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HEART WEIGHT

I. THE WEIGHT OF THE NORMAL HUMAN HEART

PEARL M. ZEEK, M.D.
CINCINNATI

The purpose of this investigation is to find a practical method for calculating what a normal heart in a given person should weigh and within what range that expected weight may vary without the alteration being evidence of atrophy or of hypertrophy. The standards for normal cardiac weight given in textbooks of anatomy and pathology and in periodical literature differ so widely that by their use one cannot recognize the lesser degrees of myocardial hypertrophy and atrophy (table 1).

Since the early stages of these processes are so obscure both clinically and pathologically, there exists much difference of opinion concerning the etiologic role played by certain conditions, among which are coronary sclerosis, pericardial adhesions, glandular dyscrasias and vitamin deficiencies. It is hoped that more accurate and more generally utilized criteria for slight departures from the normal heart weight may provide data for diagnosing myocardial hypertrophy in its early stages, may establish a basis for the study of cardiac atrophy and may lead to a better understanding of the causes of these two conditions. Detailed reviews of the literature concerning normal heart weight have been recorded by Smith,[1] Bedford and Treadgold,[2] Stieve,[2a] Bardeen [3] and many others.

Several methods have been used in the past to determine standards for heart weight: (1) Calculation of the average weight of hearts from unselected adults dying from any cause (Shennan [4]). The sources of error in this method are obvious. (2) Calculation of the average heart weight in series of cases selected because presumably the hearts were

From the Department of Pathology of the University of Cincinnati and the Cincinnati General Hospital.

1. Smith, H. L.: Am. Heart J. **4**:79, 1928.

2. Bedford, D. E., and Treadgold, H. A.: Lancet **2**:836, 1931. Further tests of the conclusions of this report were published in 1932 by Treadgold and H. L. Burton (Lancet **1**:277, 1932).

2a. Stieve, H.: Med. Klin. **34**:5 and 42, 1938.

3. Bardeen, C. R.: Am. J. Anat. **23**:423, 1918.

4. Shennan, T.: Post Mortems and Morbid Anatomy, ed. 3, Baltimore, William Wood & Company, 1935.

normal. The reported criteria for the "normal heart" have been concerned mainly with ruling out the obviously hypertrophied ones, while little attention has been given to the ones which may have been smaller than normal. Also, few, if any, reports present convincing evidence that all cases of hypertension have been excluded from the series of cases used. (3) Calculation of the heart weight/body weight ratio. It has long been known that the size of the body has some effect on the size of the heart. Since weight has been accepted generally as the most satisfactory measurement of heart size in regard to criteria for myocardial hypertrophy, it has been considered statistically proper to correlate heart weight with body weight. This correlation has been made by many investigators. The results have not been uniform because the many factors which may exert an effect on heart weight were not constant in all the series of cases used.

The effect of sex on heart weight has been recognized by most investigators in recent years. Other factors being constant, female hearts have usually been found to be smaller than male hearts (table 1).

There is more difference of opinion concerning the effect of age on heart weight. Gray [5] wrote: "The heart continues to increase in weight and size up to an advanced period in life, and this increase is more marked in men than in women." Piersol [6] stated: "The weight of the heart increases with age up to about the seventieth year, probably a slight diminution taking place after that period." Smith [1] stated that the weight of the heart does not increase with age except as the weight of the body increases. Aschoff [7] found no correlation between age and heart weight in his series of 468 soldiers. Comeau and White [8] stated that in the adult age was of no value as a correlation factor in studying heart size as determined by orthodiascopic measurements. Greenwood [9] studied 358 apparently normal hearts and concluded that the age increase amounted to about 9.4 Gm. for each decade. Bell and Hartzell [10] studied the effect of age on the size of the heart, but they included cases of hypertension, coronary sclerosis and other conditions affecting the heart, so that the data presented by their cases formed too complicated a picture to give convincing support to their statement that "there is therefore no satisfactory evidence of a correlation of heart weight with age alone."

5. Gray, H.: Anatomy, Descriptive and Applied, edited by T. B. Johnson, ed. 26, New York, Longmans, Green & Co., 1935.

6. Piersol, G. A.: Human Anatomy, ed. 11, Philadelphia, J. B. Lippincott Company, 1916.

7. Aschoff, L.: Lectures in Pathology, New York, Paul B. Hoeber, 1924.

8. Comeau, W. J., and White, P. D.: Am. Heart J. **17**:616, 1939.

9. Greenwood, M., and Brown, J.: Biometrika **9**:473, 1913.

10. Bell, E. T., and Hartzell, T. B.: J. M. Research **44**:473, 1924.

TABLE 1.—*Previously Reported Heart Weight Standards*

Author	Heart Weight: Average, Gm. Males	Average, Gm. Females	Range, Gm. Males	Range, Gm. Females	Percentage of Body Weight: Males	Females	Unspecified
Arnold *	290	260	250-325	225-300	.....	.....	.....
Bardeen [3]	.....	.....	.....	.....	0.55	0.53	.....
Boyd *	.....	.....	.....	.....	0.59-0.84	0.51-0.80	.....
Cunningham *	310	255	.....	.....	.....	.....	0.488
Gray *	.....	.....	280-340	230-280	.....	.....	.....
Greenwood and Brown [9]	.....	.....	.....	.....	.....	.....	0.575 (0.45-0.70)
Jackson *	312	255	.....	.....	0.55	0.53	.....
Kaufmann *	300	250	.....	.....	.....	.....	.....
Müller *	.....	.....	.....	.....	0.55-0.75	0.50-0.69	.....
Peacock *	.....	.....	227-312	198-284	.....	.....	.....
Piersol [6]	312	274	266-346	230-340	0.59	0.61	.....
Saphir *	300	250	.....	.....	.....	.....	.....
Shennan *	384	326	.....	.....	0.60	0.63	.....
Smith *	294	250	155-400	110-367	0.43	0.40	.....
Thoma *	.....	.....	.....	.....	.....	.....	0.463
Vierordt *	.....	.....	275-367	264-310	.....	.....	.....
White *	300	250	.....	.....	0.40	0.45	..... (0.35-0.50)

* Reference and comment are given below.

Arnold, H. D.: M. & S. Rep. Boston City Hosp., 1899, ser. 10, p. 83: "Weights for 25 grams outside these limits may be normal; beyond that they are almost surely abnormal."

Boyd, cited by Bell and Hartzell.[10]

Cunningham, D. J.: Manual of Practical Anatomy, ed 2, New York, William Wood & Co., 1923: "The weight varies greatly, always, however, in definite relation to the weight of the body, the relative proportion changing at different periods of life."

Gray [5]: "It continues to increase in weight and size up to an advanced period in life, and this increase is more marked in men than in women."

Jackson, C. M.: The Effects of Inanition and Malnutrition upon Growth and Structure, Philadelphia, P. Blakiston's Son & Co., 1925. Morris' Human Anatomy, ed. 8, Philadelphia, P. Blakiston's Son & Co., 1925. This applies only to cases "of average build." "In emaciated individuals it usually weighs relatively more, and relatively less in the fat."

Kaufmann, E.: Pathology, Philadelphia, P. Blakiston's Son & