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THE ANTHROPOMETRY OF WORKING POSITIONS

I. A PRELIMINARY STUDY

H. T. E. HERTZBERG
AERO MEDICAL LABORATORY

IRVIN EMANUEL
AERO MEDICAL LABORATORY

MILTON ALEXANDER, 1/LT, USAF
AERO MEDICAL LABORATORY

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FOREWORD

This study was carried out under the authority of Project No. 7214, Task No. 71728, entitled "Anthropometry and Equipment Sizing". The work was a joint effort of the Anthropology Section, Biophysics Branch, Aero Medical Laboratory and Antioch College, under Contract No. AF18(600)-30. Mr H. T. E. Hertzberg served as project engineer for the Anthropology Section and Mr Irvin Emanuel was the responsible investigator for Antioch College. Following this study, Mr Emanuel left Antioch College to become a member of the Anthropology Section. Special thanks are due to Mr Bruce Truett and Mr Edmund Churchill of the Antioch staff for their statistical help and advice. Lt Frank P. Saul of the Anthropology Section deserves the authors' gratitude for his advice and assistance during the study. Mr John Wing of the Antioch staff provided assistance in various aspects of the study. Mrs Cleona Allen prepared the drawings. Miss Beverly Bruns assisted in preparing the final report.

ABSTRACT

A sample of forty adult males has been measured to ascertain new body size data for various representative working positions. Measurements were taken with the body in the standing, kneeling, crawling, and prone positions. Problems met in developing procedures for an anthropometry describing working positions are discussed, along with possible approaches for data gathering.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Jack Bollerud

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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SECTION I

Introduction

Decades of anthropometric investigation have resulted in a series of generally standardized measurements and measurement techniques (Martin, 1928; Stewart, 1952; Hooton, 1946; Montagu, 1951). Many of these measurements have been standardized because of their convenience rather than any relationship they may have to specific biological problems.

In recent years when these techniques came to be applied to practical problems of body size and equipment design, they underwent some modification, and new techniques were evolved. Throughout this period, however, such work for the most part has relied on static body positions which have only coincidental similarity to those required of men doing the world's labor. This report describes an initial attempt to develop standardized techniques for measuring human space requirements in some unusual work situations.

This is not to imply that the anthropometry of working positions has been neglected. Numerous studies have been made to ascertain the space needed for seated persons (Lay and Fisher, 1940; Randall et. al., 1946; Hooton, 1945; King, 1948; Hertzberg, Daniels and Churchill, 1954; Coakley et. al., 1953; McFarland et. al., 1953; and many others). Women's (Roberts, 1937) and children's (Martin, 1953; Martin and Thieme, 1954) dimensions relating respectively to kitchen layouts and school equipment have been investigated.

In addition, some attempts have been made to provide average dimensions for many typical working positions (Freese, 1934; Schroeder, 1951; Dreyfuss, 1955; Neufert, 1944). These reports present, in general, only averages; they do not describe the sample, state the number of subjects, illustrate the techniques or name the investigators. The data given are represented as proper for every situation and population. They ignore for the most part the high variability of body dimensions in every population and the fact that the "average man" concept of design is a fallacy. The data presented in these reports may be acceptable approximations for some situations, but the designer who must engineer his workspace efficiently will want more adequate information than is available from these sources.

The present effort was crystallized when the Anthropology Section was asked to supply data on specific body positions for a designer's handbook (Handbook of Instructions for Ground Equipment Designers, 1955). Because no reliable data were known to exist on most of the specified body positions, new techniques which could be reliably standardized were devised. The results presented herein are a first step in exploring the whole area of the anthropometry of working positions. To be investigated are the space problems of men who labor, often in cramped areas and in uncomfortable body positions -- pipefitters, plumbers, mechanics, repairmen of heavy machinery, and the like.

It should be understood that most of the dimensions determined in this study were taken with the body in rather adjustable positions. Because slight changes are possible in the placement of the various body segments, we may expect such measurements to have test-retest variabilities which are higher than measurements taken with the body in more easily controllable positions. In spite of this lower reliability, the values can

serve as valid estimates of the body dimensions in these positions. A lower reliability should be interpreted not primarily as a large duplication error, but as an indication of the possible variations in body orientation. Unfortunately for this study, there was insufficient time to ascertain the reliability quantitatively, but numerous spot checks were made.

