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DETERMINATION OF CENTERS OF GRAVITY OF CHILDREN, SITTING AND STANDING

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DETERMINATION OF CENTERS OF GRAVITY OF CHILDREN, SITTING AND STANDING

I. Introduction.

A search of the literature for data concerning the location of the center of gravity (cg) of the human body reveals that most researchers have concentrated on locating the cg of adult males and females in the standing position. A few isolated studies to determine the cg of the seated pilot and fully loaded ejection seat were made.[3,4,5] One comprehensive study of location of cg of the adult male in 21 different body positions is available.[6] The cg's of a few seated monkeys along with their seats have been made for orbital space shots.[7] Weinbach [8] found cg's of children standing through the analysis of volume contour maps and Basler[1] found cg's of children standing on a balance. The findings presented in this report furnish extensive data on location of cg's of children, both sitting and standing, for use in the design of effective restraint and flotation equipment.

II. Procedure and Discussion.

The balancing equipment used in this study has been described in detail [6] and will not be described here. Arrangements were made with the local School Board to bring in one class at a time for measurement and study. All classes from kindergarten to high-school seniors participated. Each child was first measured and weighed and then balanced in four positions on the cg machine (Figure 1). Measurements of

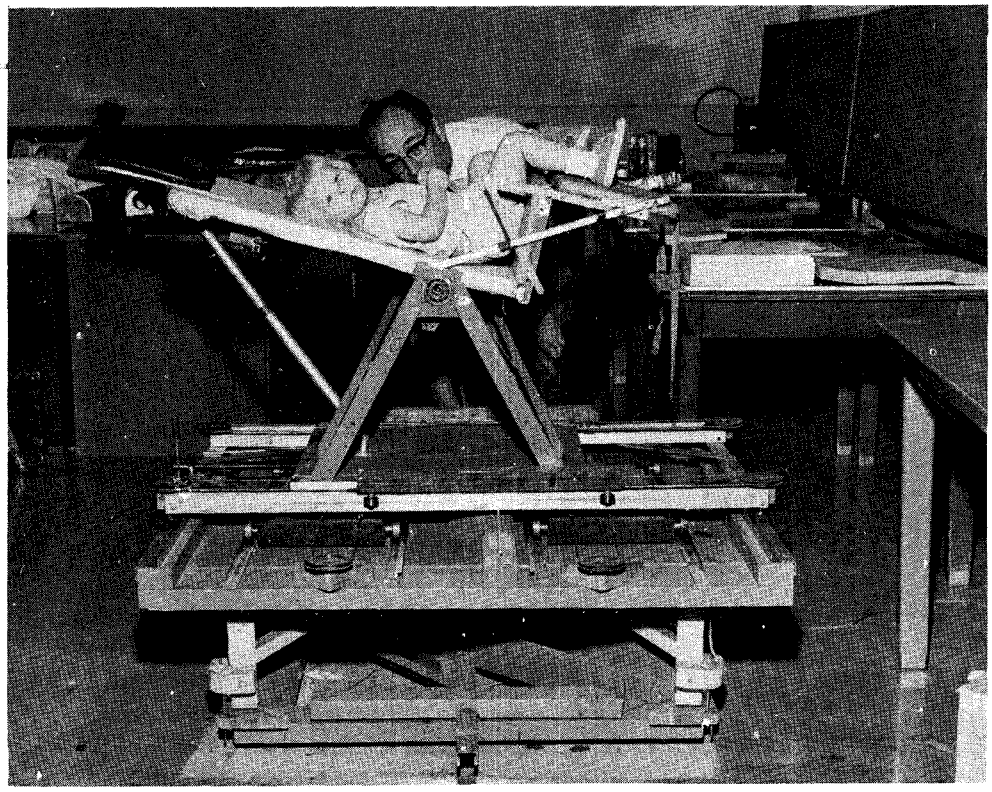

FIGURE 1. Center-of-gravity machine.

weight, stature, sitting height, stature minus sitting height, buttock-knee length, knee height, thigh-clearance height, upper-arm length, forearm-hand length, chest depth, waist depth, and buttock depth were made on each child using standard anthropometric techniques. Means, standard deviations, and ranges for these measurements for each age group are presented in the Appendix.

The sitting position used as a standard was knees bent to 90°, hip flexion 90°, trunk erect, and hands folded in the lap. The cg measurements were made vertically from the seat bottom and horizontally from the seat back. To obtain the latter measurement, it was necessary to balance the child at two angles of tilt to locate the intersecting point of the two lines through the cg and perpendicular to the seat planes.

A normal standing position with arms hanging at sides was used as a standard. The cg locations as measured up from the lower surface of the buttocks (sitting surface) and forward from the plane of the back were made using the same technique as described above; i.e., two angles of tilt.

These data are presented in the following graphs and tables. Figure 2 is a plot of the height of the cg above the seat for boys and girls of ages 5 through 18 in the sitting position. Since it may be assumed that the seat belt lies on top of the thighs, thigh-clearance heights are plotted for each age group to show the relation of the location of the cg (center of mass) with reference to seat belt. Only means for each group are plotted on the graph. Means and standard deviations are given in Table 1. It should be noted

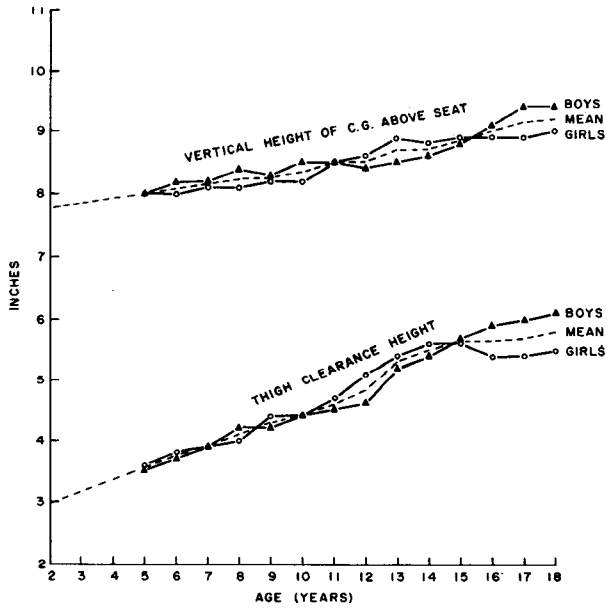

FIGURE 2. Means of height of cg above seat.

TABLE 1.—Means and standard deviations of thigh-clearance and sitting-height measurements of 1,200 children.

Age	Sex	Thigh Clearance		Sitting Height	
		Mean	Standard Deviation	Mean	Standard Deviation
5	F	3.6	0.38	23.4	0.83
	M	3.5	0.33	23.5	0.92
6	F	3.8	0.33	24.4	1.2
	M	3.7	0.43	24.6	1.2
7	F	3.9	0.39	25.3	1.2
	M	3.9	0.39	25.8	1.1
8	F	4.0	0.43	26.3	1.0
	M	4.2	0.64	26.9	1.2
9	F	4.4	0.47	27.7	1.0
	M	4.2	0.57	27.5	1.3
10	F	4.4	0.49	28.2	1.2
	M	4.4	0.56	28.8	1.2
11	F	4.7	0.58	29.9	1.7
	M	4.5	0.48	29.2	1.5
12	F	5.1	0.58	31.1	1.8
	M	4.6	0.78	30.4	1.7
13	F	5.4	0.57	32.3	1.3
	M	5.2	0.73	31.8	1.9
14	F	5.6	0.68	32.5	1.5
	M	5.4	0.59	33.3	1.8
15	F	5.6	0.57	33.2	1.2
	M	5.7	0.53	34.6	1.6
16	F	5.4	0.49	33.6	1.3
	M	5.9	0.68	35.3	1.8
17	F	5.4	0.52	34.1	1.2
	M	6.0	0.71	35.7	1.3
18	F	5.5	0.50	33.7	1.2
	M	6.1	0.48	36.6	1.1

that the cg in this position lies 3 in. above the thighs in the 18-year-old group and 4-½ in. in the 5-years olds. The situation is actually worse than these figures indicate. The tables of buttock-knee measurements in the Appendix indicate that most children are 12 years old before the upper leg measurement is equal to the length of an airline seat cushion. To sit all the way back in an airline seat in order to fasten a seat belt snuggly, they must extend the lower legs forward in line with the thighs. This raising of

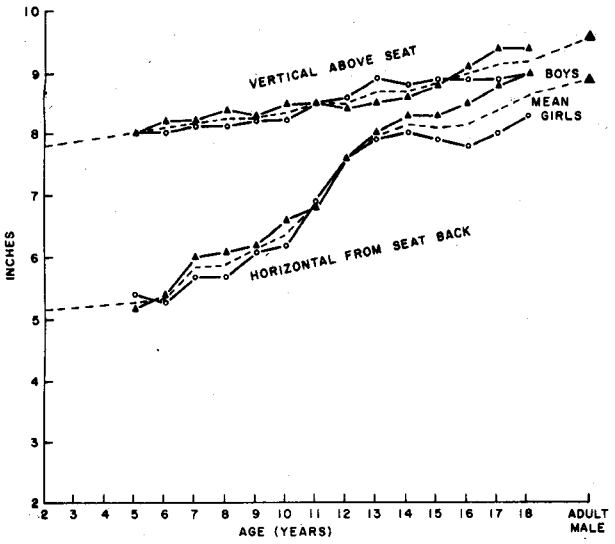

FIGURE 3. Means of cg of children sitting.

