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BODY VOLUME OF ADULT MEN

Chester L. Ward

USAF School of Aerospace Medicine
Brooks Air Force Base, Texas

June 1967

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CHESTER L. WARD, Major, MC, F/S, USA

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USAF School of Aerospace Medicine
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CHESTER L. WARD, Major, MC, F/S, USA

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FOREWORD

The research reported in this paper was conducted by personnel at the USAF School of Aerospace Medicine, Brooks AFB, Tex., under task No. 775801. The measurements for this report were obtained from 10 March 1964 through 9 December 1966 by personnel in the Physiology Branch. The report was submitted for publication on 6 March 1967.

The author gratefully acknowledges the assistance of the following persons in the Physiology and Biometrics Branches of the School: Dr. Thomas H. Allen, for technical advice and consultation; Clarence Theis, for acquisition of measurements; and Dr. Bryan Danford and CMSgt. James I. Clogston for data processing, analysis, and interpretation.

This report has been reviewed and is approved.

James B. Nuttall

JAMES B. NUTTALL
Colonel, USAF, MC
Commander

ABSTRACT

Body composition determinations were made on 404 adult men by use of a volumetric method. The testing of a proposed nomogram for estimation of body volume from height and weight revealed the chart to be biased for adult men. Body volume was found to correlate well with body weight (correlation coefficient of .996). Body volume of men in liters, V, may be estimated from body weight in kilograms, W, by using the formula: $V = -4.7573 + 1.0153\ W$.

The ideal weight given on the USAF standard weight table was found to have a correlation coefficient of only .672 with calculated percent body fat.

BODY VOLUME OF ADULT MEN

I. INTRODUCTION

Human body composition is a subject of great interest and continuing research. The component of greatest interest and that which appears to be of the greatest importance relative to health, morbidity, and mortality is the adipose tissue (8). It is often important to the armed forces, insurance companies, and other industries—as well as to the person concerned about his own appearance, efficiency, and health—to distinguish between having excessive adipose tissue and merely being "overweight." An individual may be overweight according to standard height-weight tables and still not be obese (11). This relatively increased weight may be the result of an athletic, heavy, muscular physique rather than obesity or "overfat."

The purpose of this report is to present the anthropometric data of 404 adult men, aged 17 to 51 years. These body measurements and computations of body composition will be compared and contrasted with the USAF weight table (1) and with a method recently suggested by Sendroy and Collison (10), using a nomogram, for predicting body volume from measurements of height and weight. A formula for estimating body volume from weight alone will be presented.

II. METHOD

Measurements were made and recorded for each subject's age, height, weight, observed body volume, and predicted body volume. On the basis of these measurements, the following calculations were made for the data on each subject: density, difference between measured and predicted volume, fat, percent of fat to weight, and percent of relative ideal weight. Certain descriptive statistics were derived from these data for presentation with the results.

Body composition was determined by a volumetric method (2) with appropriate deduction of measured residual lung volume. This method assumes that the greatest variable in adult human body composition is adipose tissue and that the densities of body components are relatively constant. Discussion of the validity of these premises exceeds the purpose of this report; reviews on body composition, in which these ideas are discussed, are available in the literature (4-7, 9).

Subjects

U. S. Air Force personnel on active duty constituted most of the 404 adult males measured. Significant groups of subjects included the following: normal men exposed to experimental aerospace atmospheres, altitudes, confined quarters, and foods—142; obese subjects for special diets—64; MOL astronaut candidates—45; physicians in Aerospace Medicine Residency—37; patients seen in consultation having diseases other than obesity—23; U.S. pentathlon team—14; and "skinny" men, subjects for a high fat diet study—8. The only observations used in this report are the measurements recorded the first time a subject presented himself, in his own control state, for study; repeat values and subsequent changes in an individual are excluded from this report.

Age. The subject gave his age as years at last anniversary of birth.

Height. Measurement was obtained to the nearest millimeter as the subject stood barefooted with heels together and stretched to maximum height.