Since conventional anthropometric tools used in this study are primitive for the purposes, the present study is limited to several static positions representative of working positions. It is anticipated that more effective tools will be used in future studies. Examples are stroboscopic light photography coupled with strain gauge strength measuring equipment. By such means it will be possible not only to measure the movement envelope or "kinetosphere" needed for a specific task (see Dempster, 1955), but also to measure simultaneously the muscle forces required. Such data should prove very important in determining realistic standards of the work capabilities of men.

SECTION II

The Sample

In this preliminary survey, forty selected subjects were used (with the exception of the dimension "Maximum Body Depth" discussed below). Twenty-seven individuals were Air Force personnel, consisting of twenty-three enlisted men and four officers, all rated pilots. Three of the Air Force group were Negroids. The remaining thirteen subjects were white civilians at Antioch College.

The selection procedure was used to insure a sample statistically representative of the Air Force. It was feared that, since necessity required a small sample, a random group might not be anthropometrically close to the large Air Force sample (Hertzberg, Daniels and Churchill, 1954). In order to allow greater applicability of the results, from a total of fifty-three individuals measured, forty subjects were selected to yield distributions of stature and weight as close as possible to those of the 1950 Air Force Anthropometric Survey of about 4000 men. This was done because stature generally correlates well with other length dimensions and weight correlates well with body breadths and depths.

The two samples, compared in Table I, appear close enough for practical purposes. No statistical tests were performed because of the great disparity in sample size. The largest discrepancy in values of dimensions occurs in "Arm Reach from Wall", and this may be due to slight differences in measurement technique employed in the two surveys. In the present study, the anthropometrist required that the back be in firm contact with the wall; this contact was perhaps more firm than that used in the 1950 Air Force survey. It should also be pointed out that for all the measurements in the present study, the body is in positions which allow rather large ranges of mobility. For this reason, the anthropometric differences between the two samples are probably not practically significant, since minor body adjustments to workspace can be made very easily.

The dimension "Maximum Body Depth" was determined by measuring a subseries of scaled photographs of 118 subjects from the 1950 Air Force Anthropometric Survey. This subsample is anthropometrically close to the over-all survey with respect to several basic dimensions. Table II compares the means and standard deviations of these two samples for these basic dimensions. Again, because of the large differences in sample size, no statistical tests were performed.

Table I

Anthropometric Comparison of the Present Sample
With 1950 Air Force Personnel[1]

		Present Sample N = 40		1950 Air Force Personnel[2] N = 4000+	
		M	S.D.	M	S.D.
Age	years	24.40	5.50	27.9	4.22
Weight	lbs.	160.70	21.53	163.66	20.86
Stature	inches	69.10	2.37	69.11	2.44
Shoulder Height	"	56.87	2.26	56.50	2.28
Sitting Height	"	36.22	1.31	35.94	1.29
Arm Reach from Wall	"	33.85	1.26	34.59	1.65

Table II

Anthropometric Comparison of the Photogrammetric Sample
With 1950 Air Force Personnel[1]

		Photogrammetric Sample[3] N = 118		1950 Air Force Personnel[2] N = 4000+	
		M	S.D.	M	S.D.
Weight	lbs	162.66	19.57	163.66	20.86
Stature	[illegible]	69.18	2.28	69.11	2.44
Chest Depth	[illegible]	9.14	.71	9.06	.75
Waist Depth	[illegible]	7.95	.80	7.94	.88

1. All dimensions are in inches except age and weight, which are expressed in years and pounds respectively.
2. From Hertzberg, Daniels and Churchill, 1954.
3. Used only to determine "Maximum Body Depth".

On these grounds, then, the samples used are considered to be adequately representative of the Air Force population, and to have yielded data acceptable for Air Force design purposes.

SECTION III.

Procedures and Apparatus

One difficulty with an anthropometry of working positions is that conventional instruments do not catch the variations in dimension that occur during body movement. This is one reason why classical anthropometry has had to be static. Another difficulty is in achieving adequate reliability of body positioning and measuring techniques.