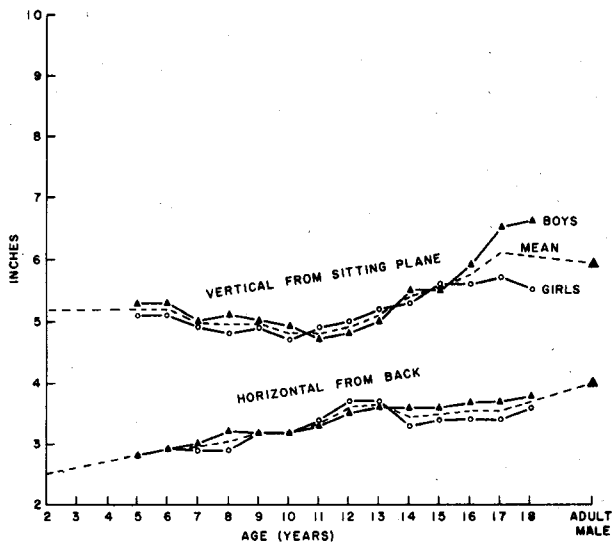

FIGURE 4. Means of cg of children standing.

TABLE 2.—Means and standard deviations of cg measurements of children in sitting and standing positions.

Age	Sex	Sitting Vertical		Sitting Horizontal		Standing Vertical		Standing Horizontal	
		Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
5	F	8.0	0.37	5.4	0.63	5.1	0.41	2.8	0.38
	M	8.0	0.43	5.2	0.60	5.3	0.71	2.8	0.55
6	F	8.0	0.33	5.3	0.66	5.1	0.44	2.9	0.49
	M	8.2	0.36	5.4	0.66	5.3	0.46	2.9	0.39
7	F	8.1	0.42	5.7	0.63	4.9	0.55	2.9	0.38
	M	8.2	0.33	6.0	0.83	5.0	0.54	3.0	0.41
8	F	8.1	0.39	5.7	0.90	4.8	0.55	2.9	0.45
	M	8.4	0.42	6.1	0.91	5.1	0.52	3.2	0.45
9	F	8.2	0.38	6.1	0.68	4.9	0.61	3.2	0.41
	M	8.3	0.39	6.2	0.77	5.0	0.60	3.2	0.55
10	F	8.2	0.39	6.2	0.75	4.7	0.63	3.2	0.39
	M	8.5	0.37	6.6	0.77	4.9	0.67	3.2	0.40
11	F	8.5	0.50	6.9	0.80	4.9	0.68	3.4	0.33
	M	8.5	0.43	6.8	0.79	4.7	0.72	3.3	0.41
12	F	8.6	0.48	7.6	0.77	5.0	0.60	3.7	0.52
	M	8.4	0.51	7.6	0.99	4.8	0.83	3.5	0.58
13	F	8.9	0.53	7.9	0.65	5.2	0.72	3.7	0.52
	M	8.5	0.67	8.0	0.72	5.0	0.81	3.6	0.53
14	F	8.8	0.58	8.0	0.73	5.3	0.73	3.3	0.44
	M	8.6	0.60	8.3	0.52	5.5	0.73	3.6	0.41
15	F	8.9	0.41	7.9	0.81	5.6	0.68	3.4	0.46
	M	8.8	0.67	8.3	0.81	5.5	0.82	3.6	0.52
16	F	8.9	0.52	7.8	0.52	5.6	0.76	3.4	0.50
	M	9.1	0.69	8.5	0.58	5.9	0.83	3.7	0.74
17	F	8.9	0.50	8.0	0.50	5.7	0.66	3.4	0.40
	M	9.5	0.55	8.8	0.70	6.5	0.92	3.7	0.46
18	F	9.0	0.49	8.3	0.59	5.5	0.66	3.6	0.45
	M	9.5	0.52	9.0	0.57	6.6	1.01	3.8	0.39

the lower legs raises the cg another inch[6] and adds to the ineffectiveness of the seat belt as a restraint device for children.

Figures 3 and 4 summarize horizontal and vertical measurements of cg locations both sitting and standing. Again only means for each age group are plotted. Standard deviations are presented in Table 2. In addition, on the right side of Figure 3, mean cg's for adult males[4] have been plotted, and it may be noted they are very close to those of the 18-year-old group.

Since all other researchers have located the cg in the standing position in terms of height above the floor, our data have been converted to the same reference point and are presented in Figure 5 with standard deviations given in Table 3.

