CHILDREN IN SPACE

by

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ABSTRACT

Title: Children In Space

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Summary:

If families/children are to be sent on space explorations, then a space cabin must be designed to accommodate children. Before designing such a space cabin, research is necessary to define children's capabilities. This project proposes to start the research by gathering certain anthropometric and physiological data of children between the ages of six and eleven. Measurements include: foot length, hand length, tibiale height, trochanteris height, standing height, bideltoid breadth, sitting height, hip breadth, grip strength, motor control, reaction time, functional reach envelope, and visual field.

ACKNOWLEDGEMENTS

The author wishes to express her appreciation to her advisor Dr. J. K. Hennigan for his foresight and guidance while overseeing this project. I would also like to acknowledge Dr. Hennigan's personability and the seemingly constant availability shown throughout this project. Dr. Hennigan is greatly appreciated by me and all students who are priviledged to work under him.

The author wishes to gratefully acknowledge the cooperation and assistance of Jeff Birkenholz. Jeff repaired, set-up and operated the functional reach envelope equipment as well as veing a member of the psycomotor skills measuring team. I also wish to give special thanks to Sheri Caldwell and Pam Hewett for their willingness and conscientiousness in helping to measure the skills of 125 children. Thanks also needs to go to Scott Hampel for building the anthropometric chair designed for this project by the author.

The author also desires to commend Zane Goff for his willingness to teach me how to use the SAS computer language and multivariant analysis used to obtain the statistical results. His time and effort is appreciated.

The author also wants to express her appreciation to the Superintendent of College Station Independent School District, Dr. H. R. Burnett, the director of curriculum, Mike Owens and to the faculty of Southwood Valley Elementary for their cooperation. Special thanks need to go to Coach Alice Keys for her help is selecting and organizing the children.

Finally the author wishes to acknowledge the children without whose willing cooperation this project would not have been successful.

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INTRODUCTION[1]:

There have been many advances in technology since the creation of man: from the use of the club for defense to the repeating rifle to the long range missile; from the use of fire for cooking to the stove to the microwave; and from the use of hand-craftsmen for production to semi-skilled assembly workers to the fully automated factories. These innovations, that help to solve the problems of man and that make him more compatible with his enviroment, developed from a deeper understanding of the natural resources and the abilities and limitations of man and his enviroment. A major source for increasing one's knowledge of man's capabilities and limitations is the study of anthropometry. According to NASA researchers (NASA, 1978a) anthropometry is "the proctice of measuring the parts and portions of the human body."

Anthropometric data can be used to design any type of system including an human and some type of equipment. The equipment can range from protective clothing, such as a space-suit, to hand tools, such as a screwdriver, to a control panal, such as found in the cockpit of an airplane or space shuttle.

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[1]Format and Style based on a recent issue of the Human Factors Journal.

In a NASA tour guide pamplet (NASA, 19??) under the description of NASA's Anthropometric Laboratory is a statement of the purpose of anthropometric data. The purpose or use of anthropometric data is to acheive "accommodation, compatibility, integration, safety, improved and logistic efficiency in man/equipment systems."

NASA's effective use of anthropometric data has allowed the United States Space Program to advance at an amazing rate from the launching of the first man-made satellite, the Sputnik VII, to the first man-made spaceship, the Vostok I. The rapidity of the growth in space exploration along with the recent developments -- the reusable space shuttle, the first women astronaut in space, and the skylab which will be the home of scientists and researchers for extended periods of time -- brings the question -- what next? A possible answer is families or more specifically children in space.

Just as with the adult space program, before attempting to send children into space, extensive research is necessary to determine children's capabilities and limitations, not only physically but also intellectually and emotionally. The main purpose of this study is to establish an anthropometric data base for the redesign of the space cabin to accommodate children. This project is only the beginning af the necessary research and does not propose to encompass its entire scope.

LITERATURE REVIEW:

A review of anthropometric literature reveals four main purposes of anthropometric research. The purposes are to provide representative data for use in the design of military equipment, equipment that is used in space exploration, industrial equipment and work-space layout, and physical education programs.

The military was responsible for the early anthropometric research. The first major anthropometric survey of the army occurred in 1946 (White, 1979). This two-part survey included measurements of 105,062 army men and 8,864 army women. Approximately ninety-two percent of the male subjects were World WarII veterans with the remainder consisting of newly enlisted men. The female subjects were a mixture of sixty percent Women's Army Corp officers and enlisted women, and forty percent army nurses. The results obtained from this survey included sixty-six anthropometric measurements from each male subject and sixty-five from each female subject. The primary purpose was to collect body dimensions of the military population for use in the designing and sizing military clothing and other personal equipment.

The military executed follow up surveys in 1966 and 1977 for army men and army women, respectively (White, 1979). The 1966 survey measured 6,686 men with the greatest percentages coming from basic trainees and infantrymen and the other scant percentages of armored crewmen and army aviation personnel.

Each subject contributed seventy body dimensions. The 1977 survey yielded sixty-nine body dimensions from each of the 1,831 women tested. The subject group consisted of 166 officers, 228 army nurses, and 987 enlisted women. The military obtained other anthropometric variables, such as facial features and grip strength, from different subsets of the original group of women to make a broader data base than the first survey.

White, (White, 1979) combined the men's data from the 1946 survey with the 1966 data and the women's data from the 1946 survey with the 1977 data to analyze the growth patterns of the military population to see if the growth was significant enough to warrant the redesigning of equipment and clothing. White also combined the male and the female body dimensions collected in all four surveys to develop a data set that would be useful in designing the personal equipment and workspaces that both male and female army personnel would use.

An important characteristic of the subjects, which must always accompany the data and have proper consideration when applying the data to design, is the clothing worn by the participants during testing. The subjects in the previous army surveys were only wearing their undergarments. The military also performed surveys with the subjects wearing specialized clothing such as the pressurized suits worn by astronauts and aviators. Alexander, Milton, Garrett and Flannery (NASA, 1978b) carried out an anthropometric study which measured one hundred and thirty-eight variables and which had a sample size of thirty-four. The subjects were either standing, sitting or supine with the suit being either inflated, uninflated or inflated while in restrained condition during testing. There were also forty circumferences measured from thirty-two subjects wearing either an inflated or an uninflated suit; however, these thirty-two subjects were independently chosen from the first thirty-four subjects. The purpose of this study was to gather more representative dimension data for use in the design of high altitude aerospace vehicles.

In the past, industry has had to rely on the military surveys for the anthropometric data used to design safety clothing, personal equipment and products, and to layout the workplace. However the military data is not as representative of the civilian work force or the consumer population as industrial designers desire due to the strict entrance requirements which eliminate the upper and lower percentiles and the particially handicapped. Therefore, from 1960 to 1962, the National Center for Health Statistics made a survey of civilians (Hutchingson, 1981). Although the subjects were civilians, the sample size of this specialized group and the limited number of variables did not allow statistically accurate generalizations; therefore, reliance on military data was still necessary. Since then government agencies as well as independent researchers have broadened the civilian data. The United States Consumer Product Safety Commission is responsible for the broader base since they research not only the work force population but also the consumer population which includes children as well as analyze practices to see if they are harmful to the growth and development of the participants. Another field besides the Consumer Product Safety Commission that uses anthropometric data to analyze practices is the field of physical education. The Medford school for boys (Clark, 1971) made an extensive twelve year longnitudinal anthropometric study to determine if the current physical education programs were harmful to the physical welfare of the participants. The subjects ranged from the age of six to the age of eighteen. Measurements included fifteen anthropometric variable as well as some basic endurance tests. Many dissertations record the results of the physical education anthropometric studies. There are dissertations (Delaneuville, 1971; Whittingham, 1978) which were comparative studies of negro and caucasian boys and girls. The purposes of these studies were to determine if there were any anthropometric differences between the races; to determine if these differences gave either one of the races an advantage over the other in athletics; and to determine if the differences are significant enough to warrant different phsical education programs.

In summary, literature revealed four basic areas of anthropometric research -- military, industrial, space exploration, and physical education. It also showed a common characteristic of the anthropometric studies. Although the subjects differed in age and background, they all had one thing in common -- they represented the population that would use the designs developed from the research. Even though the variables measured in the different surveys were generally the same, they differed slightly in definition of reference points. These differences, although small, do not allow the data to be transferred from one study to the next if the variable will be used for a critical dimension. The findings in this literature review must be considered in designing any type of anthropometric study.

METHODS AND PROCEDURES:

Project Design:

As stated in the project proposal (see Appendix I-A) the aim of this study was to gather anthropometric and physiological data from one hundred children between the ages of six and thirteen. However, due to the age divisions in the school system, this aim changed to include only children between the ages of six and eleven.

Other changes occurred due to the responses from letters, intended to determine the worthiness of this project, sent to NASA (see Appendix I-B). Upon NASA's request the measurements of functional reach and visual field joined the data base. However, due to time limitations per child, only peripheral vision, a subset of one's visual field, entered the data base.

Before beginning the experiment, since it involved humans, it was necessary to obtain the approval of the Committee for

Research with Humans. After reviewing the submitted proposal and application for approval, the committee determined that the proposal was "exempt from full review of the Institutional Review Board" (see Appendix I-C) and granted its approval.

Measurements:

When collecting or applying anthropometric data, it is important to consider the clothing worn by the subjects during testing and the definitions of reference points. Due to the constraints placed on the project by the public school system, nude body dimensions were not obtainable; therefore, correction factors for light clothing will be necessary to apply the data to designs. Different reference points may lead to different values for one dimension for example: The Medford study (Clark, 1971) defined stature as the vertical distance from the floor to the top of a fully tilted-back head; while NASA (NASA, 1978b) defines it from the floor to the top of the head with the subject looking straight ahead. Although the differences may be small and there are correction factors available, to make the data as directly applicable as possible NASA's definitions of reference points determined the measurements.

The anthropometric measurements and their respective definitions (NASA, 1978b) are as follows:

(1) Stature or Standing Height-- The vertical distance from the standing surface to the top of the head. The subject stands errect and looks

straight ahead. (see Figure 1)

(2) Trochanteric height-- The vertical distance from the standing surface to the most superior point of the greater trochanter of the femur. The subject stands erect looking straight ahead, heels together and weight distributed equally on both feet. (see Figure 1)

(3) Tibiale Height-- The vertical distance from the standing surface to the proximal medial margin of the tibia. The subject stands erect, heels together and weight distributed equally on both feet. (see Figure 1)

(4) Bideltoid Shoulder Breath-- The horizontal distance across the body at the level of the deltoid landmarks. The subject stands erect with his arms hanging naturally at his side.

(5) Hand Length-- The distance from the wrist landmark to dactylion. The subject sits with the hand flat on a table, palm up, with fingers together and straight. (see Figure 2)

(6) Foot Length-- The distance, parallel to the long axis of the foot, from the back of the heel to the tip of the most protruding toe. The subject stands with weight equally distributed on both feet. (see Figure 3)