For this study, all dimensions except "Maximum Body Depth", were taken directly on the subject. This dimension was determined from a subsample of 118 photographs taken during the Air Force Anthropometric Survey of 1950. These pictures, although originally taken for purposes of body-typing, include both horizontal and vertical linear scales which were used to convert measurements on the photographs to actual values.

The other measurements were ascertained by the use of one or more of the following pieces of apparatus: anthropometer, prone measuring board marked off in tenths of inches, and a measuring block. For the measurement "Overhead Reach", the anthropometer was attached to a table top by means of a base and C-clamps, as pictured in Section IV.

For the kneeling and crawling position measurements, the shaft of the anthropometer served as a measuring block to determine lengths, while the heights were found simultaneously in the usual fashion (see Section IV).

SECTION IV

Results

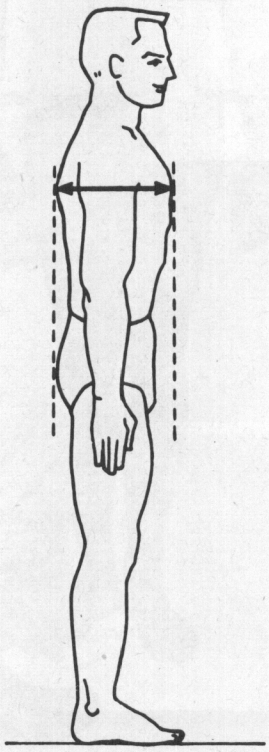
All dimensions are expressed in inches.

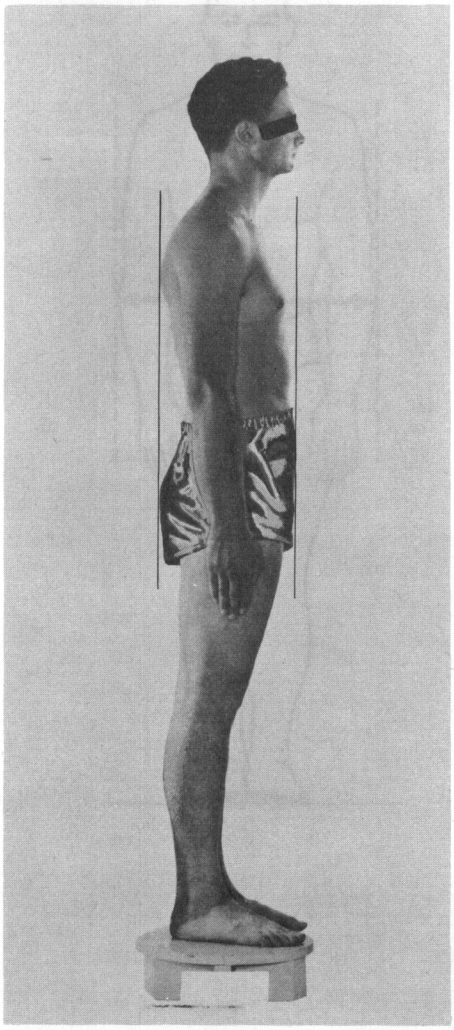
1. Maximum Body Depth (N = 118)

Subject stands in the body-typing position (Sheldon, Stevens and Tucker, 1940) and a right lateral view is photographed. The maximum horizontal distance is measured between the vertical planes passing through the most anterior and posterior points on the trunk. The head, legs, feet and genitalia were not included in this measurement. The actual points involved were either on the chest or abdomen anteriorly and in the shoulder or buttock region posteriorly.