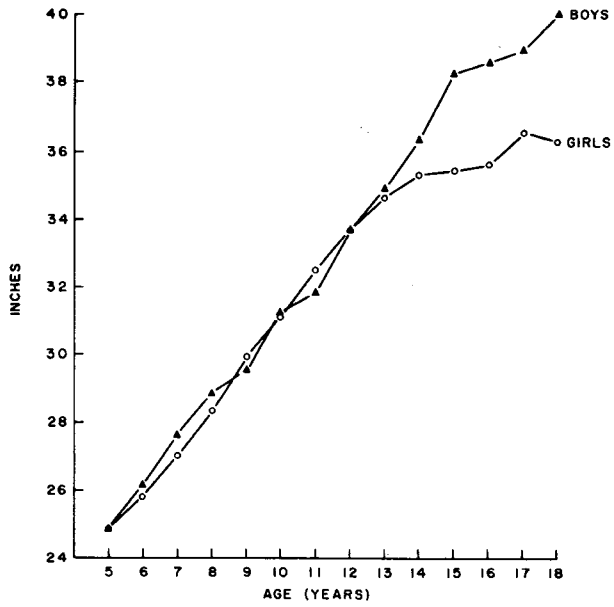

FIGURE 5. Means of cg height from floor in standing position.

Examining Figure 3, we see that in the sitting position the height of the cg above the seat bottom rises only about 1 in. in growing from 4 years old to adulthood. However, the horizontal measurement from the seat back increases rapidly from 5 to 9 in. This is undoubtedly due to leg growth and changes in proportions of leg length to trunk length.

In the standing position (Figure 4), the vertical measurement of the cg above the reference point on the pelvis remains fairly constant for the first 13 years and increases gradually, about 1 in. as the child matures.

Cotton[2] states that the mean height of cg from the floor in the standing position is 56.7% of stature for the male and 56.1% for the female. Weinbach[8] reports a mean height of cg for children (1.4 to 3.5 years of age) as 54.7% of stature. Table 3 shows heights of cg in terms of percent of stature for the boys and girls of different ages studied here. The 5-year-old group mean height of cg was 57.5%, while that of the 18-year olds was 56.7%. Basler[1] reports an average height of cg value of 56.62% for 507 girls between the ages of 6-½ to 17-½ years and 57.11% for 438 boys between the ages of 6-¼ to 14-½ years. It is evident then that if the standing height of cg is measured from the floor in terms of percent of stature, the figure remains relatively constant with growth.

TABLE 3.—Means and standard deviations of children's cg height from floor in the standing position.

Age	Sex	Height of cg Above Floor (Inches)		Height of cg Above Floor (_ of Stature)	
		Mean	Standard Deviation	Mean	Standard Deviation
5	F	24.8	0.7	57.5	0.73
	M	24.8	1.2	57.5	1.4
6	F	25.8	1.1	57.2	1.0
	M	26.1	1.3	57.5	0.75
7	F	27.0	1.2	57.0	0.83
	M	27.6	1.2	57.0	0.89
8	F	28.3	1.1	56.8	0.71
	M	28.8	1.1	56.9	0.84
9	F	29.9	1.2	56.7	1.0
	M	29.5	1.2	56.7	0.84
10	F	31.0	1.5	56.8	0.85
	M	31.2	1.4	56.6	0.74
11	F	32.5	1.7	56.5	0.88
	M	31.8	1.5	56.5	0.93
12	F	33.7	1.6	56.4	0.84
	M	33.6	2.1	56.8	0.74
13	F	34.6	1.5	56.0	1.1
	M	34.9	1.9	56.6	0.73
14	F	35.3	1.3	56.4	0.74
	M	36.3	2.0	56.6	0.69
15	F	35.4	1.3	56.2	0.66
	M	38.2	1.9	56.8	1.1
16	F	35.6	1.5	56.0	0.76
	M	38.5	1.7	56.7	0.69
17	F	36.5	1.2	56.3	0.62
	M	38.9	1.7	57.0	0.81
18	F	36.3	1.2	56.3	0.85
	M	40.0	1.2	57.1	0.70

III. Conclusions.

Extensive data concerning horizontal and vertical measurements of location of cg's of children (5 to 18 years) sitting and standing are presented.

The cg's of small children (10 years and younger) seated in an aircraft seat fall well above the seat belt and render the present seat belt a very ineffective restraint device for them in crash decelerations. Data presented here will be used for designing safer restraint equipment for children.

Height of the cg from the floor in the standing position when expressed in percent of stature remains relatively constant at about 57% regardless of age.

