The list of references follows the text.

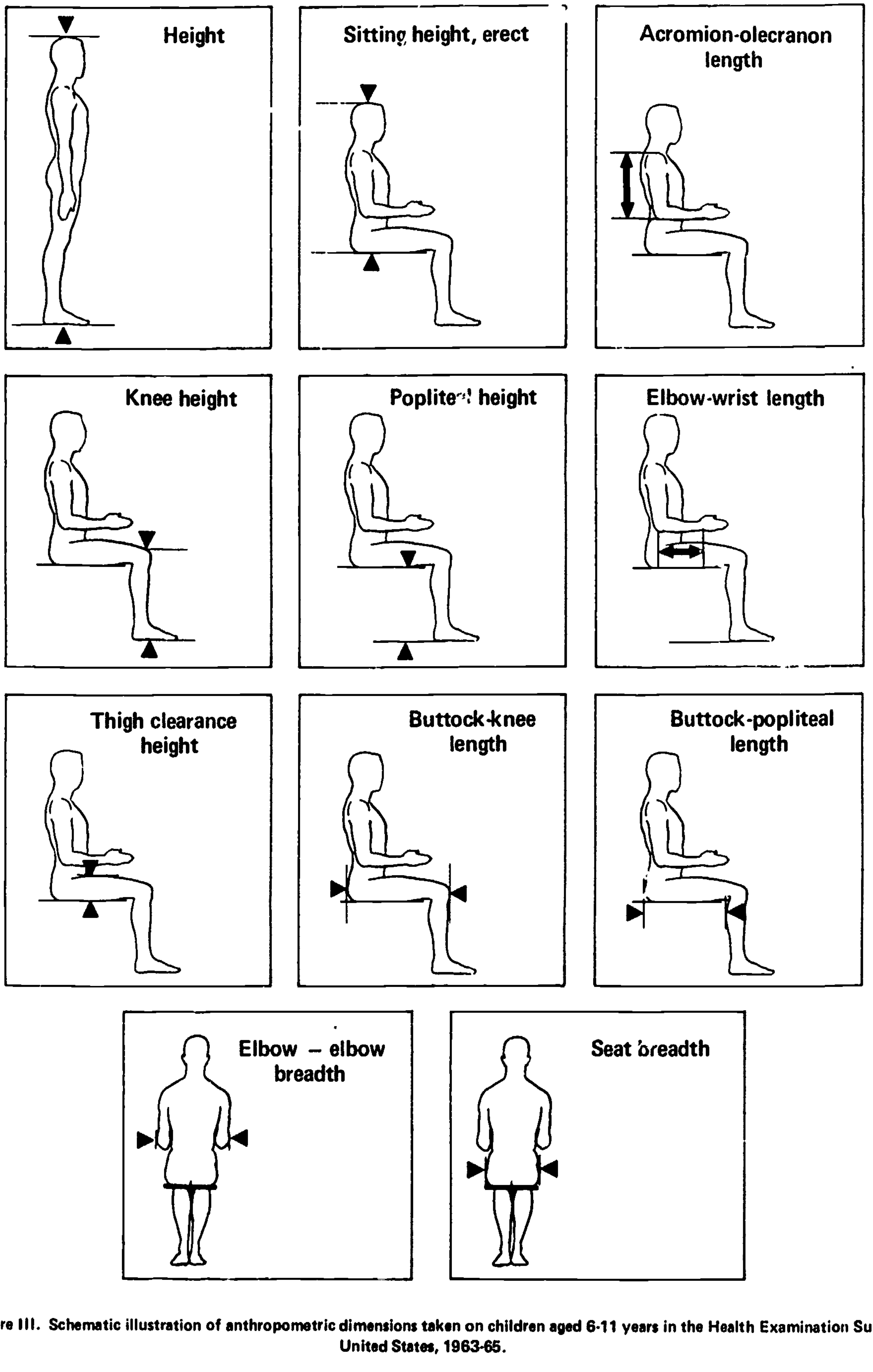

Figure III. Schematic illustration of anthropometric dimensions taken on children aged 6-11 years in the Health Examination Survey, United States, 1963-65.

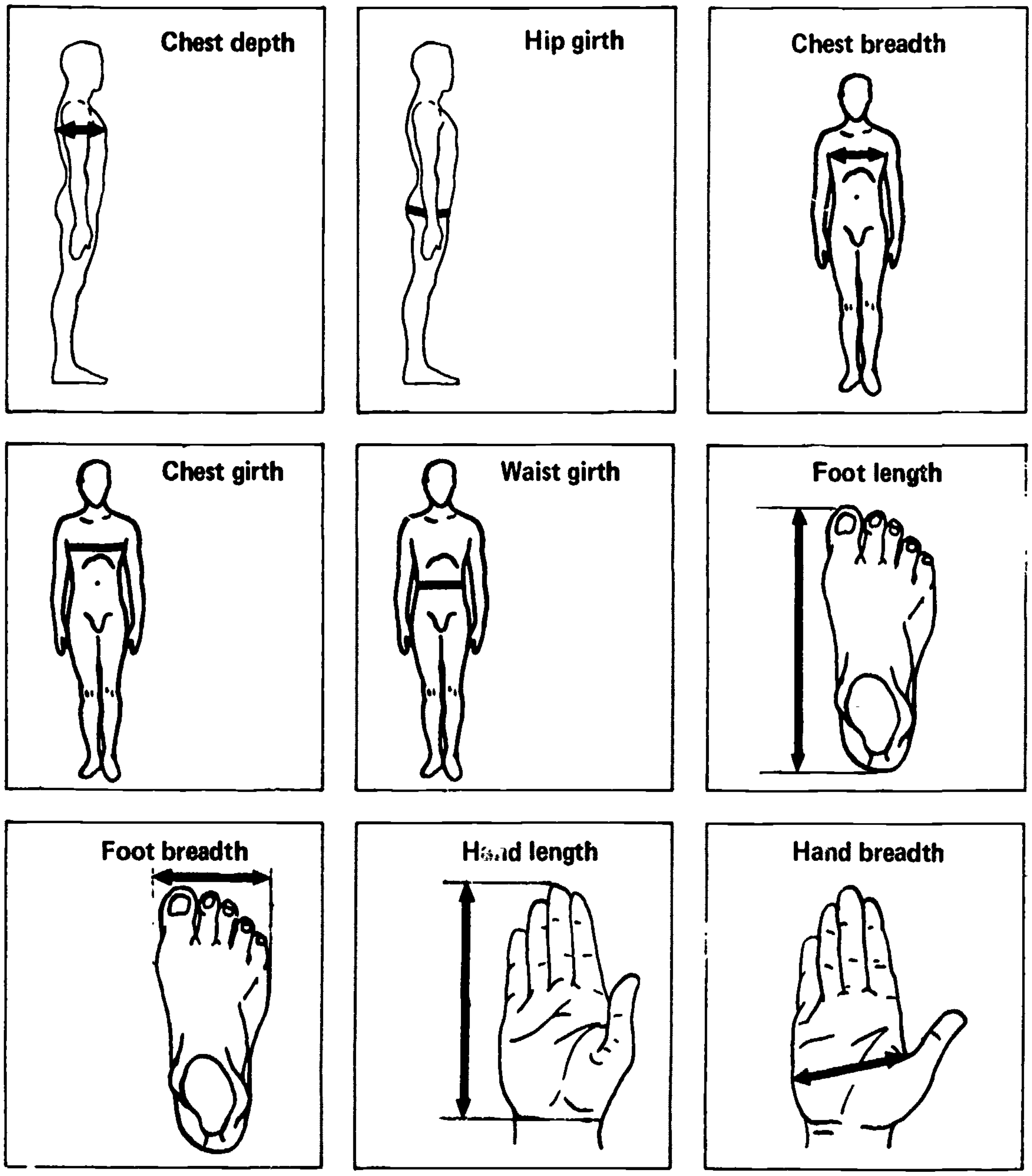

Figure III. Schematic illustration of anthropometric dimensions taken on children aged 6-11 years in the Health Examination Survey, United States, 1963-65—Con.

crossbar of the caliper was placed in *light contact* with the distal tip of the middle finger.

Hand breadth was measured as the breadth across the palm. With the right hand fully extended, palm up and thumb straight but relaxed, the fixed end of the sliding caliper was placed in *light contact* at the base of the angle formed by the thumb and index finger, and the movable crossbar of the caliper was placed in *light contact* with the ulnar side of the palm at the point midway between the base of the little (fifth) finger and the groove at the base of the hand.

Chest breadth was measured as the breadth of the rib cage under *firm pressure.* With the subject standing and breathing normally, the fixed crossbar of the anthropometer was applied firmly at one side of the rib cage and the movable crossbar was applied firmly to the other side at the level of the nipples. The crossbars were angled slightly downward to avoid slipping into the spaces between the ribs. At all times the rod of the anthropometer was parallel to the floor. In older girls who had a noticeable degree of breast development, the level of the junction of the fourth rib with the sternum was used as the measurement landmark.

Chest depth was measured as the distance or depth from the front to the back of the rib cage under *firm pressure* during normal breathing. With the subject in the same position as for the chest breadth measurement and with the observer approaching the child from the right side, the fixed arm of the anthropometer was applied firmly to the back of the chest and the movable arm was applied firmly to the sternum at the level of the nipples. At all times the measuring instrument was parallel to the floor. In older girls who had a noticeable degree of breast development, the level of the junction of the fourth rib with the sternum was used as the measurement level.

Elbow-elbow breadth was measured as the distance across the lateral surfaces of the right and left elbows. With the subject seated as previously described, elbows held *tightly to his sides,* the arms of the anthropometer were *firmly applied* at the lateral surfaces of each elbow (at the lateral epicondyles). Special care was taken to avoid slipping of the anthropometer arms off the lateral epicondyles.

Seat breadth was measured as the distance across the widest lateral protrusions of the buttocks. With the child seated as previously described, hands on knees, the crossbars of the anthropometer were placed *lightly but in firm contact* with the most lateral protrusion on each side of the buttocks. The arms of the anthropometer were angled slightly forward and downward, while the rod of the anthropometer was parallel with the sitting surface.

Thigh clearance was measured as the vertical distance from the sitting surface to the top of the right thigh. With the child seated as previously described, the lower end of the anthropometer with its attached base was placed on the sitting surface adjacent to the right thigh, and the movable arm was brought to the highest point of the thigh with minimum pressure to compensate for clothing.

Chest girth was measured as the circumference of the chest during normal breathing at the level of the fourth intercostal space. With the subject standing as for the measurement of chest breadth and depth, the steel tape was applied *firmly but without depressing the skin.* Special care was taken to make certain that the tape was horizontal.

Waist girth was measured as the circumference of the waist, abdomen relaxed, at the level midway between the lower edge of the ribs and the iliac crests. With the subject standing and breathing normally, the steel tape was applied *firmly but without depressing the skin.* Special care was taken to make certain the tape was horizontal.

Hip girth was measured as the circumference of the hips at the level of the greater trochanters (the widest bony part of the hips). With the child standing, feet together, the steel tape was applied *firmly* to compensate for clothing (this girth was measured over shorts). Special care was taken to make certain the tape was horizontal.

Each dimension measured is schematically illustrated in figure III.

Quality Control and Estimation of Residual Measurement Error[c]

Monitoring Systems

Despite efforts to reduce measurement errors, residual errors of a magnitude large enough to warrant concern occur with some regularity in any anthropometric survey. There is, therefore, a real and urgent need to have a system whereby these residual errors can be monitored. The concept of quality control is based on the desire to obtain end products of a specified quality. Thus, one of the main purposes of a monitoring system is to indicate whether the measurements produced by a certain measurement process have attained the desired quality. A second major purpose is to make possible quantitative summary descriptions of residual measurement errors to aid in the interpretation of survey data.

Perhaps the most direct monitoring system used in the Health Examination Survey was *observation of the measurement process* as it was being applied to an examinee. Medical, dental, and psychological advisors from HES and other advisors and consultants regularly visited the examination center to observe examination procedures and to retrain examiners if necessary. A good example of how routine observation

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[c] This section is in part based upon Schaible's lucid and systematic discussion of quality control and error estimation in the HES, Series 2, No. 44.[18]

was used as a monitoring system can be found in the taking of body measurements. One member of the examining team, a trained anthropometrist, acted as a recorder and aided in positioning of the examinees, while he was additionally responsible for observing and correcting any errors in measurement technique.

As a careful and thoughtful quality control program tends to be an evolving process, the most extensive systematic monitoring of body measurements performed in any of the cycles of the Health Examination Survey was achieved in Cycle III (youths 12-17 years, data collection 1966-70). The formal system of replicate examinations which was finally instituted in Cycle III is described later in this appendix along with a discussion of its applicability to Cycle II.

Replicate measurements are useful for a variety of reasons. e.g., as a means of increasing precision of individual measurement estimates, as a training technique, and as a monitoring system which includes the objective of final evaluation of measurement errors. These three objectives are compatible. and replicate data collected primarily for one of them often indirectly, if not directly. accomplish one or both of the remaining two. For this reason replicate data are most often collected with a combination of these objectives in mind. The single most important source of replicate data in Cycle III was the replicate examination procedure, in which approximately 5 percent of the regular examinees were returned to the examination center for a second complete examination (except for drawing blood and taking X-rays).

Biases and Controls in Replicate Measurements

A major source of uncertainty in estimates derived from replicate measurements is inability to make the replicate measurement under precisely the same conditions and in the same manner as the original measurement. This uncertainty is difficult to evaluate, and most attempts to do so are restricted to subjective statements concerning the direction and/or size of the bias and the need for concern in the analysis of data.