(7) Sitting Height-- The vertical distance from the

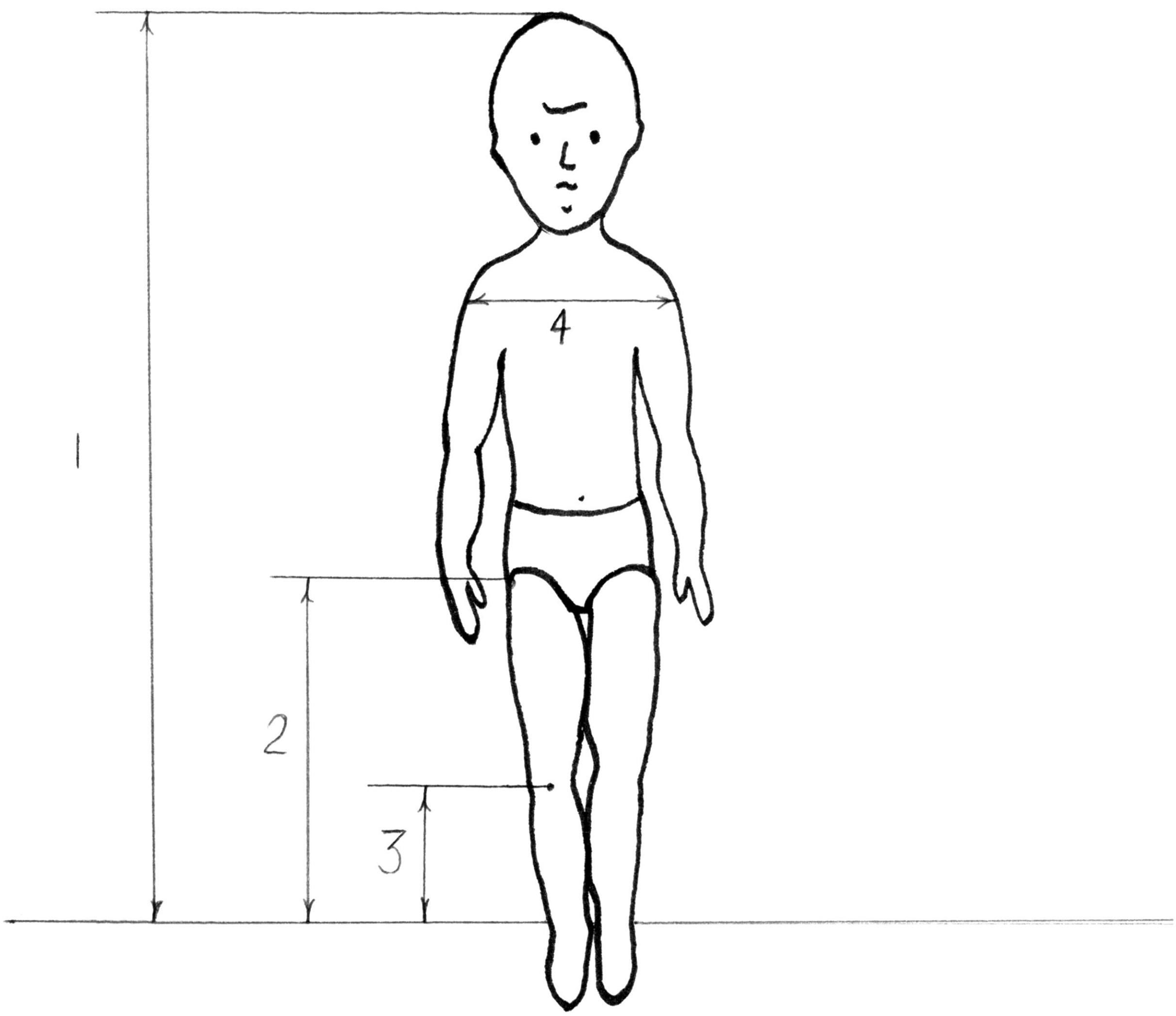

FIGURE 1 - Antropometric Dimensions

(1) Standing Height (2) Trochanteris Height

(3) Tibiale Height (4) Bideltoid Breadth

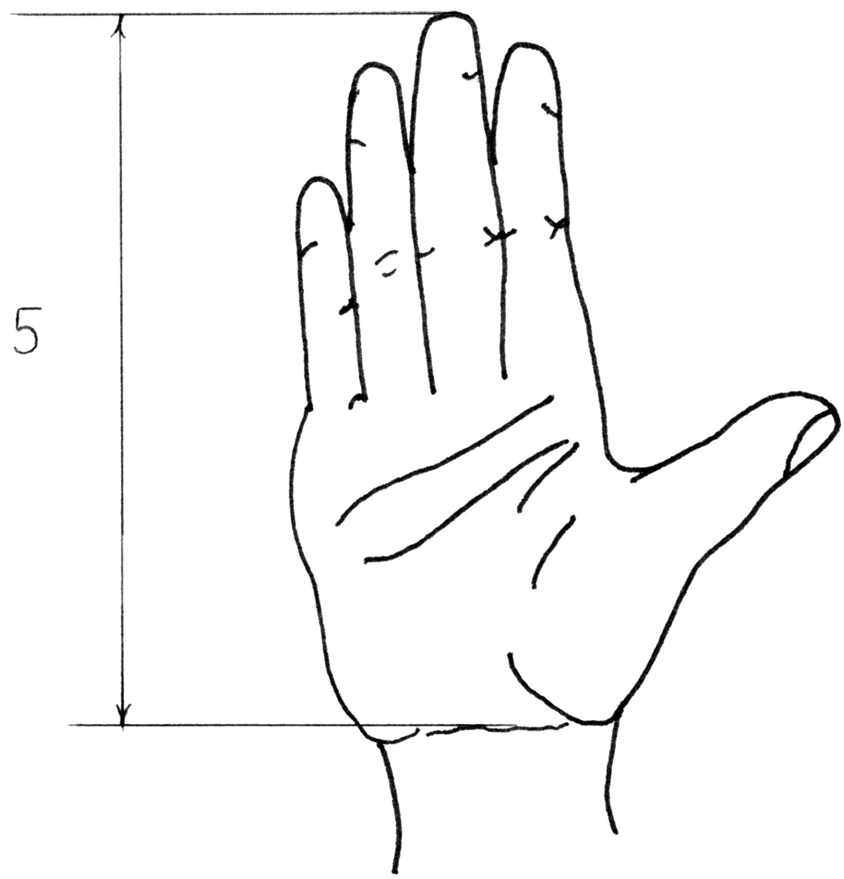

FIGURE 2 - Anthropometric Dimension

(5) Hand Length

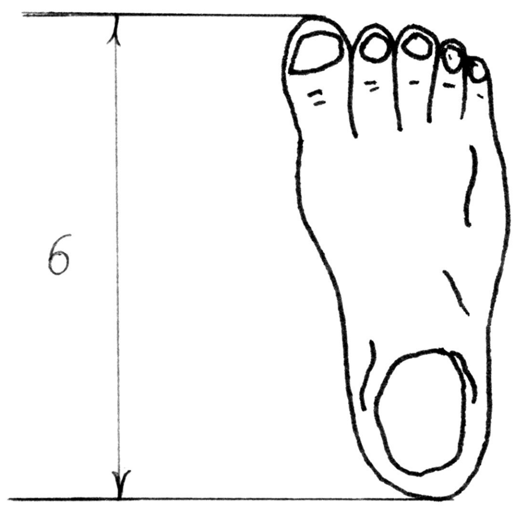

FIGURE 3 - Anthropometric Dimension

(6) Foot Length

sitting surface to the top of the head. The subject sits erect, looking straight ahead. (see Figure 4)

(8) Hip Breadth-- The maximum horizontal distance across the thighs. The subject sits erect, upper arms relaxed, forearms extended forward horizontally, thighs completly supported by the sitting surface, and the long axis of the thighs parallel. (see Figure 4)

Also included with the measurements are the psycomotor skills: (1) grip strength; (2) reaction time; (3) motor control or eye hand coordination; (4) peripheral vision, the horizontal range of eye movement; and (5) functional reach envelope, the range of arm movement in three dimensions. All subjects used in the statistical analysis completed all measurements and tests.

Data Collection Procedure:

Southwood Valley Elementary of College Station Independent School District (CSISD) provided the subjects through the physical education program. Coach Alice Keys selected the children randomly from all skill levels in her classes. Requirements such as the age divisions, the numbers per division, and approximately equal numbers of boys and girls governed the random selection.

Assisting the author in measuring the psycomotor skills were Jeff Birkenholz, Sheri Caldwell and Pam Hewett, all students in Industrial Engineering at Texas A&M University.

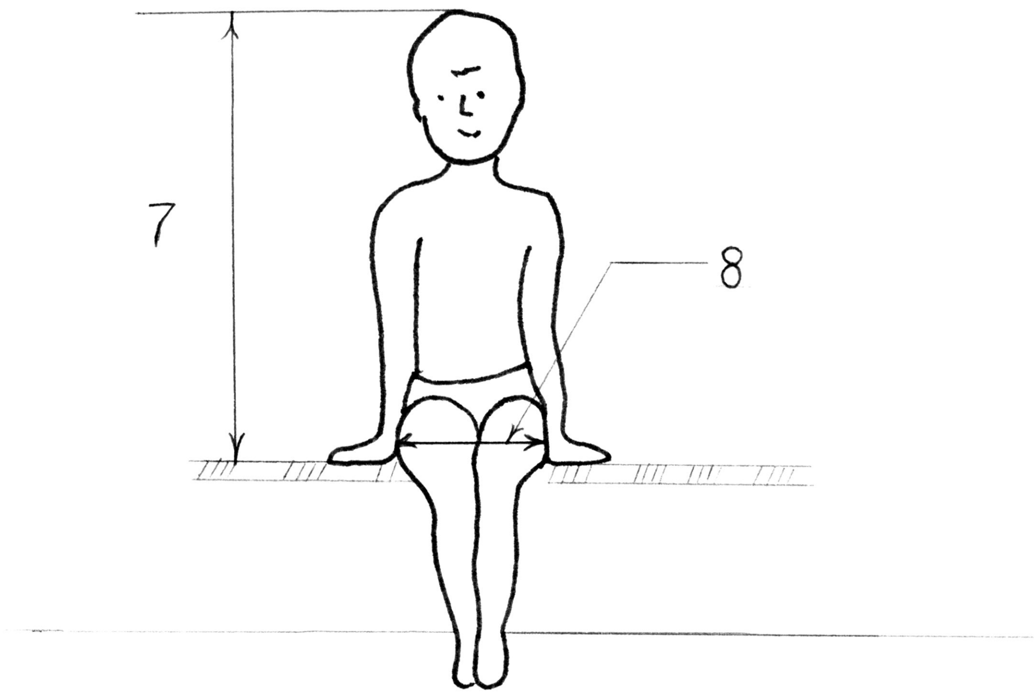

FIGURE 4 - Anthropometric Dimensions

(7) Sitting Height (8) Hip Breadth

Each member of the team had experience with the equipment from previous courses. Jeff Birkenholz also collected the functional reach envelope data. Time limitations, ten to fifteen minutes per child, imposed by the Superintendent of CSISD made this team necessary for permission to use CSISD students (see Appendix I-D)

Measuring - Strategy, Equipment and Procedures:

Before setting up the measuring sessions, the variables were divided into two basic categories to minimize the overall time per child and to maximize the number of children per forty-five minute class period. The first category, including the variables which required a table, contained reation time, motor control, grip strength, hand lengths, and peripheral vision. The second category included all of the body dimensions with the exception of hand lengths and functional reach envelope.

During the measuring sessions five to ten children would come to the testing area at a time and would select a starting point. To minimize the idle time of both the measuring team and the children the starting point was constant per child. When measuring the first category there were always two and sometimes three of the measuring team present. Since determining the location of some of the reference points, such as the approximate median of the tibia for tibiale height, are subjective, the author measured all the body dimensions. However, the psycomotor skills tests did not involve subjectivity;

therefore, the measurer could vary throughout the data collecting period. The team member measuring the motor control also measured grip strength during the idle time while the subject performed the test. During the measuring session for the second category, there were always two measurer, the author for body dimensions and Jeff Birkenholz for functional reach. These two sets of measurements took approximately the same amount of time; therefore, a child could start in either spot and use the same amount of time.

When collecting experimental data, it is essential to have a set method and to follow it consistently throughout the whole experiment so that results of one set of experimental data will be comparable with another set of the same type of experimental data. For example, for reaction time of two subjects to be comparable it would be necessary that the stimulus be the same for both measurements. The equipment used to collect the data and a knowledge of its features is important to the researcher and the user of the research. The following paragraphs include descriptions of the methods and the equipment used in this research.

Peripheral vision employed the table top perimeter pictured in Figure 5-1. The perimeter consisted of a stand which held a semicircle bar with the degrees marked on its circumference. This bar could be rotated to measure the angles of visual field. The bar was in the horizontal plane to measure peripheral vision. The perimeter also contained a chin rest and a focus point, both aligned with the short axis of the semicircle at the center and the edge, respectively. The subject placed his chin on the rest and kept his eyes on the focus point while the tester, standing behind the subject, moved an object, in this case a blue pencil, in from behind following along the outside of the bar. When the subject indicated that he could see the pencil the tester recorded the position of the pencil to the closest 2.5 degrees. Since the bar markings were 5 degrees apart and there was a reponse time involved in stopping the pencil, the author felt that 2.5 degrees was the approximate accuracy of the reading. Since the equipment did not read above 90 degrees, a 90+ was the reading applied to all angles exceeding the capacity of the perimeter.

Measuring motor control required two peices of equipment, a standard stopwatch and a photoelectric rotary pursuit (see Figure 5-2). The rotary pursuit employed an one-and-a half inch square light source rotating in a twelve inch outer diameter-ten and half inch inner diameter circle, a light sensitive wand, and a timing device which records the amount of time to the one hundredth second that the wand is over the light. The stopwatch records the total operating time. Each subject started with the first click of the timing device after the "go" signal to eliminate reaction time considerations. Each subject performed a two minute cycle at twenty rpm's given an one minute, a thirty second, a fifteen second and a five second warning. The operator turned the machine off instead of saying

TOP--
FROM LEFT TO RIGHT-
1. Top of perimeter
2. Rotary Track Pursuit
3. Reaction Timer

1. 2. 3.

BOTTOM--
FROM RIGHT TO LEFT-
4. Dynamometer
5. Reaction Timer

4.

5.

FIGURE 5 - Psychomotor Equipment

"stop" to eliminate the reation time.

There are certain factors to consider when analyzing reaction time. One factor is the type of signal, aucile or visual. If the signal is visual, then considerations would be the color or wavelength of the light and the intensity and whether the intensity is a constant on/off or may vary from a fixed prelevel intensity. The multi-reaction timer (see Figure 5-3&5) used was capable of signaling with three colors using either an on/off intensity or a prelevel intensity. The reponse panel contained three color coded buttons to depress after receiving the signal. The reaction timer also had the capability to require the depression of the same colored button or a different colored button in response to the signal. The difference between the two gives an indication to decision-making time. However, for simplicity, the machine gave only one color stimulus, red, and required the depression of the same colored button. The subjects responded to two trials with five stimuli per trial . Each trial started directly after a "ready" audile signal with the intervals between the stimuli following a 10-20-15-10 second pattern. There was not an audile clue given during these intervals other than the click of the clock when reset immediately after the reading. An internal clock started with the stimuli, stopped with the response, and got reset to zero after the reading. The subject kept its preferred hand flat on the table directly in front of the panel.

A dynamometer (see Figure 5-4) is the device which measured the maximum grip strength of the subjects. The grip strength test consisted of two trials per hand per subject. The subject stood, grasp the handle of the device in an palm-up fashion with the top of the dynamometer resting on the table and squeezed the handle. The reading was in kilograms.

The body dimension measurements required the simplest equipment, a set of calipers, a meter stick and a chair with 90 degree angles. While measuring the hand lengths the subject held his hand flat palm up on the table the calipers measured the distance from the wrist landmark to the tip of the longest protruding finger. To measure standing heights, including tibiale and trochanteris heght, bideltoid breadth and stature, the subject stood against the wall with his weight equally distributed of both feet and looking straight ahed. After finding the reference points for the tibiale and the trochanteris heights, the calipers measured the distance. The standing height, found by placing a flat surface on the subjects head perpendicular to the wall and measuring the distance from a reference point on the wall, marked by a meter stick, to the bottom of the surface. Measuring the distance from a reference point on the wall instead of from the floor minimized the error by keeping the readings within the limits of the calipers thereby avoiding having to use the less accurate technique employing to metersticks and having the subject move from under the surface to read the measurement. The calipers also measured the

the bideltoind soulder breadth.

The anthropometric chair designed for this experiment (see Figure 6), to assure perpendicular angles, featured one fixed arm rest and one adjustable arm rest. The subject sat straight in the chair up against the fixed arm rest with the other arm rest adjusted to accommodate the hip breadth. The subject's feet rested on a stool adjusted to the proper height by adding two centemeter thick boards. The calipers measured the distance between the arm rests which was equivalent to hip breadth. The sitting height reading was the distance between the top of the back of the chair to the bottom of a flat surface held perpendicular on the top of the subject's head. Measuring the sitting position from this reference point was more accurate than measuring it directly because it eliminated the error of having to measure the back of the chair each time. The back of the chair was 49.1 cm high. After obtaining the sitting dimension the subject stood, weight equally distributed on both feet, on the stool while the calipers measured the foot lengths.

The functional reach envelope apparatus (see Figure 6) had four main components:

(1) The base boards which support the seat and the boom-arc assembly so there is a fixed distance of 40 inches between the seat reference point and the 0 degree edge of the boom-arc assembly. A second function of the chair base board was to provide horizontal reference points. A semicircle whose center lay directly under the seat reference point and incremented every 90 degrees. Located directly in front of the

RIGHT--
Anthropometric
Chair

LEFT--
Functional
Reach
Device

FIGURE 6 - Anthropometric Equipment

subject when the subject has his shoulders perpendicular to the boom-arc assembley is the 0 degree horizontal. Marked directly to the right of the subject in the above position is 90 degrees right and directly to the left is 90 degrees 90 degrees left.

(2) The chair, made of molded plastic, swivelled horizontally and fit into the predrilled holes in the base boards. A thin rod extended from the seat reference point to the round foot rest on the chair base. The slots in the foot rest coinsided with the markings on the base board facilitating the proper alignment of the chair with the boom-arc assembly. There was also a locking device attached to the chair to keep the chair stationary while measuring.