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APPENDIX

WEIGHT: MALE

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	41.47	4.04	35.00– 50.00
6	56	46.70	7.44	33.25– 78.00
7	48	52.60	7.32	37.75– 77.00
8	54	60.50	10.03	44.50–102.50
9	60	66.68	14.01	47.75–129.00
10	55	76.46	14.63	55.50–123.00
11	51	81.69	14.78	60.00–124.00
12	38	91.86	22.11	67.00–150.75
13	52	104.29	24.69	63.75–202.75
14	41	116.16	20.21	85.25–175.25
15	33	131.80	19.26	99.50–176.75
16	48	144.29	26.20	95.00–213.25
17	41	152.93	27.53	99.50–238.00
18	24	158.72	17.29	126.25–190.75

STATURE: MALE

Subject stands erect with head positioned in Frankfort plane.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	43.22	1.68	36.25–46.75
6	56	45.42	2.44	40.75–52.25
7	48	48.35	2.12	43.00–54.50
8	54	50.61	2.05	45.50–55.00
9	60	52.02	2.33	47.00–58.00
10	55	55.09	2.43	49.75–60.25
11	51	56.34	2.83	50.50–63.75
12	38	59.26	3.77	52.75–66.75
13	52	61.71	3.34	55.25–69.00
14	41	64.18	3.38	55.25–73.25
15	33	67.27	2.73	60.75–73.75
16	48	67.88	3.08	57.00–74.25
17	41	68.16	2.37	61.75–72.25
18	24	69.95	2.04	66.00–73.75

WEIGHT: FEMALE

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	40.07	3.32	36.00– 46.25
6	45	43.94	5.62	35.00– 55.50
7	42	50.46	8.90	37.75– 78.00
8	46	55.58	7.18	44.00– 68.00
9	52	66.78	12.49	49.00–112.25
10	53	71.46	12.04	44.50–118.50
11	36	85.84	19.94	60.00–139.00
12	36	96.01	19.83	61.25–144.00
13	49	108.56	16.98	81.00–148.50
14	30	112.88	23.92	74.00–168.75
15	53	115.36	16.18	90.00–158.00
16	44	118.63	16.74	84.50–171.25
17	38	120.95	18.38	85.75–174.75
18	13	124.88	14.21	93.00–145.50

STATURE: FEMALE

Subject stands erect with head positioned in Frankfort plane.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	43.05	1.19	40.75–45.00
6	45	45.12	2.07	41.75–49.50
7	42	47.46	2.19	44.00–53.25
8	46	49.75	1.88	46.00–55.00
9	52	52.65	1.98	49.50–58.25
10	53	54.55	2.47	48.75–59.25
11	36	57.50	2.89	50.25–64.75
12	36	59.81	2.95	53.25–66.50
13	49	61.70	2.20	58.00–67.75
14	30	62.54	2.25	57.25–67.00
15	53	62.93	2.17	59.25–68.70
16	44	63.63	2.57	54.25–68.00
17	38	64.82	2.00	60.50–69.05
18	13	64.52	2.14	61.00–68.25

SITTING HEIGHT: MALE

Subject sits erect with head positioned in Frankfort plane.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	23.54	0.92	22.00–25.50
6	56	24.59	1.15	22.25–27.75
7	48	25.77	1.08	23.00–28.25
8	54	26.88	1.17	24.50–30.00
9	60	27.45	1.32	24.75–30.50
10	55	28.79	1.22	26.00–32.00
11	51	29.21	1.49	26.00–32.25
12	38	30.41	1.72	27.00–34.50
13	52	31.78	1.91	27.25–36.00
14	41	33.30	1.83	29.50–38.00
15	33	34.60	1.59	31.00–38.00
16	48	35.30	1.81	28.00–39.00
17	41	35.73	1.33	32.75–38.00
18	24	36.61	1.12	34.00–39.00

STATURE MINUS SITTING HEIGHT: MALE

Difference between measurements.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	19.59	1.03	17.00–21.50
6	56	20.81	1.43	18.00–24.50
7	48	22.59	1.19	20.00–26.50
8	54	23.74	1.06	21.00–26.00
9	60	24.57	1.21	21.25–27.75
10	55	26.28	1.50	23.25–29.25
11	51	27.13	1.57	23.75–32.25
12	38	28.84	2.25	25.50–33.00
13	52	29.92	1.70	27.00–34.75
14	41	30.87	1.76	25.75–35.25
15	33	32.67	1.58	29.00 36.50
16	48	32.57	1.73	29.00–36.50
17	41	32.44	1.44	29.00–34.50
18	24	33.33	1.52	31.00–36.75

SITTING HEIGHT: FEMALE

Subject sits erect with head positioned in Frankfort plane.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	23.39	0.83	21.25–25.00
6	45	24.38	1.15	21.25–26.75
7	42	25.33	1.15	23.00–28.00
8	46	26.29	1.03	24.00–29.00
9	52	27.67	1.04	25.75–30.50
10	53	28.22	1.22	25.25–30.25
11	36	29.94	1.70	26.00–33.75
12	36	31.10	1.79	28.50–35.00
13	49	32.29	1.33	29.75–34.25
14	30	32.53	1.49	28.25–35.00
15	53	33.16	1.18	31.00–35.75
16	44	33.57	1.27	30.00–35.50
17	38	34.08	1.21	31.50–36.75
18	13	33.73	1.23	31.25–36.50