Several policies regarding Cycle III replicate examinations were designed specifically to obtain measurements under the same conditions and in the same manner as the initial (original) exam. Replicate examinations were not conducted at a specific time. Whenever possible, they were interspersed among the regular examinations. An original examination was given priority over a replicate examination in that none would be scheduled if it occupied time needed for a regular examination. There was often space to interject replicate examinations in the schedule without interfering with regular examinations, but this priority, plus the fact that replicates were drawn from those previously examined, increased the likelihood that a replicate examination would be scheduled toward the end of the examination period. Nevertheless, the attempt to space replicate examinations throughout the regular schedule was a valuable policy in that the interspacing of replicate and original examinations created an atmosphere more conducive to both examinations being conducted in essentially the same manner.

The examiners were informed of the purpose and importance of the reexaminations. It was emphasized that they should not vary their procedures on a replicate examination or in any way try to collect "better" data than they would normally. Thereafter, instructions on the conduct of replicate examinations were not given greater emphasis than any other instruction because overemphasizing "sameness" might have created more bias than it would have eliminated.

At the time of the original examination neither the observer nor the examinee knew whether or not the examinee would be returned for a replicate examination. During the replicate examination, observers were not specifically informed that an examinee was a replicate, although no attempt was made to conceal this fact since in an examination as lengthy as that given in HES the examinee would undoubtedly be remembered by several, if not all, examiners. Even though an examinee might be remembered, it was extremely unlikely that an examiner would remember a specific measurement after a time lapse of 2 or 3 weeks. Some bias might be introduced by the examiner's knowledge of the replicate status of an examinee, but generally this bias would seem quite small when compared to the measurement error and in some cases to the biases associated with the knowledge and familiarity gained by the examinee during the original examination. Examinee bias can be important, especially when a response is elicited or when the true value of the measurement has changed because of a time lapse. Since the time lapse was usually 2 or 3 weeks, some appreciable changes might occur in certain measurements such as weight. However, for most of the data collected, the actual change over this short period of time can only be very small and this effect may usually be neglected. Previous experience is much more likely to affect the true replicability of psychological tests and those physiologic tests requiring high levels of subject participation (such as the treadmill and spirometry); with procedures in which the subject is *passive* and very little learning is involved, such as EKG and body measurements, the effect of previous experience is almost zero.

In Cycle III replicate data were obtained on approximately 70 percent of those selected for such examinations. One explanation for this low rate is that persuasion and followup efforts were not as intensive as for regular examinees. This is partially because regular examinees were given priority if interviewer or examination time was limited. There also appeared to be an increased frequency of objection to returning for a second examination, as demonstrated in the most frequent reasons for refusal: "One time is enough" and "I can't miss school again."

Selection of Replicate Examinees

The selection of Cycle III youths for replicate examinations was random within certain restrictions imposed by practical considerations. One restriction was that replicates were selected only from those examined during the first week and a half of the approximately 3½ weeks of examinations at any one location. This time period was chosen to facilitate the interspersing of replicate examinations with originals in the examining schedule without interfering with the time allotted for original examinations and without scheduling additional time to accommodate replicates. In a voluntary survey it is obviously impossible to follow a statistically random process in scheduling subjects, so those scheduled during the first week and a half are not, in the strict sense, a random sample of all those scheduled, though they may be randomly distributed for those features which are significant. Evidence that replicates might be considered "representative" is found in the fact that youths of certain ages, locations, incomes, etc., were not routinely more likely to be scheduled during any particular segment of the examination schedule. However, the availability and desires of the subjects do influence the composition of the replicate sample. For instance, an examinee whose participation in an original examination was achieved only after repeated contacts by survey personnel was less likely to have been included in a replicate examination since it is unlikely that he would have received an original examination during the first week and a half. The schedule of locations, time of year, sequence of examinations, and other related factors which might make subjects more or less readily available show no obvious discriminatory effect in the selection of replicate examinees. After examining these and other relatively minor considerations, there appears to be no reason to believe that subjects scheduled and examined during the first part of a stand differed from those scheduled and examined during the latter portion with respect to the data gathered.

Another restriction on complete randomness in the selection of youths for replicate examinations was the exclusion of those examinees living somewhere "geographically inconvenient" to the examination center. "Geographically inconvenient" was arbitrarily defined as a distance of 30 miles or more although exceptions were sometimes allowed if conditions dictated. A primary consideration in choosing a site for the examination center was the centrality of the location in relation to the sample segments (a segment is a cluster of households). Since segments were drawn with probability proportional to population, most segments were in relatively populated areas, so the examination center was also in or adjacent to a relatively populated area. Therefore, the subjects deleted by this 30-mile restriction usually resided in relatively less populated areas. Thus this restriction may create a bias in replicate data if, in fact, characteristics differed with population density. Even if differences did exist, the total effect of this restraint would not be great since it excluded only approximately 10 percent of the eligible examinees. There were other minor restrictions of a medical and operational nature imposed on the complete randomness of the replicate sample. They were not, however, readily associated with large differences since at most only 1-2 percent of the eligible examinees were deleted for these reasons.

Since the purpose of replicate examinations is to give information about errors, the matter of concern between those excluded and those eligible for selection is not possible differences in measurement values but possible differences in the errors associated with measurements as shown by the discrepancy between two measurements on the same subject. For example, measurements may vary markedly by some demographic classification, but this is not as relevant as the question of whether or not the measurement errors vary by this classification. A similar differential in the *active* and *passive* participation of subjects (e.g., spirometry versus body measurements) is assumed to operate here also, but in a different way. That is, it must be assumed that the most cooperative subjects, by and large, self-select themselves, and that their scores are truer estimates of the variable being tested. It is thus likely that their test-retest difference would be *smaller*. On the other hand, although subjects did influence measurement errors, it should also be noted that the environment, procedures, and examiners were also highly influential in the final measurement. Consideration of these additional influences causes a completely random selection of subjects to be of somewhat less concern.

The Analysis of Replicate Data on Body Measurements

Although a variety of monitoring systems for body measurements were in effect in HES from the beginning of Cycle I, it was not until Cycle III that a formal system was instituted of recalling approximately 5 percent of the subjects already examined for a replicate examination. However, during Cycle II, which is the concern of the present report, several "in-field" attempts at assessing replicate body measurements were made. These included the following:

(1) Several formal training sessions were held in which the examining technicians performed duplicate sets of measurements on a small group of subjects producing data for immediate examination of intra- and inter-examiner differences.

(2) The two Cycle II examining caravans converged from the east and west for a measurement stand in the Greater Chicago area. After scheduled examinations were completed in the normal manner, one of the caravans (Caravan I) reexamined (for our purposes, remeasured) approximately 50 children who had been initially examined by the staff of the other caravan (Caravan II), and vice versa. This operation permitted the technicians an "in-field" examination and discussion of the replicate measurements.

