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SELECTED INFANT ANTHROPOMETRY
CRIB SLAT SUB-STUDY

HIGHWAY SAFETY RESEARCH INSTITUTE

THE UNIVERSITY OF MICHIGAN

UM-HSRI-BI-72-4

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CRIB SLAT SUB-STUDY

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18 December 1972

(Revised February, 1973)

This work was conducted as a sub-task under a study funded by the Consumer Product Safety Commission under contract FDA 72-70. The full study is contained in final report Physical Characteristics of Children as Related to Death and Injury for Consumer Product Design and Use, UM-HSRI-BI-75-5, 31 May 1975 (PB-242-221), and has also been published as Anthropometry of U.S. Infants and Children, Society of Automotive Engineers, Inc., Warrendale, Pa., as SP-394 and technical paper no. 750423. The content of this publication does not necessarily reflect the views of the Commission, nor does mention of trade names, commercial products, or organizations imply endorsement by the Commission.

SELECTED INFANT ANTHROPOMETRY

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December 18, 1972

I. SUMMARY AND CONCLUSIONS

An infant population consisting of 69 infants ranging from 2 1/2 to 6 1/2 months of age, composed of 34 females and 35 males, was measured at three separate well-child clinics in the Ann Arbor area. Measurements were recorded for 11 measures, including weight, crown-sole length, shoulder breadth, chest breadth, hip breadth, buttocks breadth, chest A-P depth, hip A-P depth, buttocks A-P depth, head breadth, and head length. These measurements were taken by a team of two, utilizing a specially designed and constructed sliding-caliper, and anthropometer equipped with electrical digital readout and pressure transducer in the paddle-blades. All measurements except head breadth and length, weight and C-R length, were taken at a uniform contact pressure of 0.5 lbs. providing a reproducible and reliable value for soft tissue where appropriate skeletal landmarks are not available. Tabulations and statistics are provided relative to all of these measures, with breakdowns by sex and observations of limited age (2 1/2 to 4 1/2 months, and 4 1/2 to 6 1/2 months). Tests with infants and a crib slat interspace of 2 1/4 inches, and with a crib slat interspace of 3 1/4 inches were reported in the appendix.

It was determined that the most critical measurement is that of buttocks depth, measured from the maximum protrusion of the buttocks in the rear to the anterior surface of the upper legs. This measure ranged from 2.4 inches to 4.6 inches in this population. The middle 90%, with a confidence level of 95%, lies between a combined sex value of 2.8 inches and 4.7 inches for 4 1/2 to 6 1/2 month old infants, and 2.9 inches to 4.3 inches for 2 1/2 to 4 1/2 month old infants. However, since these measurements were taken on soft tissue in a relatively non-compressed condition (0.5 lb contact pressure), they should

be considered as extremely conservative values in relation to the question of whether or not an infant can squeeze through a given crib slat interspace.

II. OBJECTIVE

The purpose of this study was to obtain basic body measurement data on 3 to 6 month old infants which would be most appropriate for application in evaluating crib slat spacing to safely restrain infants of this age range in cribs.

III. SCHEDULE

November 1 - November 27 design, obtain electronic components, fabricate,
test and calibrate instrumentation
November 28 - December 15 collect data, Child Health Clinics
December 15 - December 18 reduce and analyze data, complete report

The initial schedule established above was followed closely. Nearly five of the seven weeks were necessary in designing and modifying an anthropometer with a pressure transducer, the majority of this time being required to obtain electronic components. The anthropometer had previously been designed and fabricated with electrical digital instrumentation to provide direct digital readout or computer input. It was felt to be essential to have a valid means of accurately reproducing measures which were not available through standard techniques or equipment, and the pressure criteria was demonstrated to be a significant new technique.

IV. METHODS AND TECHNIQUES

The population sample consisted of 69 infants from ages 2 1/2 to 6 1/2 months, composed of 34 females and 35 males, of which racially 48 were reported as Caucasoid, 12 Negroid and 4 Mongoloid.* This sample is believed to be a reasonable representation of the U.S. infant population for this age range. The major problem in collecting data was that this period coincided with the season's worst storms to date and a substantial number of mothers canceled clinic appointments for their children during this time.

Infants were measured at three different well-child clinics, located at The University of Michigan Medical School, St. Joseph's Hospital in Ann Arbor, and at Ypsilanti, ten miles to the east of Ann Arbor. The predominant patient in the first two clinics was from middle or lower economic income families and in the latter from a lower income environment with a higher proportion of Negroes.

Equipment consisted of a specially designed automated anthropometer, a specially designed sliding caliper, and auxiliary instrumentation. Weight was taken on standard scales available in the clinics. The primary instrument was a Siber Hegner anthropometer which had been highly modified by the addition of an electrical digital readout and a pressure transducer built into the in-board surface of one paddle blade. This allowed accurate and instantaneous digital readout on a Digilin Model 340-A digital multimeter, and was also designed for direct tie-in with a computer system.

The advantages of instantaneous digital readouts were that considerable time was saved in obtaining and recording data, and accuracy was greatly improved. The laborious task of trying to read a complex scale with a moving child was eliminated, and potential recorder error, either in reading the instrument or writing down the data, was considerably reduced. This anthropometer

* 5 of mixed race or unknown, reported as "other."

was also equipped with a pressure transducer built into the inboard surface of one of the specially constructed plexiglass paddle blades.

Since infants have few useful skeletal landmarks for measurement at this age, this allowed measurements to be taken at a constant pressure which resulted in a significant increase in reliability and reproducible measures. Besides assuring that measurements were comparable and reproducible, it provided consistent and conservative tissue compression. It also solved the problem of what criteria to use for an infant since the classical landmarks are missing or incompletely formed, and tissue compressibility made standard contact measures exceedingly unreproducible. Output from a pressure transducer was processed by an instrumentation amplifier and displayed on an analog meter as pounds/inches². An operational amplifier was used to supply power to the full bridge semiconductor pressure transducer.

After much experimentation, it was our opinion that 0.5 pounds represented the best arbitrary standard for these particular measures, and could be described as contact with slight compression. This equipment and instrumentation is shown in Figure 1.