Mean	S.E.	S.D.	5th Percentile	95th Percentile
11.48	.08	.88	10.1	13.0

inches

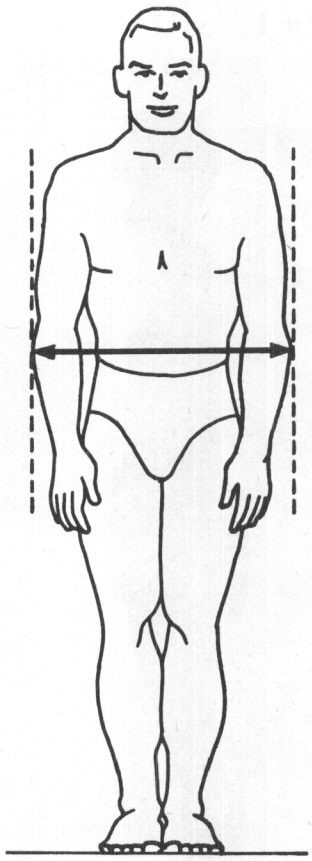


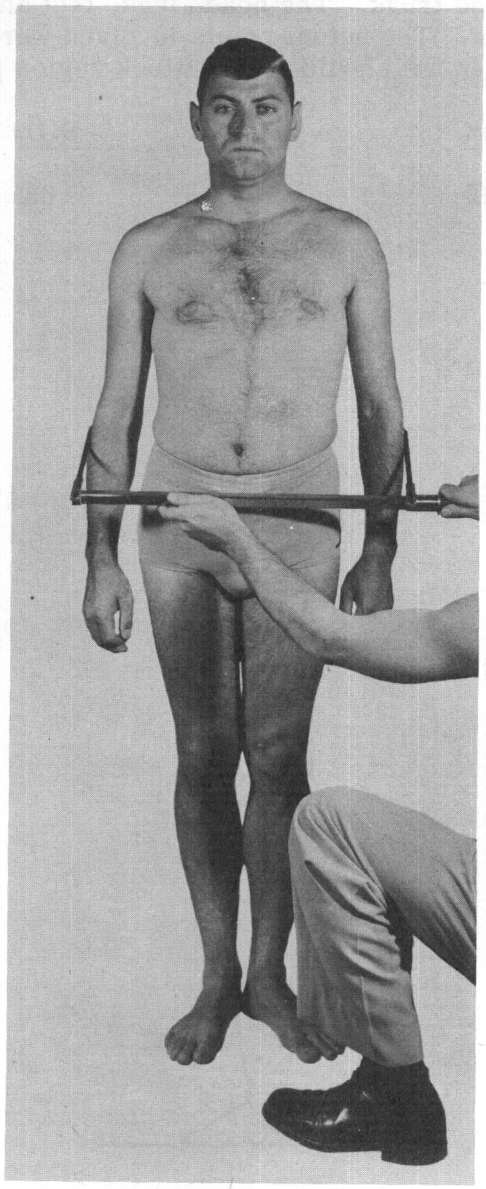


2. Maximum Body Breadth (N = 40)

Subject stands erect with his arms hanging relaxed at his sides. Using the anthropometer, measure the maximum breadth of the body, including the arms.

