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16. Abstract

This study defines and evaluates the size, shape, and mass distribution characteristics of masterbody forms representative of 3-year-old and 6-year-old U.S. children.

Based on the author's collective judgment of available data, 98 anthropometric dimensions were selected and used to develop full-scale clay masterbody forms for reproduction in casting stone. The stone models were segmented into 10 primary body components representing the head, neck, upper torso, lower torso, upper arm, lower arm, hand, upper leg, lower leg, and foot. Weight, volume, center of mass, and mass moments of inertia measured on each body segment are presented in this report.

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I. Introduction.

A significant problem in biokinematic research with humans is the potential for injury to test subjects during experimentation. A consequence of this inherent danger has been the limiting of the experimental research with humans in both its intensity and its scope. One method of circumventing the problem of possible subject injury has been to substitute anthropomorphic dummies for human subjects in high-stress experiments.

During its 1968 meeting, the Crash Test Dummy Task Force of the Society of Automotive Engineers decided to standardize certain test-dummy body forms (external shapes) to improve comparability of research results among investigators. This resulted in the development of master models of seated human body forms representing 95th- and 50th-percentile-size males and a 5th-percentile-size female as standard shapes depicting United States adults. The need for a comparable standard representative of infants and children at various age levels was also recognized. There has never been a study specifically designed to collect the types of information necessary to develop infant and child body forms.

In 1971, Stoudt undertook a research program under a National Highway Traffic Safety Administration (NHTSA) contract to review the available state-of-the-art anthropometric data for the design of child restraint systems. His primary objective was to determine how much information existed in this field and if these data were available. He believed that because future restraint systems could require unique anthopometric information, an enumeration of the desired dimensions would be necessary but tenuous. He cited 44 dimensions as the minimal number needed for the construction of manikin and mathematical models and 196 dimensions as a comprehensive list. In his investigation he noted the lack of accurate and comprehensive anthrometric data available for the task.

The deficiencies that Stoudt pointed out in existing data were also noted in a 1972 study on infant and child measurements compiled by Snyder et al. for the Children's Hazards Division, Bureau of Product Safety, Food and Drug Administration. Although this study was an attempt to bring together data useful to designers of children's products and for Federal standards, the authors concluded, for a number of reasons, that child measurement data available at that time were of limited value.

To follow that work, this four-phase study was undertaken to develop 3- and 6-year-old-child standard seated body forms. Phase I established the anthropometric criteria and constructed clay masterbody forms that were considered representative of unisexual 3- and 6-year-old United States children. A list of measurements necessary for the construction of seated child manikins was selected, and a review of the available anthropometric literature on 3- and 6-year-old children in the United States was accomplished.

Phase II consisted of a mathematical modeling task using available mathematical modeling programs. The anthropometry required for the mathematical model was measured on the 3- and 6-year-old-child clay forms, and the model was then used to estimate the mass and the principal moments of inertia of the body segments.

Phase III developed a composite casting mold of the 3- and 6-year-old-child clay master forms of orthopedic plaster and duplicated the body forms in dental stone of known density.

In Phase IV, each stone body form was segmented and the mass, center of mass, and principal moments of inertia were experimentally determined for each body segment.

This report describes the conduct of this research and the result obtained.

II. Anthropometric Basis for 3- and 6-Year-Old-Child Masterbody Forms.

In 1964 a comprehensive literature search with an objective of bringing together all of the child data then available was initiated by the Division of Accident Prevention, U.S. Department of Health, Education, and Welfare, ". . . to meet the urgent need for accumulations of statistical data on child measurements to be used in testing dummies" (McConville and Churchill, 1964). The resulting survey attempted to collect design data that would describe the circumference, breadth, and depth of the body at specific levels; the lengths of body segments; and the location of primary hinge points for the infant at birth and 6 months, the unisexual child at 3, 6, 8, and 12 years, and males and females at age 18 years. Of 87 proposed anthropometric dimensions determined to be necessary for manikin design, they found that 22 major dimensions were completely unavailable in the literature. McConville and Churchill observed: "This lack of detailed anthropometric information is somewhat surprising in view of the number of such studies which have been carried out in the past few decades." They found few studies provided all the desired statistics and they had to take "certain liberties" in the treatment of those that were available.

The most recent comprehensive review of the anthropometric literature for children was conducted for the Children's Hazards Division, Bureau of Product Safety, Food and Drug Administration. The resulting publication, "Source Data of Infant and Child Measurements, Interim Data, 1972" (Snyder et al., 1972), provided a handbook of 23 measurements from 35 studies and references for more than 800 worldwide studies.

In using data from this publication, one must consider several limitations. Many growth studies indicate that the secular trend in size is observable in children as well as in adults. In this regard, only one-third of the studies reported in the Snyder et al., 1972, collation were conducted in the past decade. Some studies may not be representative of the U.S. population but describe highly selected populations, such as White school children in Philadelphia. Furthermore, many of these studies report data that were collected by inexperienced measurers using nonstandard measurement techniques. The measurements are often not reproducible and are poorly or inaccurately defined (e.g., bitrochanteric diameter defined as hip width). In addition to these technical problems, past studies have been orientated either toward longitudinal or cross-sectional means of assessing the anthropometric characteristics of children. These two approaches have different methods of data presentation that result in incomparable data sets. Similarly, age values are reported in different ways in the literature. For example, age 6 in one study many mean exactly 6 years past birth but more often includes subjects 5.5 to 6.5 years old; other studies may include those 6 to 7 years. All these considerations make it difficult to evaluate and compare data that may appear in the literature and often are not known or are not obvious to the user. A further problem with the limited numbers of measurements available in the literature is that these are generally traditional measurements developed for growth studies or population description and provide insufficient basis for the design of children's body forms.

In 1956 the National Center for Health Statistics (NCHS) was authorized to conduct a nationwide Health Examination Survey (HES). As part of the first cycle conducted between 1959 and 1962, individuals aged 18 to 79 years were measured. A second cycle conducted from 1963 through 1965 was directed at measurements of 6- to 11-year-old children. A third cycle was conducted between 1966 and 1970 with youths aged 12 to 17 years. As part of this third survey, body measurements were included but, unlike the body measurements selected in Cycles I and II, human engineering-type measures were excluded because "*it was decided for Cycle III that accurate biologic data on growth and development in U.S. children had a higher priority than human-engineering data*, so the battery of body measurements is basically the traditional anthropometry used in the longitudinal studies of growth and development conducted in this country over the past 40 years." (NCHS, Series 1, No. 8, 1969, pp. 5–6.)

Because phyiscal measurements were accessory information in the HES study, the time per subject restricted the number of measurements that could be taken. Nevertheless, 38 measurements were obtained (Hamill et al., 1970; Malina et al.,

1973) and used as part of this anthropometric design data base.

Martin's (1954, 1955) data are 20 years old and measurements were made on fully clothed school children in southern Michigan. More recently, Stoudt's 1971 compilation, which is the most complete, reports data on 2.5- and 6.8-year-old children; these data had to be adjusted to conform with 3-year and 6-year age dimensions for the masterbody forms. The data reported by Malina (1973) are on a nationwide sample but include no data on 3-year-old children. Furthermore, they reported dimensions on 21 measurements that were selected primarily " to define a normal pattern of growth and development in children in the United States in the middle 1960's."

The most recent comprehensive study of children's measurements is by Snyder et al. (1975). Forty-one body measurements were taken on 4,027 infants and children representing the U.S. population, ranging in age from 2 weeks to 13 years. While these data represent a number of functional measurements particularly useful for product designers and Federal standards for children's products, no attempt was made to obtain all of the measurements needed to construct a child anthropomorphic dummy.*

Thus, the anthropometric requirements for defining the morphology of child manikins are not met in any of the preceding documents nor in any of the others noted in the list of references. The data that do exist in the literature provide limited information on heights, breadths, circumferences, and body proportions of 3- and 6-year-old children.

Most of the missing data in the anthropometric literature are unique to the requirements of sculpturing a masterbody form. For example, the shape of the torso at the nipples is described by circumference, breadth, depth, and height from seat pan. Chest circumference and depth are available in the literature but the additional information is not. Two children, ages 3.5 and 5.5 years, were measured during this study to obtain the additional data the team used as guidelines for estimating the desired dimensions.

* The data from this survey were not available for use at the time the body sizes of the 3- and 6-year-old children were being determined.

In summary, 30 dimensions on the list are based on data in the literature whereas 68 dimensions are either estimated by the team or based on adjusted values derived from measurements of the two children. The complete list of anthropometric variables with selected dimensions is given in Table 1. Landmark definitions and measurement descriptions can be found in Appendix A.

Clay masterbody forms were sculptured to meet the design values within ±2 mm of all established dimensions. During the course of sculpturing the masterbody forms, every effort was made to adjust the shape of the segments to conform to the breadth, depth, and circumference within the desired tolerance. In some instances, however, where the three dimensions had apparently irreconcilable differences, breadth and depth were given a higher design priority than circumference. The completed clay masterbody forms for the 3- and 6-year-old child respectively are shown in Figures 1 and 2.

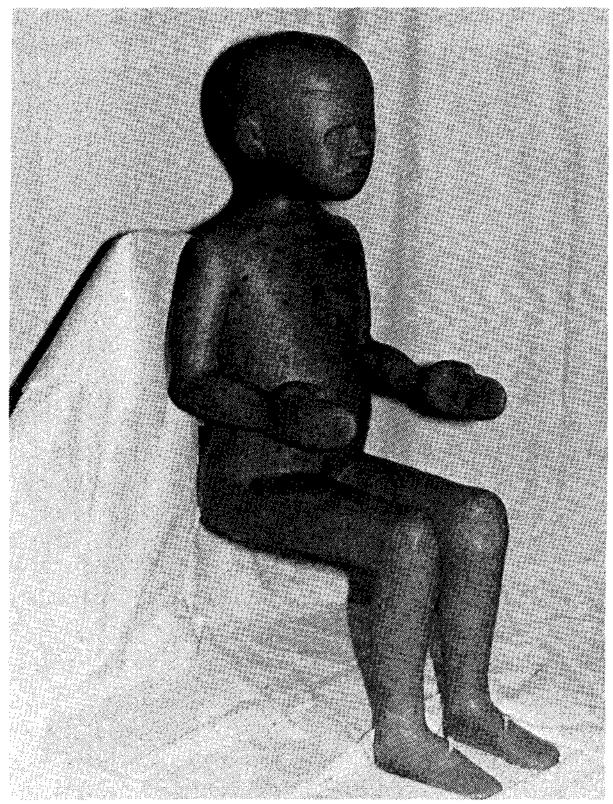

FIGURE 1.—Three-year-old-child clay masterbody form.

FIGURE 2.—Six-year-old-child clay masterbody form.

III. Mass Distribution Properties of the 3- and 6-Year-Old-Child Masterbody Segments.

In addition to determining the sizes and shapes of the 3- and 6-year-old-child masterbody forms, it was necessary to determine their segmental mass distribution characteristics. Dental stone reproductions of the clay masterbody forms were made and segmented at approximated joint locations. Mass, volume, center of mass, and mass moments of inertia of the resulting segments were then experimentally determined. The following discussion describes the technique used with the resultant data from the stone reproductions.

Surfaces of sculptured clay masterbody forms were smoothed prior to preparing the mold sections for casting the dental stone. Figure 3 illustrates one of the clay masterbody forms in the process of constructing the molds. These molds were made in keyed sections by overlaying several thicknesses of orthopedic plaster on the clay masterforms. After each section had cured, it was keyed and the next appropriate section was cast with a slight overlap to prevent any undercutting in the positive. A rigid 3/8- to 1/2-inch-thick composite wall resulted in the mold.

For casting the dental stone model, the composite mold was assembled and held in position by glass fiber tape. The tape stabilized the keyed sections in position and prevented distortion from internal forces while pouring and curing took place. The whole-body cast was made of dental stone (Coe Laboratories, Chicago, Illinois) with a measured density of 1.7. The casting material was poured continuously into the mold, which was gently vibrated to insure a homogenous cast free of faults and trapped air bubbles.

After curing for 24 hours, the mold was removed and the stone model examined for any imperfections observable on the cast surface. All porous areas on the model surface were removed and filled with dental stone, and all excess stone (between the upper arm and torso and at the site of adjoining section seams) was removed. During this repair and smoothing procedure, all landmarks and most of the other body dimensions

FIGURE 3.—Six-year-old-child masterbody form in the process of mold casting.

TABLE 1.
Anthropometric Data for Design of 3- and
6-Year-Old-Child Masterbody Forms

No.	Variable Name	Dimension 3-yr-old		Source	Dimension 6-yr-old		Source
1	Weight	33 lb		(10)*	46 lb		(10)
		cm	in		cm	in	
2	Stature	96.5	38.0	(10)*	116.8	46.0	(10)
3	Sitting height	55.9	22.0	(1,2,3)	63.5	25.0	(1,2,3)
4	Eye height	45.5	17.9	(10)	51.8	20.4	(10)
5	Tragion height	45.0	17.7	(9,10)	51.3	20.2	(9,10)
6	Cervical height	38.3	15.1	(3,10)	44.2	17.4	(3,10)
7	Acromion height	34.6	13.6	(3,10)	39.4	15.5	(3,10)
8	Biacromial breadth	21.8	8.6	(2)	25.4	10.0	(2,4)
9	Suprasternale height	35.2	13.9	(4,10)	40.1	15.8	(4,10)
10	Substernale height	25.2	9.9	(4,10)	27.3	10.7	(4,10)
11	Torso height, axilla	29.9	11.8	(9)	34.0	13.4	(9)
12	Torso breadth, axilla	17.6	6.9	(9)	20.3	8.0	(9)
13	Torso depth, axilla	12.1	4.8	(9)	13.2	5.2	(9)
14	Torso height, nipple	27.2	10.7	(10)	31.0	12.2	(10)
15	Torso breadth, nipple	17.4	6.9	(10)	19.2	7.6	(4,10)
16	Torso depth, nipple	12.9	5.1	(3,6)	14.3	5.6	(3,4,7)
17	Torso circumference, nipple	51.0	20.1	(2)	59.4	23.4	(2,4)
18	Internipple distance	11.4	4.5	(9,10)	11.4	4.5	(9,10)
19	Torso depth, substernale	12.9	5.1	(9,10)	14.3	5.6	(9)
20	Torso height, 10th rib	17.3	6.8	(9)	19.3	7.6	(9)
21	Torso breadth, 10th rib	15.2	6.0	(9)	19.5	7.7	(10)
22	Torso height, waist	15.5	6.1	(10)	17.5	6.9	(9)
23	Torso breadth, waist	16.1	6.3	(2.9)	19.4	7.6	(2,9)
24	Torso depth, waist	16.4	6.5	(10)	16.7	6.6	(9)
25	Torso circumference, waist	52.7	20.7	(10)	57.2	22.5	(4,10)
26	Torso height, iliocristale	13.2	5.2	(3,9)	15.7	6.2	(3,9)
27	Torso breadth, iliocristale	16.5	6.5	(9,10)	19.8	7.8	(4,9,10)
28	Torso depth, iliocristale	15.8	6.2	(10)	16.6	6.5	(10)
29	Torso circumference, iliocristale	53.7	21.1	(10)	58.0	22.8	(10)
30	Anterior superior iliac spine height	11.9	4.7	(9)	12.4	4.9	(9)
31	Bispinous breadth	13.7	5.4	(10)	15.0	5.9	(9)
32	Trochanterion height	5.2	2.0	(9)	5.6	2.2	(9)
33	Torso breadth, trochanterion	20.8	8.2	(10)	23.5	9.3	(10)
34	Trochanterion-to-seat back distance	7.5	3.0	(10)	9.1	3.6	(9)
35	Maximum hip breadth	20.2	8.0	(3,9)	23.1	9.1	(3,4,9)
36	Sitting hip circumference	59.2	23.3	(9)	68.0	26.8	(10)
37	Thigh-abdominal junction height	8.0	3.1	(3,9)	10.2	4.0	(2,3,4,9)
38	Thigh-abdominal junction-to-seat back distance	14.4	5.7	(9)	15.2	6.0	(9)
39	Thigh circumference, thigh-abdominal junction	28.4	11.2	(2,9)	34.5	13.6	(2,9)
40	Thigh circumference, popliteal	24.0	9.4	(9)	26.8	10.6	(9)
41	Thigh depth, popliteal	7.8	3.1	(9,10)	8.5	3.3	(6,9)

*Numbers in parentheses refer to references at end of table.