Two research assistants were required to obtain data. While one concentrated on taking the measurement at the correct location while applying a constant pressure reading, the other assisted by holding the infant in position, reading out, and subsequently recording, the digital measurement figure.

The procedure was similar at each clinic. An infant would be weighed and recumbent height taken by a nurse, and then assigned to a private treatment room. While the mother and infant waited for the pediatrician, the measurement team would bring the instrumentation into the treatment room.

Information consisting of name, date, birthdate, sex, race, location, and hospital record number had previously been obtained for each. They would place the infant in the crib, unclothe the infant and set up the instrumentation, checking the calibration each time. Figure 2 shows measurements being initiated on an infant in a well-child examination room at The University of Michigan. The mother normally observed and in this case was feeding a second infant. The nude weight previously taken (and observed by one of the team) was recorded, and a series of ten additional measures taken. In addition, notations were made of any unusual physical factors, health, or other information which might influence any measurement or be of significance. In one clinic, St. Joseph's, the team was provided a room into which the mothers and infants were directed in turn.

Weight was not taken directly by the measurement team for these subjects, but was recorded from the clinic measurement. It was observed that nude weights were taken if the infant weighed under 10 pounds, but for those heavier, weight included diapers and in occasional cases, undershirts. Each nurse used a somewhat different value for a correction factor if diapers were worn, however if they were wet, 2 oz. were deducted. Our team did not reweigh these infants since this measure was not of primary concern to this task.

Height was initially taken in the clinics, at the same time as weight, by the attending nurse, who was often a volunteer worker. The usual procedure was to lay the recumbent infant on a measuring board device, which was either equipped with a tape or sliding head and foot-boards, depending upon which clinic was involved. Such techniques are common in clinical studies. Once the infant was removed to the examination room, however, our measurement team remeasured the crown-sole length, using the anthropometer. As a matter of

interest, a comparison of the clinical measure for each child's height was made with our more precise and standardized technique.

Ten measurements in addition to weight were made. The crown-sole length was taken with the anthropometer even though a nurse had previously measured the child on a flat surface with a tape marker. Other measurements consisted of shoulder breadth, chest breadth, hip breadth, buttocks breadth, chest (A-P) depth, hip (A-P) depth, buttocks (A-P) depth, head width and head length. A description of these measures and illustration of many of them follows in figures 3 - 10, and a sample anthropometry form is shown in Appendix A.

As an indication of the difficulty encountered in comparing data collected in different studies due to differing techniques, non-standardization, and use of many measurers, a brief comparison was made between the crown-sole height of the infants recorded by the three clinics, and our data obtained by a single measurer with standardized techniques and instrumentation. In not one case did any of our 62 C-R height measurements match theirs. In 18 subjects our measurements were larger than those of the clinics ($\bar{x} = .59$). In 44 subjects their measurements were larger than ours ($\bar{x} = .56$). Differences exceeding one inch were noted in 10 of the 62 (or in approximately 1/6 of the total). Differences exceeding 1 1/2 inches were noted in two cases.

The following figures illustrate the methods and techniques utilized and provide definitions of the Anthropometry used in this series. As is shown, it requires two people to make these measures, one holding the child, while the other applies the instrument. Photos for all positions are not shown.

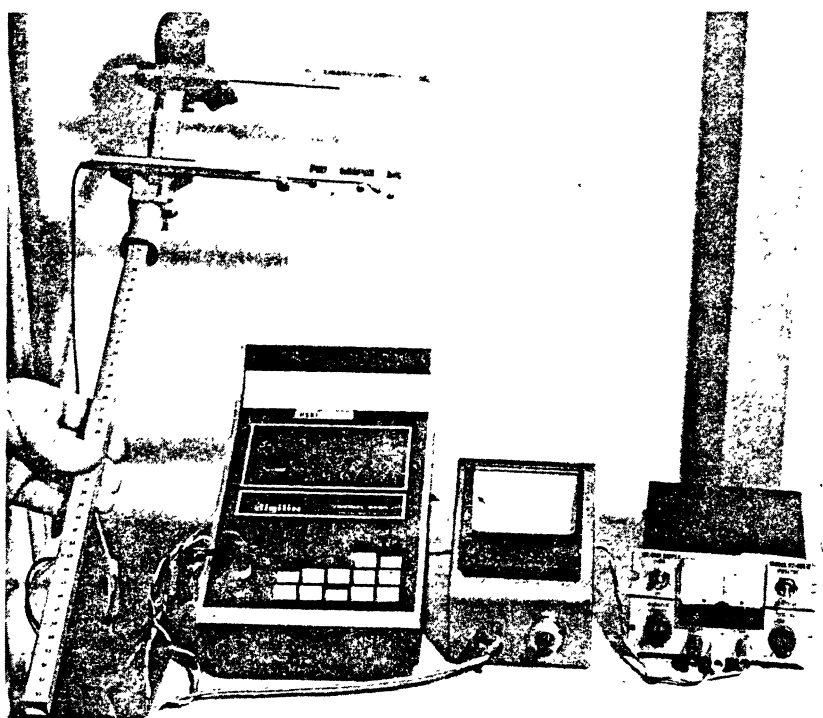


Figure 1. Equipment used to make infant measurements included this specially designed and modified anthropometer which provided both a pressure measurement through a transducer located in the sliding paddle blade, and an instantaneous digital readout through a potentiometer mounting. A digilin Model 340-A digital multimeter provided the direct measurement readout, while a Simpson DC Microampere meter provided a direct measure of the pressure application, backed up by a Model PZ-455-A power supply. The anthropometer is also equipped for direct linkage to a computer system.



Figure 2. Anthropometric measurements being conducted on a subject at the Well-Child Clinic of The University of Michigan. The equipment shown in Figure 1 was located beside the crib in view of the two measurement specialists.

Anthropometry included the following measurements. In taking each measurement, an assistant helps to hold the infant as required, check the pressure reading, and record the digital readout measurement. Contact measures were made of the head, while all other measures except weight were uniformly taken at .5 lb. pressure.

1. Weight - The infant is measured in the recumbent supine position in an infant weighing device, to the closest 1/4 pound.

(Photo not available.)

2. Crown-sole height - The infant's crown-sole height is measured with an automated paddle-blade anthropometer, while lying supine on a flat surface. The measurement is made, with an assistant holding the infant's right leg out straight, from the top of the head (oriented as much as possible in the Frankfurt Plane) to the bottom of the right heel.

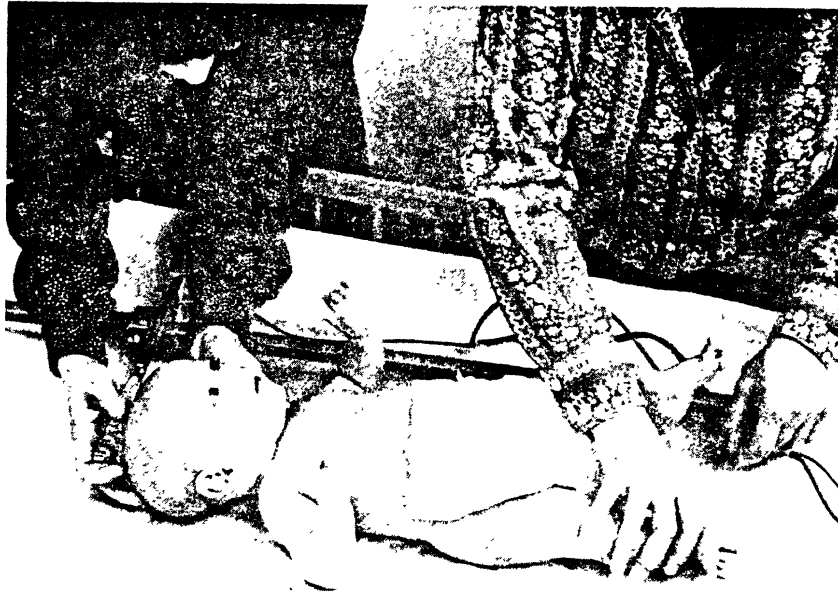


Figure 3 Measurement of Crown-Sole Height

3. Shoulder Breadth (pressure) - The maximum breadth of the recumbent infant's shoulders are measured with his arms held at his side using the automated paddle-blade anthropometer. The measurement is taken across the maximum lateral protrusion of the deltoid muscles at .5 lb. pressure.



Figure 4 Measurement of Shoulder Breadth

4. Chest Breadth (pressure) - The infant is maintained in a recumbent (supine) position. The minimum breadth of the chest at the level of the nipples across the chest, and inside the arms, is measured with an automated paddle-blade anthropometer. A pressure of .5 lb. is momentarily applied, as indicated by the pressure transducer reading.

(Photo not available.)

5. Hip Breadth (pressure) - The infant is maintained on his back and the minimum breadth across the hips below the iliac crests is measured horizontally with the automated paddle-blade anthropometer, applying .5 lbs. of pressure as indicated by the pressure transducer reading.

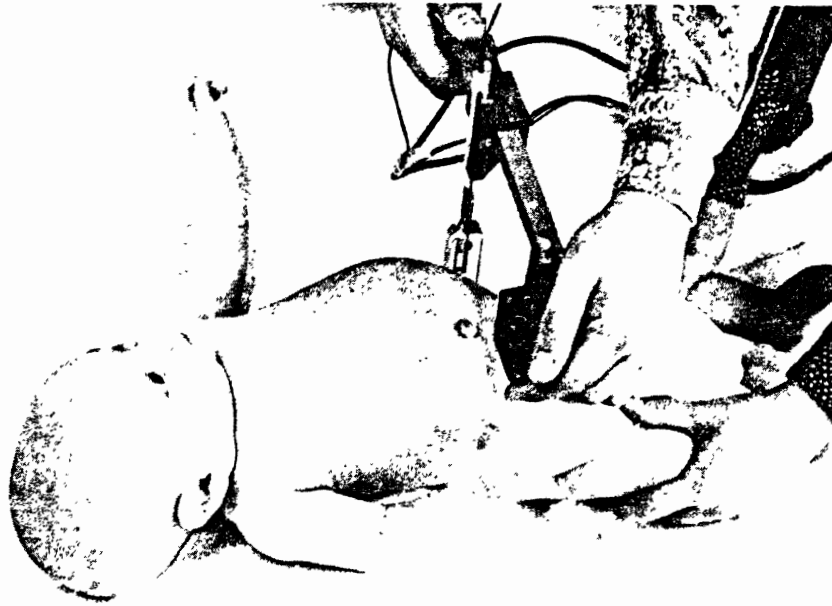


Figure 5 Measurement of Hip Breadth

6. Buttocks Breadth (pressure) - The infant is maintained on his back and the maximum breadth across the buttocks (gluteal muscles of the upper legs) is measured horizontally with the automated paddle-blade anthropometer, applying 0.5 lbs. of pressure as indicated by the pressure transducer reading.



Figure 6 Measurement of Buttocks Breadth

7. Buttocks Depth (pressure) - The infant is placed on his right side and the depth is measured from the maximum protrusion of the buttocks in the rear to the anterior surface of the upper legs in front at the level previously established for buttocks breadth, measurement No. 6. The automated paddle-blade anthropometer is used, and a pressure of 0.5 lbs., as indicated by the pressure transducer reading, is applied.

(Photo not available.)

8. Chest Depth (pressure) - The infant is placed on his right side. The depth of the infant's chest is measured front to rear at the level of the nipples during normal breathing, while a pressure of .5 lbs. is exerted, using an automated paddle-blade anthropometer equipped with a pressure transducer.



Figure 7 Measurement of Chest Depth

9. Hip Depth (pressure) - The infant is placed on his right side. The depth of the infant's hip is measured from the buttocks in the rear to the point below the iliac crests in front (previously measured for hip breadth). This is taken with the automated paddle-blade anthropometer, applying 0.5 lbs. of pressure as indicated by the pressure transducer reading.



Figure 8 Measurement of Hip Depth (pressure)

10. Head Breadth (contact) - The recumbent infant's head is measured at the maximum breadth of the head with a paddle-blade sliding caliper above and behind the ears, applying sufficient pressure only to contact the surface.



Figure 9 Measurement of Head Breadth

11. Head Length (contact) - The maximum length of the recumbent infant's head is measured from the rear of the head (occiput) to the forehead (at glabella), using a paddle-blade sliding caliper. Sufficient pressure is applied only to contact the surface.



