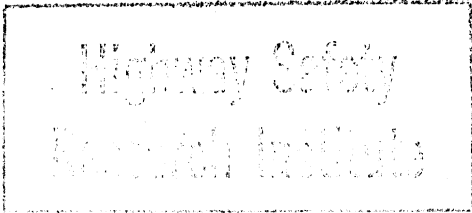


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16. Abstract  Mastermodel Body Forms were created to reflect the size and shape of the average three and six year old children. The mastermodels were erected on the basis of available U.S. population data and/or estimates interpolated from such data and on the basis of the collective judgment of a panel of experts in anthropometry. Ninety-eight dimensions were generated to describe the external morphology of the children. The description includes dimensions and definitions for each of the measurements as well as the associated landmark definitions. A bibliographical reference used for collation of child anthropometry and a list of other selected references are attached.  Attachment 		13. Type of Report and Period Covered September '74-April '75 Final Report	
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## FOREWORD

Rapid developments in the area of child restraint systems and the worldwide clamor to provide more effective protection for children in the automotive crash environment require the use of better and more accurate test tools to assess the value and effectiveness of such restraint systems. The National Highway Traffic Safety Administration has initiated a number of actions designed to improve child restraint test capability. One such study, titled "Anthropometry for Child Restraints," conducted by the Harvard University School of Public Health, Boston, Massachusetts, reviewed the available data and developed a preliminary definition of critical measurements, and established related measure methodology.

In a related activity, a compilation of anthropometric data, titled "Source Data of Infant and Child Measurements, 1972," was developed by R.G. Snyder, et al, of the University of Michigan. A review of 63 data sets within these two documents by Messrs. Backaitis and Radovich of the Office of Crashworthiness of NHTSA revealed a number of inconsistencies. It was determined that the data did not provide an adequate basis for establishing a reliable set of dimensions characterizing three and six year old children. This question was discussed further in July 1974 with Messrs. R. Chandler and J. Young of the Civil Aeromedical Institute of the FAA which has also a parallel need for such data.

As a result of these discussions, it was decided to enlist the help of recognized experts on child anthropometry to reconcile inconsistencies

in the data and to develop master models representing 50th percentile three and six year old children. This report describes the results of this joint NHTSA-FAA program.

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EVALUATION OF MASTERBODY FORMS FOR  
3-YEAR- AND 6-YEAR-OLD CHILD DUMMIES

Memorandum Report  
AAC-119-75-2

I. STATEMENT OF THE PROBLEM.

The Department of Transportation needs representative 3-year and 6-year child dummies to test child restraint systems for use in transportation vehicles. The dummies must therefore be based on anthropometric dimensions representative of the United States 3-year- and 6-year-old populations. These data could serve as standards for the surface morphology of the child dummies to be used in impact testing and for dimensioning child restraint systems.

The purpose of the present report is to:

- 1) Review the available anthropometric literature on 3-year- and 6-year-old children in the United States;
- 2) Present a list of measurements necessary for the construction of seated child manikins;
- 3) Provide dimensional guidance to construct clay masterbody forms.

II. DISCUSSION OF SOLUTION TO PROBLEM.

The panel collected for this task consisted of Mr. Joseph W. Young (Project Coordinator), Dr. John McConville, Dr. Herbert Reynolds and Dr. Richard Snyder. The following discussion is based upon their knowledge of the literature and their best, collected judgment when data were not available in the literature.

A. Review of the Literature.

There are no published studies to date that have measured on United States children the complete list of measurements determined by the panel to be

necessary for the construction of child manikins. The attached bibliography provides a list of the documents reviewed; all of which have limitations in their use.

Martin's<sup>9-11\*</sup> data are 20 years old and measured on fully clothed school children in southern Michigan. More recently, Stoudt's<sup>3</sup> compilation, which is the most complete, reports on 2.5-year- and 6.8-year-old children and had to be adjusted to conform with the 3-year and 6-year age dimensions for the masterbody forms. The data reported by Malina, et al.<sup>8</sup> are on a nationwide sample and do not include any data on 3-year-old children. Furthermore, they reported dimensions on 21 measurements which were selected primarily "... to define a normal pattern of growth and development in children in the United States in the middle 1960's...(p. 1)." Additional data from two recent studies conducted by the Public Health Service (National Health Survey) and the University of Michigan (HSRI) were not available, but neither of them would have provided the extensive list of dimensions required in the present effort. The other references are included in the "Source Data of Infant and Child Measurements, Interim Data, 1972"<sup>2</sup>.