No.	Variable Name	Dimension 3-yr-old cm	in	Source	Dimension 6-yr-old cm	in	Source
42	Buttock-knee length	34.4	13.5	(10)	38.1	15.0	(2,3,4,9)
43	Buttock-popliteal length	27.1	10.7	(10)	30.2	11.9	(10)
44	Knee height	28.4	11.2	(3,9)	35.8	14.1	(2,3,9)
45	Popliteal height	20.6	8.1	(3,9)	27.7	10.9	(3,4,9)
46	Knee circumference	25.8	10.2	(9,10)	26.6	10.5	(9,10)
47	Knee breadth	6.6	2.6	(7,9)	7.5	3.0	(4,7,9)
48	Lower leg circumference, popliteal	21.2	8.3	(9)	22.1	8.7	(9)
49	Lower leg depth, popliteal	6.4	2.6	(9,10)	6.9	2.7	(9,10)
50	Lower leg circumference, maximum	21.1	8.3	(2,3,9)	23.5	9.3	(2,3,9)
51	Lower leg height, maximum circumference	18.4	7.2	(9)	21.6	8.5	(9)
52	Lower leg depth, maximum circumference	6.8	2.7	(9)	7.6	3.0	(9)
53	Lower leg breadth, maximum circumference	6.3	2.5	(9)	7.4	2.9	(9)
54	Lower leg circumference, minimum	14.9	5.9	(9,10)	16.1	6.3	(4,9,10)
55	Lower leg height, minimum circumference	6.2	2.4	(9)	7.1	2.8	(9)
56	Lower leg depth, minimum circumference	5.1	2.0	(9)	5.8	2.3	(9)
57	Lower leg breadth, minimum circumference	4.2	1.7	(9)	4.5	1.8	(9)
58	Ankle breadth	4.7	1.9	(9,10)	5.7	2.2	(9,10)
59	Sphyrion height	3.6	1.4	(9)	4.1	1.6	(9)
60	Foot length	15.8	6.2	(3,9)	17.8	7.0	(2,3,4)
61	Foot breadth	5.9	2.3	(3,9)	6.7	2.6	(2,3,4)
62	Heel breadth	3.8	1.5	(9)	3.8	1.5	(9)
63	Shoulder-elbow length	18.5	7.3	(3,9)	23.4	9.2	(2,3,4)
64	Upper arm circumference, axilla	17.8	7.0	(9)	20.8	8.2	(9)
65	Upper arm depth, axilla	7.1	2.8	(9)	7.8	3.1	(9)
66	Upper arm circumference, mid-arm	17.5	6.9	(2,3,9)	21.1	8.3	(2,3,4,9)
67	Upper arm depth, mid-arm	6.1	2.4	(9)	7.5	3.0	(9)
68	Upper arm circumference, antecubital	16.8	6.6	(9)	19.2	7.6	(9)
69	Upper arm depth, antecubital	5.9	2.3	(9)	6.9	2.7	(9)
70	Elbow breadth	4.4	1.7	(9)	4.8	1.9	(9)
71	Elbow circumference	18.5	7.3	(9)	21.4	8.4	(9)
72	Forearm-hand length	26.0	10.2	(3,9)	31.0	12.2	(2,3,9)
73	Forearm circumference, maximum	17.0	6.7	(3,9)	19.9	7.8	(3,4,9)
74	Forearm depth, maximum circumference	5.1	2.0	(9)	6.4	2.5	(9)
75	Wrist circumference, minimum	11.2	4.4	(9)	13.3	5.2	(3,9)
76	Wrist breadth, minimum circumference	4.0	1.6	(2,3,9)	4.8	1.9	(9)
77	Wrist depth, minimum circumference	2.7	1.1	(9)	3.3	1.3	(9)

*Numbers in parentheses refer to references at end of table.

No.	Variable Name	Dimension 3-yr-old cm	in	Source	Dimension 6-yr-old cm	in	Source
78	Hand length	11.4	4.5	(2,3)	13.4	5.3	(2,3,4)
79	Hand breadth, metacarpale III	5.3	2.1	(3.9)	6.1	2.4	(3,5,9)
80	Hand depth, metacarpale III	1.9	0.7	(9)	1.9	0.7	(9)
81	Palm length	6.4	2.5	(9)	7.1	2.8	(9)
82	Head length	17.9	7.0	(3,7,9)	18.1	7.1	(2,3,8,9)
83	Head breadth	13.5	5.3	(3,7,9)	14.1	5.6	(2,3,8,9)
84	Head circumference	50.8	20.0	(2,3,9)	52.2	20.6	(3,5,9)
85	Tragion-to-vertex distance	11.0	4.3	(9,10)	12.2	4.8	(9,10)
86	Tragion-to-wall distance	9.0	3.5	(9,10)	9.8	3.9	(9,10)
87	Menton-to-vertex distance	17.5	6.9	(9)	20.4	8.0	(10)
88	Menton-to-wall distance	16.0	6.3	(9)	17.0	6.7	(9)
89	Glabella-to-vertex distance	7.9	3.1	(9)	9.2	3.6	(9)
90	Bitragion breadth	10.7	4.2	(9)	11.7	4.6	(9,10)
91	Bitragion-coronal arc	31.7	12.5	(9,10)	32.9	13.0	(9,10)
92	Bitragion-glabella arc	25.6	10.1	(9,10)	24.2	9.5	(9,10)
93	Bitragion-menton arc	25.0	9.8	(9,10)	25.4	10.0	(9,10)
94	Bigonial breadth	8.1	3.2	(9)	9.4	3.7	(8,9)
95	Neck circumference	23.3	9.2	(3,9)	27.5	10.8	(2,3,9)
96	Neck breadth	7.0	2.8	(9)	8.0	3.1	(9)
97	Neck depth	6.7	2.6	(9,10)	8.9	3.5	(9,10)
98	Suprasternale-cervicale distance	8.2	3.2	(9)	8.7	3.4	(9)

Sources: The references cited here are those from which the anthropometric data for the 3- and 6-year-old-child body forms were obtained. In many instances the design value for a particular dimension is not the value reported in these references but, instead, is one adjusted to the average stature and weight of a hypothetical 3- or 6-year-old child.

(1) McConville and Churchill, 1964.
(2) Snyder et al., 1972.
(3) Stoudt, 1971.
(4) Malina et al., 1973.
(5) Martin, 1954.
(6) Martin, 1955.
(7) Meredith and Boynton, 1937.
(8) Young, 1966.
(9) Reynolds, personal communication.
(10) Team estimate.

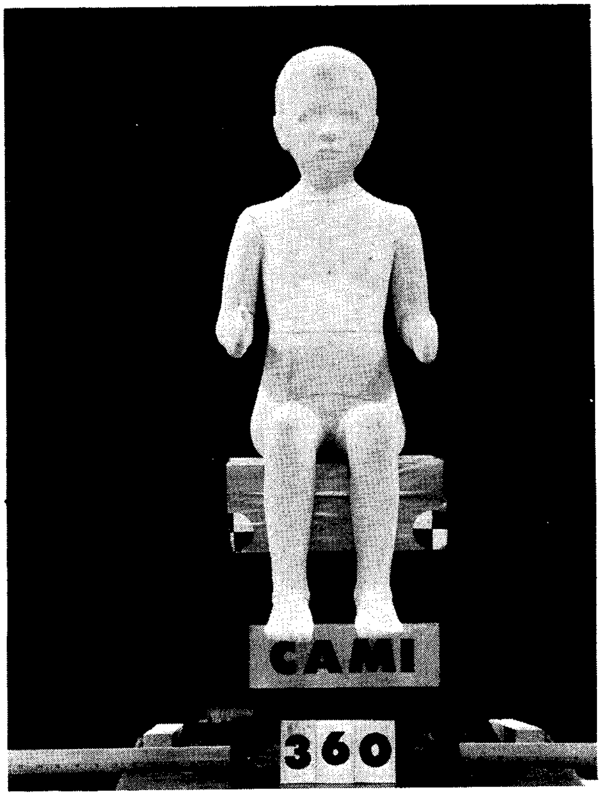

FIGURE 4.—Front view of 3-year-old-child stone model.

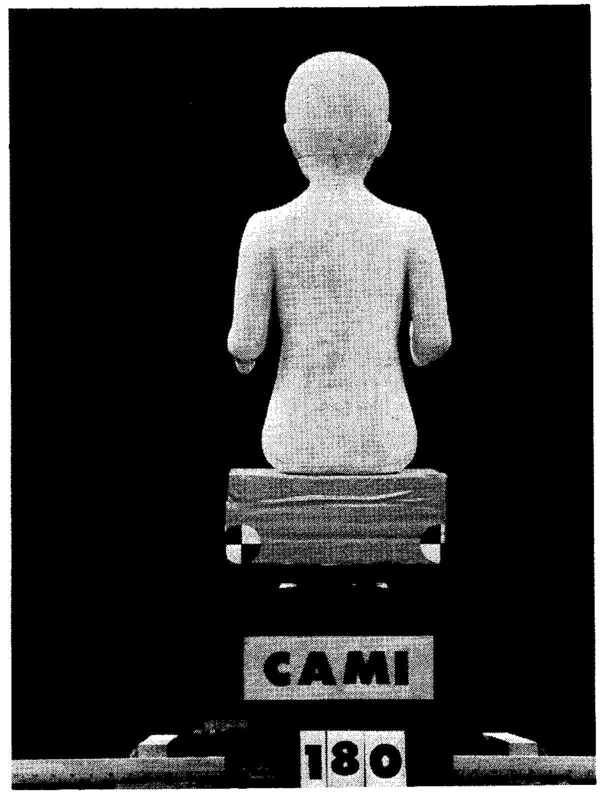

FIGURE 6.—Rear view of 3-year-old-child stone model.

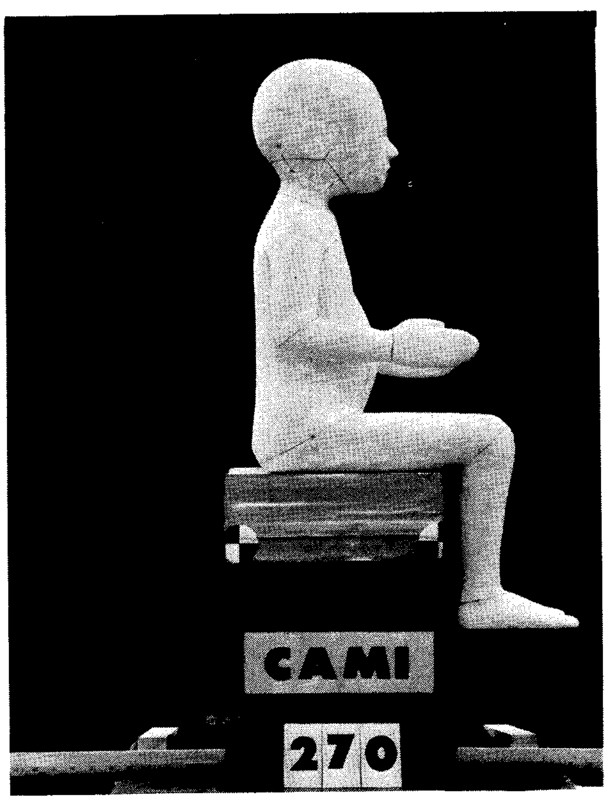

FIGURE 5.—Side view of 3-year-old-child stone model.

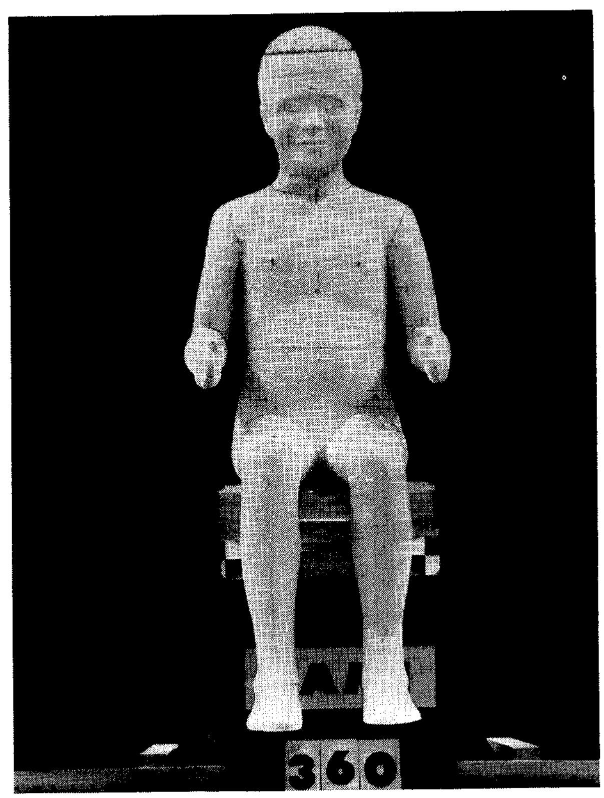

FIGURE 7.—Front view of 6-year-old-child stone model.

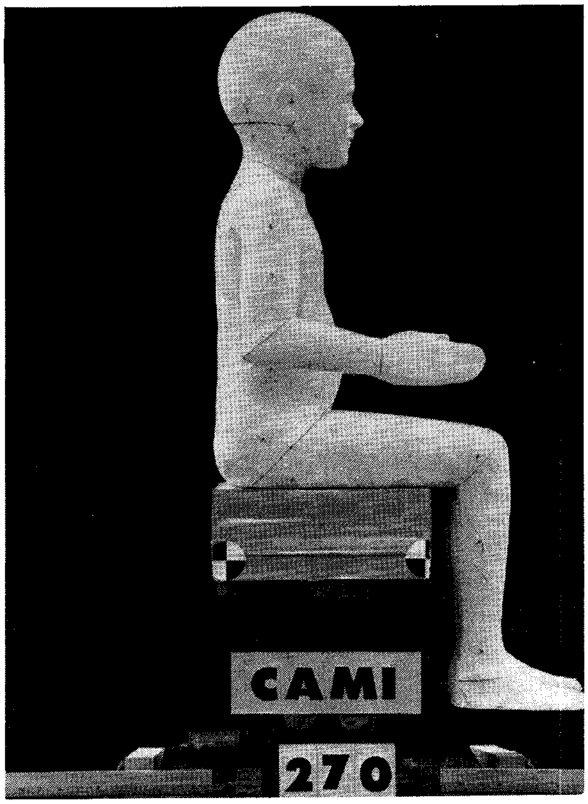

FIGURE 8.—Side view of 6-year-old-child stone model.

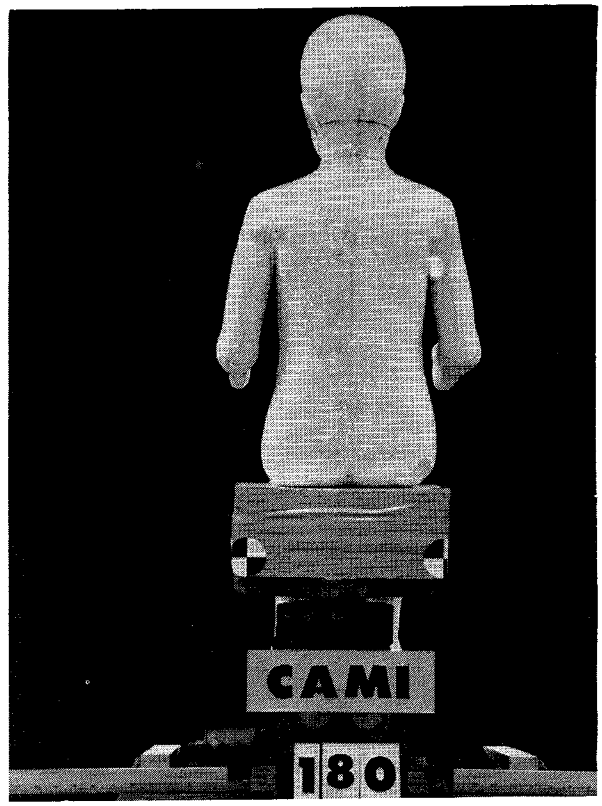

FIGURE 9.—Rear view of 6-year-old-child stone model.

(circumferences, heights, breadths, and depths) were remeasured to insure that a precise duplication of the master models was achieved. The dental stone cast duplicated the master model with less than 1 mm distortion.

The dental stone model was then marked in preparation for segmentation. First, all anthropometric landmarks were marked with an indelible pen. Second, an axis system was established and drawn on the segments to define the principal anatomical planes (sagittal, transverse, and horizontal) for the seated position of the models. Third, three tick marks were made on each cut plane of segmentation (see Chandler et al., 1975, for details of this marking technique) to establish these planes in three-dimensional space.

The model cured under room environmental conditions for 144 hours while it was being prepared for segmentation. The total weight for each of the stone models at the time of segmentation was 38.266 kg for the 6-year-old-child model and 24.460 kg for the 3-year-old-child model.

The cut planes of the segments are illustrated in Figures 4 through 9. The cut planes were established to pass through an estimated joint center to keep the segments as anatomically distinct as possible. The location of these cut planes resulted in head, neck, upper torso, lower torso, right upper arm, right lower arm, right hand, right upper leg, right lower leg, and right foot body segments for both the 3- and 6-year-old-child stone models. The cut planes were located on the dental stone models in the approximate equivalent locations of the following anatomical planes:

Head. A compound cut separated the head and neck. The cut passed along the base of the skull to the ear and then continued to an anterior-inferior direction to pass approximately tangent to the gonial angles of the mandible.

Neck. The superior cut was as described for the head/neck separation. The inferior cut passed along an anteriorly depressed horizontal plane at the approximate posterior level of cervicale and the anterior level of suprasternale.

Upper Torso. The superior cut was the neck inferior cut. The inferior cut was a horizontal plane that passed through the torso at the level of the 10th rib.

Lower Torso. The superior cut was the upper torso inferior cut. The inferior cut passed through the hip as a plane defined by the right trochanterion, left trochanterion, and thigh-abdominal junction landmarks. This cut passed along an estimated hip joint center of rotation as defined by an axis passing through the right and left trochanterion landmarks.

Upper Arm. The superior cut passed from the most superior point in the axilla through acromion. The inferior cut bisected the elbow at approximately 45°, passing through the olecranon process and the antecubital region of the elbow.

Lower Arm. The superior cut was the upper arm inferior cut. The inferior cut passed through the distal wrist crease approximately perpendicular to the long axis of the segment.

Hand. The cut was the inferior cut for the lower arm.

Upper Leg. The superior cut was the lower torso inferior cut. The inferior cut bisected the knee at approximately 45°, passing through the patella and the popliteal region of the knee.

Lower Leg. The superior cut was the upper leg inferior cut. The inferior cut passed tangent to sphyrion and bisected the ankle with the least amount of foot possible attached to the lower leg.

Foot. The cut was the inferior cut for the lower leg.

The resulting body segments are illustrated in Figures 10 and 11. The cuts were made by using a Biro electric saw. The total kerf loss by weight of dental stone for the 6-year-old-child model was 552 g (1.4 percent of its total body weight) and for the 3-year-old-child model was 319 g (1.2 percent of its total body weight).

The weight of each segment was recorded from either of two scales.* These weights were used in adjusting the mass moments of inertia equivalent to those of a segmental mass with density equal to 1 g/cm^3 (Zook, 1932) and have, therefore, not been reported.

Volume was measured on each segment by using the water displacement technique (Clauser et al., 1969; Chandler et al., 1975). Volume was measured by lowering each segment into a tank and displacing water equal to the volume of the specimen, then weighing the displaced water and correcting for temperature. This corrected weight is equal in magnitude to the volume of the specimen with a density of unity (1 g/cm^3). The combined weight of the 3-year-old-child model was 14.507 kg (31.98 lb) and for the 6-year-old-child model was 21.108 kg (46.57 lb). These values compare very well with the design values of 15 kg (33 lb) for the 3-year-old-child model and 20.9 kg (46 lb) for the 6-year-old-child model. The measured data do not include the kerf loss, which would raise the values to approximately 14.682 kg (34.3 lb) for the 3-year-old-child model and 21.515 kg (47.3 lb) for the 6-year-old-child model.

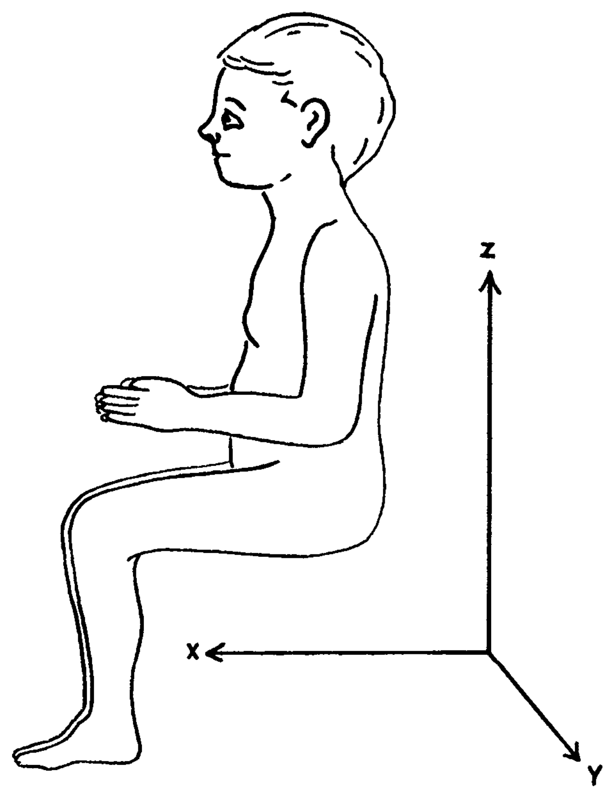

FIGURE 10.—Three-dimensional axis system of the 3- and 6-year-old-child masterbody forms.

The segment volume and adjusted weight of the 3- and 6-year-old-child body forms, along with the ratio of the segment's measurement to that of the total body, are given in Table 2.

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* Mettler P10N/7 Mettler Instrument Corporation, Heightstown, New Jersey. Howe Richardson Scale Company Model 3305, Rutland, Vermont.

TABLE 2.
Segmental Weights of 3- and 6-Year-Old-Child
Masterbody Forms

Segment	3-Year-Old-Child: Segment Weight (g) or Segment Volume (cm^3)	3-Year-Old-Child: SW/BW* (%)	6-Year-Old-Child: Segment Weight (g) or Segment Volume (cm^3)	6-Year-Old-Child: SW/BW* (%)
Head	2,305	15.9	2,765	13.1
Neck	280	1.9	329	1.6
Upper Torso	3,524	24.3	5,342	25.3
Lower Torso	2,816	19.4	4,176	19.8
Upper Arm	304	2.1	524	2.5
Lower Arm	217	1.5	343	1.6
Hand	110	0.8	168	0.8
Upper Leg	1,406	9.7	2,009	9.5
Lower Leg	546	3.8	931	4.4
Foot	208	1.4	273	1.3
Total Body Weight	14,507	100.1	21,088	100.0

*SW/BW is the ratio of segment weight to total body weight.

The center of mass for each body segment was determined by a suspension technique. Segments were suspended in each of the three axes of the three-dimensional axis system (defined in Figure 10) and then were marked on opposite segment surfaces at points along a vertical line intersecting the suspension axis. The locations of the center of mass marked on the surfaces of each model were used in measuring the mass moments of inertia about axes passing through these marks. The locations of these marks on each segment, relative to other landmarks, are shown in Appendix B.

After location of the center of mass, two transverse moments of inertia (three for the head) were measured on each specimen. The moments of inertia were measured on a torsional pendulum* This instrument has a maximum test weight of 113.6 kg (250 lb) with an accuracy (which does not include alignment or gravity errors) of ±0.25 percent of total moment of inertia. The instrument was locally calibrated and found to perform within factory specification. The moment of inertia was measured for the specimen and a specimen holder about an estimated center of mass of the combination. The moment of inertia of the specimen holder was then measured and subtracted from the total to provide the moment of inertia for the specimen in lb/in². This unit of measurement was converted to g/cm² and adjusted for the difference in density of the actual specimen relative to a density equal to 1 g/cm³. The adjustment divided the measured moment of inertia by the measured density of the segment. The corrected moments of inertia, relative to an axis system approximately through the center of mass parallel to the axis system shown in Figure 10, are presented in Table 3.

The final set of data was taken by locating the cut plane tick marks, centers of mass, cut plane centroids,* and anthropometric landmarks in three-dimensional space. The measurement technique consisted of transferring each point to a horizontal plane (recorded as a point on a sheet of paper) and measuring its elevation above the plane. These data, in combination with the established anthropometric data base, provide a means of mathematically reassembling the specimen in

* Model XR250, Space Electronics, Inc., Wallingford, Conn.

* These were approximated as the center of cut plane surface and should not be construed as centers of joint rotation.

TABLE 3.
Measured Moments of Inertia About Transverse Axes of 3- and 6-Year-Old-Child Body Segments of Masterbody Forms

Segment*	3-Year-Old-Child			6-Year-Old-Child		
	I_X	I_Y	I_Z	I_X	I_Y	I_Z
Head	61,607	80,524		76,331	110,073	
Neck	2,558	2,190		2,918	2,902	
Upper Torso	177,105	150,544		372,238	282,663	
Lower Torso	105,196	91,228		232,173	166,455	
Upper Arm	5,490	5,806		15,090	16,080	
Lower Arm		2,826	2,757		6,403	6,178
Hand		1,118	926		2,837	1,964
Upper Leg		83,677	86,268		128,719	132,621
Lower Leg	22,670	20,613		61,409	62,256	
Foot	3,415	3,299		6,073	5,842	

*All measurements in g/cm^2, adjusted to a specimen density equal to 1 g/cm^3.

spatial location and shape. The data are presented in Appendix B with a discussion of their possible use and interpretation.

IV. Mathematical Model Estimates of Weight and Moments of Inertia of the 3- and 6-Year-Old-Child Materbody Segments.

The modeling effort in the present study was undertaken to determine how well a simple geometric mathematical model could predict mass and mass moments of inertia from masterbody segment data. It was anticipated that the model would perform satisfactorily because the segments modeled were homogenous, rigid bodies and the measured data were adjusted for a mass with density equal to unity. The models chosen and the anthropometric variables used to describe the geometric figure are as follows:

Ellipsoid

Head: Maximum menton-occiput distance*
Bitragion breadth
Crinion-mastoid distance*

Right Circular Cylinder

Neck: Neck circumference
Anterior neck length*
Posterior neck length*

Lower arm: Forearm-hand length
Hand length
Forearm circumference
Wrist circumference

Upper leg: Buttock-knee length
Trochanterion-to-seat back distance
Thigh circumference, thigh-abdominal junction
Thigh circumference, popliteal

Lower leg: knee height
Sphyrion height
Lower leg circumference, maximum
Lower leg circumference, minimum

Right Elliptical Cylinder

Upper torso: Cervicale height
Torso height, 10th rib
Torso breadth, nipple
Torso depth, nipple

* Dimensions taken directly from the body form. All other dimensions are listed in Table 1.