Figure 10 Measurement of Head Length

V. RESULTS AND DISCUSSION

Tables II through VI present the data in tabular format with statistical analysis. The total number of subjects was divided into four cells, male and female, under 4 1/2 months and equal to over 4 1/2 months. 4 1/2 months was selected for division since it was the middle of the age span measured.

Several measurements were eliminated and not included in the statistical design, and the numbers of observations for a particular measure also vary due to several factors. Similarly, some contact measurements taken in addition to the pressure measures have not been included because they were considered to be too unreliable and were omitted after the first twenty subjects were measured. No weight or stature measures were eliminated, although data for some individuals were not recorded.

A Compucorp Model 142 E Statistical Calculator was utilized to calculate mean and standard deviation for each of the measures in each cell. Several comparisons of means were made among the four cells. Lumping all infants together appeared impractical, because males were, overall, consistently larger than females and the lumped averages obtained would tend to obscure those differences. Further, because growth was indicated in every category of measurement, no attempt was made to compare all males to all females. The high-low range of most of the measurements would have been much larger, and consequently the standard deviations would have been much less precise. Comparing age groups without regard to sex appeared to be another approach. It was found that in the younger age group, males were larger than females in each measurement, but not by a significant amount. The older age group was more random, males being larger in seven categories, females larger in

three, while both were the same in one. Again, size differences were insignificant. Also the standard deviation, statistical variance, for each measure was nearly the same for both males and females. These factors indicated that lumping of data by age group would produce statistically meaningful results, and the data were lumped this way. Analysis by race was not attempted, due to the small sample size in each cell for any but caucasians.

The very small value of standard deviation (less than 1.0 in many instances) is an indication of little variance between infants in the given groups. Chest, hip and head measures, particularly, had very narrow ranges (and very little variance) regardless of sex or age. For the sample sizes obtained, these measures could probably be considered very reliable.

Stature, weight, and soft tissue (buttocks) measures were, as expected, the most variable. Larger sample sizes are needed to establish reliable statistics in these categories.

It was our impression that the most critical measurement is that of buttocks A-P depth (and breadth), since the infant whose legs are extended through a crib slat interspace must squeeze by this level in order to get into a more injurious situation. The smallest value measured for buttocks A-P depth was 7.4 cm (2.9 in.) for one 4 month old female infant, while tolerance limits (Table VI) at the 5th percentile limit were calculated to be 6.0 cm. (2.4 in.) for males in the younger age group. The largest value measured in this category was a one month old male having an 11.6 cm. (4.6 in.) buttocks A-P depth. The mean value under 2 1/2-4 1/2 months age was 8.9 cm. (3.5 in.) for females and 9.5 cm. (3.7 in.) for males. The mean value for females 4 1/2 - 6 1/2 months was 9.9 cm. (3.9 in.) and 9.3 cm. (3.6 in.) for males.

The middle 90% of this population, with 95% confidence, lies between a combined sex value of 7.1 (2.8 in.) and 12.0 cm. (4.7 in.) for 4 1/2 to 6 1/2 months, and a combined sex value of 7.5 cm. (2.9 in.) and 11.0 cm. (4.3 in.) for age 2 1/2 to 4 1/2 months. Further values can be obtained by reference to Table I through VI.

Table I. Females

2 1/2 - 4 1/2 months

Subject	WEIGHT (lbs.)	CROWN-SOLE LENGTH (cm.)	SHOULDER BREADTH (cm.)	CHEST WIDTH (cm.)	HIP WIDTH (cm.)	BUTTOCKS WIDTH (cm.)	CHEST A-P (cm.)	HIP A-P (cm.)	BUTTOCKS A-P (cm.)	HEAD WIDTH (cm.)	HEAD LENGTH (cm.)	RACE
1. C.G.	12.25	61.1	16.9	13.2	11.7	12.5	9.3	6.9	7.4	11.4	13.6	N
2. G. Mc.	12.63	57.7	17.2	14.0	11.8	13.2	9.4	8.1	8.7	10.9	14.0	N
3. K.P.	13.38	60.5	17.5	13.5	11.0	13.3	9.2	8.1	9.2	10.6	13.6	C
4. C.V.	13.25	61.2	17.8	12.6	10.0	11.5		6.6	9.4	11.2	13.7	C
5. K.K.	ND	55.6	17.5	13.0	12.5	13.4	8.9	8.1	8.7	10.2	14.0	C
6. K.H.	12.63	63.0	17.2	12.8	10.6	10.8	10.7	7.3	7.6	11.0	14.3	C
7. D.S.	14.75	60.8	19.1	13.9	14.0	15.3	10.2	9.2	10.1	11.1	14.1	N
8. L.J.	12.38	59.6	17.2	12.9	11.4	12.9	10.2	8.7	9.2	10.9	14.4	C
9. K.H.	11.25	56.6	16.7	13.5	11.9	13.3	8.9	9.7	8.6	10.6	13.2	N
10. J.S.	13.00	58.6	17.7	13.2	12.4	13.2	10.4	8.3	10.1	11.5	14.0	M
11. K.W.	11.63	58.9	17.8	12.5	12.3	12.5	10.6	9.2	9.5	10.5	13.8	C
12. K.G.	13.25	60.4	17.7	12.8	ND	12.3	8.7	ND	9.6	10.5	14.3	C
13. J.G.	11.63	57.9	15.7	12.2	10.8	11.6	10.2	ND	8.2	10.9	13.5	C
14. N.A.	13.00	60.0	18.0	13.2	ND	12.8	9.1	ND	8.8	10.8	14.0	
N	13	14	14	14	12	14	13	11	14	14	14	
Mean	12.69	59.42	17.43	13.09	11.70	12.76	9.68	8.20	8.94	10.86	13.89	
Std. Dev.	0.920	1.999	0.760	0.515	1.058	1.073	0.718	0.980	0.821	0.365	0.343	