Weight. The nude subject, fasting or after a very light breakfast, was weighed dry in the morning after a shower, micturition, and defecation, if possible. Weight was determined to the nearest 5 gm. on a standard beam balance scale.

Body volume. The subject's volume was measured by water displacement using the technic and volumeter developed by Allen (2). After the subject was weighed, as described above, and before he was immersed in the volumeter, his residual lung volume was determined to the nearest mean cubic millimeter on three consistent trials by the method using open circuit nitrogen washout (with oxygen). Body volume of tissue was determined to the nearest cubic millimeter by subtracting the subject's measured residual lung volume from his submerged volume after complete underwater expiration of his vital capacity.

Predicted body volume. A nomogram proposed by Sendroy and Collison (10) for determining body volume was tested. Predicted volume was determined by interpolation to the nearest liter from an enlarged nomographic chart in the manner recommended by the authors named above. Predicted volumes were determined by an independent second reading and all differences in interpolation were arbitrated.

Difference. Measured volume minus the predicted volume ($\Delta = Vo - Vp$) was calculated.

Density. Weight divided by measured volume was calculated to six decimal places ($D = W/V$).

Percent fat. Weight of fat was calculated using the formula $F = c_1V - c_2W$ where F is fat in kilograms, $c_1 = 4.878$ (kg. liter^{-1}), V is volume in liters, $c_2 = 4.415$ (kg. kg.$^{-1}$), and W is weight in kilograms (3). Weight of the body fat was divided by total body weight and multiplied by 100 ($\%F = 100\ [F/W]$).

Percent ideal weight. The "ideal weight" used was the standard weight for the 26- to 30-year age group in the USAF weight table (1). The difference of observed and ideal weight divided by ideal weight, all multiplied by 100, is defined as percent ideal weight ($\%Wi = 100\ [(Wo - Wi)/Wi]$).

III. RESULTS

Descriptive data on the 404 subjects are presented in table I and data means for 5-year age groupings are presented in table II.

The expected increase in the mean weight with advancing age is noted in the 5-year age

TABLE I

Descriptive data, 404 subjects

Variable	Mean	Range		S. D.
		Minimum	Maximum	
Age, years*	31.70	17	51	8.06
Height, cm.	178.10	157.7	196	5.86
Weight, kg.	77.61	47.59	117.98	10.95
Volume, liters	74.05	44.31	119.15	11.16
Density	1.050	.990	1.097	.016
Percent fat	23.31	3.21	51.13	7.06
Percent ideal weight	9.68	−24.52	72.25	13.68

*Number for age grouping is 403: one age was not recorded.

groupings except for the 41- to 45-year aged subject grouping. The reason for the deviation from the progression of increasing weight, volume, percent fat, and percent ideal weight and the decreasing density observed in the means for the 41- to 45-year age group is unknown.

The testing of a chart-nomogram method (10) for predicting body volume is presented in the "Liters difference" row of table II. The enlarged nomographic chart was found relatively difficult to read and, at best, can be interpolated only to the nearest full liter of predicted body volume. The mean difference between the measured body volume and predicted volume for the 404 subjects was 1.755 liters with a standard deviation of 1.234 liters.

If a *rough* body volume *estimate* is needed for such purposes as calculating predicted body fat (see formula above) or for other clinical and practical purposes, body volume may be estimated for adult men using the formula, $V = -4.757 + 1.015\ W$, derived from the plot of the regression illustrated by the scattergram in figure 1. The correlation coefficient of weight and volume is .996; thus, volume in liters, V, may be fairly accurately predicted from weight in kilograms, W. If one uses the formula $V = -4.757 + 1.015\ W$ to predict volume from weight, then the 95% confidence limits on the predicted volume, V_p, is $V_p \pm 1.9$ liters.

Percent ideal weight has correlation coefficients with density and percent fat of only −.672 and +.672, respectively. It should be observed that the information content of density and percent fat is the same. This relationship may be verified algebraically as wel. as empirically, as shown in the correlation coefficients above.