Lower torso: Torso height, 10th rib
Torso breadth, iliocristale
Torso depth, iliocristale

Upper arm: Shoulder-elbow length
Upper arm breadth, mid-arm*
Upper arm depth, mid-arm

Parallelepiped

Hand: Hand length
Hand breadth
Hand depth

Foot: Foot length
Foot breadth
Foot depth

The standard mathematical equations for determination of volume and mass moment of inertia of the geometric elements are found in Eshbach (1936). In these computations, volume equaled mass in magnitude, the anthropometric circumferences and diameters were averaged when necessary and converted to radii, and the anthropometric lengths were entered directly or subtracted to determine the appropriate segment length.

* Dimensions taken directly from the body form. All other dimensions are listed in Table 1.

A comparison of the model segment weight estimates with the measured segment weight is presented in Table 4. Most of the segments' weights were estimated with a reasonable error, as shown in the percentage differences between the estimated and measured body segment weights. The head, neck, upper arm, and foot are, however, poorly modeled for both the 3-year-old and 6-year-old masterbody forms.

Table 5 presents the mathematical model estimates of the principal moments of inertia as a percentage deviation from the measured moments of inertia. The model does not perform as well for these data as it does for the mass estimates. The poorest model estimates are for the head, neck, upper arm, and foot, which are also the segments having the poorest mass estimates.

On careful examination of these data and on the basis of past modeling experience with baboons (Reynolds, 1974) and adult male cadavers (Chandler et al., 1975), the following

TABLE 4.
Mathematical Model Estimates of Body Segment Weights for 3- and 6-Year-Old-Child Masterbody Forms

3-Year-Old-Child Masterbody Form

Body Segment	Segment Weight in Grams			Percent Total Body Weight		
	Estimated	Measured	%	Estimated	Measured	%
Head	1,624	2,305	-29.5	10.3	15.9	-35.2
Neck	123	280	-56.1	0.8	1.9	-57.9
Upper Torso	3,731	3,524	+ 5.9	23.8	24.3	- 2.1
Lower Torso	3,564	2,816	+26.6	22.7	19.4	+17.0
Upper Arm	495	304	+62.8	3.2	2.1	+52.4
Lower Arm	230	217	+ 6.0	1.5	1.5	0.0
Hand	115	110	+ 4.5	0.7	0.8	-12.5
Upper Leg	1,470	1,406	+ 4.6	9.4	9.7	- 3.1
Lower Leg	627	546	+14.8	4.0	3.8	+ 5.3
Foot	382	208	+83.7	2.4	1.4	+41.7
TOTAL	15,700	14,507	+ 8.2	100.0	100.1	- 0.1

6-Year-Old-Child Masterbody Form

Body Segment	Segment Weight in Grams			Percent Total Body Weight		
	Estimated	Measured	%	Estimated	Measured	%
Head	1,919	2,765	-30.6	8.6	13.1	-34.4
Neck	216	329	-34.3	1.0	1.6	-37.5
Upper Torso	5,364	5,342	+ 0.4	24.0	25.3	- 5.1
Lower Torso	4,982	4,176	+19.3	22.3	19.8	+12.6
Upper Arm	731	524	+39.5	3.3	2.5	+32.0
Lower Arm	363	343	+ 5.8	1.6	1.6	0.0
Hand	155	168	- 7.7	0.7	0.8	-12.5
Upper Leg	2,170	2,009	+ 8.0	9.7	9.5	+ 2.1
Lower Leg	988	931	+ 6.1	4.4	4.4	0.0
Foot	524	273	+91.9	2.3	1.3	+76.9
TOTAL	22,343	21,088	+ 6.0	99.9	100.0	- 0.1

TABLE 5.
Comparison of the Mathematical Model Estimates Vs. the Experimentally Measured Moments of Inertia on the Body Segments of the 3- and 6-Year-Old-Child Masterbody Forms*

	3-Year-Old-Child			6-Year-Old-Child		
	I_x (%)	I_y (%)	I_z (%)	I_x (%)	I_y (%)	I_z (%)
Head	-148.4	- 56.9	-62.9	- 58.8	- 38.5	-34.5
Neck	- 69.2	- 63.6		- 27.6	- 27.6	
Upper Torso	+ 17.1	+ 17.3		+ 6.5	+ 21.0	
Lower Torso	+ 42.9	+ 58.4		+ 19.2	+ 44.5	
Upper Arm	+185.5	+155.2		+139.1	+114.3	
Lower Arm		+ 57.1	+57.1		+ 40.6	+45.2
Hand		+ 36.4	+44.4		+ 20.0	+16.7
Upper Leg		+ 13.5	+10.1		+ 28.2	+24.4
Lower Leg	+ 49.8	+ 65.0		+ 38.8	+ 36.8	
Foot	+167.6	+175.8		+159.0	+153.4	

*Compared as a percentage deviation from the experimentally measured moments of inertia.

observations are suggested to account for the poor estimates derived from the model. The model is deterministic, requiring a single number to describe an absolute dimension. Obviously, the geometric forms used in the model do not perfectly describe the shape of the segment specimens, but the referenced studies indicate greater comparability than the present data.

One of the main problems lies in the deterministic nature of the model. For example, the upper arm is defined in the model as a right elliptical cylinder described by upper arm length, upper arm breadth, and upper arm depth. This model has a finite, absolute length measured between two parallel surfaces. However, as can be seen by reference to Figures 11 and 12, the actual segment was cut in such a manner as to produce two nonparallel surfaces, neither of which is perpendicualr to the long axis of the limb. This shape presents a distinct and easily identifiable problem for the mathematical modeler. What is the finite length of the segment? In the two previously mentioned studies on baboons and cadavers, the length used in the model was a proximal joint centroid to distal joint cen-

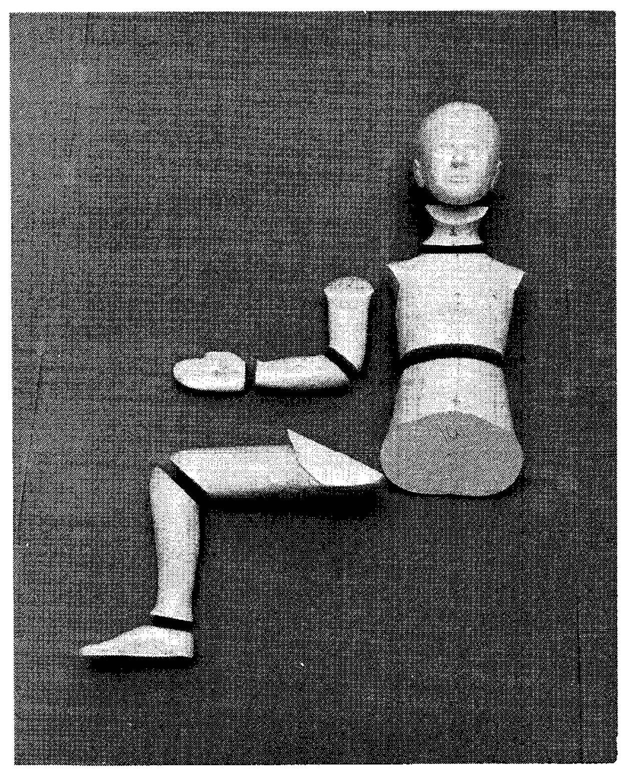

FIGURE 11.—Exploded view of 3-year-old-child stone body segments.

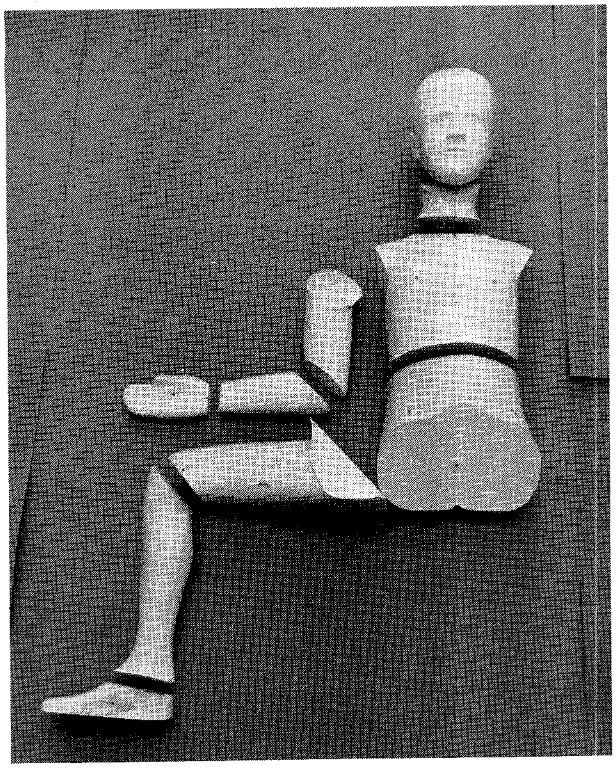

FIGURE 12.—Exploded view of 6-year-old-child stone body segments.

troid, which provided an averaged segment length corresponding to its approximate link length. This approach reduces the error as a function of the square of the difference in distance between the surface length (shoulder-elbow length) and the internal link length (centroid-centroid length). Since there are no bony landmarks on or in a stone model, centroid distance was not used. It is assumed that this approach has produced most of the errors in the models reported in Table 4.

To reduce these errors, future models should consider an anthropometric description of the subject that accurately reflects the linkage system of the human body.

V. Discussion.

This study was undertaken to define, construct, measure, and evaluate the size, shape, and mass distribution of masterbody forms representative of 3- and 6-year-old U.S. children.

Based on the authors' collective judgment of available data, a list of 98 anthropometric dimensions was selected and used to develop full-scale masterbody forms for reproduction in dental stone. The stone models were segmented into 10 body segments representing the head, neck, upper torso, lower torso, upper arm, lower arm, hand, upper leg, lower leg, and foot. Weight, volume, center of mass, and mass moments of inertia measured on each body segment have been presented in preceding sections of this report.

These data were assembled and measured to provide a state-of-the-art estimate of the size, shape, and mass distribution of representative 3- and 6-year-old U.S. children. The need for these data has long been recognized, but the lack of certain types of anthropometric data presents several limitations on the use of the data given.

While many of the initial shape dimensions are based on what is presumed to be representative U.S. population data or estimates interpolated from such data, these were necessarily supplemented by a large number of dimensional values based on the collective judgment of the team or measurements from personal data. The data available in the literature often provided sound guidelines but, in numerous instances, these forms represent a judgment of the authors rather than empirically derived U.S. population data.

These manikins and their associated anthropometric data base do not contain any information on the biokinematic properties of the two ages represented. The planes of segmentation, and thus the mass distribution data on dental stone casts, have been measured by making several assumptions regarding a body linkage system and the homogenous nature of the human body. The planes of segmentation that produced the 10 segments were theoretically designed to pass through estimated link endpoints or joint centers of rotation. As has been pointed out previously, little information exists on adult joint centers of rotation and no information exists on linkage system of children. Thus, the required data base on linkage systems relies solely on estimates rather than measured data from the living. The planes of segmentation provide segments that approximate the linkage defined in adults (Dempster, 1955). Qualitatively, the authors have the most confidence in the limb segments and the least confidence in the torso segments.

The torso presents unique problems. The best current data available on the adult male torso linkage system are found in Snyder et al. (1972).

TABLE 6.
COMPARISON OF BODY SEGMENT WEIGHTS OF MASTERBODY FORMS, ADULT MALE CADAVERS, AND ADULT FEMALE BABOONS

	Present Study					
	3-yr-old-Child	3-yr-old-child Density Adjusted	6-yr-old-child	6-yr-old-child Density Adjusted	Six Adult Male Cadavers	Adult Female Baboons
Head*	15.9%	16.0%	13.1%	13.2%	6.1%	8.3%
Torso	45.6	45.2	46.7	46.2	52.2	53.2
Upper Arm	2.1	2.1	2.5	2.5	2.9	3.1
Lower Arm	1.5	1.5	1.6	1.6	1.7	2.5
Hand	0.8	0.8	0.8	0.8	0.6	0.7
Upper Leg	9.7	9.8	9.5	9.6	10.2	8.4
Lower Leg	3.8	3.8	4.4	4.4	4.1	2.8
Foot	1.4	1.4	1.3	1.3	1.3	1.1
Tail	-		-		-	1.1
Sum of Parts	100.1%	100.0%	100.0%	99.8%	99.9%	99.8%

*Segment weight as a ratio of total body weight.

Their data suggest a multilinkage model of the torso that would not have been practical for the present study segmentation plan. Therefore, it was decided that the torso and neck would be segmented according to a rationale based on anatomy and anthropometry. The segmentation planes must be anthropometrically identifiable in the living and they must reflect anatomical differences that indicate different mass properties. The torso was segmented into neck, thorax, and abdominal-pelvic regions whose segmentation planes were described previously. Any attempt at this time to infer a torso linkage system from this plan of segmentation is unfounded and possibly misleading.

Table 6 gives the weight distributions for the 3- and 6-year-old-child stone casts of this study and for the data of this study adjusted to empirically selected densities of 0.9 in the upper and lower torso segments and 1.1 in all other segments, six adult male cadavers (Chandler et al., 1975), and adult female baboons (Reynolds, 1974). No data for torso weights corresponding to the segmentation plan are used in the present study; therefore, the torso weight as a percentage of total body weight is given for the whole torso including the neck. Differences among the groups are particularly observable in the head and torso weights. One should consider differences when examining data based on baboons as child or adult surrogates, particularly because mathematical models of vehicle crash dynamics indicate that the mass of a rigid body more significantly affects the results than does moment of inertia (Bowman and Robbins, 1972).

The inertia data given for the dental stone segments are not the principal moments of inertia. These data report two transverse moments of inertia (three for the head) measured about defined axes that pass through the measured center of mass of the segment. The principal moments were not measured because, after a comparison of the inertial data in the two previously noted reports (Reynolds, 1974; Chandler et al., 1975) was made, it was found that the principal axis is approximately equal to an observed anatomical axis. The only exception is the head segment; the principal moments of inertia for the adult male head indicate that the mass is distributed approximately in the shape of a sphere. As a result, minor variations in shape and tissue distribution cause great variations in the location of the principal axis. Therefore, the head moments of inertia were measured about three axes that are appropriate to the observed geometrical shape of the head. The same approach was used on each of the other body segments. Two transverse axes were located through the center of mass of the segment and oriented in a functionally useful direction. The data given in this report, therefore, represent appropriate values for calculating body kinetics but are not principal moments of inertia. These data should be interpreted not as biological population parameters, but as approximations that can be used to design and construct anthorpomorphic test devices or be useful in mathematical calculations.