STATURE MINUS SITTING HEIGHT: FEMALE

Difference between measurements.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	19.67	0.68	17.75–20.75
6	45	20.74	1.09	17.75–22.75
7	42	22.12	1.21	20.25–25.25
8	46	23.46	1.15	21.25–26.75
9	52	24.96	1.15	23.00–27.75
10	53	26.31	1.44	23.50–29.50
11	36	27.56	1.38	24.25–31.00
12	36	28.71	1.39	25.75–32.25
13	49	29.42	1.41	27.00–33.00
14	30	30.01	1.35	26.75–32.50
15	53	29.77	1.47	27.25–33.00
16	44	30.05	1.75	24.25–32.75
17	38	30.74	1.30	28.50–34.00
18	13	30.79	1.29	29.00–34.00

BUTTOCK-KNEE LENGTH: MALE

Greatest horizontal distance buttock and anterior knee surface with subject sitting erect and 90° hip and knee angles.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	13.59	0.75	12.00–15.50
6	56	14.47	0.99	12.50–16.75
7	48	15.61	0.83	13.75–18.00
8	54	16.42	0.85	14.75–18.25
9	60	17.05	0.95	15.00–19.25
10	55	18.56	1.04	16.25–21.00
11	51	19.00	1.18	17.00–22.00
12	38	20.36	1.76	17.00–25.50
13	52	21.34	1.34	19.25–24.25
14	41	22.16	1.37	19.50–25.75
15	33	23.08	1.16	20.75–26.50
16	48	23.44	1.17	20.00–25.25
17	41	23.36	1.08	21.00–26.00
18	24	23.85	1.08	22.25–26.75

KNEE HEIGHT: MALE

Vertical distance between footrest surface and top of knee with subject sitting erect and 90° hip and knee angles.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	12.84	0.56	11.25–14.00
6	56	13.62	0.92	12.25–16.50
7	48	14.70	0.70	13.00–16.75
8	54	15.54	0.80	14.00–17.25
9	60	16.11	0.91	14.00–18.50
10	55	17.16	0.97	15.00–19.25
11	51	17.66	1.03	15.50–20.75
12	38	18.85	1.36	16.75–21.75
13	52	19.50	1.26	17.50–22.50
14	41	20.30	1.10	17.50–23.75
15	33	21.23	0.98	19.25–23.25
16	48	21.30	1.11	18.25–23.75
17	41	21.29	0.81	18.75–22.75
18	24	21.79	0.79	20.50–23.75

BUTTOCK-KNEE LENGTH: FEMALE

Greatest horizontal distance buttock and anterior knee surface with subject sitting erect and 90° hip and knee angles.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	14.01	0.57	12.50–15.50
6	45	14.67	0.77	12.75–16.75
7	42	15.62	0.92	14.00–17.75
8	46	16.50	0.82	15.00–18.50
9	52	17.58	0.97	16.00–20.25
10	53	18.45	1.08	16.25–21.05
11	36	19.78	1.38	16.25–23.70
12	36	21.03	1.22	17.50–24.25
13	49	21.85	1.16	19.75–25.00
14	30	22.12	1.20	20.00–24.25
15	53	22.10	0.96	20.50–24.75
16	44	22.44	1.12	19.75–25.25
17	38	22.71	0.87	21.25–24.50
18	13	22.98	0.98	21.00–25.00

KNEE HEIGHT: FEMALE

Vertical distance between footrest surface and top of knee with subject sitting erect and 90° hip and knee angles.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	12.83	0.39	12.25–13.50
6	45	13.55	0.73	11.50–15.00
7	42	14.38	0.84	13.25–16.50
8	46	15.16	0.72	14.00–17.25
9	52	16.20	0.80	14.50–17.75
10	53	16.96	1.00	15.00–18.75
11	36	18.09	1.13	15.50–21.75
12	36	18.72	0.92	16.75–21.25
13	49	19.17	0.92	17.50–21.50
14	30	19.57	0.86	17.75–21.50
15	53	19.65	0.80	18.00–21.25
16	44	19.73	1.03	16.25–21.75
17	38	20.18	0.74	18.75–21.75
18	13	20.19	0.59	19.25–21.25

THIGH-CLEARANCE HEIGHT: MALE

Vertical distance between seat surface and top of thigh at abdominal-thigh junction with full surface thigh-seat contact.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	3.51	0.33	2.75–4.25
6	56	3.71	0.43	2.75–5.50
7	48	3.94	0.39	3.00–5.00
8	54	4.15	0.64	3.00–6.25
9	60	4.22	0.57	3.00–6.50
10	55	4.43	0.56	3.25–6.00
11	51	4.50	0.48	3.50–5.50
12	38	4.63	0.78	3.25–6.50
13	52	5.17	0.73	4.00–8.00
14	41	5.37	0.59	4.50–6.75
15	33	5.69	0.53	4.50–7.25
16	48	5.88	0.68	4.25–7.50
17	41	5.97	0.71	4.50–8.00
18	24	6.13	0.48	5.00–7.00