Mean	S.E.	S.D.	5th Percentile	95th Percentile
20.90	.19	1.19	18.8	22.8

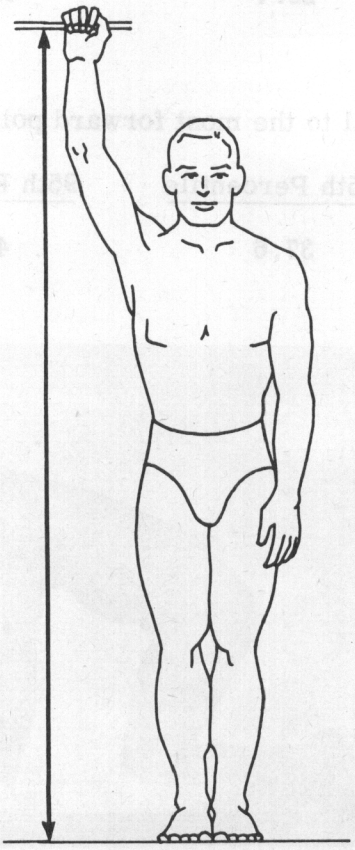


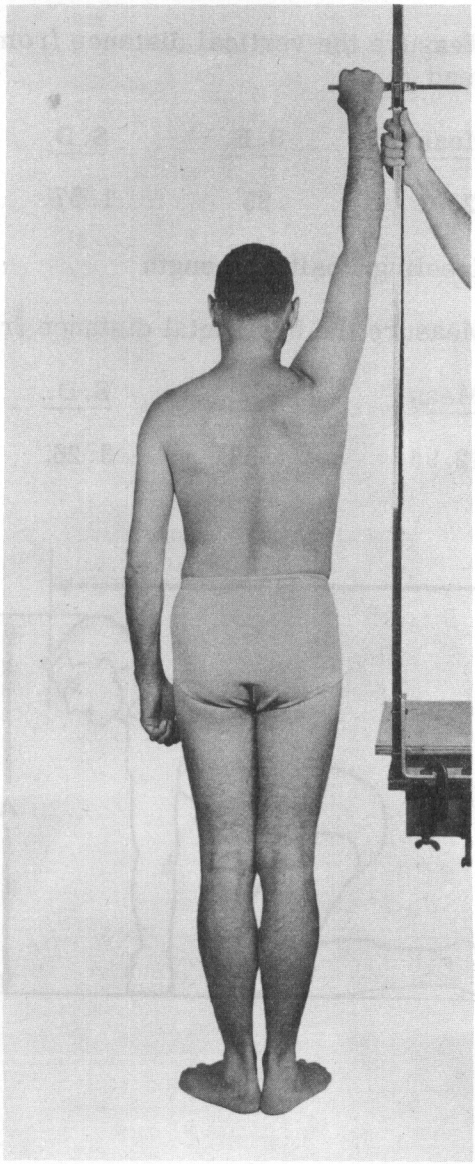


3. Overhead Reach (N = 40)

The anthropometer is secured to a table of known height. The subject stands erect with the anthropometer directly at his right side so that he can raise his right arm without leaning against the anthropometer. Subject grasps the anthropometer arm at the slide with his right hand (at the bend formed by the palm and fingers), closes his fist and holds the first phalanges facing directly upward. The anthropometer arm is then raised to the highest position attainable without strain, and the dimension is read to the top of the anthropometer arm.

Mean	S.E.	S.D.	5th Percentile	95th Percentile
82.54	.53	3.33	76.8	88.5





4. Kneeling Position (N = 40)

Subject kneels on the measuring board, knees together, feet together and comfortably extended, and toes just touching the wall. The subject rests his thighs on his calves with his torso straight and for the moment at about right angles to his thighs. He clenches his fists, with the backs of the hands facing to the sides, and extends his arms forward and downward, by raising the thighs from the calves and bending further at the hips to bring his fists almost into contact with the floor in front of knees. The forward movement is continued until the body just begins to topple over. Now the subject bends his body at the hips slightly backward, his fists still close to the board, so that he is well-balanced and capable of considerable arm movement. Subject then plants his fists on the board, with arms straight, and his head in line with the long axis of the body.

A. Kneeling Position Height

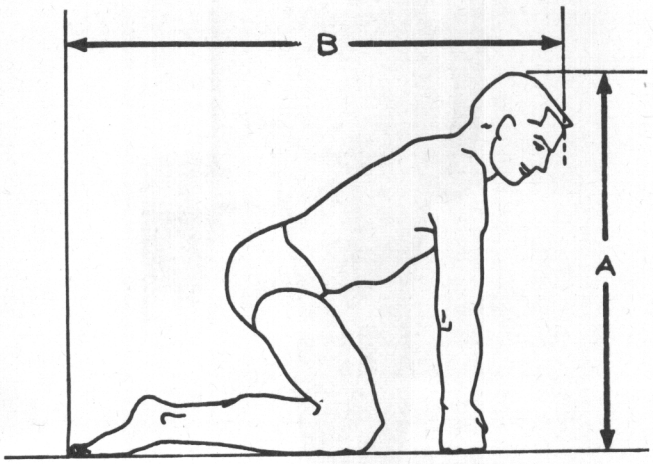
Measure the vertical distance from the measuring board to the highest point of the head.