VI Conclusions.

On the basis of this research, the following conclusions are drawn:

A. The proportional segmental volumes and/or weights adequately reflect the mass distribution of the two age groups. As more segmental information on biological specimens, particularly relating to segment densities, becomes available, the estimates of segment weight should be reexamined.

B. Use of the data on segmental center of mass should consider the manner in which the data are reported in the present study. There are several possibilities for arriving at dimensional location of the center of mass. The data can be used as they are in Table 3, but the user is reminded that the total segment length includes part of the segmentation plane flap in its dimension. Alternately, the three-dimensional data in Appendix B provide the user with several alternatives for describing the location of the center of mass relative to body landmarks or link lengths. These data are expressed as three-dimensional points in the axis reference system for each segment, relative to an indicated center of mass with coordinate values of 0, 0, and 0. In any event, the user must keep in mind that these data are from dental stone casts and have no demonstrated relationship to living subjects at this time.

C. For future research, data on segmental volume, link lengths and locations, and anthropometric shape dimensions (height, breadth, width, and circumference) should be collected on living subjects.

D. For future research, data on segment mass, segmental volume, segmental center of mass, link lengths and locations, and segmental mass moments of inertia should be collected on fresh cadaver specimens.

E. As an immediate problem, more information is urgently needed on the anthropometric descriptions of link lengths and the torso/neck linkage system with its associated mass distribution.

F. The available anthropometric data base (size, shape, linkage, and mass distribution) was found to be deficient for the purpose of developing anthropomorphic test devices. Although available resources prohibited significant data collection efforts in this study, this research should be encouraged.

APPENDIX A

Anthropometry

I. Anthorpometric Definitions.

1. Weight: Measure nude body weight on a scale.

2. Stature: Subject stands erect in bare feet with head in Frankfort Plane. Measure with an anthropometer the perpendicular distance from floor to vertex.

3. Sitting Height: Subject sits erect with head in the Frankfort Plane. Measure with an anthropometer the perpendicular distance from the seat pan to vertex.

4. Eye Height: Subject sits erect with head in the Frankfort Plane. Measure with an anthropometer the perpendicular distance from the seat pan to the ectocanthus.

5. Tragion Height: Subject sits erect with head in the Frankfort Plane. Measure with an anthropometer the perpendicular distance from the seat pan to tragion.

6. Cervicale Height: Subject sits erect with head in the Frankfort Plane. Measure with an anthropometer the perpendicular distance from the seat pan to cervicale.

7. Acromion Height: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the perpendicular distance from the seat pan to acromion.

8. Biacromial Breadth: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal breadth between the right and left acromion landmarks.

9. Suprasternale Height: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the perpendicular distance from the seat pan to suprasternale.

10. Substernale Height: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the perpendicular distance from the seat pan to substernale.

11. Torso Height, Axilla: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. From the subject's back, measure with an anthropometer the perpendicular distance from the seat pan to the most superior point in the axilla.

12. Torso Breadth, Axilla: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal breadth of the torso at the level of the axilla.

13. Torso Depth, Axilla: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal depth (antero-posterior) of the torso at the level of the axilla.

14. Torso Height, Nipple: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the perpendicular distance from the seat pan to the nipple.

15. Torso Breadth, Nipple: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal breadth of the chest at the nipple level.

16. Torso Depth, Nipple: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal (antero-posterior) depth of the chest at the nipple level.

17. Torso Circumference, Nipple: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a flexible steel tape during normal breathing the horizontal circumference of the chest at the nipple level.

18. Internipple Distance: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the distance between the nipples.

19. Torso Depth, Substernale: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal depth (antero-posterior) of the torso at the level of substernale during normal breathing.

20. Torso Height, 10th Rib: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the perpendicular distance from the seat pan to the inferior margin of the 10th Rib.

21. Torso Breadth, 10th Rib: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal breadth of the chest at the lowest level of the inferior margin of the 10th Rib.

22. Torso Height, Waist: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the perpendicular distance from the seat pan to the waist.

23. Torso Breadth, Waist: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal breadth of the waist.

24. Torso Depth, Waist. Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal (antero-posterior) depth of the waist.

25. Torso Circumference, Waist: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a flexible steel tape the horizontal circumference of the waist.

26. Torso Height, Iliocristale: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the perpendicular distance from the seat pan to iliocristale.

27. Torso Breadth, Iocristale: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal breadth of the torso at iliocristale level.

28. Toros Depth, Iliocristale: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal (antero-posterior) depth of the torso at iliocristale level.

29. Torso Circumference, Iliocristale: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a flexible steel tape the horizontal circumference of the torso at iliocristale level.

30. Anterior Superior Iliac Spine Height: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the perpendicular distance from the seat pan to the most anterior projection of the anterior superior iliac spine.

31. Bispinous Breadth: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal breadth between the right and left anterior superior iliac spines.

32. Trochanterion Height: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the perpendicular distance from the seat pan to trochanterion.

33. Torso Breadth, Trochanterion: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal breadth of the torso at trochanterion.

34. Trocanterion-to-Seat Back Distance: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the horizontal distance from the seat back to trochanterion.

35. Maximum Hip Breadth: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan. Measure with an anthropometer the maximum breadth of the hip.

36. Sitting Hip Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan. Measure with a flexible steel tape the diagonal circumference around the hip, laying the tape over the thigh-abdominal junction and just superior to the resting portion of the buttocks.

37. Thigh-Abdominal Junction Height: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan. Measure with an anthropometer the perpendicular distance from the seat pan to the thigh-abdominal junction.

38. Thigh-Abdominal Junction-to-Seat Back Distance: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan. Measure with an anthropometer the horizontal distance from the seat back to the thigh-abdominal junction.

39. Thigh Circumference, Thigh-Abdominal Junction: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan. Measure with a flexible steel tape the circumference perpendicular to the long axis of thigh at the level of the thigh-abdominal junction.

40. Thigh Circumference, Popliteal: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to floor, feet resting on a horizontal platform. Measure with a flexible steel tape the circumference perpendicular to the long axis of the thigh at the popliteal level.

41. Thigh Depth, Popliteal: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to the floor, feet resting on a horizontal platform. Measure with an anthropometer the perpendicular depth (superoinferior) of the high at the popliteal level.

42. Buttock-Knee Length: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to the floor, feet resting on a horizontal platform. Measure with an anthropometer the horizontal distance from the most posterior plane of the buttock to the most anterior point on the knee.

43. Buttock-Popliteal Length: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to the floor, feet resting on a horizontal platform. Measure with an anthropometer the horizontal distance from the most posterior portion of the buttocks to the popliteal region at the back of the calf.

44. Knee Height: Subject sits erect, uperr arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to the floor, feet resting on a horizontal platform. Measure with an anthropometer the perpendicular distance from the footrest platform to the top of the knee.

45. Popliteal Height: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to the floor, feet resting on a horizontal platform. Measure with an anthropometer the perpendicular distance from the footrest platform to the popliteal region at the back of the knee.

46. Knee Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to the floor, feet resting on a horizontal platform. Measure with a flexible steel tape the diagonal circumference around the flexed knee.

47. Knee Breadth: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, feet resting on a horizontal platform. Measure with sliding calipers the horizontal breadth between the femoral condyles of the knee.

48. Lower Leg Circumference, Popliteal: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to floor, feet resting on a horizontal platform. Measure with a flexible steel tape the horizontal circumference of the lower leg at the popliteal level.

49. Lower Leg Depth, Popliteal: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to the floor, feet resting on a horizontal platform. Measure with sliding calipers the horizontal depth of the lower leg at the popliteal level.

50. Lower Leg Circumference, Maximum: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to the floor, feet resting on a horizontal platform. Measure with a flexible steel tape the maximum horizontal circumference of the calf.

51. Lower Leg Height, Maximum Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to the floor, feet resting on a horizontal platform. Measure with an anthropometer the perpendicular distance from the footrest platform to the level of the maximum circumference of the calf.

52. Lower Leg Depth, Maximum Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower leg perpendicular to the floor, feet resting on a horizontal platform. Meaure with sliding calipers the horizontal depth at the level of the maximum circumference of the calf.

53. Lower Leg Breadth, Maxximum Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on seat pan, lower legs perpendicular to the floor, feet resting on a horizontal platform. Measure with sliding calipers the horizontal breadth at the level of the maximum circumference of the calf.

54. Lower Leg Circumference, Minimum: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on seat pan, lower legs perpendicular to the floor, feet resting on a horizontal platform. Measure with a flexible steel tape the minimum horizontal circumference of the ankle above the malleoli.

55. Lower Leg Height, Minimum Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on seat pan, lower legs perpendicular to the floor, feet resting on a horizontal platform. Measure with an anthropometer the perpendicular distance from the footrest platform to the level of the minimum circumference of the ankle.

56. Lower Leg Depth, Minimum Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on seat pan, lower legs perpendicular to the floor, feet resting on a horizontal platform. Measure with sliding calipers the horizontal breadth at the level of the minimum circumference of the ankle.

57. Lower Leg Breadth, Minimum Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on seat pan, lower legs perpendicular to the floor, feet resting on a horizontal platform. Measure with sliding calipers the horizontal breadth at the level of the minimum circumference of the ankle.

58. Bimalleolar Breadth: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on seat pan, lower legs perpendicular to the floor, feet resting on a horizontal platform. Measure with sliding calipers the breadth between the lateral and medial malleoli of the ankle.

59. Sphyrion Height: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on seat pan, lower legs perpendicular to the floor, feet resting on a horizontal platform. Measure with an anthropometer the perpendicular distance from the footrest platform to sphyrion.

60. Foot Length: Subjects sits rect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on seat pan, lower legs perpendicular to the floor, feet resting on a horizontal platform. Measure with sliding calipers the maximum horizontal length parallel to the long axis of the foot from heel to toe.

61. Foot Breadth: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower legs perpendicular to the floor, feet resting on a horizontal platform. Measure with sliding calipers the maximum breadth across the distal ends of the metatarsals.

62. Heel Breadth: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally, thighs parallel and resting completely on the seat pan, lower legs perpendicular to the floor, feet resting on a horizontal platform. Measure with sliding calipers the breadth of the heel across the superior portion of the calcaneous.

63. Shoulder-Elbow Length: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the distance parallel to the long axis of the upper arm from acromion to the inferior tip of the olecranon process.

64. Upper Arm Circumference, Axilla: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a flexible steel tape, perpendicular to the long axis of the arm, the circumference of the arm at the axilla.

65. Upper Arm Depth, Axilla: Subject sits erect, upper arms relaxed, forearms and hand extended forward horizontally. Measure with sliding calipers the horizontal (anteroposterior) depth of the upper arm in the axilla.

66. Upper Arm Circumference, Mid-Arm: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measured with a flexible steel tape, perpendicular to the long axis of the upper arm, the circumference of the arm midway between acromion and the olecranon process.

67. Upper Arm Depth, Mid-Arm: Subject sits erect, upper arms relaxed, forearms and hand extended forward horizontally. Measure with sliding calipers the horizontal (anteroposterior) depth of the upper arm midway between acromion and the olecranon process.

68. Upper Arm Circumference, Antecubital: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a flexible steel tape, perpendicular to the long axis of the upper arm, the circumference of the arm at the antecubital level.

69. Upper Arm Depth, Antecubital: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with sliding calipers the horizontal (anteroposterior) depth of the upper arm at the antecubital level.

70. Elbow Breadth: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with sliding calipers the breadth between the medial and lateral humeral condyles.

71. Elbow Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a flexible steel tape the diagonal circumference around the elbow.

72. Forearm-Hand Length: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with an anthropometer the distance parallel to the long axis of the limb from the posterior tip of the olecranon process to dactylion.

73. Forearm Circumference, Maximum: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a flexible steel tape, perpendicular to the long axis of the forearm, the maximum circumference of the forearm just below the antecubital level.

74. Forearm Depth, Maximum Circumference: Subject sits erect, upper arms extended, forearms and hands extended forward horizontally. Measure with sliding calipers the vertical (superoinferior) depth of the forearm at the level of the maximum circumference.

75. Wrist Circumference, Minimum: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a flexible steel tape, perpendicular to the long axis of the forearm, the minimum circumference of the wrist.

76. Wrist Breadth, Minimum Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with sliding calipers the horizontal (mediolateral) breadth of the forearm at the level of the minimum circumference of the wrist.

77. Wrist Depth, Minimum Circumference: Subject erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with sliding calipers the vertical (superoinferior) depth of the forearm at the level of the minimum circumference of the wrist.

78. Hand Length: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with sliding calipers the distance parallel to the long axis of the hand from the distal wrist crease to dactylion.

79. Hand Breadth, Metacarpale III: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with sliding calipers the breadth at the level of Metacarpale III.

80. Hand Depth, Metacarpale III: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with spreading calipers the depth of the hand at Metacarpale III.

81. Palm Length: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with sliding calipers the length parallel to the long axis of the hand from the distal wrist crease to the crease at the base of the third digit.

82. Head Length: Subject sits erect with head in the Frankfort Plane. Measure with sliding calipers the maximum length in the midsagittal plane from glabella to the back of the head on the occiput.

83. Head Breadth: Subject sits erect with head in the Frankfort Plane. Measuring with spreading calipers the maximum breadth of the head parallel to the midcoronal plane.

84. Head Circumference: Subject sits erect with head in the Frankfort Plane. Measure with a flexible steel tape the maximum circumference of the head just above glabella.

85. Tragion-to-Vertex-Distance: Subject sits erect with head in the Frankfort Plane. Measure with an anthropometer the vertical distance from tragion to vertex.

86. Tragion-to-Wall Distance: Subject sits erect with head in the Frankfort Plane. Measure with an anthropometer the horizontal distance from tragion to the most posterior projection of the head that would contact the wall.

87. Menton-to-Vertex Distance: Subject sits erect with head in the Frankfort Plâne. Measure with an anthropometer the vertical distance from menton to vertex.

88. Menton-to-Wall Distance: Subject sits erect with head in the Frankfort Plane. Measure with an anthropometer the horizontal distance from menton to the most posterior projection of the head that would contact the wall.

89. Glabella-to-Vertex Distance: Subject sits erect with head in the Frankfort Plane. Measure with an anthropometer the vertical distance from glabella to vertex.

90. Bitragion Breadth: Subject sits erect with head in the Frankfort Plane. Measure with spreading calipers the breadth between right and left tragions.

91. Bitragion-Coronal Arc: Subject sits erect with head in the Frankfort Plane. Measure with a flexible steel tape the length of the arc formed by passing the tape from right to left tragion over the top of the head in the coronal plane.