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 bibliography. The data that do exist in the literature provided limited information on heights, breadths, circumferences and body proportions of 3-year- 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 a 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 for the additional data which the panel used as guidelines for estimating the desired dimensions.<sup>17</sup>

In summary, 30 dimensions in the list are based on data in the literature, whereas 68 dimensions are either estimated by the panel or based on adjusted values derived from limited personal data. The total list of 98 dimensions is an ideal anthropometric data set for describing the external morphology of a child manikin. The complete list with design dimensions and definitions is enclosed as Exhibit A.

#### B. Construction of the Clay Masterbody Forms

The construction of the clay masterbody forms followed a three-step process outlined in the following discussion.

1. A metal "skeleton" was constructed of cast iron pipe and pipe fittings. A wire-net skin was attached to provide a surface upon which modeling clay could be placed.
2. The general shape was built up with clay on the wire frame.
3. The dimensions in the list were then marked with pins and the masterbody forms were sculptured to meet the design values within  $\pm 2$  mm of the desired dimension value.

### III. EVALUATION OF THE RESULTS.

The masterbody forms are based on data discussed previously. They, however, have some limitations which are pointed out in the following discussion.

First, while many of the most critical dimensions are based upon 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 upon the collective judgment of the panel or from personal data. The data available in the literature often provided sound guidelines but in numerous instances these forms represent a judgment of a team of experts rather than empirically derived U. S. population data.

Second, these manikins and their associated anthropometric data base contain no information on the properties required for construction of the interior mechanisms of anthropometric test devices such as the location of joint centers of rotation, centers of mass, mass moments of inertia, joint range of motion or joint stiffness. These factors lie outside the scope of this effort and information in these areas is needed since there are no data in the literature on 3-year- and 6-year-old children.

In conclusion, every effort has been made by the panel of experts to provide the Department of Transportation with two clay masterbody forms based on the best available information and judgment. Succeeding research in this area, however, will provide a better data base and modifications to these existing forms may become necessary.



IV. EXHIBIT A

LIST OF ANTHROPOMETRIC DIMENSIONS

No.	Variable Name	Dimension 3 yr. old		Source	Dimension 6 yr. old		Source
		cm.	in.		cm.	in.	
1	Weight	33 lbs.		(18)	46 lbs.		(18)
2	Stature	96.5	38.0	(18)	116.3	46.0	(18)
3	Sitting Height	55.9	22.0	(1,2,3)	63.5	25.0	(1,2,3)
4	Eye Height	45.5	17.9	(18)	51.8	20.4	(18)
5	Tragion Height	45.0	17.7	(17,18)	51.3	20.2	(17,18)
6	Cervicale Height	38.3	15.1	(3,18)	44.2	17.4	(3,18)
7	Acromion Height	34.6	13.6	(3,18)	39.4	15.5	(3,18)
8	Biacromial Breadth	21.8	8.6	(2)	25.4	10.0	(2,8)
9	Suprasternale Height	35.2	13.9	(8,18)	40.1	15.8	(8,18)
10	Substernale Height	25.2	9.9	(8,18)	27.3	10.7	(8,18)
11	Torso Height, Axilla	29.9	11.8	(17)	34.0	13.4	(17)
12	Torso Breadth, Axilla	17.6	6.9	(17)	20.3	8.0	(17)
13	Torso Depth, Axilla	12.1	4.8	(17)	13.2	5.2	(17)
14	Torso Height, Nipple	27.2	10.7	(18)	31.0	12.2	(18)
15	Torso Breadth, Nipple	17.4	6.9	(18)	19.2	7.6	(18,8)
16	Torso Depth, Nipple	12.9	5.1	(3,13)	14.3	5.6	(3,8,13)
17	Torso Circumference, Nipple	51.0	20.1	(2)	59.4	23.4	(2,8)
18	Internipple Distance	11.4	4.5	(17,18)	11.4	4.5	(17,18)
19	Torso Depth, Substernale	12.2	4.8	(17,18)	14.3	5.6	(17)
20	Torso Height, 10th Rib	17.3	6.9	(17)	19.3	7.6	(17)
21	Torso Breadth at 10th Rib	15.2	6.0	(17)	19.5	7.7	(18)
22	Torso Height, Waist	15.5	6.1	(18)	17.5	6.9	(17)
23	Torso Breadth, Waist	16.1	6.3	(2,17)	19.4	7.6	(2,17)
24	Torso Depth, Waist	16.4	6.5	(18)	16.7	6.6	(17)