UPPER-ARM LENGTH: MALE

Distance between point acromion and inferior surface of elbow with upper arm abducted normally to side and 90° elbow flexion angle.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	8.29	0.49	7.50 –9.50
6	56	8.74	0.79	5.25–10.75
7	48	9.38	0.68	7.50–11.00
8	54	10.00	0.51	9.00–11.25
9	60	10.36	0.57	8.75–11.75
10	55	11.21	0.76	9.50–13.00
11	51	11.50	0.68	10.00–13.50
12	38	11.89	0.96	9.75–13.75
13	52	11.98	0.84	10.00–13.25
14	41	12.22	0.83	10.25–14.25
15	33	13.04	0.77	11.75–15.00
16	48	13.05	0.76	11.00–15.00
17	41	13.29	0.65	12.00–14.25
18	24	13.82	0.88	12.75–17.25

THIGH-CLEARANCE HEIGHT: FEMALE

Vertical distance between seat surface and top of thigh at abdominal-thigh junction with full surface thigh-seat contact.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	3.64	0.40	2.75–4.50
6	45	3.72	0.33	3.00–4.50
7	42	3.88	0.39	3.25–5.50
8	46	4.04	0.43	3.00–5.00
9	52	4.38	0.47	3.25–5.50
10	53	4.40	0.49	3.25–6.00
11	36	4.73	0.58	3.75–6.00
12	36	5.10	0.58	4.25–6.50
13	49	5.42	0.57	4.25–6.75
14	30	5.55	0.68	4.25–7.00
15	53	5.58	0.57	4.50–7.25
16	44	5.43	0.49	4.50–7.00
17	38	5.43	0.52	4.75–6.75
18	13	5.52	0.49	4.50–6.25

UPPER-ARM LENGTH: FEMALE

Distance between point acromion and inferior surface of elbow with upper arm abducted normally to side and 90° elbow flexion angle.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	8.04	0.51	6.75 –9.25
6	45	8.49	0.71	7.50–10.25
7	42	9.21	0.67	7.75–10.75
8	46	9.78	0.67	8.50–11.25
9	52	10.52	0.52	9.00–12.25
10	53	10.96	0.71	9.50–12.25
11	36	11.70	0.79	10.25–13.50
12	36	11.83	1.05	9.75–14.25
13	49	11.96	0.74	10.50–13.50
14	30	11.86	0.68	10.00–13.00
15	53	12.07	0.51	10.75–13.00
16	44	12.16	0.69	10.00–13.50
17	38	12.56	0.72	11.50–15.00
18	13	12.44	0.47	11.75–13.25

FOREARM-HAND LENGTH: MALE

Distance between posterior surface of elbow and tip of longest finger with elbow angle flexed at 90° and fingers extended.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	11.46	0.51	10.50–12.50
6	56	12.10	0.76	10.75–14.25
7	48	12.78	0.69	11.50–14.75
8	54	13.58	0.65	12.00–15.00
9	60	13.89	0.66	12.50–15.50
10	55	14.72	0.79	13.00–16.25
11	51	15.16	0.84	13.50–17.75
12	38	16.21	1.20	14.00–18.75
13	52	16.83	0.92	15.00–19.50
14	41	17.36	1.06	15.00–20.50
15	33	18.52	0.97	16.50–20.50
16	48	18.36	1.28	15.25–20.75
17	41	18.68	0.74	16.75–20.25
18	24	19.19	0.66	17.75–20.25

CHEST DEPTH: MALE

Greatest horizontal distance between the sternal surface and the back with subject standing erect.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	5.53	0.33	5.00–6.25
6	56	5.71	0.38	5.00–6.75
7	48	5.93	0.35	5.25–6.75
8	54	6.21	0.49	5.50–7.75
9	60	6.50	0.56	5.50–8.75
10	55	6.83	0.65	5.75–9.00
11	51	6.90	0.54	6.00–8.50
12	38	7.28	0.77	6.00–9.25
13	52	7.56	0.81	6.00–10.25
14	41	7.95	0.68	7.00–9.75
15	33	8.26	0.55	7.25–10.00
16	48	8.63	0.74	7.25–11.00
17	41	8.93	0.93	7.75–12.25
18	24	9.03	0.57	7.75–10.50