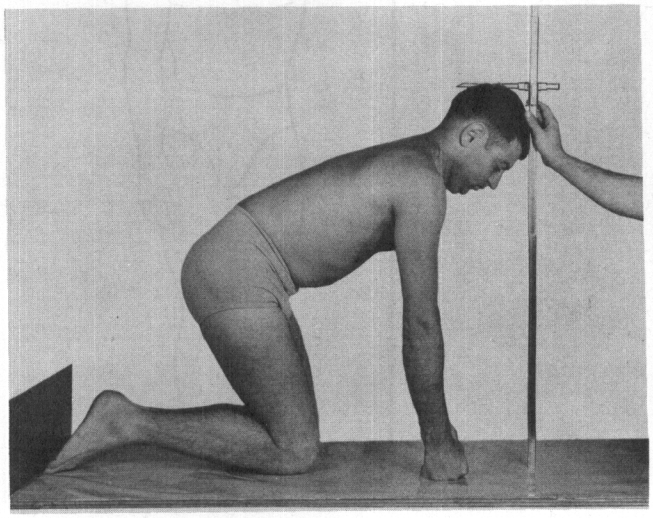
Mean	S.E.	S.D.	5th Percentile	95th Percentile
32.01	.25	1.57	29.7	34.5

B. Kneeling Position Length

Measure the horizontal distance from the wall to the most forward point of the head.

Mean	S.E.	S.D.	5th Percentile	95th Percentile
42.95	.52	3.26	37.6	48.1





5. Crawling Position (N = 40)

Subject assumes the crawling position on the measuring board, his feet comfortably extended and spaced, and the toes just touching the wall. Subject rests on his flattened palms, with arms and thighs perpendicular to the floor, and body held straight and head held in line with the long axis of the body.

A. Crawling Position Height

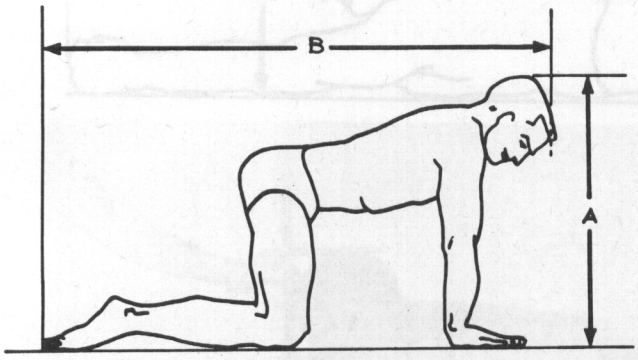
Measure the vertical distance from the measuring board to the highest point of the head.

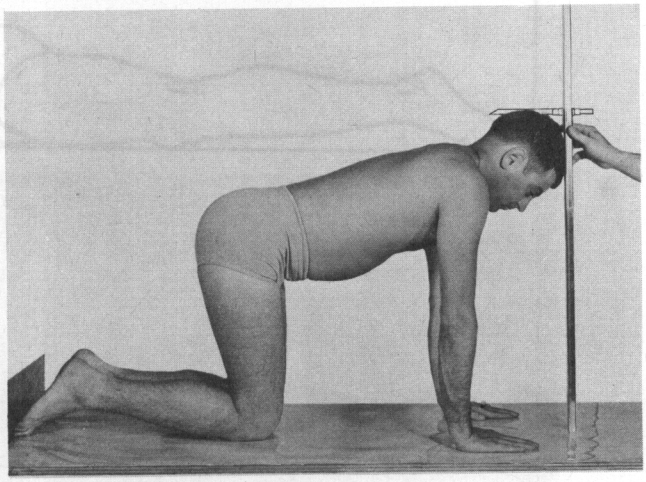
Mean	S.E.	S.D.	5th Percentile	95th Percentile
28.43	.21	1.30	26.2	30.5

B. Crawling Position Length

Measure the horizontal distance from the wall to the most forward point on the head.

Mean	S.E.	S.D.	5th Percentile	95th Percentile
53.15	.41	2.61	49.3	58.2





6. Prone Position (N = 40)

Subject lies prone on the measuring board, feet together and comfortably extended with toes just touching the wall. The arms are extended forward to a maximum unstrained position, and clenched fists are held with the first phalanges directed forward and the backs of the hands facing to the sides.