IV. DISCUSSION

The preceding results have demonstrated that a recently proposed nomogram for the determination of human body volume from height and weight is biased. A more accurate and easier-to-use formula for estimating the body volume of adult males has been presented.

The estimation of fatness in the 404 measured subjects by equating fatness or obesity with the concept of overweight, as compared to an "ideal" weight from a height-weight table, revealed a correlation coefficient of only .67 between calculated percent fat and departure from ideal weight. This relatively poor correlation between measured fatness and a weight table indicates that charts or tables based upon

TABLE II

Means of variables in 5-year age groups

Variable	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55
Height, cm.	179.0	178.3	178.4	177.9	177.4	177.1	179.4	182.5
Weight, kg.	72.30	75.39	78.69	78.90	79.42	75.86	83.04	91.17
Volume, liters	68.10	71.41	74.96	75.31	76.34	72.75	80.07	87.94
Liters predicted	67.20	70.30	73.24	73.53	73.87	70.58	77.88	86.00
Liters difference	.90	1.11	1.72	1.78	2.47	2.17	2.19	1.94
Density	1.064	1.058	1.051	1.049	1.041	1.044	1.038	1.037
Percent fat	17.06	19.74	22.73	23.72	27.05	25.99	28.52	29.00
Percent ideal weight	1.56	6.20	10.78	11.66	13.15	8.42	15.58	22.08
Number subjects*	35	63	94	81	52	59	17	2

*See footnote, table I.

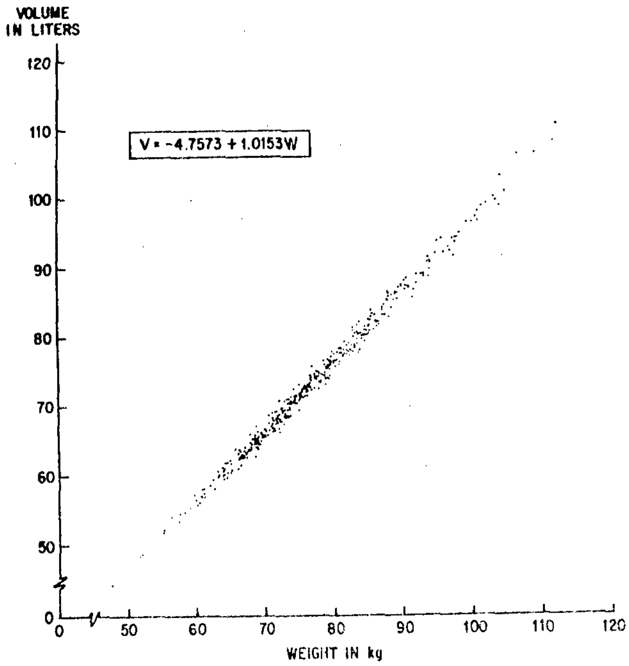

FIGURE 1

Scatter diagram showing relationship between volume and weight.

age, height, and weight are an inadequate method for the evaluation of a person's body composition. Overweight means only that when compared to an observed mean weight from a population with the subject's same height and age, the subject has somewhat more than the expected weight. The subject's relatively high weight might very well be due to a heavy skeletal system and a large, well-developed, muscle mass rather than excess fat or obesity as the term *overweight* implies—often incorrectly.

The concept that obesity rather than overweight may adversely affect health and longevity requires that methods better than reference to age-height-weight tables be used to estimate body composition. Clinical judgment, testing of functional capacity, and measurement of skin-fold thickness are quite useful; but for exceptional individuals (those who do not conform to the model or physical stereotype) additional and more accurate methods of determining body composition are necessary.

The volumetric method for determining density and estimating body fat, using a standard table to estimate residual lung volume if necessary, is readily usable in nearly any situation because it requires no complex equipment, is relatively simple to operate, and has a low initial cost with minimal upkeep. A volumeter could be easily fabricated from materials available in most remote or undeveloped areas. The use of this volumeter would give an accurate method of determining body composition.

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	ROLE	WT	ROLE	WT	ROLE	WT
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Nomogram, body volume						
Weight tables						
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