(3) Finally, a total of five intensive 2-day sessions were conducted by P.V.V.H. and F.E.J. in the field examination centers.

No formal, detailed analysis of the data in the statistical sense was carried out, primarily because the above attempts were more training than evaluation sessions.

In Cycle III, on the other hand, a systematic attempt at analysis of replicate body measurements was made. A total of 301 replicate examinations from Cycle III were collected and subjected to an extensive analysis of intra- and inter-examiner variation in body measurements, i.e., variation within the same observer and variation between different observers. Since the *conditions* under which the body measurements were made were *essentially identical* in Cycles II and III, there is reason to believe that the results of the quantitative assessment of replicate measurements of data collected in Cycle III can be effectively applied to Cycle II. In other words, should the analysis indicate a reasonably good degree of accuracy within and between examiners in Cycle III, it can be safely assumed that a similar degree of measurement accuracy was apparent in Cycle II.

Although the anthropometry in Cycles II and III was very similar, there were four relatively minor differences. First, the children in Cycle II were younger and smaller in size. (There is, however, no reason to assume that the *relative measurement error* is different for younger and smaller individuals.) Second, four of the human engineering measurements taken in Cycle II were not measured in Cycle III; they were replaced by several segmental length measurements of greater biological significance and interest. Third, a total of 11 technicians made measurements during Cycle III, but in Cycle II, the same four technicians participated in equal degrees throughout the entire cycle. Fourth, a more elaborate, systematic collection of replicate data with greater numbers of subjects was utilized in Cycle III. Other factors—the instruments and their calibration, techniques of measurement, methods of training, selection of technicians, examination environment, and the chief medical examiner and the physical anthropologic consultant—were the same. It should be noted further that two of the four technicians who participated in Cycle II of the HES continued for several years into Cycle III. In summary, the only significant differences in quality control considerations for body measurements between Cycles II and III were the addition of the systematic collection of replicate data and the use of a greater number of technicians in Cycle III. The authors have concluded that these two differences approximately counterbalance one another, resulting in equivalent degrees of measurement variation.

Cycle III Systematic Replicate Procedure

Body measurements were taken on 6,768 youths and these data comprise the HES findings. Replicate body measurements were obtained on 301 youths at 30 of the 40 locations (or stands) visited throughout the United States. That is, an average of 10 youths were reexamined at each stand. Of the 301 youths, 224 were reexamined by a technician other than the one initially measuring the youth, while the remaining 77 were reexamined by the same technician. Altogether during the 4 years, 11 technicians participated in replicate measurements for this phase of the quality control program.

It is of interest to ascertain whether each of the examiners had a representative number of replicate measurement sessions with respect to the number of examinations he performed during the survey. It should be carefully noted that it was not possible to insure that each technician had equal chances to measure replicate examinees since the length of time technicans were associated with the survey team varied. Table 1 presents the percentages of total examinations, intra-examiner replicates, and inter-examiner replicates participated in by each of the 11 technicians.

Table 1 clearly indicates some possible sources of bias which may affect the analysis of replicate data. For example, assume technician No. 9 was able to replicate his own measurements well but his readings were very different from the other examiners. Obviously, his results would be overrepresented in the replicate analysis since he examined only 11.3 percent of all youths in the actual survey but did 16 percent of the intra-examiner replicate examinations and 13.3 percent of the inter-examiner replicate examinations. Because of this technician's overrepresentation, the distribution of intra-examiner differences would cluster closer to zero than it really should have since this examiner self-replicated well. On the other hand, the inter-examiner distribution of differences would be considerably more skewed than it should have been since this technician did not agree well with the other technicians' measurements. Similar discrepancies are obvious for other technicians. An example of an opposite effect to that cited above is technician No. 2, who did only 2.7 percent of the intra-examiner replicate measurements and 10.2 percent of the inter-examiner replicate measurements, but did 13.4 percent of all examinations in Cycle III.

Thus, the various combinations of observers for the inter-examiner replicates and the proportions of intra-examiner replicates were not controlled so as to be

Table I. Percentage of regular and replicate examinations performed by each technician

Technician number	Percentage of regular Cycle III examinations	Replicate examinations	
		Percentage of intra-examinations	Percentage of inter-examinations
1	0.8	1.3	0.9
2	13.4	2.7	10.2
3	22.8	21.3	21.4
4	6.1	4.0	2.7
5	13.5	10.7	16.7
6	6.1	5.3	6.5
7	3.7	5.3	4.9
8	15.1	24.0	16.4
9	11.3	16.0	13.3
10	3.0	2.7	3.6
11	4.1	6.7	3.6

balanced among the observers. In the survey proper the examinations were similarly not proportionately distributed among the observers, since the length of time the various technicians were associated with the survey varied.

The foregoing indicates that the distribution of numbers of replicate examinations done by each technician is not the same as the distribution of the total number of survey examinations done by each in Cycle III. This represents one of the inherent problems of the present replicate data and limits to some extent implications to the survey as a whole. Nevertheless, the reader should be aware of the many problems confronting those who conduct large-scale health surveys, and in this context, the present systematic approach to the collection of replicate body measurement data is adequate.

Results of the Replicate Analysis

The absolute differences between the first and second measurements of the same child were computed for each dimension measured during Cycle III. The present analysis concerns itself with all body measurements except skinfold thicknesses, which have been reported separately with the results of the analysis of skinfold data.[3]

A distribution of absolute differences was compiled for each body measurement for the intra- and inter-examiner groups separately. The median and mode for each body measurement were extracted from the distribution of absolute differences. The mean absolute difference ($\bar{X}_d$) was computed by summing the differences and dividing by either 77 or 224, depending on which group (intra- and inter-examiner, respectively) was being considered.

A widely used measure of replicability is the statistic σ_e, the "technical error of measurement." It is defined as $\sigma_e = \sqrt{\Sigma d^2/2n}$, the square root of the sum of the squared differences of replicates divided by twice the number of pairs. This statistic assumes that the distribution of replicate differences is normal and that errors of all pairs can be pooled.

Since squaring a technical error of measurement yields a variance, and since the ratio of two variances has the *F* distribution, a very simple test exists for comparing intra- and inter-examiner replicability. In table II the final column gives, for each variable, the *F* ratio (i.e., the ratio of the squares of the inter-examiner σ_e to the intra-examiner σ_e). As will be noted later, in three instances the variance for the intra-examiner group was larger and in these cases the ratios were reversed. A significant *F* statistic indicates the presence of a "technician-effect" or some characteristic which makes a particular measurement more easily replicated by the same technician than by another.

The coefficient of variation (CV), $\sigma_e/\bar{X}$, the technical error of measurement divided by the overall mean (the mean of all subjects) for the particular variable under study, was also calculated. The coefficient of variation is a measure of relative variability, i.e., variation in replicability relative to the overall magnitude of the measure.