Table II. Females

4 1/2 - 6 1/2 months

Subject	WEIGHT (lbs.)	CROWN-SOLE LENGTH (cm.)	SHOULDER BREADTH (cm.)	CHEST WIDTH (cm.)	HIP WIDTH (cm.)	BUTTOCKS WIDTH (cm.)	CHEST A-P (cm.)	HIP A-P (cm.)	BUTTOCKS A-P (cm.)	HEAD WIDTH (cm.)	HEAD LENGTH (cm.)	RACE
1. T.R.	15.88	64.5	17.5	14.9	13.6	15.6	10.4	8.9	9.4	11.3	14.1	O
2. M.N.	13.00	63.1	17.4	13.1	10.6	13.1	8.9	7.4	9.1	11.4	14.0	O
3. R.V.	16.75	63.4	18.3	13.4	12.5	15.4	10.2	10.0	9.9			C
4. R.A.	19.25	65.4	21.4	15.5	14.5	16.4	10.6	9.1	10.9	11.8	15.7	C
5. S.	ND	68.1	19.9	15.4	10.5	13.5		10.7	11.8	11.8	15.0	N
6. J.C.	16.75	64.2	19.4	14.1	13.5	15.9	9.9	9.0	12.0	11.7	14.2	C
7. T.N.	15.63	69.2	17.6	13.9	12.9	14.2	9.8	8.7	8.5	11.2	15.4	C
8. C.L.	15.38	65.6	19.8	15.2	13.1	14.2	10.2	9.6	10.0	11.4	13.7	M
9. L.P.	14.63	66.2	19.4	13.8	13.4	14.9	10.7	8.5	9.7	11.2	13.8	N
10. D.J.	17.88	70.0	20.6	14.8	12.1	14.4	11.0	8.1	9.3	12.0	14.4	O
11. A.H.	16.75	68.4	19.7	13.7	11.4	15.4	10.4	9.4	10.2	12.0	14.2	C
12. K.S.	17.50	69.0	18.9	14.6	12.6	15.2	10.9	8.7	10.7	11.4	15.4	C
13. R.G.	19.00	67.6	21.2	15.3	13.7	16.4	11.7	9.5	8.1	12.5	15.6	C
14. A.L.	17.88	67.6	20.3	14.2	14.1	14.7	11.2	9.9	9.5	11.4	15.1	N
15. K.H.	18.25	69.2	20.5	14.1	13.4	15.3	9.9	ND	10.7	12.4	15.1	M
16. M.S.	13.63	61.7	17.6	13.1	11.5	12.6	9.9	ND	9.0	11.5	14.2	C
17. A.S.	16.88	68.8	18.3	13.4	12.2	14.2	9.6	ND	9.5	11.5	14.6	C
18. K.R.	15.00	67.2	17.5	13.4	ND	ND	ND	ND	ND	10.3	14.4	N
19. J.P.	17.00	67.6	17.9	13.4	12.7	15.4	10.4	9.2	9.8	11.3	15.2	
20. M.D.	15.38	65.2	19.1	13.4	13.4	15.5	10.7	10.2	9.0	11.3	14.7	
N	19	20	20	20	19	19	18	16	19	19	19	
Mean	16.44	66.60	19.12	14.14	12.72	14.86	10.36	9.18	9.85	11.55	14.67	
Std. Dev.	1.701	2.359	1.304	0.803	1.114	1.043	0.651	0.826	1.022	0.486	0.625	

TABLE III. MALES

2 1/2 - 4 1/2 months

SUBJECTS	WEIGHT (lb.)	CROWN - SOLE LENGTH (cm.)	SHOULDER BREADTH (cm.)	CHEST WIDTH (cm.)	HIP WIDTH (cm.)	BUTTOCKS WIDTH (cm.)	CHEST A-P (cm.)	HIP A-P (cm.)	BUTTOCKS A-P (cm.)	HEAD WIDTH (cm.)	HEAD LENGTH (cm.)	RACE
1. M.S.	14.13	62.7	17.7	12.3	12.1	13.6	9.5			11.5	14.4	C
2. E.S.	15.25	59.7	18.3	13.5	13.6	14.8	10.6	8.2	9.7	11.8	14.9	C
3. D.O.C.	ND	61.8	17.5	13.0	12.3	14.6	9.5	7.6	9.4	11.3	14.4	C
4. G.F.	14.13	64.9	17.0	13.1	13.0	13.9	10.6	9.0	10.3	11.0	14.2	C
5. R.F.	10.50	52.5	16.2	12.0	10.0	11.6	8.8	7.5	7.7	10.7	13.7	C
6. O.W.	11.75	54.0	16.3	11.9	11.0	12.4	9.5	8.3	8.3	10.4	14.1	C
7. S.H.	15.00	61.8	18.2	14.1	13.2	14.0	11.2	9.0	10.2	11.1	14.8	N
8. T.C.	15.63	64.4	18.0	12.9	13.4	15.0	9.7	9.3	9.6	11.4	15.6	C
9. H.A.R.	12.25	57.7	19.0	13.6	11.6	13.4	10.5	8.5	9.4	11.5	13.0	O
10. B.A.	15.50	62.0	18.1	12.6	12.5	14.6	10.5	9.4	10.6	11.6	14.4	C
11. R.D.	16.88	64.2	20.8	14.8	13.6	14.9	10.7	9.9	10.6	10.8	15.0	N
12. J.W.	11.13	58.5	17.2	13.2	11.5	13.2	10.1	8.3	9.3	10.4	13.7	C
13. A.S.	11.00	51.5	16.1	12.8	11.9	13.3	11.2	8.6	8.7	10.4	13.5	N
14. G.L.C.	16.13	63.4	20.0		ND	14.5	9.9	ND	9.8	11.5	14.3	C
15. M.S.	17.13	58.4	17.8	12.1	11.8	11.0	10.0	ND	9.5	10.8	14.3	C
16. P.Z.	13.63	64.4	18.0	13.2	11.1	12.0	9.2	ND	8.2	11.7	14.3	C
17. G.M.	13.75	62.5	18.7	14.2	ND	13.0	11.1	ND	9.5	11.0	14.4	C
18. M.L.	13.50	63.2	17.5	14.0	ND	12.5	10.2	ND	9.5	10.6	14.1	C
19. E.W.	11.38	57.3	ND	12.5	ND	13.3	9.6	ND	10.2	11.3	14.8	C
20. M.P.	14.63	61.2	17.5	12.9	ND	14.3	9.0	ND	9.5	11.3	14.1	C
N	19	20	19	19	15	20	20	12	19	20	20	
MEAN	13.86	60.31	17.89	13.09	12.17	13.50	10.07	8.63	9.47	11.11	14.30	
Std. Dev.	2.042	4.025	1.190	0.796	1.059	1.150	0.720	0.719	0.790	0.451	0.574	