(3) The boom-arc assembly is a supporting device. The boom supports the arc which supports the measuring rods in blocks mounted to the surface of the arc which is a quarter of a circle. These blocks located the 0, 45, and 90 degrees of the vertical plane. A feature of the arc and boom assembly allowed vertical and horizontal adjustments to accommodate the different sizes of subjects. The arc also adjustable to several other vertical angle than measured in this experiment.

(4) The measuring rods incremented in inches slid backwards and forwards in the felt lined blocks with adjustable tension so that the rod stayed in place upon release for reading. A knob attached to the end of the rods was the object grasped while measuring the reach.

The functional reach envelope is a complicated device.

Its use was to measure the functinal grasping reach from a seat reference point. The seat reference point was the midpoint of the intersection of the plane of the seating surface with the plane of the back rest surface of the seat. After instructing the subject to keep his back against the chair, the subject grasped the knob extended from the end of the measuring rods between his thumb and forefinger and pushed the rod to his maximum reach. The reading on the rods showed the distance the rod extended from a reference point on the boom-arc assembly; therefore, the maximum reach would be the reading subtracted from the distance between the seat reference point and the boom-arc reference point.

Reliability:

The most important feature of any experimental procedure is its accuracy or reliability. One common method of determining reliability of an experimental procedure is the use of a control group. For example, when trying to determine if a noise level has detrimental effects on production, a control group would work under a zero noise level or a slight noise level in comparison with the rest of the subjects. This particular method is not completely applicable to anthropometric measurements; however, the control group technique is adaptable.

To determine the reliability of the measuring techniques, a control group was selected randomly from the other subjects to execute the tests twice. If it is shown that the measurements are the same given a desired level of accuracy then the techniques are reliable.

Data Handling, Editing and Analysis Procedure:

The two data pages pictured in Figures 7 and 8 kept track of the necessary background information and the test dat during testing. The name facilitated keeping the subjects' data together throughout the measuring sessions; however, to assure privacy to the subject data analysis disregarded the subject's name.

Before statistically analyzing the data the analyst made corrections so that the data would conform to the definitions The tibiale, trochanteris, sitting and standing heights needed to increase by 1.5 cm due to the width of the caloper prongs. The standing height also needed to increase by the distance from the floor to the reference point on the wall which was 106.0 cm when measuring on the cafeteria stage and 100.0 cm when measuring in the conference room due to the design of the base boards. Sitting height also neede to increase by 49.1 cm to account for the back of the chair.

Other measurements needed conversions. The motor control reading needed to be converted to a percent of total time by taking the raw score and dividing by the maximum score of 120 seconds for the two minute time interval. The two trials made for grip strength needed to be converted to one number as well as the trials of the reaction times. Arithmatic averaging

NAME ______________________

BIRTHDAY__________________ AGE__________

WRITING HAND RIGHT____ LEFT_____ SEX BOY ____ GIRL____

STANDING DIMESIONS:

Foot Length R_________ L__________

Tibiale Hieght ______________

Trochanteris Height ____________

Standing Height______________

Bideltoid Breadth_____________

SITTING DIMENSIONS:

Sitting Height _____________

Hip Breadth_______________

Hand Length_______________

PSYCOMOTOR SKILLS:

Grip Strength R_________ L__________

Motor Control _______________

Reation Time

Interval	set 1	set 2
	________	________
10	________	________
20		
15	________	________
10	________	________
	________	________

Visual Field __________/______________

FIGURE 7 - Anthropometric and Psycomotor Data Sheet

NAME: ______________________

VERTICAL

RIGHT ARM

	HORIZONTAL		
DEGREE	90R	0	90L
0			
45			
90			

VERTICAL

LEFT ARM

	HORIZONTAL		
DEGREE	90R	0	90L
0			
45			
90			

FIGURE 8 - Functional Reach Data Sheet

of grip strengths and averaging of the average reation time per trial gave the desired number. Also conversion of the functional reach envelope data to the correct number by subtracting the raw score from the overall distance between the reference points and conversion to centemeters was necessary.

The statistical analysis (SAS) computer language facilitated the analysis of the data. A paired comparison regression technique demonstrated the reliability of the measurements. SAS's software perfotmed the statistical analysis using matrix manipulation to mold the data into usable forms.

RESULTS:

Description of sample:

There were 125 subjects tested during the measuring sessions. Since there were only a few subjects that were not caucasian and other research showed that race effects anthropometric results (Delaneuville, 1971; Wittingham, 1978) and since only a small percent of the subjects had handicaps or injuries that would affect the results, only the 119 non-handicapped, caucasian subjects' data were analyzed. Table 1 shows the distribution of boys and girls by age. There were approximately equal numbers of boys and girls in each age category.

Determination of age group began by converting the ages

TABLE 1

SUBJECT DISTRIBUTION

AGE	BOYS	GIRLS	TOTALS
72 - 99 months	N = 17 50.0%	N = 17 50.0%	N = 34 100.0%
99 - 117 months	N = 27 57.4%	N = 20 42.6%	N = 47 100.0%
117- 141 months	N = 20 52.6 %	N = 18 47.4%	N = 38 100.0%
TOTALS	N = 64 53.8%	N = 55 46.2%	N =119 100.0%

to months. These calculated ages were the ages, to the nearest tenth of a month, from the day that testing began. Next, a frequency diagram showed the distribution of ages for the six to eleven year range. The age groups resulted from dividing the frequency diagrams at low to no frequency points. No subjects age fell on the dividing lines.

Reliability of Results:

It was desirable to show that the measurements were repeatable which would show that the results were reliable. A paired comparison regression model designed to show that

$$\text{Measurement } 2 = B_0 + B_1 * \text{Measurement } 1$$

where B_0 is an intercept and B_1 is the slope of the line which maps measurement 1 to measurement 2. For 100% reliability B_1 must exactly equal to one implying an one to one ratio. A t test with level of significance of 0.05 and 12 degrees of freedom using the $H_0: B_1 = 1$ vs $H_1: B_1 \neq 1$ showed the acceptable and rejectable measuring techniques which are listed in Table 2.

Results by Age Group:

It would be difficult to use the results of any anthropometrical or physiological research data in its raw form to design equipment to fit an entire or at least 90% of a population. Individual results are only properly applicable to personalized equipment which is an expensive and often imprac-

TABLE 2

RELIABILITY OF MEASUREMENTS

CONTROL GROUP N = 13

$\alpha = 0.025$ d.f. = 12 t = 2.719

VARIABLE	t_c	ACCEPT
Right Foot	1.610	YES
Left Foot	0.486	YES
Tibiale Height	1.44[illegible]	YES
Trochanteris Height	1.07	YES
Standing Height	0.750	YES
Bideltoid Breadth	1.21	YES
Sitting Height	0.442	YES
Hip Breadth	0.862	YES
Right Hand	0.119	YES
Left Hand	1.09	YES
Right Hand Grip Strength	0.486	YES
Left Hand Grip Strength	1.27	YES
Motor Control	1.79	YES
Reaction Time	1.96	YES
Right Peripheral Vision	2.167	YES-marginal
Left Peripheral Vision	5.12	REJECT

TABLE 2 CONTINUED

RELIABILITY OF MEASUREMENTS

CONTROL GROUP N = 13

$\alpha = 0.025$ d.f. = 12 t = 2.719

VARIABLE	t_c	ACCEPT
FUNCTIONAL REACH ENVELOPE RIGHT ARM --		
(0,90R)	2.282	REJECT
(0,0)	0.405	YES
(0,90L)	0.606	YES
(45,90R)	1.54	YES
(45,0)	1.55	YES
(45,90L)	1.37	YES
(90,0)	1.89	YES
FUNCTIONAL REACH ENVELOPE LEFT ARM --		
(0,90R)	4.41	REJECT
(0,0)	0.024	YES
(0,90L)	0.298	YES
(45,90R)	0.947	YES
(45,0)	1.12	YES
(45,90L)	0.534	YES
(90,0)	0.680	YES

tical design technique; therefore, it is desirable to show the results in a statistical form which describes the whole population. The mean, the standard deviation and the fifth and the ninty-fifth percentiles for each variable descreved the population is each age bracket. The assurity of the mean is shown by the upper (CU) and the lower (CL) limits of a 95% confidence interval included in the tables of results. Pictorial representations of the means of the functional reach are presented along with the tabular results.

The following tables and figures show the results for the different age groups:

I. Ages 72 - 99 months
   A. Boys
      1. Tables 3, 4, & 5
      2. Figures 9 & 10
   B. Girls
      1. Tables 6, 7, & 8
      2. Figures 11 & 12

II. Ages 99 - 117 months
   A. Boys
      1. Tables 9, 10, & 11
      2. Figures 13 & 14
   B. Girls
      1. Tables 12, 13, & 14
      2. Figures 15 & 16

III. Ages 117 - 141 months

A. Boys

    1. Tables 15, 16, & 17

    2. Figures 17 & 18

B. Girls

    1. Tables 18, 19, & 20

    2. Figures 19 & 20

AGES - 72 - 99 MONTHS

TABLE 3

ANTHROPOMETRIC AND PHYSIOLOGICAL DATA- BOYS 72 - 99 MONTHS

VARIABLES	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
Age (months)	90.24	5.44	90.91 89.56	80.74	99.73
Right Foot (cm)	20.26	1.21	20.41 20.11	18.16	22.37
Left Foot (cm)	20.07	0.960	20.19 19.95	18.40	21.75
Tibiale Height (cm)	36.51	1.94	36.75 36.27	33.13	39.90
Trochanteris Height (cm)	59.80	3.85	60.28 59.32	53.07	66.53
Standing Height (cm)	125.73	7.20	126.63 124.84	113.16	138.30
Bideltoid Height (cm)	32.21	1.93	32.45 31.97	28.84	35.58
Sitting Height (cm)	67.45	4.44	68.00 66.90	59.71	75.19

TABLE 3 CONTINUED

VARIABLE	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
HIP BREADTH (cm)	25.89	1.94	26.13 25.65	22.51	29.27
Right Hand (cm)	13.42	0.994	13.54 13.29	11.68	15.15
Left Hand (cm)	13.52	0.972	13.64 13.40	11/83	15.22
Right Hand Grip Strength (kg)	14.46	3.08	14.84 14.07	9.07	19.84
Left Hand Grip Strength (kg)	13.82	3.00	14.20 13.45	8.58	19.07
Motor Control (%)	33.2	13.10	34.83 31.57	10.34	56.06
Right Peripheral Vision ($^{\circ}$)	71.47	22.20	74.24 68.70	32.70	110.24
Left Peripheral Vision ($^{\circ}$)	74.12	21.16	76.76 71.48	37.18	111.06
Reaction Time (sec)	0.575	0.090	0.586 0.564	0.419	0.731

TABLE 4

FUNCTIONAL REACH ENVELOPE DATA - BOYS 72 - 99 MONTHS

RIGHT ARM

DEGREES	cm	90R	0	90L
0	MEAN	72.75	61.30	60.61
	STD	7.65	5.47	10.13
	CU	73.71	61.98	61.87
	CL	71.81	60.62	59.35
	5TH %TILE	59.41	51.76	43.15
	95TH %TILE	86.08	70.85	78.30
45	MEAN	91.24	81.28	82.24
	STD	6.99	7.30	6.60
	CU	92.11	81.28	82.24
	CL	90.37	80.41	81.41
	5TH %TILE	79.04	68.58	70.71
	95TH %TILE	103.44	94.07	93.77
90	MEAN		97.40	
	STD		6.37	
	CU		98.20	
	CL		96.61	
	5TH %TILE		86.29	
	95TH %TILE		108.52	

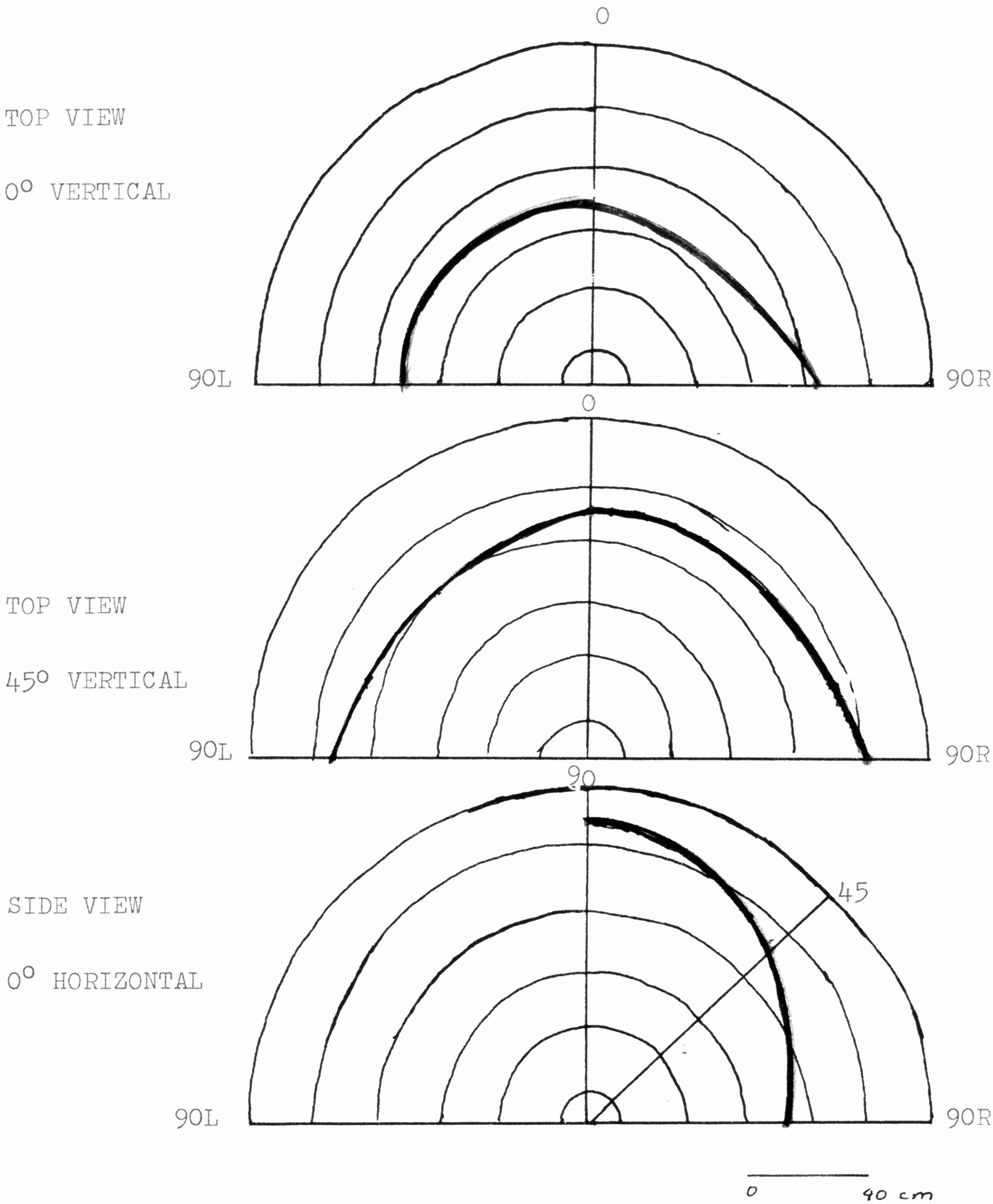

FIGURE 9 -
FUNCTIONAL REACH ENVELOPE - BOYS 72 - 99 MONTHS RIGHT ARM

TABLE 5

FUNCTIONAL REACH ENVELOPE DATA - BOYS 72 - 99 MONTHS

LEFT ARM

DEGREES	cm	90R	0	90L
0	MEAN	62.63	59.57	70.41
	STD	7.30	6.25	7.90
	CU	63.54	60.35	71.40
	CL	61.72	58.79	69.43
	5TH %TILE	49.88	48.65	56.62
	95TH %TILE	75.37	70.48	84.21
45	MEAN	82.16	83.08	91.18
	STD	7.15	7.17	7.43
	CU	83.05	83.97	92.11
	CL	81.27	82.18	90.26
	5TH %TILE	69.68	70.56	78.21
	95TH %TILE	94.65	95.60	104.16
90	MEAN		96.41	
	STD		5.42	
	CU		97.08	
	CL		95.73	
	5TH %TILE		86.94	
	95TH %TILE		105.87	