92. Bitragion-Glabella Arc: Subject sits erect with head in the Frankfort Plane. Measure with a flexible steel tape the length of the arc formed by passing the tape from right to left tragion over glabella.

93. Bitragion-Menton Arc: Subject sits erect with head in the Frankfort Plane. Measure with a flexible steel tape the length of the arc formed by passing the tape from right to left tragion over menton.

94. Bigonial Breadth: Subject sits erect with head in the Frankfort Plane. Measure with spreading calipers the breadth between the right and left gonial angles of the mandible.

95. Neck Circumference: Subject sits erect with head in the Frankfort Plane. Measure with a flexible steel tape the horizontal circumference of the middle of the neck.

96. Neck Breadth: Subject sits erect with head in the Frankfort Plane. Measure with an antropometer the horizontal breadth of the middle of the neck.

97. Neck Depth: Subject sits erect with head in the Frankfort Plane. Measure with an anthropometer the horizontal (anteroposterior) depth of the middle of the neck.

98. Suprasternale-Cervicale Distance: Subject sits erect with head in the Frankfort Plane. Measure with spreading calipers the distance from suprasternale to cervicale.

II. Body Landmarks.

1. Acromion: The most lateral point on the lateral edge of the acromial process of the scapula.

2. Antecubital Region: A region formed at the junction of the forearm and upper arm on the anterior surface when the arm is in the anatomical position.

3. Anterior Superior Iliac Spine: A spinous process on the pelvis located at the most anterior projection of the superior spine on the iliac portion of the pelvis.

4. Axilla: The armpit.

5. Calcaneous: The posterior bone in the heel of the foot.

6. Cervicale: The most posterior projection of the dorsal spine of the seventh cervical vertebra.

7. Dactylion: The distal tip of the third digit.

8. Ectocanthus: The point at the lateral margin of the eye where the eyelids meet.

9. Femoral Condyles: The most lateral and medial bony projections on the distal end of the femur.

10. Frankfort Plane: A plane formed by aligning the head along an axis through tragion and infraorbitale (lowest point on the inferior margin of the bony eye orbit) perpendicular to the gravity vector.

11. Glabella: The most anterior point on the forehead that lies between the brow ridges in the midsagittal plane.

12. Humeral Condyles: The mos lateral and medial bony projections on the distal end of the humerus.

13. Iliocristale: The most superior point on the iliac crest of the pelvis.

14. Malleoli: The most medial and lateral projections on the distal ends of the tibia and fibula respectively.

15. Menton: The most anteroinferior point on the chin in the midsagittal plane.

16. Metacarpale III: The knuckle of the third metacarpal bone in the hand (often the largest knuckle on the hand).

17. Occiput: The bone at the posterior and inferior surfaces of the skull.

18. Olecranon Process: The proximal portion of the ulna that forms the bony projection in the posterior projection of the elbow.

19. Popliteal Region: The region at the back of the knee formed by the junction of the thigh and lower leg.

20. Sphyrion: The distal tip of the tibia below the medial malleolus.

21. Substernale: The lowest bony projection of the sternum at the tip of the xiphoid process.

22. Suprasternale: A point on the most inferior margin of the sternal notch at the top of the manubrium.

23. Tenth Rib: The lowest point on the inferior margin of the lowest rib on the lateral surface of the rib cage to fully articulate with the sternum.

24. Thigh-Abdominal Junction: The junction of the upper leg with the torso.

25. Tragion: The notch in the cartilage of the ear at the superior margin of the tragus.

26. Trochanterion: The most lateral projection of the greater trochanter of the femur.

27. Vertex: The most superior point in the midsagittal plane on the head.

28. Waist: Level on the torso located midway between the 10th rib and iliocristale heights.

APPENDIX B

Three-Dimensional-Point Locations of Anthropometrical Landmarks and Segment Center of Mass

The collection of three-dimensional-point anthropometric data presents interesting problems for both the measurer and the user of such data. First, they must be measured within a defined orthogonal axis system. Second, the measurement technique must be precise both in the identification of the point and in the coordinate location of the point. Third, these data must be presented in a format that allows the user freedom to interpret the data according to his needs. These problems were resolved in the following manner in the present study.

First, a three-dimensional, inertial-axis system was defined external of the specimen. All points were located relative to a plane parallel to the floor that establishes the "i" and "j" axes. Elevation from the plane provides coordinate data for the "k" axis. Thus, the paper on which the points were reproduced served as the reference plane and the elevation from that plane was given for each point. All segments were measured in positions and orientations selected for convenience and accessibility of points in the measurement device described in two previous studies (Reynolds, 1974; Chandler et al., 1975). These measured values were then converted into correct coordinate values to reorient and reposition each segment relative to the original unsegmented body form, the external axis system (Figure 12), and the indicated center of mass.

The three-dimensional-point data can be used directly, and coordinates for each point can be determined for an external axis system. Any axis system can be constructed by using four of these points and the data translated into the new axis system. The data were intentionally left in their present format so that the user would have the freedom to use and interpret the data as his needs arise. The reader and/or user is urged to interpret these data carefully. These points are located on dental stone model surfaces that do not have an associated internal skeleton on which they could have been based. The surface locations of these ponts are based on the anthropometric data, and team estimates have been previously discussed. Furthermore, the location of a cut surface centroid reflects only the center of a dental stone model cut surface and may not have any meaning relative to a human linkage system. There are no data available in the literature that define the linkage system for children, yet these three-dimensional-point data appear to reflect such a linkage system. Similar caution must be exercised in using the location of the center of mass data. Because there are no standard definitions to determine the proximal and distal relationships of a composite or segmented torso, the authors have assumed that absolute proximal is coincident with the cut plane separating the upper and lower torso segments.

These data are provided to aid the users in reconstructing the shape, size, and location of the segments. They present a geometric description of the cut plane relative to each segment and define the locations of the anthropometric and anatomical landmarks in three dimensions. The user should not be misled into utilizing these data as if they were collected on living 3- and 6-year-old children. These data remain to be collected.

Number Code of Surface Landmarks for Three-Dimensional-Point Locations

1. Sagittal Proximal Tick Mark: A point that lies in the midsagittal or parasagittal plane at the proximal cut plane intersect with the anterior skin surface.

2. Medial Proximal Tick Mark: A point at the proximal cut plane intersect with the medial skin surface.

3. Lateral Proximal Tick Mark: A point at the proximal cut plane intersect with the lateral skin surface.

4. Sagittal Distal Tick Mark: A point that lies in the midsagittal or parasagittal plane at the distal cut plane intersect with the anterior skin surface.

5. Medial Distal Tick Mark: A point at the distal cut plane intersect with the medial skin surface.

6. Lateral Distal Tick Mark: A point at the distal cut plane intersect with the lateral skin surface.

7. Anterior Center of Mass: Considering the body in a standing position, a point that defines the location of the center of mass on the anterior surface of the skin, in the sagittal or parasagittal plane, of each segment. This point is located on the dorsal surface of the foot and in the frontal area of the head.

8. Posterior Center of Mass: Considering the body in a standing position, a point that defines the center of mass location on the posterior surface of the skin, in the sagittal or parasagittal plane, of each segment. This point is located on the plantar surface of the foot and in the inferior occipital area of the head.

9. Lateral Center of Mass: A point that defines the location of the center of mass on the lateral surface of the skin in a plane approximately perpendicular to the sagittal plane.

10. Medial Center of Mass: A point that defines the location of the center of mass on the medial surface of the skin in a plane approximately perpendicular to the sagittal plane.

11. Proximal Centroid: A point that defines the approximate center of the proximal cut plane surface.

12. Distal Centroid: A point that defines the approximate center of the distal cut plane surface.

13. CN1: A point (tick mark) that defines the cut plane at the chin/neck separation.

14. CN2: Same as CN1.

15. CN3: Same as CN1.

16. F4: A point (tick mark) that defines the cut plane at the occiput/neck separation paprallel to the Frankfort Plane.

17. F5: Same as F4.

18. F6: Same as F4.

19. A7: A point (tick mark) that defines the intersection of the two cut planes separating the head and neck.

20. A8: Same as A7.

21. Right Tragion: See Landmark Definitions, Appendix A.

22. Left Tragion: See Landmark Definitions, Appendix A.

23. Right Ectocanthus: See Landmark Definitions Appendix A.

24. Left Ectocanthus: See Landmark Definitions, Appendix A.

25. Glabella: See Landmark Definitions, Appendix A.

26. Menton: See Landmark Definitions, Appendix A.

27. Suprasternale: See Landmark Definitions, Appendix A.

28. Cervicale: See Landmark Definitions, Appendix A.

29. Right Acromion: See Landmark Definitions, Appendix A.

30. Left Acromion: See Landmark Definitions, Appendix A.

31. Right Shoulder Sagittal Tick Mark: A point on the right shoulder separation plane corresponding to the sagittal proximal tick mark on the upper arm.

32. Right Axilla Anterior: See Landmark Definitions, Appendix A.

33. Left Axilla Anterior: See Landmark Definitions, Appendix A.

34. Right Axilla Posterior: See Landmark Definitions, Appendix A.

35. Left Axilla Posterior: See Landmark Definitions, Appendix A.

36. Right Shoulder Centroid: A point that defines the appropriate center of the right shoulder segmentation cut plane on the upper torso.

37. Left Shoulder Centroid: A point that defines the appropriate center of the right shoulder segmentation cut plane on the upper torso.

38. Right Nipple: A point used in measurements 14, 15, and 16.

39. Left Nipple: A point used in measurements 14, 15, and 16.

40. Substernale: See Landmark Definitions, Appendix A.

41. Omphalion: A point that defines the location on the living of umbilicus.

42. Right Anterior Superior Iliac Spine: See Landmark Definitions, Appendix A.

43. Left Anterior Superior Iliac Spine: See Landmark Definitions, Appendix A.

44. Right Iliocristale: See Landmark Definitions, Appendix A.

45. Left Iliocristale: See Landmark Definitions, Appendix A.

46. Right Trochanterion: See Landmark Definitions, Appendix A.

47. Left Trochanterion: See Landmark Definitions, Appendix A.

48. Right Midbiceps: A point on the lateral surface of the upper arm that defines the level of upper arm circumference (measurement 66).

49. Right Thumb Tip: A point on the right thumb that defines the most anterior point.

50. Right Knee Point: A point on the superior surface of the right knee that defines the location of knee height (measurement 44).

51. Right Lateral Knee Point: A point on the lateral surface of the right knee that defines the location of knee breadth (measurement 47).

52. Right Midcalf: A point on the lateral surface of the calf that defines the level of lower leg circumference, maximum (measurement 50).

53. Right Sphyrion: See Landmark Definitions, Appendix A.

54. Right Minimum Ankle: A point on the lateral surface of the lower leg that defines the level of the minimum circumference and other measurements (54, 55, 56, and 57).

TABLE B-1. Three-Dimensional-Point Locations of 3-Year-Old-Child Head Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
7	+ 5.6	+ 2.2	+ 0.8	+ 0.3	+ 6.1	+ 2.4
8	- 5.3	- 2.1	- 0.8	- 0.3	- 5.6	- 2.2
9, left	- 0.8	- 0.3	+ 6.4	+ 2.5	0.0	0.0
9, right	+ 0.8	+ 0.3	- 6.4	- 2.5	0.0	0.0
11	- 1.0	- 0.4	- 0.3	- 0.1	- 5.6	- 2.2
13, right	+ 2.5	+ 1.0	- 3.6	- 1.4	- 8.1	- 3.2
14, mid-sagittal	+ 3.6	+ 1.4	0.0	0.0	- 9.9	- 3.9
15, left	+ 1.8	+ 0.7	+ 4.3	+ 1.7	- 7.6	- 3.0
16, left	- 3.3	- 1.3	+ 6.9	+ 2.7	- 5.6	- 2.2
17, mid-sagittal	- 6.9	- 2.7	0.0	0.0	- 5.6	- 2.2
18, right	- 4.8	- 1.9	- 4.1	- 1.6	- 5.6	- 2.2
19, left	+ 0.3	+ 0.1	+ 4.8	+ 1.9	- 5.6	- 2.2
20, right	+ 0.5	+ 0.2	- 4.6	- 1.8	- 5.6	- 2.2
21	0.0	0.0	- 5.6	- 2.2	- 3.3	- 1.3
22	- 0.5	- 0.2	+ 5.8	+ 2.3	- 3.3	- 1.3
23	+ 7.6	+ 3.0	- 3.0	- 1.2	- 2.8	- 1.1
24	+ 7.1	+ 2.8	+ 4.1	+ 1.6	- 2.5	- 1.0
25	+ 8.6	+ 3.4	0.0	0.0	- 0.5	- 0.2
26	+ 7.6	+ 3.0	0.0	0.0	- 9.4	- 3.7

TABLE B-2. Three-Dimensional-Point Locations of 6-Year-Old-Child Head Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
7	+ 6.1	+ 2.4	- 0.3	- 0.1	+ 5.1	+ 2.0
8	- 6.1	- 2.4	+ 0.3	+ 0.1	- 6.4	- 2.5
9, left	+ 0.3	+ 0.1	+ 6.6	+ 2.6	- 0.5	- 0.2
9, right	- 0.3	- 0.1	- 6.9	- 2.7	+ 0.5	+ 0.2
11	- 0.3	- 0.1	+ 0.3	+ 0.1	- 6.4	- 2.5
13, right	+ 2.5	+ 1.0	- 3.6	- 1.4	- 1.8	- 0.7
14, mid-sagittal	+ 4.3	+ 1.7	0.0	0.0	-10.7	- 4.2
15, left	+ 2.8	+ 1.1	+ 3.3	+ 1.3	- 9.4	- 3.7
16, left	- 4.1	- 1.6	+ 4.6	+ 1.8	- 6.4	- 2.5
17, mid-sagittal	- 7.6	- 3.0	- 0.3	- 0.1	- 6.4	- 2.5
18, right	- 5.1	- 2.0	- 4.1	- 1.6	- 6.4	- 2.5
19, left	+ 0.5	+ 0.2	+ 4.8	+ 1.9	- 6.4	- 2.5
20, right	+ 0.5	+ 0.2	- 4.6	- 1.8	- 6.4	- 2.5
21	+ 0.3	+ 0.1	- 5.8	- 2.3	- 3.0	- 1.2
22	+ 0.3	+ 0.1	+ 5.8	+ 2.3	- 3.0	- 1.2
23	+ 6.9	+ 2.7	- 4.6	- 1.8	- 2.3	- 0.9
24	+ 7.1	+ 2.8	+ 3.6	+ 1.4	- 2.3	- 0.9
25	+ 8.1	+ 3.2	- 0.3	- 0.1	+ 0.3	+ 0.1
26	+ 7.6	+ 3.0	- 0.5	- 0.2	-10.4	- 4.1