Table IV. Males

4 1/2 - 6 1/2 months

Subject	WEIGHT (lbs.)	CROWN-SOLE LENGTH (cm.)	SHOULDER BREADTH (cm.)	CHEST WIDTH (cm.)	HIP WIDTH (cm.)	BUTTOCKS WIDTH (cm.)	CHEST A-P (cm.)	HIP A-P (cm.)	BUTTOCKS A-P (cm.)	HEAD WIDTH (cm.)	HEAD LENGTH (cm.)	RACE
1. S.A.	20.00	72.4	19.2	15.7	13.6	15.9	11.4	9.3	10.1	12.0	15.0	C
2. J.D.	15.25	68.5	18.5	13.6	12.2	13.0	10.6	8.3	8.4	11.8	15.1	C
3. K.D.W.	ND	66.7	19.2	14.4	11.6	14.1	8.4	7.7	8.8	11.5	14.4	C
4. A.	18.50	69.8	20.6	14.7	13.2	15.8	10.6	9.2	10.1	11.7	15.3	N
5. A.D.C.	18.25	68.7	18.8	14.9	13.6	15.1	11.2	8.8	8.6	12.2	16.2	O
6. D.L.	13.88	66.8	17.0	13.6	11.7	12.5	11.2	8.5	7.0	12.0	14.7	C
7. K.W.	16.00	65.5	18.7	13.7	13.6	15.3	10.6	9.0	10.0	12.1	14.5	C
8. A.B.	17.25	64.5	20.0	14.2	14.4	15.4	11.5	9.5	9.2	12.3	14.5	C
9. J.L.	19.25	69.8	20.8	14.9	14.0	15.8	10.7	10.4	9.6	12.5	15.3	C
10. J.d1 I.	14.50	65.1	19.7	14.3	13.7	14.5	10.7	9.3	11.6	12.0	15.6	C
11. L.M.	ND	66.0	19.7	14.8	15.7	16.9	11.8	10.7	10.3	11.9	14.6	C
12. R.H.	18.88	68.1	20.5	15.5	13.5	13.6	9.8	7.3	8.2	12.1	14.8	C
13. E.L.	19.00	65.2	19.9	15.9	ND	15.4	10.5	ND	11.0	12.0	15.0	M
14. C.J.	14.63	62.9	15.3	12.8	ND	12.4		ND	7.2	11.6	15.4	C
15. R.W.	18.25	67.7	18.9	13.4	ND	14.3	11.2	ND	9.0	12.3	15.2	C
N	13	15	15	15	12	15	14	12	15	15	15	
Mean	17.20	67.18	19.12	14.43	13.40	14.67	10.73	9.00	9.27	12.00	15.04	
Std. dev.	2.085	2.457	1.434	0.897	1.147	1.336	0.843	0.985	1.298	0.272	0.487	

Table V. Male and Female Combined

(2 1/2 - 6 1/2 months)

	WEIGHT (lbs.)	CROWN-SOLE LENGTH (cm.)	SHOULDER BREADTH (cm.)	CHEST WIDTH (cm.)	HIP WIDTH (cm.)	BUTTOCKS WIDTH (cm.)	CHEST A-P (cm.)	HIP A-P (cm.)	BUTTOCKS A-P (cm.)	HEAD WIDTH (cm.)	HEAD LENGTH (cm.)
2 1/2 - 4 1/2 months											
N	32	34	33	33	27	34	33	23	33	34	34
Mean cm.	13.39	59.94	17.69	13.09	11.96	13.19	9.92	8.43	9.25	11.01	14.13
Standard cm. Deviation	1.757	3.331	1.042	0.682	1.065	1.162	0.734	0.862	0.835	0.429	0.527
Mean (inches)		23.60	6.96	5.15	4.71	5.19	3.90	3.32	3.64	4.33	5.56
Standard Deviation (inches)		1.311	0.410	0.268	0.419	0.458	0.289	0.340	0.329	0.169	0.207
4 1/2 - 6 1/2 months											
N	32	35	35	35	31	34	32	28	34	34	34
Mean cm.	16.75	66.85	19.12	14.26	12.98	14.77	10.52	9.10	9.59	11.75	14.84
Standard cm. Deviation	1.873	2.383	1.34	0.847	1.158	1.165	0.752	0.885	1.170	0.461	0.590
Mean (inches)		26.32	7.53	5.61	5.11	5.81	4.14	3.58	3.78	4.63	5.84
Standard Deviation (inches)		0.938	0.528	0.333	0.456	0.459	0.296	0.348	0.461	0.181	0.232

One statistically meaningful technique for design purposes involves evaluating or comparing observations of a population in terms of tolerance limits, or percentile. The following tabulation (Table VI) presents tolerance limits covering the middle 90% of the sample population, assuming a normal distribution, with 95% confidence. These limits provide estimates of the 5th and 95th percentiles. Thus the middle 90% of the population of observations lies between these upper and lower limits. Due to the large amount of growth in the 2 1/2 - 6 1/2 month age span, the population is arbitrarily divided into two age groups, with both individual breakdowns by sex, and combined.

TABLE VI

Tolerance Limits for 5th and 95th Percentile

The upper figure in each column represents the 5th percentile value for each variable, while the lower figure represents the 95th percentile value. The middle 90%, with 95% confidence, lies between these values.