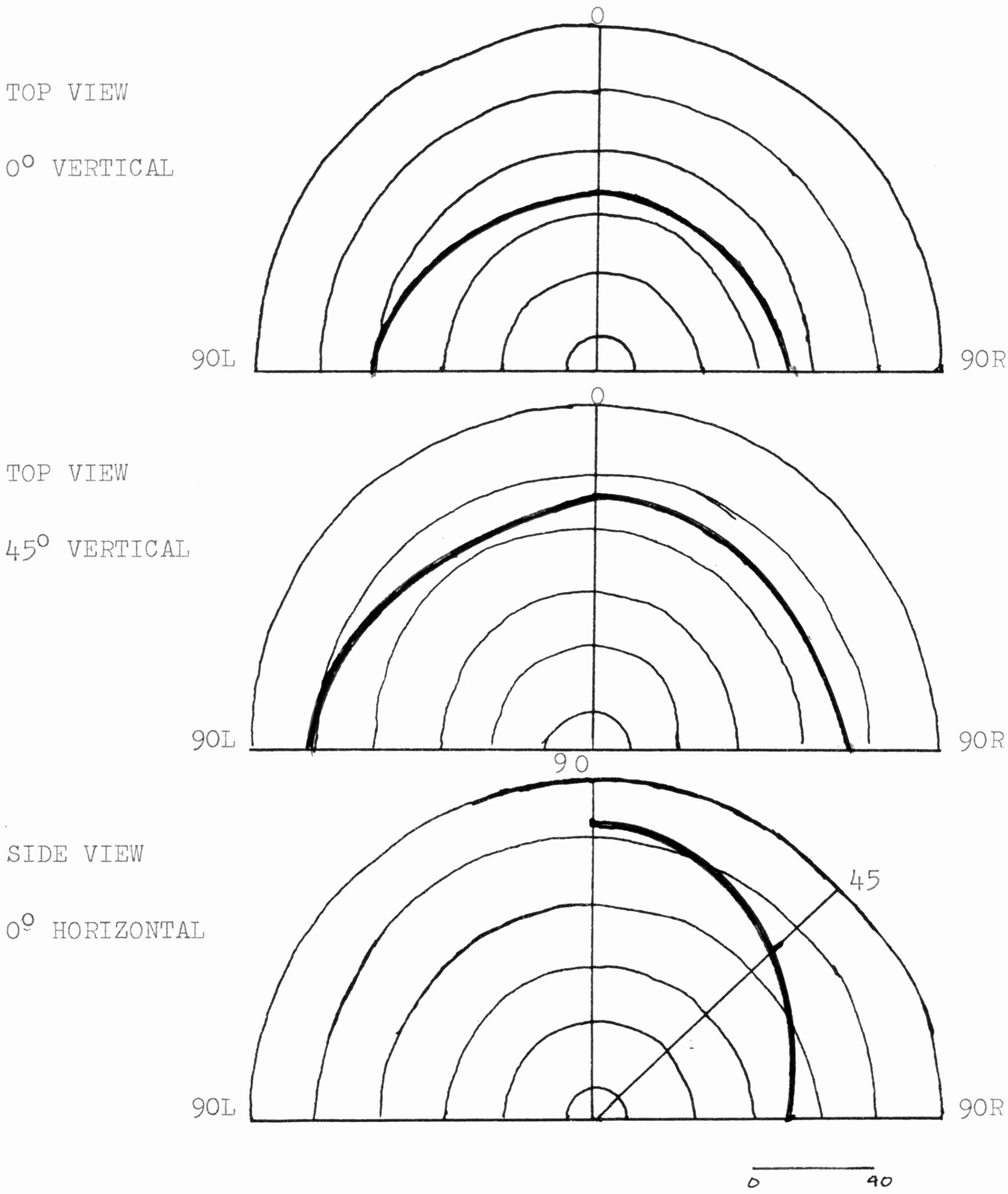

FIGURE 10 -
FUNCTIONAL REACH ENVELOPE - BOYS 72 - 99 MONTHS LEFT ARM

TABLE 6

ANTHROPOMETRIC AND PHYSIOLOGICAL DATA - GIRLS 72 - 99 MONTHS

VARIABLES	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
Age (months)	86.71	6.05	87.47 85.96	76.15	97.28
Right Foot (cm)	19.75	0.955	19.87 19.63	18.08	21.42
Left Foot (cm)	19.54	0.848	19.65 19.44	18.06	21.02
Tibiale Height (cm)	35.06	1.88	35.79 34.82	31.78	38.34
Trochanteris Height (cm)	60.52	3.41	60.94 60.09	54.56	66.47
Standing Height (cm)	120.27	4.53	120.84 119.71	112.36	128.19
Bideltoid Height (cm)	31.37	1.74	31.59 31.16	28.34	34.41
Sitting Height (cm)	67.31	3.44	67.74 66.88	61.29	73.32

TABLE 6 CONTINUED

VARIABLE	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
Hip Breadth (cm)	26.22	1.95	26.47 25.98	22.83	29.63
Right Hand (cm)	13.01	0.485	13.08 12.95	12.17	13.86
Left Hand (cm)	13.16	0.505	13.22	12.28	14.04
Right Hand Grip Strength (kg)	10.51	2.44	10.82 10.21	6.25	14.77
Left Hand Grip Strength (kg)	8.97	2.69	9.31 8.64	4.27	13.67
Motor Control (%)	19.52	10.86	20.47 17.76	0.157	38.07
Right Peripheral Vision (°)	67.94	16.68	70.02	38.81	97.07
Left Peripheral Vision (°)	67.35	19.45	69.78 64.93	33.38	101.32
Reaction Time (sec)	0.605	0.056	0.612 0.598	0.508	0.702

TABLE 7

FUNCTIONAL REACH ENVELOPE DATA - GIRLS 72 - 99 MONTHS

RIGHT ARM

DEGREES	cm	90R	0	90L
0	MEAN	65.36	58.09	59.62
	STD	8.54	4.78	7.65
	CU	66.42	58.69	60.58
	CL	64.29	57.49	58.67
	5TH %TILE	50.45	49.74	46.26
	95TH %TILE	80.26	66.44	72.99
45	MEAN	84.41	78.38	76.83
	STD	3.64	3.80	4.71
	CU	84.86	78.85	77.41
	CL	83.95	77.90	76.24
	5TH %TILE	78.05	71.74	68.60
	95TH %TILE	90.76	85.01	85.05
90	MEAN		94.67	
	STD		8.07	
	CU		95.68	
	CL		93.67	
	5TH %TILE		80.58	
	95TH %TILE		108.77	

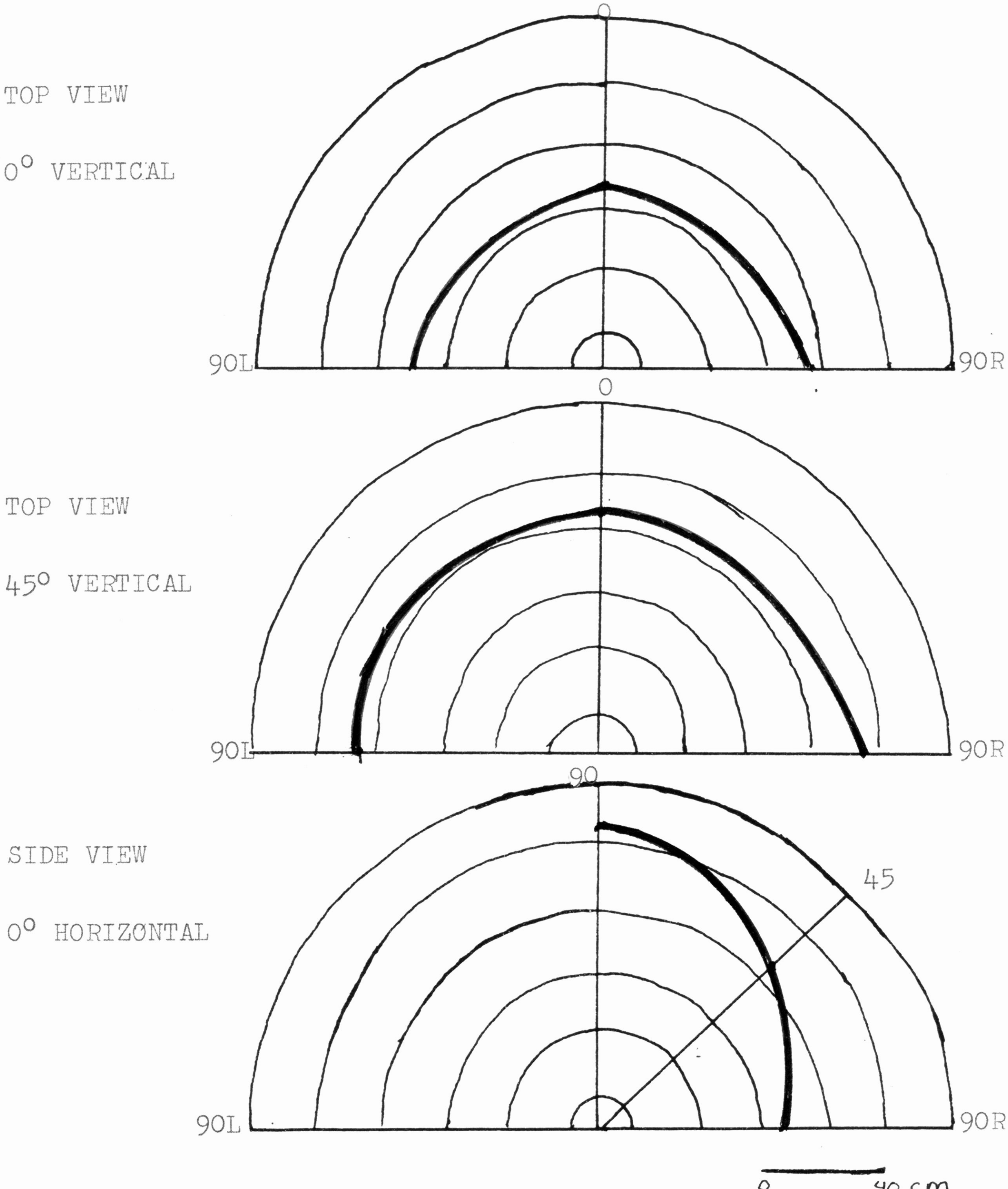

FIGURE 11 -
FUNCTIONAL REACH ENVELOPE -GIRLS 72 - 99 MONTHS RIGHT ARM

TABLE 8

FUNCTIONAL REACH ENVELOPE DATA - GIRLS 72 - 99MONTHS

LEFT ARM

DEGREES	cm	90R	0	90L
0	MEAN	53.59	56.09	67.50
	STD	10.10	5.18	5.69
	CU	54.85	56.74	68.21
	CL	52.33	55.44	66.79
	5TH %TILE	35.96	47.05	57.57
	95TH %TILE	71.23	65.14	77.43
45	MEAN	77.03	77.44	85.17
	STD	4.36	4.27	3.86
	CU	77.57	77.97	85.65
	CL	76.49	76.49	84.69
	5TH %TILE	69.43	69.99	78.43
	95TH %TILE	84.64	84.89	91.91
90	MEAN		94.53	
	STD		8.12	
	CU		95.54	
	CL		93.51	
	5TH %TILE		80.36	
	95TH %TILE		108.70	