<u>No.</u>	<u>Variable</u> <u>Name</u>	<u>Dimension</u> <u>3 yr. old</u>			<u>Dimension</u> <u>6 yr. old</u>		
		<u>cm.</u>	<u>in.</u>	<u>Source</u>	<u>cm.</u>	<u>in.</u>	<u>Source</u>
25	Torso Circumference, Waist	52.7	20.7	(8)	57.2	22.5	(18,8)
26	Torso Height, Iliocristale	13.2	5.3	(3,17)	15.7	6.2	(3,17)
27	Torso Breadth, Iliocristale	16.5	6.5	(17,18)	19.8	7.8	(17,18,8)
28	Torso Depth, Iliocristale	15.8	6.2	(18)	16.6	6.5	(18)
29	Torso Circumference, Iliocristale	53.7	21.1	(18)	58.0	22.8	(18)
30	Anterior Superior Iliac Spine Height	11.9	4.7	(17)	12.4	4.9	(17)
31	Bispinous Breadth	13.7	5.4	(18)	15.0	5.9	(17)
32	Trochanterion Height	5.2	2.0	(17)	5.6	2.2	(17)
33	Torso Breadth, Trochanterion	20.8	8.2	(18)	23.5	9.3	(18)
34	Trochanterion-to-Seat Back Distance	7.5	3.0	(18)	9.1	3.6	(17)
35	Maximum Hip Breadth	20.2	8.0	(3,17)	23.1	9.1	(3,8,17)
36	Sitting Hip Circumference	59.2	23.3	(17)	68.0	26.8	(18)
37	Thigh-Abdominal Junction Height	8.0	3.1	(3,17)	10.2	4.0	(2,3,8,17)
38	Thigh-Abdominal Junction-to- Seat Back Distance	14.4	5.7	(17)	15.2	6.0	(17)
39	Thigh Circumference, Thigh- Abdominal Junction	28.4	11.2	(2,17)	34.5	13.6	(2,17)
40	Thigh Circumference, Popliteal	24.0	9.4	(17)	26.8	10.6	(17)
41	Thigh Depth, Popliteal	7.8	3.1	(17,18)	8.5	3.3	(11,17)
42	Buttock-Knee Length	34.4	13.5	(18)	38.1	15.0	(2,3,17,8)
43	Buttock-Popliteal Length	27.1	10.7	(18)	30.2	11.9	(18)
44	Knee Height	28.4	11.2	(3,17)	35.8	14.1	(2,3,17)

No.	Variable Name	Dimension 3 yr. old			Dimension 6 yr. old		
		cm.	in.	Source	cm.	in.	Source
44	Popliteal Height	20.6	8.1	(3,18)	27.7	10.9	(3,18,8)
45	Knee Circumference	25.8	10.2	(17,18)	26.6	10.5	(17,18)
47	Knee Breadth	6.6	2.6	(13,17)	7.5	3.0	(13,17,8)
48	Lower Leg Circumference, Popliteal	21.2	7.8	(17)	22.1	8.7	(17)
49	Lower Leg Depth, Popliteal	6.4	2.7	(17,18)	6.9	2.7	(17,18)
50	Lower Leg Circumference, Maximum	21.1	8.3	(2,3,17)	23.5	9.3	(2,3,17)
51	Lower Leg Height, Maximum Circumference	18.4	7.2	(17)	21.6	8.5	(17)
52	Lower Leg Depth, Maximum Circumference	6.8	2.7	(17)	7.6	3.0	(17)
53	Lower Leg Breadth, Maximum Circumference	6.3	2.5	(17)	7.4	2.9	(17)
54	Lower Leg Circumference, Minimum	14.9	5.9	(17,18)	16.1	6.3	(17,18,8)
55	Lower Leg Height, Minimum Circumference	6.2	2.4	(17)	7.1	2.8	(17)
56	Lower Leg Depth, Minimum Circumference	5.1	2.0	(17)	5.8	2.4	(17)
57	Lower Leg Breadth, Minimum Circumference	4.2	1.7	(17)	4.5	1.8	(17)
58	Ankle Breadth	4.7	1.9	(17,18)	5.7	2.2	(17,18)
59	Sphyrion Height	3.6	1.4	(17)	4.1	1.6	(17)
60	Foot Length	15.8	6.2	(3,17)	17.8	7.0	(2,3,8)
61	Foot Breadth	5.9	2.3	(3,17)	6.7	2.6	(2,3,8)
62	Heel Breadth	3.8	1.5	(17)	3.8	1.5	(17)
63	Shoulder-Elbow Length	18.5	7.3	(3,17)	23.4	9.2	(2,3,8)