FOREARM-HAND LENGTH: FEMALE

Distance between posterior surface of elbow and tip of longest finger with elbow angle flexed at 90° and fingers extended.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	11.31	0.32	10.75–11.75
6	45	11.77	0.62	10.00–13.25
7	42	12.49	0.73	11.00–14.00
8	46	13.03	0.63	12.25–14.50
9	52	13.90	0.62	12.75–15.50
10	53	14.50	0.72	13.00–15.75
11	36	15.35	0.89	13.50–17.25
12	36	16.03	0.74	14.25–17.75
13	49	16.48	0.77	15.25–18.50
14	30	16.78	0.76	15.25–18.00
15	53	16.71	0.67	15.50–18.25
16	44	16.94	0.83	14.75–18.50
17	38	17.20	0.97	16.00–18.50
18	13	17.17	0.90	15.75–18.50

CHEST DEPTH: FEMALE

Greatest horizontal distance between the sternal surface and the back with subject standing erect.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	5.38	0.31	5.00–6.00
6	45	5.55	0.33	5.00–6.25
7	42	5.77	0.41	4.75–6.75
8	46	5.95	0.38	5.25–6.75
9	52	6.31	0.54	5.50–8.25
10	53	6.48	0.65	5.25–8.50
11	36	6.89	0.77	5.75–8.75
12	36	7.14	0.68	5.75–8.50
13	49	7.30	0.59	6.25–8.75
14	30	6.99	0.56	6.25–8.00
15	53	7.23	0.56	5.75–8.50
16	44	7.29	0.64	6.00–9.00
17	38	7.45	0.59	6.50–8.75
18	13	7.56	0.61	6.75–9.00

WAIST DEPTH: MALE

Horizontal anterior-posterior distance between the abdomen and back at the natural waist line level with subject standing erect.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	5.26	0.41	4.25–6.00
6	56	5.46	0.50	4.50–7.50
7	48	5.65	0.46	5.00–7.25
8	54	5.87	0.62	5.00–8.50
9	60	6.08	0.77	5.00–9.50
10	55	6.23	0.79	5.25–9.25
11	51	6.36	0.59	5.50–8.00
12	38	6.77	0.88	5.75–9.25
13	52	6.98	0.90	5.75–10.50
14	41	7.01	0.69	5.75–9.25
15	33	7.24	0.66	5.75–8.75
16	48	7.56	0.83	6.25–9.75
17	41	7.75	1.02	6.50–11.25
18	24	7.74	0.68	6.50–9.25

BUTTOCK DEPTH: MALE

The greatest horizontal anterior-posterior distance with subject standing erect.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	23	5.11	0.44	4.25–6.00
6	56	5.38	0.61	4.50–8.00
7	48	5.66	0.55	4.75–7.25
8	54	6.04	0.81	4.75–9.25
9	60	6.30	0.83	4.75–8.50
10	55	6.79	0.97	5.00–9.25
11	51	6.75	0.90	5.25–9.50
12	38	7.26	1.12	5.50–9.75
13	52	7.97	0.89	6.25–11.00
14	41	8.35	0.81	5.75–10.00
15	33	8.56	0.56	7.50–9.75
16	48	9.07	0.78	7.50–11.75
17	41	9.18	0.83	7.75–11.75
18	24	9.42	0.69	8.00–10.50

WAIST DEPTH: FEMALE

Horizontal anterior-posterior distance between the abdomen and back at the natural waistline level with subject standing erect.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	5.25	0.38	4.75–6.00
6	45	5.29	0.37	4.75–6.00
7	42	5.47	0.46	4.50–6.50
8	46	5.59	0.43	4.75–6.75
9	52	6.00	0.71	5.00–8.25
10	53	6.13	0.66	5.00–8.75
11	36	6.44	1.01	4.25–9.25
12	36	6.67	0.87	5.25–9.25
13	49	6.77	0.79	5.50–8.50
14	30	6.58	0.80	5.50–8.50
15	53	6.44	0.72	5.50–8.50
16	44	6.53	0.65	5.50–9.25
17	38	6.68	0.60	5.75–8.25
18	13	6.77	0.67	5.50–8.00

BUTTOCK DEPTH: FEMALE

The greatest horizontal anterior-posterior distance with subject standing erect.

Age	Number of Subjects	Mean	Standard Deviation	Range
5	24	5.10	0.45	4.00–6.25
6	45	5.36	0.51	4.25–6.50
7	42	5.61	0.55	4.50–7.25
8	46	5.83	0.63	4.75–7.50
9	52	6.29	0.87	4.75–8.75
10	53	6.46	0.76	5.00–9.25
11	36	7.14	1.06	5.50–10.25
12	36	7.55	1.05	6.00–10.00
13	49	7.97	0.82	6.25–10.50
14	30	8.13	0.96	6.75–10.25
15	53	8.26	0.77	7.00–10.25
16	44	8.30	0.84	7.00–11.25
17	38	8.26	0.71	7.25–10.00
18	13	8.62	0.77	7.00–9.50