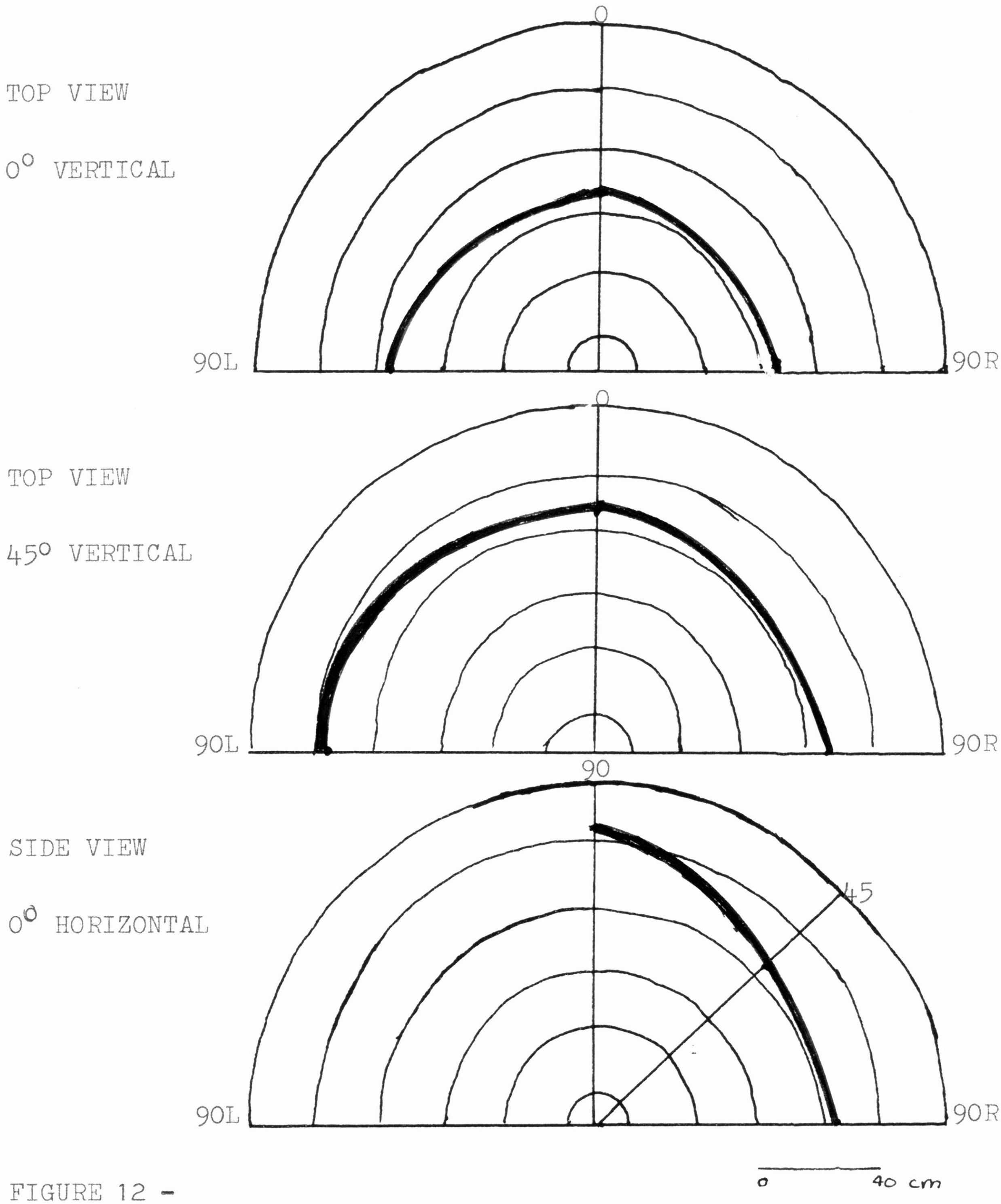

FIGURE 12 -
FUNCTIONAL REACH ENVELOPE - GIRLS 72-99 MONTHS LEFT ARM

AGES - 99 - 117 MONTHS

TABLE 9

ANTHROPOMETRIC AND PHYSIOLOGICAL DATA - BOYS 99 - 117 MONTHS

VARIABLES	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
Age (months)	107.99	5.27	108.39 107.59	99.01	116.98
Right Foot (cm)	21.14	1.31	21.24 21.04	18.90	23.38
Left Foot (cm)	21.24	1.51	21.35 21.12	18.67	23.81
Tibiale Height (cm)	38.71	2.28	38.89 38.54	34.81	42.61
Trochanteris Height (cm)	64.37	3.51	64.64 64.10	58.38	70.37
Standing Height (cm)	131.10	6.49	131.59 130.60	120.04	142.17
Bidetoid Breadth (cm)	33.72	2.55	33.91 33.53	29.37	38.08
Sitting Height	70.87	2.99	71.10 70.65	65.78	75.97

TABLE 9 CONTINUED

VARIABLE	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
Hip Breadth (cm)	27.50	2.17	27.67 27.34	23.81	31.20
Right Hand (cm)	14.49	0.868	14.55 14.42	13.01	15.97
Left Hand (cm)	14.50	0.813	14.56 14.43	13.11	15.88
Right Hand Grip Strength (kg)	16.77	3.11	17.01 16.53	11.47	22.07
Left Hand Grip Strength (kg)	15.90	3.78	16.19 15.61	9.45	22.34
Motor Control (%)	39.45	12.81	40.43 38.38	17.61	61.31
Right Peripheral Vision (^{o})	81.85	12.18	82.78 80.92	61.07	102.63
Left Peripheral Vision (^{o})	86.02	8.27	86.65 85.39	71.91	100.13
Reaction Time (sec)	0.536	0.078	0.542 0.530	0.403	0.669

TABLE 10

FUNCTIONAL REACH ENVELOPE DATA - BOYS 99 -117 MONTHS

RIGHT ARM

DEGREES	cm	90R	0	90L
0	MEAN	74.22	65.58	65.12
	STD	10.66	7.30	8.56
	CU	75.03	66.13	65.77
	CL	73.41	65.02	64.46
	5TH %TILE	56.03	53.12	50.52
	95TH %TILE	92.41	78.03	79.71
45	MEAN	93.37	87.55	84.88
	STD	6.71	6.05	5.48
	CU	93.88	88.02	85.30
	CL	92.86	87.09	84.46
	5TH %TILE	81.93	77.24	75.53
	95TH %TILE	104.81	97.87	94.23
90	MEAN		103.88	
	STD		6.54	
	CU		104.38	
	CL		103.39	
	5TH %TILE		92.74	
	95TH %TILE		115.03	

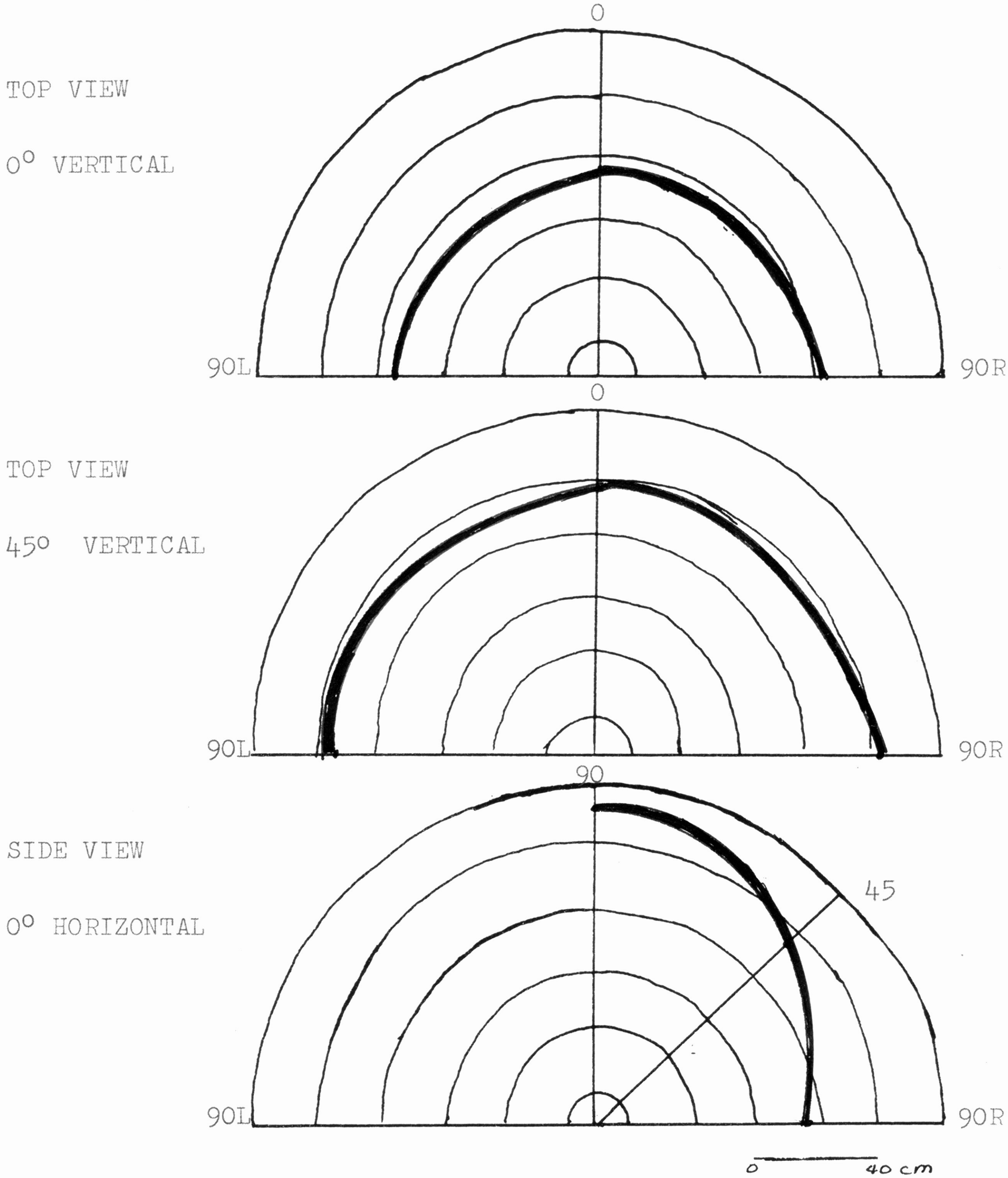

FIGURE 13-
FUNCTIONAL REACH ENVELOPE - BOYS 99 - 117 MONTHS RIGHT ARM

TABLE 11

FUNCTIONAL REACH ENVELOPE DATA - BOYS 99 - 117 MONTS
LEFT ARM

DEGREES	cm	90R	0	90L
0	MEAN	62.71	66.18	74.46
	STD	6.89	8.22	14.94
	CU	63.23	66.81	75.59
	CL	62.18	65.56	73.32
	5TH %TILE	50.95	52.17	48.97
	95TH %TILE	74.46	80.20	99.94
45	MEAN	84.60	86.53	93.09
	STD	5.75	5.79	6.46
	CU	85.04	86.97	93.58
	CL	84.17	86.09	92.60
	5TH %TILE	74.80	76.66	82.06
	95TH %TILE	94.41	96.41	104.11
90	MEAN		104.11	
	STD		7.56	
	CU		104.68	
	CL		103.53	
	5TH %TILE		91.21	
	95TH %TILE		117.01	

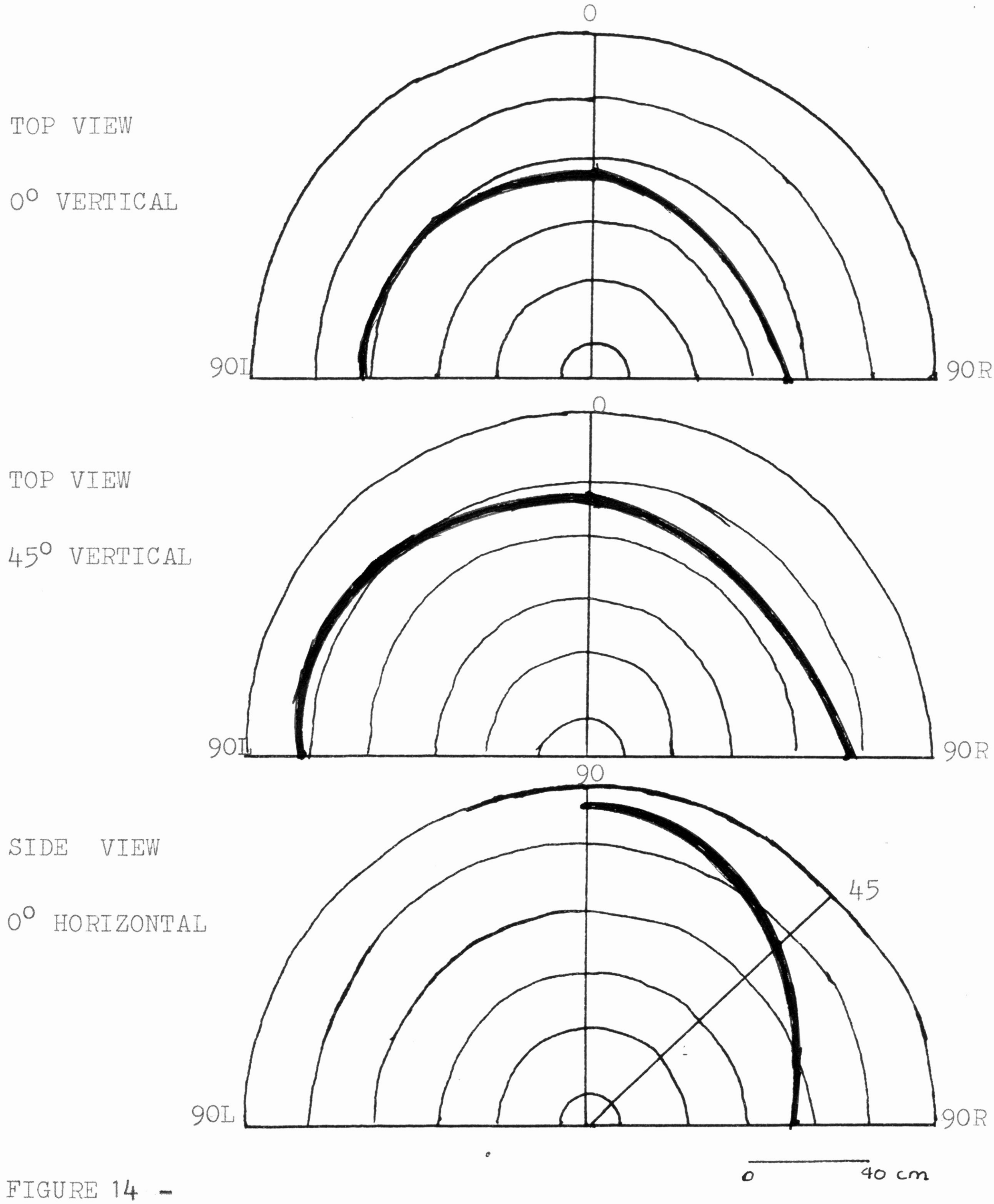

FIGURE 14 -
FUNCTIONAL REACH ENVELOPE - BOYS 99 -117 MONTHS LEFT ARM

TABLE 12

ANTHROPOMETRIC AND PHYSIOLOGICAL DATA - GIRLS 99 - 117 MONTHS

VARIABLE	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
Age (months)	106.65	4.97	107.17 106.13	98.06	115.24
Right Foot (cm)	21.47	1.56	21.63 21.30	18.76	24.17
Left Foot (cm)	21.45	1.49	21.61 21.29	18.87	24.03
Tibiale Height (cm)	39.04	2.57	39.30 38.77	34.58	43.49
Trochanteris Height (cm)	67.01	5.09	67.54 66.47	58.20	75.81
Standing Height (cm)	131.36	8.21	132.22 130.50	117.15	145.56
Bidetoid Breadth (cm)	34.34	3.91	34.75 33.93	27.57	41.11
Sitting Height	70.05	3.79	70.45 69.65	63.50	76.60

TABLE 12 CONTINUED

VARIABLE	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
Hip Breadth (cm)	28.60	3.48	28.96 28.23	22.57	34.62
Right Hand (cm)	14.61	1.07	14.72 14.49	12.75	16.46
Left Hand (cm)	14.71	1.05	14.82 14.60	12.90	16.52
Right Hand Grip Strength (kg)	14.56	3.53	14.93 14.19	8.46	20.66
Left Hand Grip Strength (kg)	14.00	3.46	14.36 13.64	8.02	19.98
Motor Control (%)	30.56	13.18	31.94 29.18	7.78	53.34
Right Peripheral Vision (°)	83.65	8.44	84.53 82.77	69.06	98.24
Left Peripheral Vision (°)	86.00	7.36	86.77 85.23	73.27	98.73
Reaction Time	0.583	0.072	0.591 0.576	0.458	0.708

TABLE 13

FUNCTIONAL REACH ENVELOPE DATA - GIRLS 99 -117 MONTHS
RIGHT ARM

DEGREE	cm	90R	0	90L
0	MEAN	76.81	65.73	62.55
	STD	7.99	6.50	11.13
	CU	77.65	66.41	63.72
	CL	75.97	65.05	61.39
	5TH %TILE	70.62	54.48	43.30
	95TH %TILE	90.62	76.97	81.80
45	MEAN	92.75	86.93	87.37
	STD	7.15	6.94	7.35
	CU	93.50	87.66	88.14
	CL	92.00	86.21	86.60
	5TH %TILE	80.39	74.92	74.67
	95TH %TILE	105.11	98.95	100.08
90	MEAN		103.24	
	STD		7.00	
	CU		103.97	
	CL		102.51	
	5TH %TILE		91.14	
	95TH %TILE		115.34	

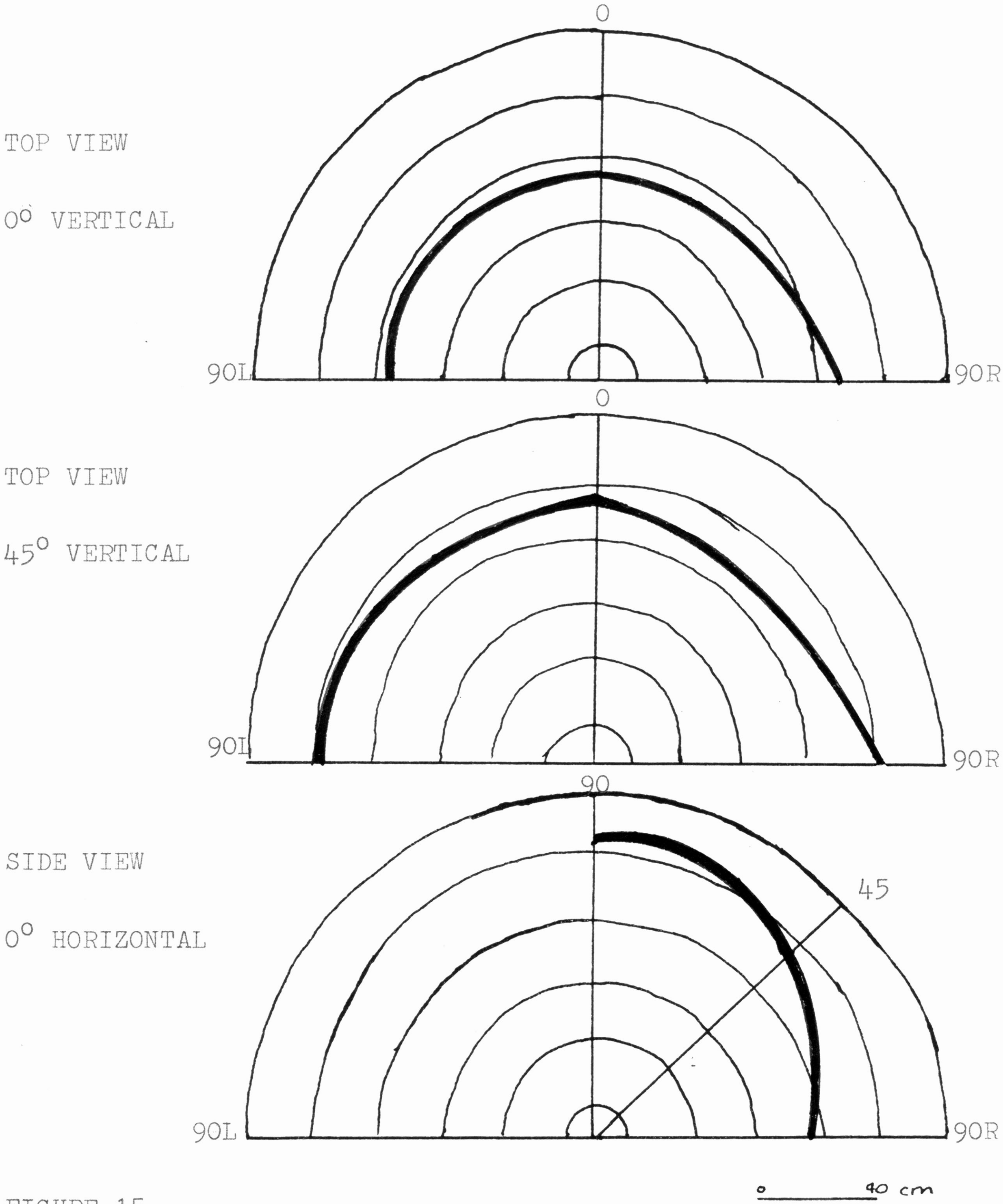

FIGURE 15 -
FUNCTIONAL REACH ENVELOPE - GIRLS 99 - 117 MONTHS RIGHT ARM

TABLE 14

FUNCTIONAL REACH ENVELOPE DATA - GIRLS 99 - 117 MONTHS
LEFT ARM

DEGREE	cm	90R	0	90L
0	MEAN	65.06	64.50	76.51
	STD	8.20	7.66	6.82
	CU	65.92	65.30	77.22
	CL	64.20	63.70	75.79
	5TH %TILE	50.89	51.25	64.72
	95TH %TILE	79.23	77.75	88.30
45	MEAN	85.56	86.51	93.29
	STD	5.92	8.40	7.00
	CU	86.18	87.38	94.02
	CL	84.94	85.63	92.55
	5TH %TILE	75.32	71.99	81.18
	95TH %TILE	95.80	101.03	105.40
90	MEAN		102.83	
	STD		6.41	
	CU		103.50	
	CL		102.16	
	5TH %TILE		91.74	
	95TH %TILE		113.92	

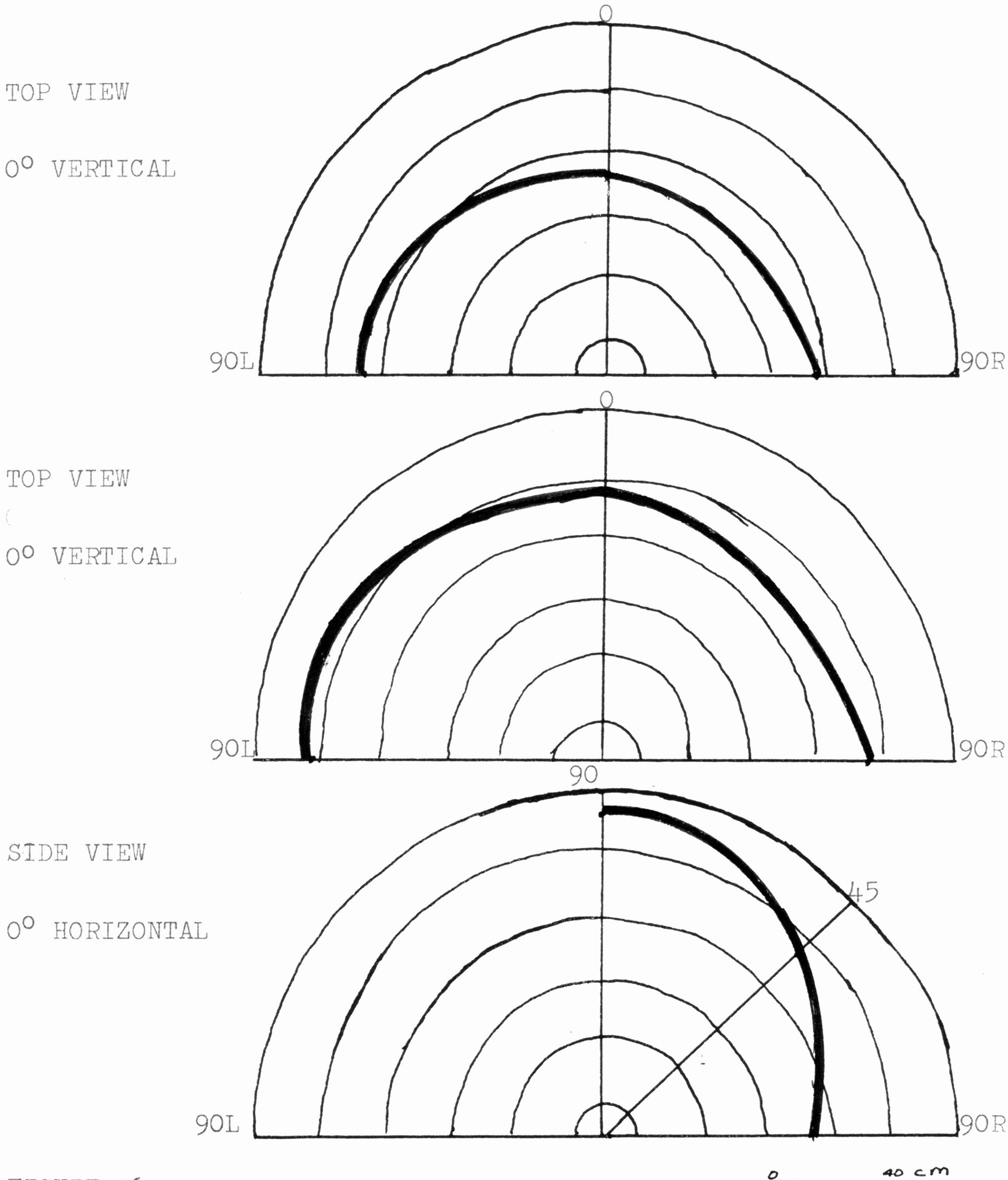

FIGURE 16 -
FUNCTIONAL REACH ENVELOPE - GIRLS 99 - 117 MONTS LEFT ARM

AGES - 117 - 141 MONTHS

TABLE 15

ANTHROPOMETRIC AND PHYSIOLOGICAL DATA - BOYS 117 - 141 MONTHS

VARIABLE	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
Age (months)	129.11	6.35	129.77 128.44	118.13	140.08
Right Foot (cm)	23.15	1.38	23.29 23.00	20.76	25.53
Left Foot (cm)	23.21	1.51	23.37 23.05	20.60	25.82
Tibiale Height (cm)	42.08	2.27	42.32 41.84	38.15	46.01
Trochanteris Height (cm)	69.63	3.67	70.01 69.25	63.29	75.97
Standing Height (cm)	140.52	6.47	141.20 139.85	129.33	151.72
Bideltoid Breadth (cm)	36.11	2.39	36.36 35.85	31.97	40.24
Sitting Height (cm)	74.14	3.47	70.01 73.78	68.14	80.14

TABLE 15 CONTINUED

VARIABLE	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
Hip Breadth (cm)	29.64	2.73	29.92 29.35	24.91	34.35
Right Hand (cm)	15.62	0.960	15.72 15.52	13.96	17.28
Left Hand (cm)	15.72	0.942	15.82 15.62	14.09	17.35
Right Hand Grip Strength (kg)	20.65	4.30	21.10 20.20	13.22	28.08
Left Hand Grip Strength (kg)	19.80	4.92	20.32 19.28	11.29	28.31
Motor Control (%)	52.89	16.05	54.57 51.21	25.14	80.64
Right Peripheral Vision (^{o})	86.13	7.23	86.88 85.37	73.62	98.63
Left Peripheral Vision (^{o})	87.63	4.69	88.12 87.13	79.51	95.74
Reaction Time (sec)	0.463	0.087	0.472 0.454	0.313	0.613

TABLE 16

FUNCTIONAL REACH ENVELOPE DATA - BOYS 117 -141 MONTHS
RIGHT ARM

DEGREES	cm	90R	0	90L
0	MEAN	82.75	71.00	68.17
	STD	5.73	4.98	5.82
	CU	85.35	71.52	68.78
	CL	82.15	70.48	67.56
	5TH %TILE	72.84	62.39	58.11
	95TH %TILE	92.65	79.73	78.23
45	MEAN	101.64	93.50	94.67
	STD	6.04	5.32	6.92
	CU	102.27	94.05	95.39
	CL	101.00	92.94	93.94
	5TH %TILE	91.20	84.30	82.70
	95TH %TILE	112.08	102.70	106.64
90	MEAN		110.68	
	STD		5.79	
	CU		111.29	
	CL		110.08	
	5TH %TILE		100.68	
	95TH %TILE		120.69	