In the context of the present analysis, great care must be used in dealing with this statistic. It is not a coefficient of variation in the traditional sense since the numerator contains a measure of dispersion of *differences* (between replicates) whereas the denominator contains a *mean*—not a mean difference but a mean magnitude of the measurement taken.

The value of this statistic lies in its adjustment of the technical error by the magnitude of the original measurement. It attempts to answer the argument that replicability is likely to be much better for a variable

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NOTE The list of references follows the text.

Table II. Results of intra-examiner and inter-examiner replicate analysis

Measuring device and dimension measured	Intra-examiner results					Inter-examiner results					F value
	$\bar{X}_d$	Median	Mode	σ_e	CV	$\bar{X}_d$	Median	Mode	σ_e	CV	
Automated recording											
Height	0.549	0.5	0.1	0.494	0.302	0.563	0.4	0.1	0.681	0.417	1.90
Weight	1.325	1.0	1.0	1.173	2.119	1.335	1.0	1.0	1.228	2.218	1.10
Anthropometer—height measurement											
Standing											
Cervicale height	0.714	0.6	0.1	0.692	0.500	1.054	0.9	0.5	0.953	0.689	1.90
Acromial height	0.752	0.6	0.2	0.795	0.601	0.875	0.75	0.1	0.891	0.673	1.26
Radial height	0.890	0.7	0.1	1.063	1.044	0.916	0.7	0.2	0.949	0.932	1.25
Stylion height	1.114	0.7	0.1	1.424	1.819	1.032	0.8	0.1 0.5 0.7	1.010	1.290	1.99
Iliac crest height	0.700	0.6	0.3	0.646	0.644	1.134	0.9	0.3	1.059	1.055	2.69
Trochanteric height	1.413	1.0	0.6	1.466	1.672	1.600	1.3	0.1	1.510	1.722	1.06
Tibial height	0.613	0.5	0.1	0.565	1.229	0.769	0.6	0.3	0.719	0.564	1.62
Sphyrion height	0.266	0.2	0.1	0.247	3.815	0.380	0.3	0.1	0.343	5.298	1.93
Sitting											
Sitting height	0.578	0.4	0.2	0.535	0.631	0.767	0.7	0.2	0.705	0.832	1.74
Thigh clearance	0.495	0.4	0.2	0.439	2.853	0.595	0.5	0.2	0.544	3.535	1.54
Anthropometer—length and breadth measurement											
Foot measurements											
Foot length	0.238	0.2	0.1	0.264	1.087	0.296	0.2	0.2	0.524	2.158	3.94
Foot breadth	0.138	0.1	0.1	0.122	1.329	0.226	0.2	0.1	0.202	2.200	2.74
Across bony landmarks on torso											
Biacromial breadth	0.553	0.4	0.1 0.2	0.544	1.529	0.807	0.5	0.1	0.915	2.571	2.54
Bicristal breadth	0.775	0.6	0.1	0.711	2.926	1.590	1.1	0.1	1.545	6.358	4.72
Bitrochanteric breadth	0.552	0.4	0.1	0.523	1.778	1.760	0.5	0.1	0.836	2.843	2.56
Across torso											
Seat breadth	0.610	0.4	0.3	0.921	2.835	0.909	0.7	0.8	0.993	3.057	1.16
Elbow-elbow breadth	1.104	0.8	0.8	1.131	3.415	1.425	1.2	0.3	1.346	4.065	1.42
Sliding caliper											
Knee breadth	0.112	0.1	0.1	0.106	1.165	0.183	0.1	0.1	0.244	2.683	5.30
Elbow breadth	0.105	0.1	0.1	0.117	1.799	0.152	0.1	0.1	0.154	2.368	1.73
Ankle breadth	0.097	0.1	0.1	0.092	1.367	0.186	0.2	0.1	0.171	2.540	3.45
Wrist breadth	0.108	0.1	0.1	0.115	2.208	0.150	0.1	0.1	0.139	2.669	1.46
Spreading caliper											
Bizygomatic breadth	0.075	0.1	0.0	0.076	0.589	0.158	0.1	0.1	0.162	1.255	4.54
Bigonial breadth	0.147	0.1	0.1	0.156	1.575	0.295	0.2	0.2	0.272	2.746	3.04
Steel tape											
Torso girths											
Chest girth	1.297	1.1	0.8	1.096	1.362	1.970	1.6	0.6	1.816	2.256	2.75
Waist girth	1.470	1.2	1.1	1.308	1.927	1.621	1.3	0.6	1.561	2.300	1.42
Hip girth	1.168	0.9	0.3	1.234	1.398	1.514	1.3	1.7	1.375	1.558	1.24
Extremity circumference											
Upper arm girth	0.339	0.3	0.1	0.347	1.358	0.458	0.4	0.3	0.425	1.664	1.50
Forearm girth	0.319	0.2	0.2	0.304	1.281	0.404	0.3	0.2	0.582	2.453	3.67
Calf girth	0.491	0.3	0.2	0.872	2.588	0.353	0.3	0.2	0.340	1.009	6.58

NOTE: For definition of symbols, see page 42.

of small magnitude than for one of great magnitude. As will be expanded later, dividing by the mean measurement may overadjust for such biases.

In the presentation of results of the replicate observation analysis, data were grouped according to the measuring instrument used in order to facilitate comparison since there is the possibility that differences between or within certain examiners might be peculiar to the particular measuring device used. First, height and weight were treated as a single group because they were machine-recorded. Note, however, that height measurement can be affected by variations in positioning. The second group was comprised of various height measurements which include the distance from the standing or sitting surface to the specific landmark. In most instances, the anthropometer was used to its full extent; nevertheless, as the landmarks approached the leg and ankle, the measuring distance was shorter. The third group of measurements included those made with the upper portion of the anthropometer. These measurements were made with the fixed arm of the anthropometer at one landmark while the free end was moved to the other landmark, which defined the measurement. This group included two foot measurements, three bony breadth measurements across the torso which required firm pressure, human engineering measurements which required light surface contact of the anthropometer. The fourth group included those made with a small sliding caliper. As a group these measurements represent the distance across a single bone or two bones at specific extremity joints. Compared to the height measurements mentioned above, the distance traversed by these measurements is rather small. The fifth group comprised only two facial breadths made with a spreading caliper. The sixth group consisted of measurements made with a steel tape and included six circumferences, three on the torso and three on the extremities.

Clearly body weight differs from all other values here since it was measured to the nearest half pound, while all others were measured to the nearest tenth of a centimeter, i.e., the nearest millimeter. Body weight is the only variable in which there is no chance of either intra- or inter-observer error. All weights were taken on a Toledo self-balancing scale which mechanically printed the child's weight directly onto the permanent record. It was not even important that the technician position the examinee rigidly, which was a significant factor in other measurements, for example, height. Any variability evident in replicate readings would thus be due to a gain or loss of body weight by the subject between examination sessions. Note that the F ratio for body weight was not significant, thus underlining the lack of technician effect in obtaining this measurement.