<u>No.</u>	<u>Variable</u> <u>Name</u>	<u>Dimension</u> <u>3 yr. old</u>			<u>Dimension</u> <u>6 yr. old</u>		
		<u>cm.</u>	<u>in.</u>	<u>Source</u>	<u>cm.</u>	<u>in.</u>	<u>Source</u>
64	Upper Arm Circumference, Axilla	17.8	7.0	(17)	20.8	8.2	(17)
65	Upper Arm Depth, Axilla	7.1	2.8	(17)	7.8	3.1	(17)
66	Upper Arm Circumference, Mid-Arm	17.5	6.9	(2,3,17)	21.1	8.0	(2,3,17,8)
67	Upper Arm Depth, Mid-Arm	6.1	2.4	(17)	7.5	3.0	(17)
68	Upper Arm Circumference, Antecubital	16.8	6.6	(17)	19.2	7.6	(17)
69	Upper Arm Depth, Antecubital	5.9	2.3	(17)	6.9	2.7	(17)
70	Elbow Breadth	4.4	1.7	(17)	4.8	1.9	(17)
71	Elbow Circumference	18.5	7.2	(17)	21.4	8.5	(17)
72	Forearm-Hand Length	26.0	10.2	(3,17)	31.0	12.2	(2,3,17)
73	Forearm Circumference, Maximum	17.0	6.7	(3,17)	19.9	7.8	(3,17,8)
74	Forearm Depth, Maximum Circumference	5.1	2.0	(17)	6.4	2.5	(17)
75	Wrist Circumference Minimum	11.2	4.6	(2,3,17)	13.3	5.2	(3,17)
76	Wrist Depth	2.7	1.0	(17)	3.3	1.3	(17)
77	Wrist Breadth	4.0	1.6	(17)	4.8	1.9	(17)
78	Hand Length	11.4	4.5	(2,3)	13.4	5.3	(2,3,8)
79	Hand Breadth, Metacarpale III	5.3	2.1	(3,17)	6.1	2.4	(3,10,17)
80	Hand Depth, Metacarpale III	1.9	0.7	(17)	1.9	0.7	(17)
81	Palm Length	6.4	2.5	(17)	7.1	2.8	(17)
82	Head Length	17.9	7.0	(3,13,17)	18.1	7.1	(2,3,16,17)

<u>No.</u>	<u>Variable Name</u>	<u>Dimension 3 yr. old</u>			<u>Dimension 6 yr. old</u>		
		<u>cm.</u>	<u>in.</u>	<u>Source</u>	<u>cm.</u>	<u>in.</u>	<u>Source</u>
83	Head Breadth	13.5	5.3	(3,13,17)	14.1	5.6	(2,3,16,17)
84	Head Circumference	50.8	20.0	(2,3,17)	52.2	20.6	(3,10,17)
85	Tragion-to-Vertex Distance	11.0	4.3	(17,18)	12.2	4.8	(17,18)
86	Tragion-to-Wall Distance	9.0	3.5	(17,18)	9.8	3.9	(17,18)
87	Menton-to-Vertex Distance	17.5	6.9	(17)	20.4	8.0	(18)
88	Menton-to-Wall Distance	16.0	6.3	(17)	17.0	6.7	(17)
89	Glabella-to-Vertex Distance	8.5	3.4	(17)	9.2	3.6	(17)
90	Bitragion Breadth	10.7	4.2	(17)	11.7	4.6	(17,18)
91	Bitragion-Coronal Arc	31.7	12.5	(17,18)	32.9	13.0	(17,18)
92	Bitragion-Glabella Arc	25.6	10.1	(17,18)	24.2	9.5	(17,18)
93	Bitragion-Menton Arc	25.0	9.8	(17,18)	25.4	10.0	(17,18)
94	Bigonial Breadth	8.1	3.2	(17)	9.4	3.7	(16,17)
95	Neck Circumference	23.3	9.2	(3,17)	27.5	10.8	(2,3,17)
96	Neck Breadth	7.0	2.8	(17)	8.0	3.1	(17)
97	Neck Depth	6.7	2.6	(17,18)	8.0	3.5	(17,18)
98	Suprasternale-Cervicale Distance	8.2	3.2	(17)	8.7	3.4	(17)

## V. List of Measurement 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 a beam 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 a beam 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 a beam 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 a beam 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 a beam 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 a beam anthropometer the distance between the nipples.
- 19) Torso Depth, Substernale: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a beam 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 a beam 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 a beam 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 a beam 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 a beam 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, Iliocristale: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a beam anthropometer the horizontal breadth of the torso at Iliocristale level.
- 28) Torso Depth, Iliocristale: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a beam 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 a beam 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 a beam anthropometer the horizontal breadth of the torso at trochanterion.
- 34) Trochanterion-to-Seat Back Distance: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a beam 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 a beam 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 a beam 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 a beam anthropometer the perpendicular depth (supero-inferior) of the thigh 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 a beam 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, 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 foot-rest 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 foot-rest 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 a sliding caliper 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 foot-rest 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. Measure with a sliding caliper the horizontal depth at the level of the maximum circumference of the calf.
- 53) Lower Leg Breadth, Maximum 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 a sliding caliper 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 maleoli.
- 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 foot-rest 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 a sliding caliper 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 a sliding caliper the horizontal breadth at the level of the minimum circumference of the ankle.
- 58) Bimellar 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 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 foot-rest platform to sphyrion.