Variable	Age 2 1/2 - 4 1/2 months			Age 4 1/2 - 6 1/2 months		
	Males	Females	Combined	Males	Females	Combined
Weight	9.09	10.35	9.67	11.81	12.47	12.78
lbs.	18.43	15.07	17.11	22.59	20.41	20.72
Crown-Sole Length	51.02	54.37	52.92	61.09	61.16	61.87
(cm.)	69.60	64.47	66.93	73.27	72.04	71.83
Shoulder Breadth	15.11	15.51	15.50	15.57	16.11	16.32
(cm.)	20.67	19.35	19.88	22.67	22.13	21.92
Chest Breadth	11.23	11.79	11.66	12.21	12.38	12.47
(cm.)	14.96	14.39	14.52	16.65	16.00	16.03
Hip Breadth	9.55	8.90	9.65	10.36	10.12	10.52
(cm.)	14.79	14.50	14.27	16.44	15.32	15.44
Buttocks Breadth	10.85	10.05	10.75	11.36	12.43	12.33
(cm.)	16.15	15.47	15.63	17.98	17.29	17.21
Chest A-P	8.41	7.83	8.40	8.60	8.82	8.94
(cm.)	11.73	11.53	11.44	12.86	11.90	12.11
Hip A-P	6.73	5.52	6.50	6.39	7.17	7.19
(cm.)	10.53	10.88	10.36	11.61	11.19	11.01
Buttocks A-P	7.50	6.87	7.49	6.06	7.47	7.14
(cm.)	11.31	11.01	11.01	12.48	12.23	12.04
Head Breadth	10.07	9.94	10.11	11.33	10.42	10.79
(cm.)	12.15	11.78	11.91	12.67	12.68	12.71
Head Length	12.98	13.03	13.03	13.84	13.21	13.61
(cm.)	15.62	14.76	15.23	16.24	16.13	16.07

APPENDIX A
CHILD ANTHROPOMETRY FORM
CRIB SLAT SUBSTUDY

SUBJECT NAME _____ DATE _____

BIRTHDATE _____ M
F C N M O

LOCATION _____ HOSP. RECORD NO. _____

1. Weight _____
2. Crown-Sole Length _____
3. Shoulder Breadth _____
4. Chest Width _____
5. Hip Width _____
6. Buttocks Width _____
7. Chest A-P _____
8. Hip A-P _____
9. Buttocks A-P _____
10. Head Width _____
11. Head Length _____

COMMENTS: _____

APPENDIX B

Crib Slat Spacing Tests

1. 3 month old 5th percentile (buttocks and chest A-P dimensions):

It was understood that the application of these subject measurement data obtained in this task was in relation to the spacing of crib slat dimensions necessary to preclude an infant from squeezing or slipping through. Two further tests were thus conducted to provide the investigators with direct knowledge and an appreciation for how the uni-dimensional anthropometry translates in regard to this particular problem. These tests were limited to two representative subjects and two crib slat interspace distances only. Since they were not a part of the designated task of objective body anthropometry, these observations are attached as being of direct pertinence and value, however, must be viewed as indicative rather than comprehensive in scope and interpretation.

In the first test a 3 month (12 week) old infant, weighing 10 lbs. 6 oz. (naked) and having a crown-sole length of 52.5 cm. (20.7"), was utilized as representative of the smaller 3 month old body size. In comparison to the other male subjects of the 2 1/2 - 4 1/2 month (3 month \pm 1.5) age range this infant is within the lower 10th percentile in size (middle 90% weight range 9.1 to 18.4 lbs) crown-sole length middle 90% length 51.0 cm. (20.1 in.) to 69.6 cm. (27.4 in.). However, in regard to the more critical dimensions of hip and buttocks sizes, this infant was representative of the lower 5th percentile limits, having a buttocks A-P depth of 7.7 cm. (3.0 in.), hip A-P depth of 7.5 cm. (2.9 in.), and chest A-P depth of 8.8 cm. (3.5 in.). For comparison, the 5th percentile for male infants for these body measurements for the sample study was respectively, buttocks A-P depth 7.5 cm. (2.9 in.), hip A-P depth of 6.7 cm. (2.6 in.), and chest A-P depth of 8.4 cm. (3.3 in.). The hypothesis being that if this infant representative of the 5th percentile 3 month old male in these critical body measurements, or the lower limits, can not easily squeeze

through whatever slat spacing attempted, then that spacing may be estimated with reasonable confidence to adequately protect 95% of three month old or older male infants. Females of this age group would present slightly lower limits, although only two had a 7.4 - 7.6 cm. measurement for this dimension. The worst case (but probably most typical) of naked vs. diapered condition was used under careful medical supervision. The infant was positioned so that his legs were through the slats of a commercial crib having a measured space of 3 1/4 inches between slats. This infant was slipped through with ease up to his abdomen, but it was considered to be too hazardous to attempt to ease this infant further. It was the impression of the attending pediatrician that he could have burped up his milk (having a distended abdomen from just eating), and slid through the slats at least up to his chest where he could have hung with much of his body weight outside the crib, and placing additional pressure on his thorax. Since his chest A-P depth was 3.5 inches at 0.5 pound pressure, it seems apparent that he could have squeezed his chest through these 3.25 inch slats with little difficulty. If this occurred, fatal consequences of head impingement could occur. Figures 11 through 14 show photographs illustrating this trial test.

The Well-Child Clinic of The University of Michigan uses metal cribs having 2 1/4" distance between slats. A second test was conducted using this crib with the same 3 month old infant as above. In this case, as illustrated by Figures 15 - 18, the infant's legs went through the slats up to his buttocks, but no attempt was made to squeeze him further. His maximum buttocks A-P depth was 7.7 cm. (3 in.) without significant tissue compression (.5 lbs.). It would thus have required an additional 3/4 inch compression for passage of this infant's buttocks through a 2 1/4 inch crib slat inter-space.

2. Six month old female, middle 90th percentile (buttocks, hip and chest A-P dimensions).

In a subsequent test a six month (27 3/7 weeks) old female, weighing 17 lbs. and a crown-sole distance of 67.6 cm. (26.6 in.), was utilized as a test subject. This infant was slightly under the mean body length for females of this age (\bar{X} 66.6 cm.) in our sample, and slightly under the mean body weight (16.4 lbs.). In chest A-P depth she was 10.4 cm. (4.1 in.) compared with a mean of 10.4 cm. for females in that age group, 9.2 cm. (3.6 in.) in hip A-P depth compared with a mean of 9.2 cm., and 9.8 cm. in buttocks A-P diameter compared with a mean of 9.9 cm. Thus she is representative of the mean values for females 4 1/2 - 6 1/2 months in our sample, and in the middle 90th percentiles of the population.