There were a total of 77 intra-examiner replications, i.e., the same technician re-examining the subject on two different occasions, and 224 inter-examiner replications, i.e., two different technicians doing the initial examination and replicate examination respectively, performed during Cycle III. Intra-examiner and inter-examiner results are presented separately in table II, and all analyses were done within the group under consideration.

Taking the data in table II as a whole, the technical error of measurement was, with three exceptions, consistently less within examiners than between examiners. This was not entirely unexpected, for experience indicated greater intra-examiner consistency, i.e., there was greater consistency within the same technician than between different technicians. The three exceptions were radial height, stylion height, and calf circumference. Since each value was squared in calculating the technical error of measurement, this statistic can be greatly distorted by one or two highly divergent replicate values. That seems to be the case with these three divergent values.

Results of the variance analyses indicated that 25 of 31 F ratios were significant at the .05 level (or conversely, only 6 of 31 F ratios were not significant at the .05 level). Thus, in 25 measurements, intra-examiner differences were significantly smaller than inter-examiner differences. On the surface, such a tendency in the results might appear discouraging. However, such a tendency might function to eliminate or reduce systematic bias in large-scale surveys by eliminating or reducing the effects of individual idiosyncrasies (biases) of individual examiners.

For 29 out of 31 measurements, the mean differences for intra-examiner observations were less than those for inter-examiner observations. These results were in the same general direction as those reported above for the technical error of measurement. The two measurements in which intra-examiner mean differences were the greater of the two were stylion height and calf circumference, both of which, as indicated above, had discrepant replicate readings which functioned to inflate the intra-examiner mean differences.

The median represents the midpoint of the distribution, i.e., 50 percent of the cases in the distribution are above and 50 percent are below this point. As such, it is not affected by the extremes of isolated discrepant values, as is the technical error of measurement. An examination of the median differences between replicate readings on an intra- and inter-examiner basis indicated eight instances in which the median differences between replicate measurements were identical within and between examiners. In 22 instances, median differences were less within examiners than between examiners, while in one instance the median difference was less between examiners than within examiners. In this last mentioned case, the difference between medians was only 0.1 cm. Thus, these observations are in general agreement with those indicated by comparison of σ_e and $\bar{X}_d$.

The magnitude of the differences between medians of replicate readings within and between examiners was only 0.1 cm. for 13 measurements, 0.15 cm. for one measurement, 0.3 cm. for five measurements, 0.4 cm. for two measurements, and 0.5 cm. for two measurements. Incorporating the eight measurements in which median differences for replicate readings were identical within and between examiners with the above distribution indicated that in 22 of the 31 measurements the difference in median differences of replicate readings within and between examiners was 0.15 cm. or less. This indicates a reasonable degree of consistency in the replicate measurements. It does not, however, consider the magnitude of the actual differences between replicate readings by the same observer and by different observers.

Before going into a discussion of specific groups of measurements, the limitations of the technical error of measurement and the coefficient of variation should again be noted. As indicated earlier, the σ_e is generally an important and revealing statistic. By itself, however, it can be somewhat misleading at times. Consider, for example, the variables of standing height and knee breadth in table II for the intra-examiner group of data. Just considering σ_e would lead one to believe that knee breadth is a much better replicated measurement than is standing height since the variation for knee breadth is markedly smaller. It should be carefully noted, however, that the magnitude of standing height is far greater than that of knee breadth, and the margin of error is far greater for the greater measurement. To adjust for this factor, the coefficient of variation ($\sigma_e/\bar{X}$) can be used. Examination of the coefficients of variation for these two variables indicates that standing height is more closely duplicated by the same examiner than is knee breadth.

On the other hand, coefficients of variation must be used with great caution. To divide σ_e for standing height by the entire mean for standing height is a bit drastic. For example, if an individual is 172 cm. tall, repeated measurements cannot vary by the whole 172 cm. Even if a technician makes a markedly discrepant replicate measurement of 10 cm., for example, this represents only 5.8 percent of the total height measurement. On the other hand, an error of 1.0 cm. for knee breadth, which for the sake of example is assumed to be 12.0 cm., represents 9.3 percent of the measurement. What is being suggested here is that there is no way errors of sufficiently large magnitude can be made for large measurements (of the order, say, of 170 cm. for height). Thus, to divide σ_e by the full mean for the particular measurement distorts the reality of the situation. This is why it is best to compare coefficients of variation within variables measured by the same instrument and within variables of about equal magnitudes.

Results of the replicate analysis for specific measurements and/or groups of measurements are now considered. As noted earlier, the data were grouped according to measurement instrument used.

Although body weight showed some variation within and between observers, the F ratio was not significant, indicating that all observers did comparable jobs in measuring this variable. It should be noted, however, that there was no chance for individual idiosyncrasies of a given observer to affect the body weight measurement. All weights were taken on a Toledo self-balancing scale which mechanically printed the weight directly onto the child's permanent record. Hence the variation between observation sessions is due to the weight gain or loss occurring during the time lapse. Mean differences for body weight within and between examiners are well within the range of variation associated with diurnal changes in body weight.

As a group, measurements made with the sliding caliper had a high degree of replicability. This category included two measurements across single bones, i.e., knee breadth across the condyles of the femur and elbow breadth across the epicondyles of the humerus; and two measurements across two bones, i.e., ankle breadth across the distal aspects of the tibia and fibula and wrist breadth across the distal aspects of the radius and ulna. As a group the mean, median, and modal differences for the four extremity breadth measurements were the lowest relative to other variables measured during Cycle III. The technical errors of measurement were also lowest, indicating that these four measurements were quite accurately replicated. For example, these measurements averaged about 0.1 cm. difference for intra-examiner replications and about 0.16 cm. for inter-observer replications. Comparing the average differences for these four extremity breadth measurements to values for other body measurements in table II clearly indicates that precision was greater in these than in any other group of measurements considered in this report.

Attempting to compare coefficients of variation of these measurements with any others is misleading, as discussed earlier. Thus, the coefficient of variation statistics should be used only within the groups of measurements considered. For intra-examiner differences, knee breadth was best replicated, followed by ankle, elbow, and wrist breadths. For inter-examiner differences, elbow breadth had the smallest coefficient of variation, followed by ankle, wrist, and knee breadths. Testing at the .05 level, the F ratios indicated that in all instances intra-examiner differences were significantly smaller than inter-examiner differences.