- 60) Foot Length: 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 sliding caliper 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 a sliding caliper 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 a sliding caliper the breadth of the heel across the superior portion of the calcaneus.
- 63) Shoulder-Elbow Length: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a beam 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 hands extended forward horizontally. Measure with a sliding caliper the horizontal (antero-posterior) 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. Measure with a flexible, steel tape, perpendicular to the long axis of the upper arm, the circumference of the arm mid-way between acromion and the olecranon process.
- 67) Upper Arm Depth, Mid-Arm: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a sliding caliper, the horizontal (antero-posterior) depth of the upper arm mid-way 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 a sliding caliper, the horizontal (antero-posterior) 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 a sliding caliper 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 a beam 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 a sliding caliper the vertical (supero-inferior) 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 Depth, Minimum Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a sliding caliper, the horizontal (medio-lateral) breadth of the forearm at the level of the minimum circumference of the wrist.
- 77) Wrist Breadth, Minimum Circumference: Subject sits erect, upper arms relaxed, forearms and hands extended forward horizontally. Measure with a sliding caliper the vertical (supero-inferior) 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 a sliding caliper 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 arm relaxed, forearms and hands extended forward horizontally. Measure with a sliding caliper 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 a spreading caliper 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 a sliding caliper, 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 spreading calipers the maximum antero-posterior length in the mid-sagittal plane from glabella to the back of the head on the occiput.
- 83) Head Breadth: Subject sits erect with head in the Frankfort Plane. Measure with a spreading caliper the maximum breadth of the head parallel to the mid-coronal 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) Trasion-to-Vertex Distance: Subject sits erect with head in the Frankfort Plane. Measure with a beam anthropometer the vertical distance from trasion to vertex.
- 86) Trasion-to-Wall Distance: Subject sits erect with head in the Frankfort Plane. Measure with a beam anthropometer, the horizontal distance from trasion 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 Plane. Measure with a beam anthropometer the vertical distance from menton to vertex.
- 88) Menton-to-Wall Distance: Subject sits erect with head in the Frankfort Plane. Measure with a beam 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 a beam anthropometer the vertical distance from glabella to vertex.

- 90) Bitragion Breadth: Subject sits erect with head in the Frankfort Plane. Measure with a spreading caliper, 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 Frankfort Plane. Measure with a spreading caliper the breadth between the right and left gonial angles of the mandible.
- 95) Neck Circumference: Subject sits erect with head in 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 a beam anthropometer the horizontal breadth of the middle of the neck.
- 97) Neck Depth: Subject sits erect with head in the Frankfort Plane. Measure with a beam anthropometer the horizontal (antero-posterior) depth of the middle of the neck.
- 98) Suprasternale-Cervicale Distance: Subject sits erect with head in the Frankfort Plane. Measure with a spreading caliper the distance from suprasternale to cervicale.

## VI. Landmark Definitions

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

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.

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.

Axilla - The armpit.

Calcaneus - The posterior bone in the heel of the foot.

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

Dactylion - The distal tip of the third digit.

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

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

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.

Glabella - The most anterior point on the forehead that lies between the brow ridges in the mid-sagittal plane.

Humeral Condyles - The most lateral and medial bony projections on the distal end of the humerus.

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

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

Menton - The most antero-inferior point on the chin in the mid-sagittal plane.

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

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

Olecranon Process - The proximal portion of the ulna which forms the bony projection in the posterior projection of the elbow.



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

Sphyrion - The distal tip of the tibia below the medial malleolus.

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

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

Tenth (10th) 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.

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

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

Trochanterion - The most lateral projection of the Greater Trochanter of the femur.

Vertex - The most superior point in the mid-sagittal plane on the head.

Waist - Level on the torso located mid-way between the 10th Rib and Iliocristale heights.

## VII. BIBLIOGRAPHY

The references cited here are those from which the anthropometric data for the three-year-old and six-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 one adjusted to the average stature and weight of a hypothetical three-year-old and six-year-old.

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