TABLE B-3. Three-Dimensional-Point Locations of 3-Year-Old-Child Neck Landmarks

Number Code of Surface Landmarks	X Axis		Y Axis		Z Axis	
	cm	in	cm	in	cm	in
1	+ 3.0	+ 1.2	+ 0.5	+ 0.2	- 4.1	- 1.6
5	- 1.0	- 0.4	- 4.6	- 1.8	- 2.8	- 1.1
6	- 1.5	- 0.6	+ 4.8	+ 1.9	- 2.0	- 0.8
7	+ 2.8	+ 1.1	+ 0.5	+ 0.2	- 2.0	- 0.8
8	- 3.3	- 1.3	- 0.5	- 0.2	+ 2.3	+ 0.9
9, left	- 0.3	- 0.1	+ 3.8	+ 1.5	+ 0.3	+ 0.1
9, right	+ 0.3	+ 0.1	- 3.0	- 1.2	- 0.3	- 0.1
11	- 0.3	- 0.1	+ 0.5	+ 0.2	- 2.8	- 1.1
12	+ 1.3	+ 0.5	+ 0.5	+ 0.2	+ 2.3	+ 0.9
13, right	+ 3.3	+ 1.3	+ 5.1	+ 2.0	+ 1.3	+ 0.5
14, mid-sagittal	+ 5.3	+ 2.1	+ 0.8	+ 0.3	- 1.3	- 0.5
15, left	+ 4.1	+ 1.6	- 3.0	- 1.2	+ 0.8	+ 0.3
16, left	- 2.8	- 1.1	- 4.1	- 1.6	+ 2.3	+ 0.9
17, mid-sagittal	- 5.1	- 2.0	+ 0.3	+ 0.1	+ 2.3	+ 0.9
18, right	- 1.3	- 0.5	+ 4.8	+ 1.9	+ 2.3	+ 0.9
19, left	+ 1.5	+ 0.6	+ 5.6	+ 2.2	+ 2.3	+ 0.9
20, right	+ 2.3	+ 0.9	- 4.3	- 1.7	+ 2.3	+ 0.9
27	+ 3.0	+ 1.2	+ 0.5	+ 0.2	- 4.1	- 1.6
28	- 4.6	- 1.6	+ 0.5	+ 0.2	- 1.3	- 0.5

TABLE B-4. Three-Dimensional-Point Locations of 6-Year-Old-Child Neck Landmarks

Number Code of Surface Landmarks	X Axis		Y Axis		Z Axis	
	cm	in	cm	in	cm	in
1	+ 3.6	+ 1.4	+ 0.3	+ 0.1	- 4.8	- 1.9
5	- 1.0	- 0.4	- 5.1	- 2.0	- 2.8	- 1.1
6	0.0	0.0	+ 5.1	+ 2.0	- 2.8	- 1.1
7	+ 3.8	+ 1.5	+ 0.3	+ 0.1	- 1.3	- 0.5
8	- 5.6	- 2.2	- 0.3	- 0.1	+ 1.8	+ 0.7
9, left	+ 0.3	+ 0.1	+ 4.6	+ 1.8	+ 0.5	+ 0.2
9, right	- 0.3	- 0.1	- 4.3	- 1.7	- 0.5	- 0.2
11	0.0	0.0	+ 0.5	+ 0.2	- 3.0	- 1.2
12	+ 0.8	+ 0.3	- 0.3	- 0.1	+ 2.3	+ 0.9
13, right	+ 4.1	+ 1.6	+ 3.6	+ 1.4	- 0.3	- 0.1
14, mid-sagittal	+ 4.6	+ 1.8	0.0	0.0	- 1.8	- 0.7
15, left	+ 3.3	+ 1.3	- 3.8	- 1.5	- 0.3	- 0.1
16, left	- 3.8	- 1.5	- 3.8	- 1.5	+ 2.5	+ 1.0
17, mid-sagittal	- 6.1	- 2.4	+ 0.3	+ 0.1	+ 2.5	+ 1.0
18, right	- 2.3	- 0.9	- 4.8	- 1.9	+ 2.5	+ 1.0
19, left	+ 1.5	+ 0.6	+ 4.8	+ 1.9	+ 2.5	+ 1.0
20, right	+ 1.0	+ 0.4	- 4.8	- 1.9	+ 2.5	+ 1.0
27	+ 3.6	+ 1.4	+ 0.3	+ 0.1	- 4.8	- 1.9
28	- 4.3	- 1.7	+ 0.3	+ 0.1	- 1.5	- 0.6

TABLE B-5. Three-Dimensional-Point Locations of 3-Year-Old-Child Upper Torso Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	+10.4	+ 4.1	0.0	0.0	- 8.9	- 3.5
3, left	+ 0.5	+ 0.2	+ 7.1	+ 2.8	- 8.9	- 3.5
3, right	- 0.3	- 0.1	- 7.9	- 3.1	- 9.4	- 3.7
4	+ 4.6	+ 1.8	0.0	0.0	+ 8.1	+ 3.2
6, left	- 0.3	- 0.1	+ 4.3	+ 1.7	+10.9	+ 4.3
6, right	0.0	0.0	- 5.3	- 2.1	+10.2	+ 4.0
7	+ 6.6	+ 2.6	+ 0.3	+ 0.1	+ 0.5	+ 0.2
8	- 6.1	- 2.4	- 0.3	- 0.1	- 0.8	- 0.3
9, left	- 0.3	- 0.1	+ 8.4	+ 3.3	- 0.3	- 0.1
9, right	+ 1.0	+ 0.4	- 8.9	- 3.5	+ 0.3	+ 0.1
11	+ 1.8	+ 0.7	+ 0.3	+ 0.1	- 9.1	- 3.6
12	+ 0.5	+ 0.2	- 0.3	- 0.1	+10.2	+ 4.0
27	+ 4.6	+ 1.8	0.0	0.0	+ 8.1	+ 3.2
28	- 3.3	- 1.3	0.0	0.0	+11.9	+ 4.7
29	- 1.0	- 0.4	-10.9	- 4.3	+ 7.9	+ 3.1
30	- 1.5	- 0.6	+10.7	+ 4.2	+ 8.1	+ 3.2
31	+ 2.0	+ 0.8	-10.2	- 4.0	+ 6.1	+ 2.4
32	+ 5.6	+ 2.2	- 8.4	- 3.3	+ 3.6	+ 1.4
33	+ 3.0	+ 1.2	+ 8.9	+ 3.5	+ 3.0	+ 1.2
34	- 5.1	- 2.0	- 8.6	- 3.4	+ 3.3	+ 1.3
35	- 4.8	- 1.9	+ 8.6	+ 3.4	+ 3.3	+ 1.3
36	- 1.0	- 0.4	- 9.7	- 3.8	+ 5.3	+ 2.1
37	- 1.3	- 0.5	+ 9.7	+ 3.8	+ 5.1	+ 2.0
38	+ 5.8	+ 2.3	- 5.3	- 2.1	+ 0.8	+ 0.3
39	+ 6.1	+ 2.4	+ 5.3	+ 2.1	+ 1.0	+ 0.4
40	+ 7.1	+ 2.8	0.0	0.0	- 1.3	- 0.5

TABLE B-6. Three-Dimensional-Point Locations of 6-Year-Old-Child Upper Torso Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	+10.2	+ 4.0	0.0	0.0	-10.9	- 4.3
3, left	0.0	0.0	+ 9.1	+ 3.6	-11.4	- 4.5
3, right	+ 0.8	+ 0.3	- 9.9	- 3.9	-10.7	- 4.2
4	+ 4.8	+ 1.9	+ 0.3	+ 0.1	+ 9.7	+ 3.8
6, left	+ 0.8	+ 0.3	+ 4.6	+ 1.8	+12.2	+ 4.8
6, right	+ 0.5	+ 0.2	- 5.8	- 2.3	+12.2	+ 4.8
7	+ 7.4	+ 2.9	0.0	0.0	0.0	0.0
8	- 6.9	- 2.7	0.0	0.0	0.0	0.0
9, left	- 0.3	- 0.1	+ 9.9	+ 3.9	+ 0.3	+ 0.1
9, right	+ 0.3	+ 0.1	-10.2	- 4.0	- 0.3	- 0.1
11	+ 1.0	+ 0.4	0.0	0.0	-10.9	- 4.3
12	+ 1.0	+ 0.4	0.0	0.0	+12.2	+ 4.8
27	+ 4.8	+ 1.9	+ 0.3	+ 0.1	+ 9.7	+ 3.8
28	- 3.0	- 1.2	- 0.8	- 0.3	+14.2	+ 5.6
29	0.0	0.0	-12.2	- 4.8	+ 9.4	+ 3.7
30	+ 0.3	+ 0.1	+12.7	+ 5.0	+ 8.6	+ 3.4
31	+ 3.8	+ 1.5	-11.7	- 4.6	+ 7.4	+ 2.9
32	+ 4.3	+ 1.7	-10.4	- 4.1	+ 4.3	+ 1.7
33	+ 4.3	+ 1.7	+10.2	+ 4.0	+ 3.6	+ 1.4
34	- 4.6	- 1.8	-10.7	- 4.2	+ 4.1	+ 1.6
35	- 5.1	- 2.0	+ 9.7	+ 3.8	+ 3.8	+ 1.5
36	- 0.3	- 0.1	-11.2	- 4.4	+ 5.8	+ 2.3
37	0.0	0.0	+10.9	+ 4.3	+ 5.6	+ 2.2
38	+ 7.4	+ 2.9	- 5.6	- 2.2	+ 0.5	+ 0.2
39	+ 7.4	+ 2.9	+ 5.1	+ 2.0	+ 0.5	+ 0.2
40	+ 7.6	+ 3.0	0.0	0.0	- 3.8	- 1.5

TABLE B-7. Three-Dimensional-Point Locations of 3-Year-Old-Child Lower Torso Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	+ 9.7	+ 3.8	0.0	0.0	+ 6.6	+ 2.6
3, left	- 0.8	- 0.3	+ 6.9	+ 2.7	+ 6.9	+ 2.7
3, right	- 1.3	- 0.5	- 7.9	- 3.1	+ 5.8	+ 2.3
4	+ 8.4	+ 3.3	0.0	0.0	- 0.8	- 0.3
6, left	+ 1.3	+ 0.5	+10.2	+ 4.0	- 5.1	- 2.0
6, right	+ 0.8	+ 0.3	-10.2	- 4.0	- 6.1	- 2.4
7	+ 8.6	+ 3.4	0.0	0.0	+ 0.8	+ 0.3
8	- 6.4	- 2.5	0.0	0.0	- 0.5	- 0.2
9, left	- 0.8	- 0.3	+ 8.6	+ 3.4	+ 0.3	+ 0.1
9, right	+ 0.5	+ 0.2	- 8.9	- 3.5	- 0.3	- 0.1
11	+ 0.8	+ 0.3	- 0.3	- 0.1	+ 6.6	+ 2.6
12	+ 1.0	+ 0.4	- 0.5	- 0.2	- 5.3	- 2.1
42	+ 6.4	+ 2.5	- 6.9	- 2.7	+ 1.0	+ 0.4
43	+ 6.4	+ 2.5	+ 6.4	+ 2.5	+ 1.8	+ 0.7
44	- 0.3	- 0.1	- 8.6	- 3.4	+ 2.0	+ 0.8
45	+ 0.8	+ 0.3	+ 7.9	+ 3.1	+ 2.8	+ 1.1
46	+ 0.8	+ 0.3	-10.2	- 4.0	- 6.1	- 2.4
47	+ 1.3	+ 0.5	+10.2	+ 4.0	- 5.1	- 2.0

TABLE B-8. Three-Dimensional-Point Locations of 6-Year-Old-Child Lower Torso Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	+ 9.4	+ 3.7	0.0	0.0	+ 8.6	+ 3.4
3, left	- 0.5	- 0.2	+ 9.4	+ 3.7	+ 8.1	+ 3.2
3, right	+ 0.3	+ 0.1	- 9.4	- 3.7	+ 8.1	+ 3.2
4	+ 9.1	+ 3.6	0.0	0.0	+ 1.5	+ 0.6
6, left	+ 2.5	+ 1.0	+11.7	+ 4.6	- 4.6	- 1.8
6, right	+ 2.8	+ 1.1	-11.2	- 4.4	- 5.8	- 2.3
7	+ 9.1	+ 3.6	0.0	0.0	+ 1.5	+ 0.6
8	- 6.9	- 2.7	0.0	0.0	- 0.8	- 0.3
9, left	0.0	0.0	+10.7	+ 4.2	- 0.3	- 0.1
9, right	- 0.3	- 0.1	-10.4	- 4.1	+ 0.5	+ 0.2
11	+ 1.0	+ 0.4	- 0.3	- 0.1	+ 8.4	+ 3.3
12	+ 2.3	+ 0.9	0.0	0.0	- 5.6	- 2.2
42	+ 6.1	+ 2.4	- 6.6	- 2.6	+ 1.0	+ 0.4
43	+ 5.8	+ 2.3	+ 7.9	+ 3.1	+ 1.3	+ 0.5
44	+ 0.3	+ 0.1	- 9.9	- 3.9	+ 6.9	+ 2.7
45	- 0.3	- 0.1	+ 9.7	+ 3.8	+ 4.8	+ 1.9
46	+ 2.8	+ 1.1	-11.2	- 4.4	- 5.8	- 2.3
47	+ 2.5	+ 1.0	+11.7	+ 4.6	- 4.6	- 1.8

TABLE B-9. Three-Dimensional-Point Locations of 3-Year-Old-Child Upper Arm Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	+ 0.5	+ 0.2	+ 3.3	+ 1.3	+ 6.6	+ 2.6
2	+ 2.3	+ 0.9	+ 3.8	+ 1.5	+ 4.1	+ 1.6
3	- 1.3	- 0.5	+ 0.3	+ 0.1	+ 8.4	+ 3.3
4	+ 0.5	+ 0.2	+ 2.8	+ 1.1	- 4.8	- 1.9
5	+ 2.8	+ 1.1	+ 0.3	+ 0.1	- 6.6	- 2.6
6	- 1.5	- 0.6	- 0.5	- 0.2	- 8.4	- 3.3
7	+ 0.5	+ 0.2	+ 3.3	+ 1.3	0.0	0.0
8	- 0.5	- 0.2	- 2.8	- 1.1	0.0	0.0
9	- 2.5	- 1.0	+ 0.3	+ 0.1	- 0.3	- 0.1
10	+ 2.0	+ 0.8	- 0.3	- 0.1	+ 0.3	+ 0.1
11	+ 0.8	+ 0.3	0.0	0.0	+ 5.8	+ 2.3
12	+ 0.8	+ 0.3	+ 0.3	+ 0.1	- 6.9	- 2.7
29	- 1.3	- 0.5	+ 0.3	+ 0.1	+ 8.4	+ 3.3
32	+ 2.3	+ 0.9	+ 3.8	+ 1.5	+ 4.1	+ 1.6
34	- 0.8	- 0.3	- 2.5	- 1.0	+ 6.7	+ 2.7
48	- 2.5	- 1.0	+ 0.3	+ 0.1	- 0.3	- 0.1