The two measurements made with the spreading caliper, bizygomatic breadth and bigonial breadth, were likewise well replicated. The mean, median, and modal differences for these two facial breadth measurements were of approximately the same magnitude as those for the extremity breadth measurements. In fact, bizygomatic breadth had the smallest intra-examiner difference of all measurements considered, an average difference of 0.075 cm. and σ_e of 0.076. On an intra- and inter-examiner basis, bizygomatic breadth had a smaller coefficient of variation than bigonial breadth. The greater variability in replicating the latter might be related to variations in pressure in applying the spreading caliper (slight variations producing an error of 0.1 cm.) and to variations in palpating the measuring landmark, the gonial angles of the mandible. Experience indicates that some observers allow the calipers to "slip" off the landmark. Similarly, if a child tenses his lower jaw, this also alters the measurement to some extent. In contrast to the measurement of bigonial breadth, bizygomatic breadth is a maximum measurement, in which the technician moves the spreading calipers until he notes the maximum reading. For both facial breadth measurements, the intra-examiner differences were significantly smaller than the inter-examiner differences at the .05 level.

The group of dimensions measured with the upper segment of the anthropometer included two foot measurements (length and breadth), three bony breadth measurements (biacromial, bicristal, and bitrochanteric breadths), and two human engineering breadth measurements (elbow-elbow and seat breadths). In making these measurements, the fixed arm of the anthropometer is set at one landmark, while the free arm is moved to the other landmark defining the particular measurement.

The two foot dimensions showed a high degree of replicability. Mean, median, and modal differences for foot breadth were less than or equal to those for foot length and were of the same magnitude as those for measurements made with the spreading and sliding calipers. This might be a function of the overall size of the dimensions being measured. The technical errors of measurement for both foot dimensions were smaller within than between examiners, and the intra-examiner differences were significantly smaller than the inter-examiner differences. The two foot measurements had consistently smaller technical errors of measurement and coefficients of variation than the other measurements made with the upper segment of the anthropometer.

The bony breadth measurements across the shoulders (biacromial breadth) and across the hips (bicristal and bitrochanteric breadths) also appeared to be reasonably well replicable measurements. Biacromial breadth and bitrochanteric breadth had essentially identical mean differences in the intra-examiner comparisons—0.553 and 0.552 cm., respectively. Bicristal breadth, on the other hand, had a larger average error in the intra-examiner comparisons, 0.775 cm. On an inter-examiner basis, biacromial breadth had the smallest average difference (0.807 cm.), while bitrochanteric breadth had the largest (1.760 cm.), with bicristal breadth very similar to it (1.590 cm.). These average differences are misleading and are perhaps influenced by extreme readings. Median differences in the inter-examiner comparisons are identical for both biacromial and bitrochanteric breadths (0.5 cm.), while that for bicristal breadth is much greater (1.1 cm.). All mean, median, and modal differences, as well as the technical errors of measurement for the three bony breadth measurements, were smaller for intra-examiner comparisons than for inter-examiner comparisons. The intra-examiner differences were also significantly smaller than the inter-examiner differences. Within this group of three bony breadth measurements, biacromial breadth had the least relative variation, as indicated by the lower coefficients of variation on both an intra- and inter-examiner basis. Bitrochanteric breadth was close to biacromial breadth but larger in relative variation in both intra- and inter-examiner comparisons. Bicristal breadth had the largest coefficients of variation. The relative variability for the inter-examiner replicates was more than twice that noted for the intra-examiner replicates, indicating that different observers had difficulty in replicating this measurement with accuracy. These observations might be related to the nature and location of the bony landmarks involved in making these three measurements. The acromial processes are relatively close to the surface and easily located. The same applies in general to the greater trochanters of the femur. The iliac crests, though rather easily identified, are perhaps difficult to accurately replicate because of their irregular shape. Contributing to the overall variation in bony breadth measurements is the need for firm pressure in applying the arms of the anthropometer to the bony landmarks. Any inadvertent alteration of pressure applied can increase the error of measurement.

The two human engineering breadth measurements, elbow-elbow and seat breadths, appeared to be only moderately replicable when compared to other measurements made with the upper segment(s) of the anthropometer. Of the two measurements, elbow-elbow breadth had larger mean, median, and modal differences as well as larger technical errors of measurement in both the intra- and inter-examiner comparisons than did seat breadth. Elbow-elbow breadth also had a larger coefficient of variation than seat breadth. All statistics were smaller for the intra-examiner replications than for the inter-examiner replications. These two breadth measurements also had the lowest *F* ratios, the ratio for seat breadth being insignificant and that for elbow-elbow breadth barely significant at the .05 level, which would seem to suggest that in both measurements the individual idiosyncrasies of specific examiners had small effects. This interpretation is offset, however, by the fact that the magnitude of the differences between replicate readings in both the intra- and inter-examiner comparisons was rather large. This is perhaps a function of the specific measurements, since both require only light surface contact (the slightest pressure might distort replicate readings). Also, in measuring elbow-elbow breadth rather rigid positioning is required, and inadvertent alterations in positioning by the subject from one measurement session to the next might affect the replicate readings.

The six circumference measurements taken in Cycle III can be divided into those made on the torso and those made on the extremities. The three torso girths—chest, waist, and hip girths—are essentially human engineering-type measurements, and the replicate analysis is similar to that noted for the two human engineering breadth measurements above. Chest, waist, and hip girths appeared only moderately replicable. Testing at the .05 level, the *F* ratios indicated no significant differences for hip girth, just barely significant differences for waist girth ($F = 1.42$), and significant differences for chest girth ($F = 2.75$) between intra- and inter-examiner replicates. These observations suggest that in such girth measurements individual idiosyncrasies of specific examiners had small effects. This interpretation is offset, however, by the magnitude of the differences between replicate examinations in both the intra- and inter-examiner comparisons, which were among the largest for the entire series of 31 measurements. Clearly, the same observer as well as different observers had difficulty replicating these three circumference measurements.

The three extremity circumferences had considerably smaller average differences between replicate readings, both within and between examiners, than did the three torso circumferences. This is perhaps a function of the magnitude of the circumferences measured. All but calf circumference appeared to be highly replicable measurements. Mean, median, and modal differences as well as the technical errors of measurement were slightly smaller for the intra-examiner than for the inter-examiner analysis. Observations for calf circumference were in the opposite direction; the average difference and the technical error of measurement were larger for the intra-examiner than for the inter-examiner analysis. However, the median and modal differences were identical on an intra- and inter-examiner basis. The effects of two or three discrepant replicate readings were responsible for inflating the intra-examiner mean difference value and the technical error of measurement. This is contrary to general measurement experience, for calf circumference is generally a highly replicable measurement. The present observations are probably a chance occurrence.