Results were that her buttocks were easily slipped through the same 3 1/4 inch distance between crib slats used in the first test. No attempt was made to squeeze her, or to maneuver her further, as this was felt to be potentially hazardous. It was the impression of the observers that she could have gone through this size inter-space slat design further with little difficulty. A test using the 2 1/4 inch inter-slat crib was not conducted in this case.

In connection with tissue compressibility and in particular with chest compression, chest or abdominal compression of the heart between the sternum and vertebral column has been attributed to a wide variety of heart lesions in adults, ranging from fatal atrial and ventricular rupture to sudden death without demonstratable cardiac changes. (Snyder, R.G. 1970 State-of-the-Art-Human Impact Tolerance 1970 International Automobile Safety Conference Compendium, SAE publication p-30, SAE publication No. 700398.) It should be noted that recent experimental thoracic force-deflection studies on sub-human adult primates in this laboratory indicate that such excursions can compress the

chest 2/3 its depth in these adult animals. (D.L. Beckman and M.F. Palmer 1970 "Thoracic Force-Deflection Studies in Primates" Journal of Biomechanics 3:551-555.)

In infants, having immature skeletal thoracic support with pliable cartilagenous structure, compression could be large, allowing an infant (particularly when loaded by a portion of his body weight hanging outside the crib) to squeeze through spaces much less than those body dimensions measured. In each of the above tests the infant was "worst-case" from the point of view of being naked, and in positioning on the side in slat penetration trials. However even these limited trials indicate that the anthropometric data relative to body diameters represent a relatively non-compressed condition, and should be considered as extremely conservative values in relation to the question of whether or not an infant can squeeze through a given crib slat inter-space.

The photographs in Figures 11-14 were taken during this test and illustrate how easily this naked 3 month old (12 weeks) infant's buttocks slipped through crib slats having 3 1/4" distance between slats.

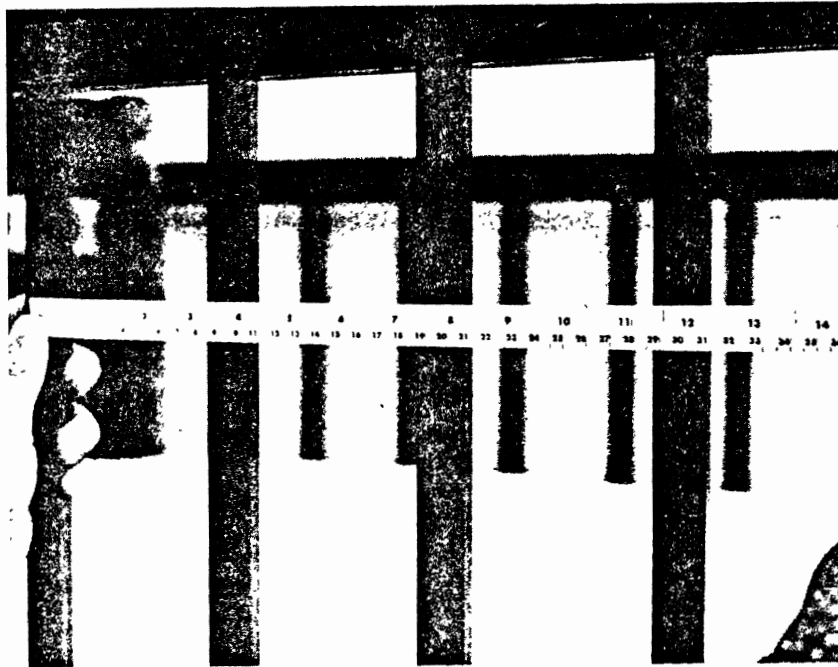


Figure 11. Distance between slats was 3 1/4 inches.



Figure 12. View showing relationship of buttocks to slat.



Figure 13. Another view of infant on left side with buttocks slid through 3 1/4" crib slats.



Figure 14. View of front of same infant lying on right side with buttocks outside crib.

The following photographs, illustrated by Figures 15-18, show the relationship of the same 3 month old infant to a crib inter-slat distance of 2 1/4 inches. This type of crib is used in The University of Michigan Well-Child Clinic.

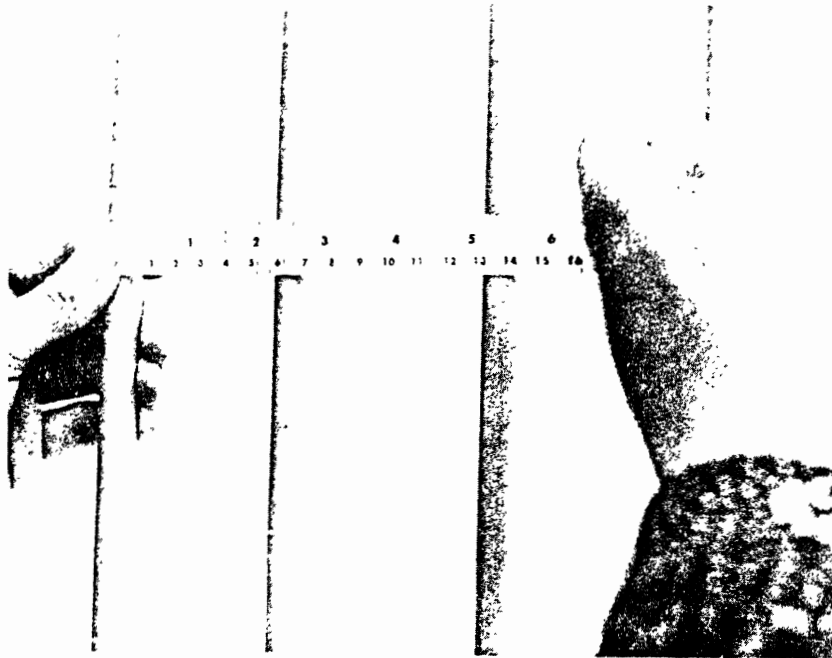


Figure 15. Distance between slats was 2 1/4 inches.



Figure 16. Infant being maneuvered by Dr. Clyde Owings.



Figure 17. No attempt was made to force the buttocks through. The infant could get his legs through to this point without forcing. This infant's maximum buttocks A-P depth was 7.7 cm. (3 in.) without significant tissue compression (0.5 lbs.).



Figure 18. Another view of same 3 month old infant in relationship to 2 1/4" distance between crib slats.