TOP VIEW

0° VERTICAL

TOP VIEW

45° VERTICAL

SIDE VIEW

0° HORIZONTAL

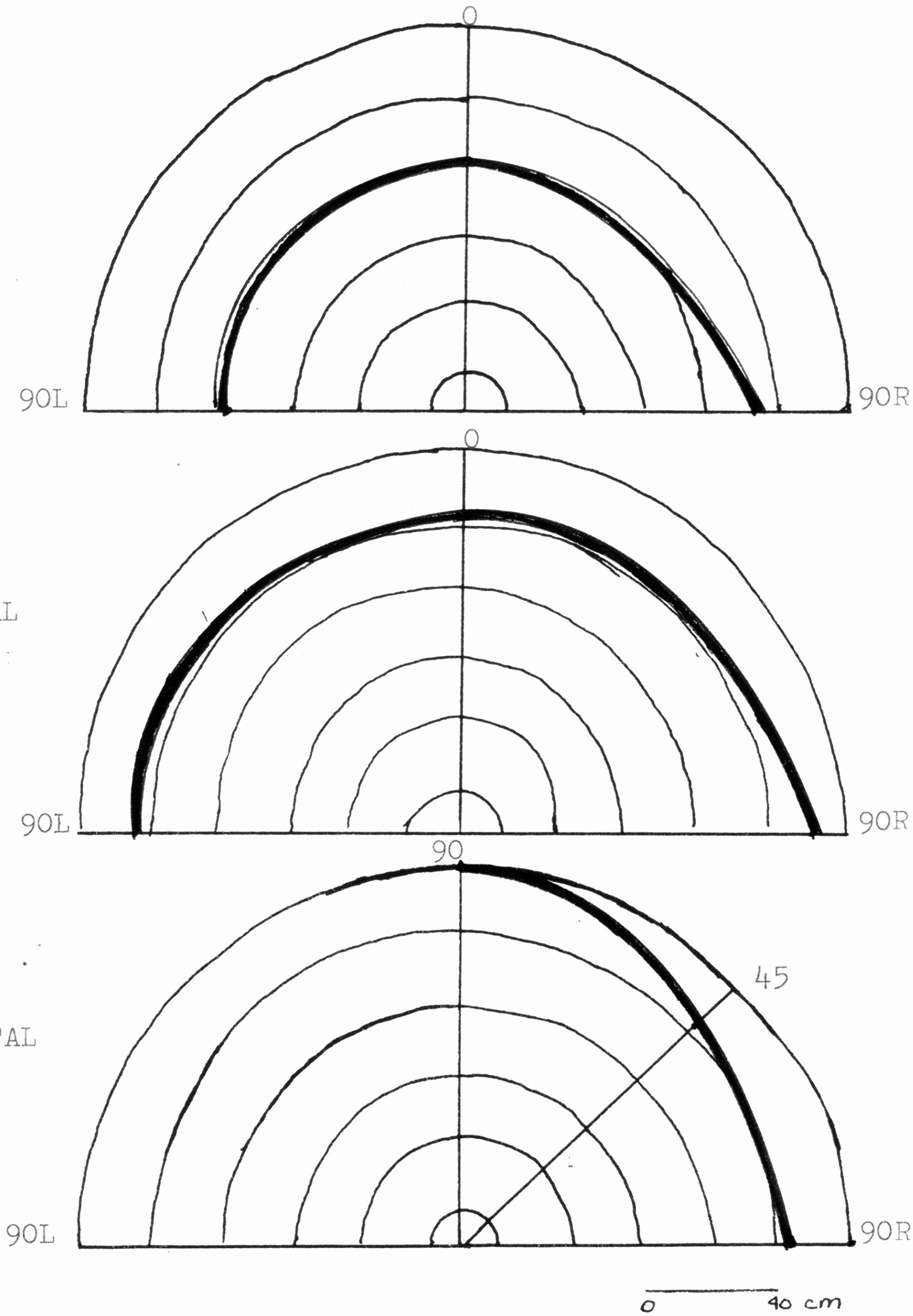

FIGURE 17 -
FUNCTIONAL REACH ENVELOPE - BOYS 117 -141 MONTHS RIGHT ARM

TABLE 17

FUNCTIONAL REACH ENVELOPE DATA - BOYS 117 - 141 MONTHS
LEFT ARM

DEGREES	cm	90R	0	90L
0	MEAN	67.41	70.28	82.65
	STD	8.10	4.71	6.43
	CU	68.26	70.78	83.32
	CL	66.56	69.79	81.98
	5TH %TILE	53.40	62.15	71.53
	95TH %TILE	81.42	78.42	93.77
45	MEAN	94.95	93.32	100.22
	STD	6.56	6.04	7.16
	CU	95.64	93.95	100.97
	CL	94.27	92.69	99.48
	5TH %TILE	83.61	82.87	87.85
	95TH %TILE	106.29	103.76	112.60
90	MEAN		109.35	
	STD		5.98	
	CU		109.98	
	CL		108.73	
	5TH %TILE		99.01	
	95TH %TILE		119.69	

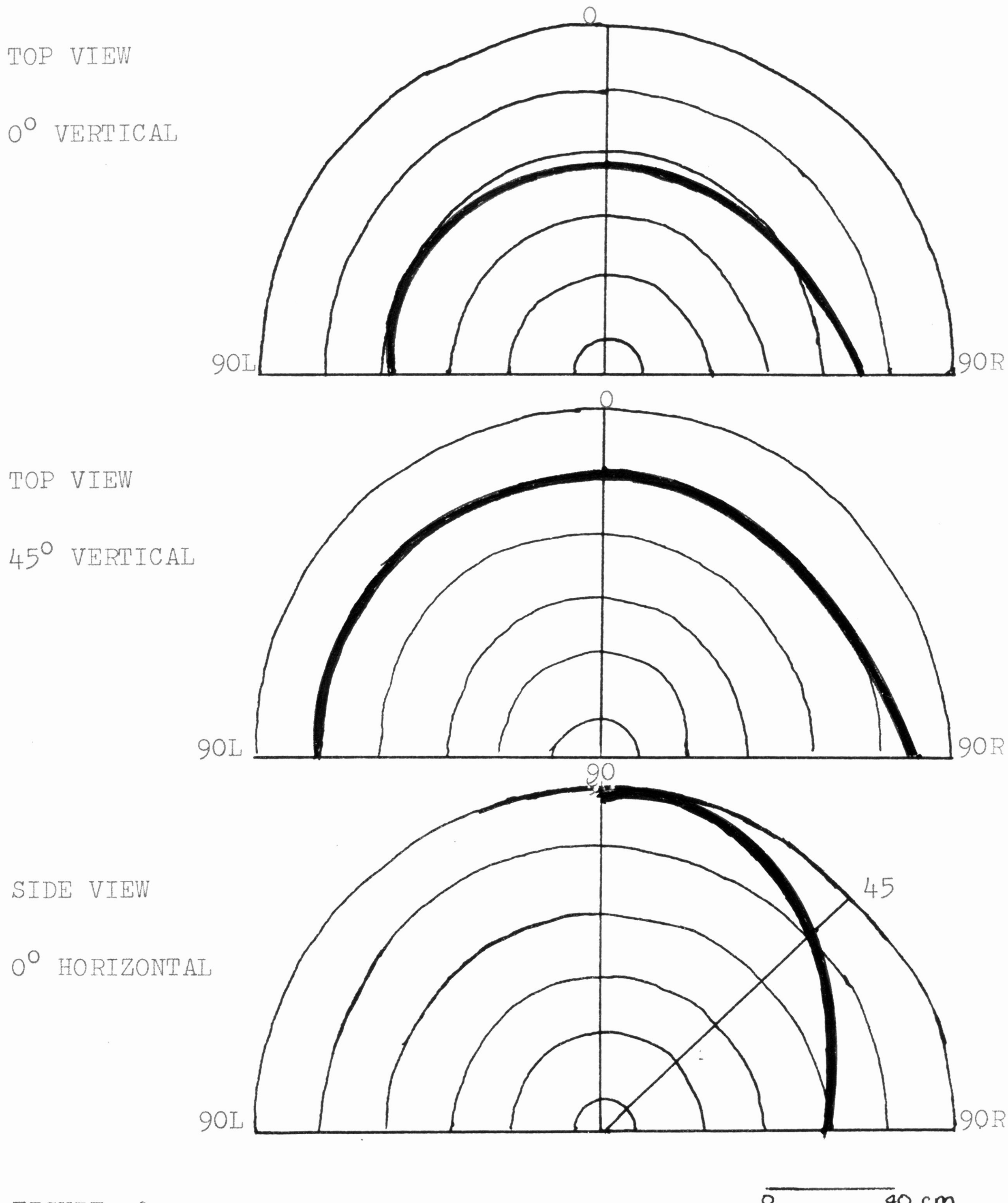

FIGURE 18 -
FUNCTIONAL REACH ENVELOPE - BOYS 117 -141 MONTHS LEFT ARM

TABLE 18

ANTHROPOMETRIC AND PHYSIOLOGICAL DATA - GIRLS 117 -141 MONTHS

VARIABLES	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
Age (months)	125.78	4.97	126.36 125.20	117.13	134.43
Right Foot (cm)	22.05	1.45	22.22 21.88	19.53	24.57
Left Foot (cm)	22.22	1.51	22.40 22.04	19.60	24.84
Tibiale Height (cm)	41.71	2.77	42.03 41.38	36.90	46.52
Trochanteris Height (cm)	72.61	3.99	73.07 72.14	65.67	79.55
Standing Height (cm)	139.52	9.33	140.67 138.42	123.29	155.75
Bideltoid Breadth (cm)	35.58	2.80	35.91 35.25	30.70	40.46
Sitting Height (cm)	74.61	4.55	75.15 74.08	66.70	82.53

TABLE 18 CONTINUED

VARIABLE	MEAN	STD	CU CL	5TH %TILE	95TH %TILE
Hip Breadth (cm)	29.67	3.05	30.03 29.31	24.37	34.97
Right Hand (cm)	15.45	1.18	15.59 15.31	13.39	17.51
Left Hand (cm)	15.44	1.12	15.57 15.31	13.50	17.38
Right Hand Grip Strength (kg)	17.33	2.24	17.60 17.07	13.44	21.22
Left Hand Grip Strength (kg)	15.35	3.81	15.79 14.90	8.72	21.98
Motor Control	44.35	16.73	46.31 42.39	15.24	73.46
Right Peripheral Vision (°)	87.78	3.42	88.17 87.38	81.83	93.73
Left Peripheral Vision (°)	88.33	3.09	88.70 87.97	82.95	93.71
Reaction Time (sec)	0.515	0.080	0.524 0.505	0.376	0.653

TABLE 19

FUNCTIONAL REACH ENVELOPE DATA - GIRLS 117 - 141 MONTHS
RIGHT ARM

DEGREES	cm	90R	0	90L
0	MEAN	80.50	67.84	67.75
	STD	5.04	6.93	9.67
	CU	81.09	68.66	68.89
	CL	79.90	67.03	66.62
	5TH %TILE	71.72	55.79	50.93
	95TH %TILE	89.27	79.90	84.58
45	MEAN	100.16	93.11	92.77
	STD	6.57	6.85	7.68
	CU	100.93	93.91	93.67
	CL	99.39	92.30	91.87
	5TH %TILE	88.81	81.19	79.40
	95TH %TILE	111.58	106.50	106.14
90	MEAN		109.80	
	STD		7.93	
	CU		110.72	
	CL		108.87	
	5TH %TILE		96.00	
	95TH %TILE		123.59	

TOP VIEW

0° VERTICAL

TOP VIEW

45° VERTICAL

SIDE VIEW

0° HORIZONTAL

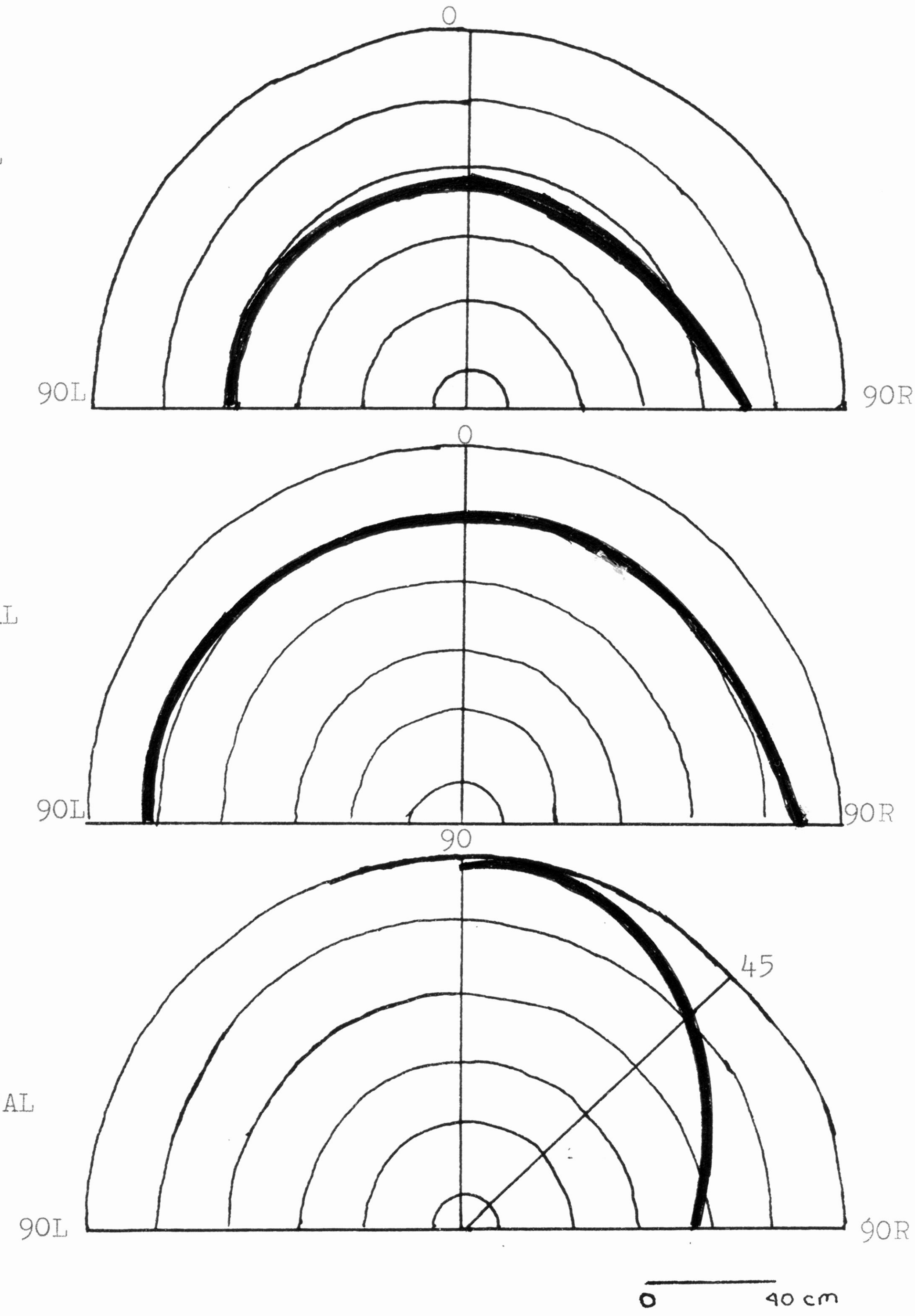

FIGURE 19 -
FUNCTIONAL REACH ENVELOPE - GIRLS 117 - 141 MONTHS RIGHT ARM

TABLE 20

FUNCTIONAL REACH ENVELOPE DATA - GIRLS 117 -141 MONTHS
LEFT ARM

DEGREES	cm	90R	0	90L
0	MEAN	69.17	70.03	80.86
	STD	9.06	5.75	6.87
	CU	70.23	70.71	83.68
	CL	68.11	69.36	80.06
	5TH %TILE	53.40	60.03	68.91
	95TH %TILE	84.94	80.03	92.81
45	MEAN	92.84	93.02	100.86
	STD	8.54	5.84	7.65
	CU	93.84	93.70	101.76
	CL	91.84	92.33	99.97
	5TH %TILE	77.98	82.86	87.55
	95TH %TILE	107.70	103.17	114.18
90	MEAN		109.40	
	STD		7.98	
	CU		110.34	
	CL		108.47	
	5TH %TILE		95.52	
	95TH %TILE		123.28	