TABLE B-10. Three-Dimensional-Point Locations of 6-Year-Old-Child Upper Arm Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	- 2.5	- 1.0	+ 3.0	+ 1.2	+ 9.1	+ 3.6
2	+ 1.3	+ 0.5	+ 4.1	+ 1.6	+ 6.6	+ 2.6
3	- 1.5	- 0.6	- 0.8	- 0.3	+11.2	+ 4.4
4	- 0.3	- 0.1	+ 3.8	+ 1.5	- 6.1	- 2.4
5	+ 2.5	+ 1.0	+ 1.5	+ 0.6	- 7.9	- 3.1
6	- 2.0	- 0.8	0.0	0.0	- 9.4	- 3.7
7	- 0.5	- 0.2	+ 4.1	+ 1.6	- 0.3	- 0.1
8	+ 0.3	+ 0.1	- 3.6	- 1.4	+ 0.3	+ 0.1
9	- 2.5	- 1.0	0.0	0.0	0.0	0.0
10	+ 2.3	+ 0.9	0.0	0.0	0.0	0.0
11	+ 0.3	+ 0.1	- 0.3	- 0.1	+ 7.6	+ 3.0
12	+ 0.5	+ 0.2	+ 0.8	+ 0.3	- 8.6	- 3.4
29	- 1.5	- 0.6	- 0.8	- 0.3	+11.2	+ 4.4
32	+ 1.3	+ 0.5	+ 4.1	+ 1.6	+ 6.6	+ 2.6
34	+ 1.3	+ 0.5	- 4.8	- 1.9	+ 6.1	+ 2.4
48	- 2.5	- 1.0	0.0	0.0	- 1.5	- 0.6

TABLE B-11. Three-Dimensional-Point Locations of 3-Year-Old-Child Lower Arm Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	- 2.8	- 1.1	0.0	0.0	+ 3.0	+ 1.2
2	- 4.8	- 1.9	+ 2.3	+ 0.9	+ 1.5	+ 0.6
3	- 6.4	- 2.5	- 2.0	- 0.8	- 0.3	- 0.1
4	+ 6.4	+ 2.5	0.0	0.0	+ 2.5	+ 1.0
5	+ 6.4	+ 2.5	+ 1.3	+ 0.5	+ 0.3	+ 0.1
6	+ 6.9	+ 2.7	- 1.3	- 0.5	0.0	0.0
7	0.0	0.0	- 0.3	- 0.1	+ 3.0	+ 1.2
8	0.0	0.0	+ 0.3	+ 0.1	- 2.3	- 0.9
9	0.0	0.0	- 2.5	- 1.0	- 0.3	- 0.1
10	0.0	0.0	+ 2.3	+ 0.9	+ 0.3	+ 0.1
11	- 5.1	- 2.0	+ 0.3	+ 0.1	+ 1.0	+ 0.4
12	+ 6.6	+ 2.6	0.0	0.0	+ 0.3	+ 0.1

TABLE B-12. Three-Dimensional-Point Locations of 6-Year-Old-Child Lower Arm Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	- 2.5	- 1.0	0.0	0.0	+ 3.6	+ 1.4
2	- 5.3	- 2.1	+ 2.5	+ 1.0	+ 1.3	+ 0.5
3	- 6.1	- 2.4	- 2.3	- 0.9	0.0	0.0
4	+ 8.4	+ 3.3	0.0	0.0	+ 2.3	+ 0.9
5	+ 8.1	+ 3.2	+ 1.8	+ 0.7	- 0.3	- 0.1
6	+ 8.4	+ 3.3	- 1.0	- 0.4	- 1.5	- 0.6
7	+ 0.3	+ 0.1	0.0	0.0	+ 3.3	+ 1.3
8	- 0.3	- 0.1	0.0	0.0	- 2.8	- 1.1
9	0.0	0.0	- 2.5	- 1.0	- 0.5	- 0.2
10	0.0	0.0	+ 2.5	+ 1.0	+ 0.5	+ 0.1
11	- 5.6	- 2.2	+ 0.3	+ 0.1	+ 0.5	+ 0.1
12	+ 8.1	+ 3.2	+ 0.5	+ 0.2	0.0	0.0

TABLE B-13. Three-Dimensional-Point Locations of 3-Year-Old-Child Hand Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	- 4.3	- 1.7	+ 0.3	+ 0.1	+ 2.3	+ 0.9
2	- 4.3	- 1.7	+ 1.3	+ 0.5	0.0	0.0
3	- 4.3	- 1.7	- 1.3	- 0.5	0.0	0.0
7	+ 0.3	+ 0.1	+ 0.3	+ 0.1	+ 3.8	+ 1.5
8	- 0.3	- 0.1	- 0.5	- 0.2	- 3.3	- 1.3
9	+ 0.5	+ 0.2	- 1.5	- 0.6	+ 0.3	+ 0.1
10	- 0.3	- 0.1	+ 0.5	+ 0.2	- 0.3	- 0.1
11	- 4.3	- 1.7	- 0.3	- 0.1	0.0	0.0
49	+ 2.5	+ 1.0	+ 0.3	+ 0.1	+ 3.0	+ 1.2

TABLE B-14. Three-Dimensional-Point Locations of 6-Year-Old-Child Hand Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	- 5.6	- 2.2	+ 0.3	+ 0.1	+ 2.0	+ 0.8
2	- 5.6	- 2.2	+ 1.8	+ 0.7	- 1.0	- 0.4
3	- 5.6	- 2.2	- 1.3	- 0.5	- 1.8	- 0.7
7	- 0.3	- 0.1	+ 0.3	+ 0.1	+ 3.3	+ 1.3
8	+ 0.3	+ 0.1	- 0.3	- 0.1	- 3.6	- 1.4
9	0.0	0.0	- 1.8	- 0.7	0.0	0.0
10	0.0	0.0	+ 0.8	+ 0.3	0.0	0.0
11	- 5.8	- 2.3	0.0	0.0	- 0.3	- 0.1
49	+ 3.0	+ 1.2	+ 0.3	+ 0.1	+ 2.8	+ 1.1

TABLE B-15. Three-Dimensional-Point Locations of 3-Year-Old-Child Upper Leg Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	- 2.5	- 1.0	+ 0.3	+ 0.1	+ 4.8	+ 1.9
3	- 8.9	- 3.5	- 5.1	- 2.0	+ 1.3	+ 0.5
4	+16.5	+ 6.5	+ 0.3	+ 0.1	+ 2.8	+ 1.1
5	+13.2	+ 5.2	+ 3.0	+ 1.2	- 0.5	- 0.2
6	+12.7	+ 5.0	- 3.3	- 1.3	- 1.0	- 0.4
7	+ 0.3	+ 0.1	0.0	0.0	+ 4.6	+ 1.8
8	- 0.3	- 0.1	0.0	0.0	- 3.3	- 1.3
9	0.0	0.0	- 4.8	- 1.9	+ 0.8	+ 0.3
10	0.0	0.0	+ 4.3	+ 1.7	- 0.8	- 0.3
11	- 9.1	- 3.6	0.0	0.0	+ 1.3	+ 0.5
12	+13.0	+ 5.1	0.0	0.0	- 0.5	- 0.2
46	- 8.9	- 3.5	- 5.1	- 2.0	+ 1.3	+ 0.5
50	+15.0	+ 5.9	+ 0.3	+ 0.1	+ 4.1	+ 1.6

TABLE B-16. Three-Dimensional-Point Locations of 6-Year-Old-Child Upper Leg Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	- 5.6	- 2.2	+ 0.3	+ 0.1	+ 5.8	+ 2.3
3	-10.2	- 4.0	- 5.3	- 2.1	+ 1.0	+ 0.4
4	+17.5	+ 6.9	+ 0.3	+ 0.1	+ 1.8	+ 0.7
5	+13.5	+ 5.3	+ 6.6	+ 2.6	- 2.3	- 0.9
6	+13.7	+ 5.4	- 3.3	- 1.3	- 2.5	- 1.0
7	+ 0.3	+ 0.1	- 0.3	- 0.1	+ 5.1	+ 2.0
8	- 0.3	- 0.1	+ 0.3	+ 0.1	- 4.6	- 1.8
9	0.0	0.0	- 4.8	- 1.9	0.0	0.0
10	0.0	0.0	+ 5.1	+ 2.0	0.0	0.0
11	-10.4	- 4.1	- 0.5	- 0.2	+ 1.3	+ 0.5
12	+14.5	+ 5.7	+ 0.3	+ 0.1	- 1.5	- 0.6
46	-10.2	- 4.0	- 5.3	- 2.1	+ 1.0	+ 0.4
50	+16.3	+ 6.4	+ 0.3	+ 0.1	+ 2.3	+ 0.9
51	+14.2	+ 5.6	- 3.8	- 1.5	- 1.3	- 0.5

TABLE B-17. Three-Dimensional-Point Locations of 3-Year-Old-Child Lower Leg Landmarks

Number Code of Surface Landmarks	X Axis		Y Axis		Z Axis	
	cm	in	cm	in	cm	in
1	+ 3.6	+ 1.4	+ 0.3	+ 0.1	+11.4	+ 4.5
2	0.0	0.0	+ 3.6	+ 1.4	+ 8.1	+ 3.2
3	0.0	0.0	- 2.8	- 1.1	+ 7.9	+ 3.1
4	+ 3.3	+ 1.3	+ 0.3	+ 0.1	-11.2	- 4.4
5	- 0.3	- 0.1	+ 2.3	+ 0.9	-11.7	- 4.6
6	+ 3.3	+ 1.3	- 2.3	- 0.9	-11.9	- 4.7
7	+ 3.0	+ 1.2	+ 0.3	+ 0.1	- 0.3	- 0.1
8	- 3.3	- 1.3	- 0.3	- 0.1	+ 0.3	+ 0.1
9	- 0.5	- 0.2	- 2.8	- 1.1	+ 0.3	+ 0.1
10	+ 0.5	+ 0.2	+ 2.8	+ 1.1	- 0.3	- 0.1
11	+ 0.3	+ 0.1	+ 0.3	+ 0.1	+ 7.9	+ 3.1
12	- 0.5	- 0.2	+ 0.3	+ 0.1	-11.7	- 4.6
53	- 0.3	- 0.1	+ 2.3	+ 0.9	-11.7	- 4.6

TABLE B-18. Three-Dimensional-Point Locations of 6-Year-Old-Child Lower Leg Landmarks

Number Code of Surface Landmarks	X Axis		Y Axis		Z Axis	
	cm	in	cm	in	cm	in
1	+ 3.0	+ 1.2	+ 0.3	+ 0.1	+15.2	+ 6.0
2	- 0.1	- 0.4	+ 3.6	+ 1.4	+10.9	+ 4.3
3	- 1.3	- 0.5	- 3.6	- 1.4	+11.2	+ 4.4
4	+ 4.6	+ 1.8	+ 0.3	+ 0.1	-15.5	- 6.1
5	+ 0.3	+ 0.1	+ 2.8	+ 1.1	-15.5	- 6.1
6	- 1.0	- 0.4	- 2.5	- 1.0	-16.3	- 6.4
7	+ 3.0	+ 1.2	- 0.3	- 0.1	+ 0.3	+ 0.1
8	- 4.3	- 1.7	+ 0.3	+ 0.1	- 0.3	- 0.1
9	- 1.0	- 0.4	- 4.1	- 1.6	- 0.8	- 0.3
10	+ 0.5	+ 0.2	+ 2.8	+ 1.1	+ 0.5	+ 0.2
11	- 0.5	- 0.2	0.0	0.0	+11.4	+ 4.5
12	0.0	0.0	+ 0.3	+ 0.1	-16.0	- 6.3
53	+ 0.3	+ 0.1	+ 2.8	+ 1.1	-15.5	- 6.1
54	- 1.0	- 0.4	- 2.0	- 0.8	-12.4	- 4.9

TABLE B-19. Three-Dimensional-Point Locations of 3-Year-Old-Child Foot Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	0.0	0.0	0.0	0.0	+ 2.8	+ 1.1
2	- 3.6	- 1.4	+ 2.3	+ 0.9	+ 2.3	+ 0.9
3	- 4.3	- 1.7	- 2.0	- 0.8	+ 2.0	+ 0.8
7	0.0	0.0	0.0	0.0	+ 2.8	+ 1.1
8	0.0	0.0	0.0	0.0	- 1.8	- 0.7
9	+ 0.3	+ 0.1	- 2.0	- 0.8	+ 0.8	+ 0.3
10	- 0.3	- 0.1	+ 1.5	+ 0.6	- 0.8	- 0.3
11	- 3.8	- 1.5	0.0	0.0	+ 2.3	+ 0.9
46	- 3.6	- 1.4	+ 2.3	+ 0.9	+ 2.3	+ 0.9

TABLE B-20. Three-Dimensional-Point Locations of 6-Year-Old-Child Foot Landmarks

Number Code of Surface Landmarks	X Axis cm	X Axis in	Y Axis cm	Y Axis in	Z Axis cm	Z Axis in
1	+ 1.3	+ 0.5	+ 0.3	+ 0.1	+ 2.8	+ 1.1
2	- 3.6	- 1.4	+ 2.8	+ 1.1	+ 2.5	+ 1.0
3	- 4.6	- 1.8	- 2.5	- 1.0	+ 2.0	+ 0.8
7	+ 0.5	+ 0.2	0.0	0.0	+ 2.8	+ 1.1
8	- 0.5	- 0.2	0.0	0.0	- 1.3	- 0.5
9	+ 0.3	+ 0.1	- 2.5	- 1.0	+ 0.5	+ 0.2
10	- 0.3	- 0.1	+ 2.3	+ 0.9	- 0.3	- 0.1
11	- 3.3	- 1.3	+ 0.3	+ 0.1	+ 2.5	+ 1.0
46	- 3.6	- 1.4	+ 2.8	+ 1.1	+ 2.5	+ 1.0

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