Although standing height was grouped with body weight on the basis of the automated measuring procedures used, the replicate observations for height will be considered here with other height measurements. Of all the height measurements, including standing height, sitting height, and segmental height measurements, it appeared that, both within and between examiners, standing height was best replicated. While sphyrion height and thigh clearance (really height above the sitting surface) had smaller technical errors of measurement, this can be attributed to the smaller margin of error in taking the measurement. Problems encountered in radial and stylion heights have been discussed earlier. In these two measurements, the technical error of measurement was larger for the intra-examiner replicates than for the inter-examiner replicates. This was entirely a function of one or two discrepant replicate readings, which distorted the technical error of measurement. Median differences between intra- and inter-examiner replicates were negligible for radial and stylion heights.

Examination of the F ratios for the various height measurements indicated that for all measurements except acromial height, radial height, and trochanteric height, there were significantly larger differences when two different observers made the measurements than when a single one did them. It should be noted in table 11 that the three height measurements for which the F ratio was not significant had among the largest mean differences both within and between examiners. For example, trochanteric height, which had the smallest F ratio ($F = 106$), had the largest mean differences on both intra-examiner replicates (1.413 cm.) and inter-examiner replicates (1.600 cm.). These observations perhaps depend on the measurements involved and factors affecting the taking of these measurements. In addition to the location of landmarks, acromial and radial height are greatly affected by slight changes in the posture and attitude of the subjects, while in the case of trochanteric height, location of the trochanteric landmark can be difficult in individuals with a lot of soft tissue over this area.

Discussion and Summary of Replicate Analysis

The preceding discussion of results of the replicate analysis of Cycle III body measurements was not aimed at determining which measurements were easiest or most difficult to perform but at evaluating the use of single and multiple examiners in a large-scale survey. Reports of large-scale surveys generally do not include discussions of replicate analyses of multiple examiner effects. One general impression derived from the analysis of the present data is that there is an obvious need to publish replicate studies in anthropometric surveys. This would insure better comparability of surveys and would aid in establishing tolerance limits for various body dimensions.

It should be emphasized that many of the measurements comprising the Cycle III (12-17 years) replicate analysis were taken in Cycle II (6-11 years). For example, 11 of the 21 dimensions described in the present report and six other dimensions utilized in the racial analysis of Cycle II data are included among the measurements discussed in the replicate analysis. Hence, of the 31 measurements used in the replicate analysis, 17 were also taken in Cycle II. The primary difference is in the replacement of traditional human engineering dimensions in Cycle II (buttock-knee length, buttock-popliteal length, popliteal height, knee height) and specific segmental lengths (acromion-olecranon length, elbow-wrist length, hand length) by eight segmental heights in Cycle III. Specific segmental lengths are estimated in the Cycle III data by subtraction. For example, acromial height minus olecranon height provides an estimate of upper arm length similar to that provided by direct measurement of acromion-olecranon length.

In addition, conditions under which the various anthropometric dimensions were measured were essentially identical in Cycles II and III, although several of the measurements were different. Instrumentation, instruction, and measurement technique were likewise basically the same in both cycles. Hence, *the observations derived from the Cycle III replicate analysis are generally applicable to the Cycle II data.*

Measurement of various body dimensions presents a unique situation. There are a large number of variables (sources of error) that must be controlled in the measurement environment in general and at the moment of measurement in particular. General sources of error can be grouped into three categories: the subject, the instrument, and the observer. Subject position, though carefully standardized, is difficult to control precisely. Postural attitude, phase of the breathing cycle, degree of tension and/or relaxation, and so on are factors which make it almost impossible to fully control the examinee so as to permit identical conditions during each of two measurement sessions that comprise replicate studies. In, for example, measurement of segmental heights, an inadvertent shifting of body weight from one leg to another can alter the height of a specific landmark from the standing surface, or tensing of the shoulders might make accurate location of acromiale difficult to replicate.

Instruments are carefully calibrated and checked out during the course of the survey. Hence, instrument variability is reasonably controlled. It is difficult, however, to control completely the observers' use and application of instruments to specific body landmarks in addition to the problem of consistently locating these landmarks. Differences between observers are inevitable, as the present replicate analysis indicates. Training, both prior to and in the field, helps reduce differences between observers, but it will not eliminate them completely. In light of this reality, there is an obvious need to establish tolerance limits within which two or more observers are permitted to vary in making a particular measurement. Similarly, the same observer varies to some extent within his own replicate measurements, although intra-observer variation, as expected, is consistently less than variation between observers. Perhaps the results of the Cycle III replicate analysis can be used to establish tolerance limits within which a single observer is permitted to vary in an intra-examiner replication and within which two or more observers are permitted to vary in an inter-examiner replication.

Since variation between observers is inevitable, what can be concluded from this analysis? In general, measurements made with the sliding and spreading calipers are highly replicable. These instruments are used in making bone-to-bone measurements requiring firm pressure and traversing relatively small distances. Further, the landmarks for these measurements are rather easily located. Measurements made with the upper segment(s) of the anthropometer appear to vary with the specific measurement. The two foot measurements, breadth and length, are highly replicable. The three bony breadth measurements across the torso—biacromial, bicristal, and bitrochanteric breadths—are reasonably replicable. The apparent problem with these measurements relates to the consistent location of the landmarks, especially the iliac crests, and the application of firm pressure to compress underlying soft tissues, especially in the case of bitrochanteric breadth. It would be interesting to see a replicate analysis of the two hip breadth measurements by sex, since adolescent girls tend to accumulate adipose tissue over these sites. The two human engineering breadth measurements, elbow-elbow breadth and seat breadth, which are made with the upper segment of the anthropometer, are somewhat difficult to replicate, perhaps because light surface contact is required in making these measurements. Girth measurements on the torso are also difficult to replicate. Like the two human engineering breadth measurements, these dimensions require light surface contact with no soft tissue compression. Girth measurements on the extremities are, in general, well replicated. The discrepancy noted for calf circumference in the present analysis is somewhat of a surprise and is probably a chance occurrence. Calf circumference is generally a well-replicated girth measurement, and the result of the present analysis can be overlooked to some extent.

Height measurements, standing or sitting, are reasonably well replicated; there is, however, considerable variation in the replicability of the series of measurements evaluated. This variation is probably related to both subject and observer variation. Although the subject's position is standardized, inadvertent change in his postural attitude can alter the height of the segment landmark from the standing surface. It is almost impossible to control for this. Interobserver variation is present for all measurements. Interestingly, it was least for standing height.

As indicated earlier, differences between examiners are inevitable in a large-scale anthropometric survey. This is true regardless of efforts at control and/or elimination. The extent of variation between observers should, however, be noted and reported. Error introduced by multiple observers, i.e., differences between examiners, have two apparent effects: first, they increase variable error, but second, they reduce the probability of a systematic error being introduced into the measuring process by idiosyncrasies of individual observers. An increase in the variable error must be tolerated to achieve a reduction of probable systematic error. Although variation is apparent in the present analysis of replicate measurements, the general impression is one of reasonable consistency in the measurement process utilizing multiple examiners. Comparative data from other large-scale anthropometric surveys of children are apparently not available.

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