TOP VIEW

0° VERTICAL

TOP VIEW

45° VERTICAL

SIDE VIEW

0° HORIZONTAL

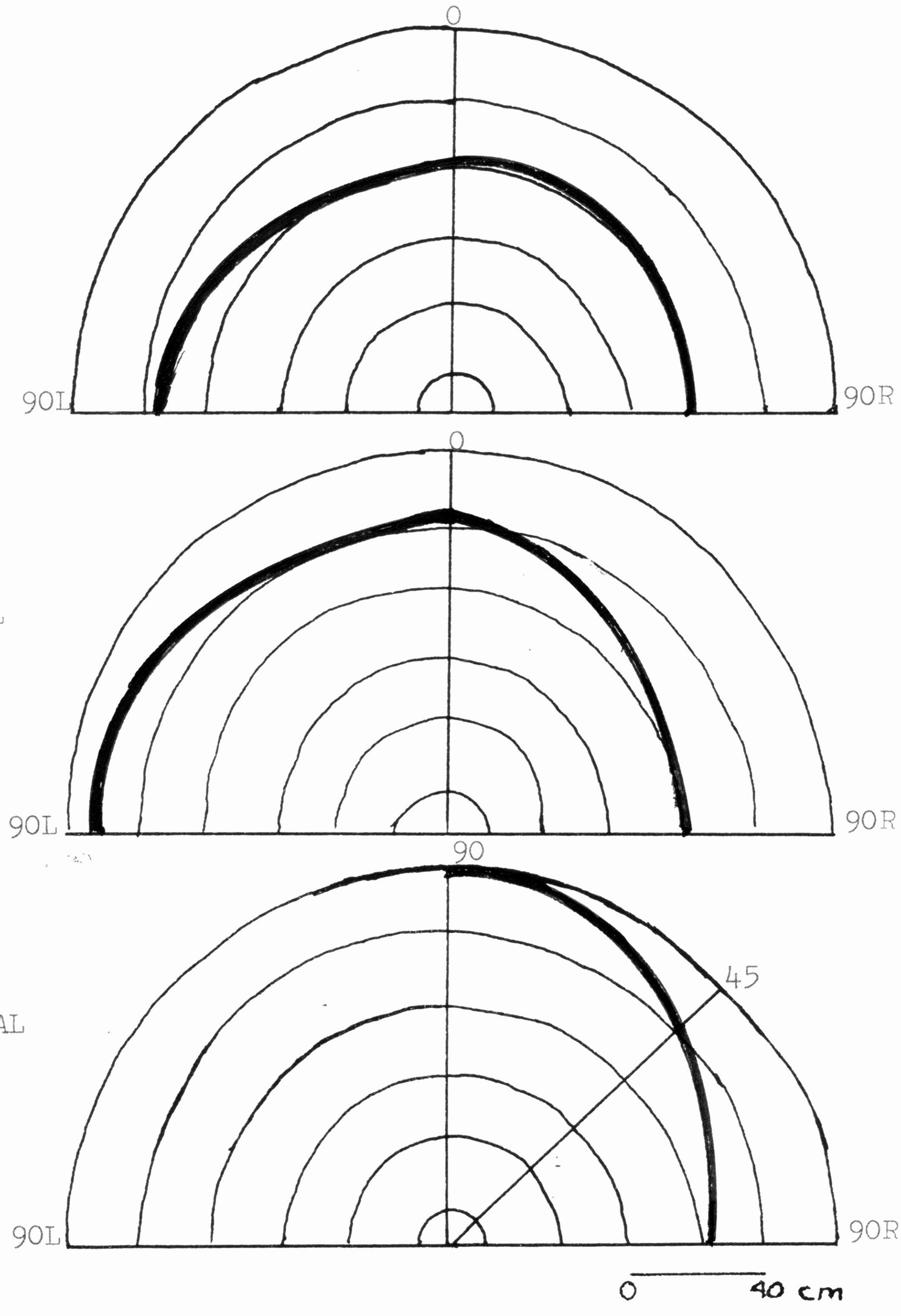

FIGURE 20 -
FUNCTIONAL REACH ENVELOPE - GIRLS 117 - 141 MONTHS LEFT ARM

SUMMARY AND DISCUSSION:

As expected the body dimensions increased and the skills improved with age for all the accepted measuring techniques. The confidence interval around the means were small which is the desirable condition for accuracy.

The analysis of the control group regected the reliability of the left peripheral vision data and only marginally accepted the right peripheral vision data. It was noted during testing that there was a problem with the procedure, either with the explanation or the design of the perimeter or both. The problem evolved around the focus point which was a small mirror. When told to watch the focus point and say when they saw the pencil, some thought that they were suppose to see it in the mirror instead of out of the corner of their eye. This cause of the problem, revealled by questioned of the older children, resulted in a change in the explanation. The changes in explaination resulted in more realistic values for the older children with smaller variations. Another design problem is with the capacity of the perimeter, since it only went to 90 degrees. The results are biased towards the lower end of the spectrum since 90+ translated to 90 for sake of the analysis.

To correct this technique and to make the data more reliable, the focus point should be changed to a non-reflecting surface and the arc of the perimeter extended to read beyond 90 degrees. Also moving the pencil through a range and asking if they could see the movement before making the actual test improves the understanding. It would also be advisable to do several trials and to take averages as the scores, especially with the younger children.

Analysis of the control group also rejected the reliability of the (0,90R) functional reach data for both the right and the left arm. A possible cause is the lack of restraints to hold the subject to the back of the chair. Another problem with this position is the ease of using momentum to push the rod past the maximum reach. Greater friction should be added to to the horizontal bar to decrease the obtainable momentum which contaminated the data.

CONCLUSIONS:

This research and these results are only the beginning of the research into the capabilities and limitations of children. The research must continure if children will succeed in space exploration. The future research must add more variables to the data base as well as increasing the sample sizes to eliminate the geographical trends. More research is needed in the area of functional reach to include more angles of reach. Plus the necessary research in visual field to develope a reliable measuring technique and to increase the number of measured angles of vision.

Since anthropometric data is essential for improvements in technology and advancements in society, there have been many anthropometric studies in the past; there continues to be studies in the present; and there will always be a continuing need for studies in the future.

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APPENDIX I

Documentation

A B S T R A C T

Title: Children in Space

Fellow: Le Michelle Purifoy

Advisor: Dr. James K. Hennigan

Department: Industrial Engineering

Summary: If families/children are to be sent on space explorations, then a space cabin must be designed to accommodate children. Before designing such a space cabin, research is necessary to define children's capabilities. This project proposes to start the research by gathering certain antropometric and physiological data of children between ages of six and thirteen. Measurements will include height, length of appendages, grip strength, reaction time and motor control. The data will then be summarized, using accepted statistical techniques.

Reference: _Anthropometric Source Book, Vol. 1_: "_Anthropometry for Designers_"; NASA Reference Publication, 1978.

CHILDREN IN SPACE
by
Le Michelle Purifoy

Objective:

To obtain certain antropometric and physiological data of children between the ages of 6 and 13 related to the man/ machine system in space.

Background:

There have been many advances in space technology since the space age began in the middle of this century. From the launching of the first satellite, the Sputnik VII, to the launching of the first manned spaceship, the Vostok I, Americans have seen science fiction novels become non fiction.

The success of a reuseable space shuttle and the impending success of a space flight with the first woman astronaut makes the fictitious family in space more realistic. However, for such a flight to be feasible, a new space cabin must be designed such that children could perform the flight operations in the event that the adults become unable to function.

When considering any man/machine system, two questions must be answered — "What can the man do?" and "What must the machine do?" — since success of the system relies on the quality of the link connecting the man with his machine. To begin to answer these questions, a knowledge of the full range of men's/children's sizes and mechanical capabilities is essential. Therefore, anthropometric and physiological studies are necessary for any successful space cabin design.

Proposal:

Hence, this project proposes to gather certain anthropometric and physiological data related to children between the ages of six and thirteen. Among the antropometric data to be collected are:

1. Standing and sitting heights
2. Lengths of the arm, the forearm and the hand
3. Lengths of the leg, the thigh and the calf.

Included in the proposed collection of physiological data are

1. Grip strength
2. Reaction time
3. Motor control.

This study should lay a firm foundation to answer the critical questions essential to the design of a space cabin equipped for launching families in space.

Method:

Approximately one hundred children from local elementary schools will be selected as subjects. These will be evenly divided into the following age catagories:

1. Ages 6 - 7
2. Ages 8 - 9
3. Ages 10 - 11
4. Ages 12 - 13

All the anthopometric measurements will be in inches, using the reference points defined by NASA in its Anthropometric Source Books.

Three techniques will be used to obtain the physiological data:

1. A hand grip device which the children will squeeze will measure grip strength.

2. Reaction time will be measured in seconds by a device that measures the time lapse between a visual or audible signal and an action. The visual signal will be colored lights; the action required will be depressing the proper button on a color-coordinated panel.

3. Motor control will be measured by a machine which has a rotating disk with a light on its perimeter. The child follows the light using a baton similar to a flashlight while the machine counts the number of times the baton is out of line with the light.

After the data is collected, the mean, the variance and the fifth percentile and the ninety-fifth percentile will be calculated, using standard statistical techniques.

Le Michelle Purifoy
411 N. Stasney #3
College Station, TX
77840

William H. Bush
Life Science Project Division
Mail Code SE
NASA
Johnson Space Center
Houston, TX 77058

Dear Sir:

I am a senior at Texas A&M participating in the University Undergraduate Fellows Program. The Fellows Program is one which allows the undergraduate to gain experience in the research aspect of their feild.

My project, Children In Space, deals with the collection of anthropometric and physiological data, related to space cabin design, of children between the ages of six and thirteen. Enclosed is a copy of my proposal.

Your opinion of the worthiness of this project and any suggestions of ideas and sources of information would be greatly appreciated.

Sincerely,

Le Michelle Purifoy
Undergraduate Fellow

enc
cc Medical Science Division
cc Medical Research Division
LMP

REPRODUCTION

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas
77058

NASA

Reply to Attn of: SD3-83-676

SEP 30

Ms. Le Michelle Purifoy
411 N. Stasney #3
College Station, TX 77840

Dear Ms. Purifoy:

Your undergraduate project, "Children in Space" should prove interesting. To my knowledge, we have not had a requirement to study anthropometry of children. Dr. Danielle J. Goldwater at the NASA Ames Research Center, Moffett Field, California, (415)965-5749 or Dr. James L. Lewis, Jr. here at the Johnson Space Center, (713)483-2845 may be able to provide the kind of guidance you are seeking. I have forwarded a copy of your letter to Drs. Goldwater and Lewis should you wish to contact either and/or both of them. Dr. Lewis mentioned NASA Reference Publication 1024 having anthropometry information on adults.

Sincerely,

Philip C. Johnson, Jr., M.D.
Chief, Space Adaptation Research Branch

cc:
239-17/D. J. Goldwater, ARC
EN44/J. L. Lewis, JSC

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas
77058

NASA

Reply to Attn of SE2/83/60

OCT 28 1983

Ms. Le Michelle Purifoy
411 N. Stasney #3
College Station, TX 77840

Dear Ms. Purifoy:

I have received and read your Fellows proposal with a great deal of interest. As an exercise in the application of scientific methodology I think that you have selected a meaningful topic that, to my knowledge, has not been researched from a human factors perspective.

I would suggest that you broaden your anthropometric measurements list by including a functional reach envelope from a seated position while maintaining a stable seat reference point. Visual field has also been an area of interest, particularly in cockpit design and windshield position/shape. Accordingly, you could make some visual field measurements using the same basic apparatus used for functional reach measurements. These are just a couple of ideas that you might consider in the enhancement of your data.

I have taken the liberty of sending a copy of your letter and proposal to another office that has expertise in this area, so you may be hearing from them also.

We would appreciate receiving a copy of your paper when it is completed and if it would not be too inconvenient. In the meantime, may I wish you the best in your research endeavors.

Sincerely,

William H. Bush

William H. Bush
Chief, Life Sciences Project Division

Form A

TO THE COMMITTEE FOR REVIEW OF RESEARCH WITH HUMANS: Appendix I-C 1

Project Title ."Children in Space" IE 485H project

Agency to Which Submitted N/A

I have read the enclosed exerpts of the Declaration of Helsinki, and unreservedly subscribe to the principles it contains. In light of this Declaration, I present for the Committee's consideration the following information about the proposed research which will be explained to the subject:

1. The procedures to be followed, including an identification of those which are experimental: Anthropometric measurements and perfomance tests-- reaction time, grip strength, rotary pursuit, visual field, and functional reach envelope. See attached proposal.

2. The attendant discomfort and risk: Minimal-- those associated with performance tests.

3. The benefits to be expected: none

4. The appropriate alternative procedures that would be advantageous for the subject: not participating.

5. The steps to be taken to assure confidentiality of results: Statistical presentation of results only.

6. I will offer to answer any inquiries concerning the procedures.

7. I will assure the subject that he is free to withdraw his consent and to discontinue participation in the project or activity at any time.

In addition, I will include no exculpatory language through which the subject is made to waive, to release the institution or its agents from liability for negligence.

Should any changes in methods become advisable, I will bring this to the Review Committee before such changes are initiated.

Date 11-28-83 Project Director Dr. Hennigan Department Industrial Engineering

Advisor or Committee Chairman Signature

Texas A&M University

College Station, Texas 77843
(409) 845-1811

OFFICE OF UNIVERSITY RESEARCH SERVICES

February 10, 1984

MEMORANDUM

TO: Ms. Le Michelle Purifoy

FROM: Allen Martin *Allen Martin*
IRB Coordinator

It has been determined that your proposal, "Children in Space", is exempt from a full review of the Institutional Review Board; however, to complete our files, we do need one copy of the attached Exempt Protocol form completed and returned to this office.

Your immediate attention to this will be appreciated.

Attch.

College Station Independent School District
100 Anderson
College Station, Texas 77840
409-696-8893

February 7, 1984

Ms. Le Michelle Purifoy
411 N. Stasney #3
College Station, TX 77840

Dear Ms. Purifoy:

Thank you for considering College Station I.S.D. in your study of anthropometric measurements of children. Please feel free to contact Mr. Bill Eitel at Southwood Valley Elementary School, 2700 Brothers in College Station to setup a schedule of events for your data collection. The possibility of providing data that could be used in designing space cabins for children is very exciting. If you need further assistance, please feel free to call on me.

Sincerely,

Michael Owens
Director of Curriculum
and Instruction

MO:ao

cc: Dr. H. R. Burnett, Superintendent

MICHAEL OWENS
Director of Curriculum and Instruction

H. RICHARD BURNETT
Superintendent of Schools