A. Prone Position Height

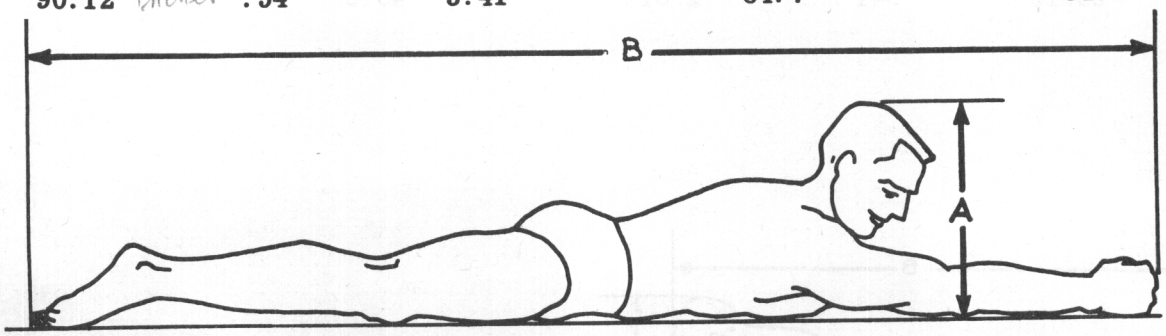
Keeping the chest on the board, the subject raises his head as high as possible to look forward. Measure the vertical distance from the measuring board to the top of the head.

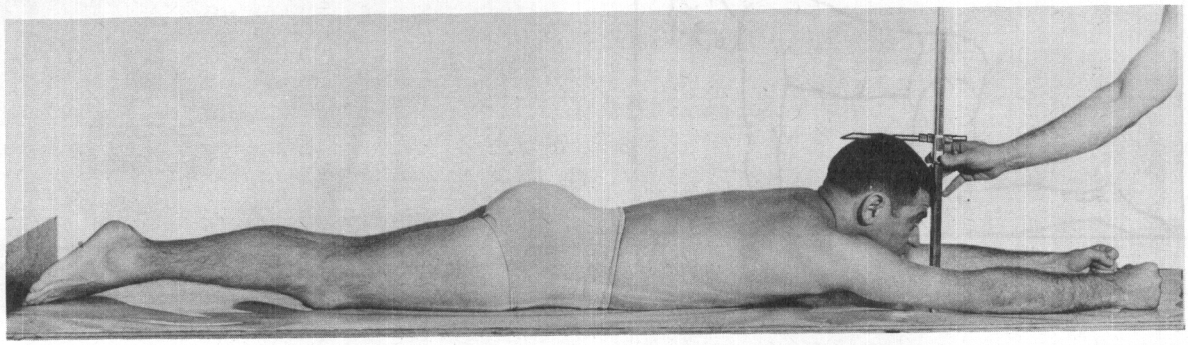
Mean	S.E.	S.D.	5th Percentile	95th Percentile
14.46 inches	.20	1.28	12.3	16.4

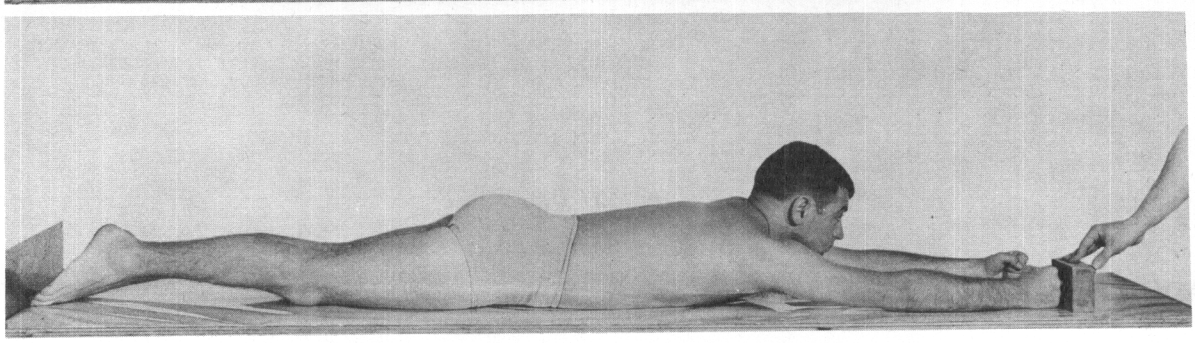
B. Prone Position Length

Measure the length of the body from the wall to the ends of the fists.

Mean	S.E.	S.D.	5th Percentile	95th Percentile
90.12 inches	.54	3.41	84.7	95.8







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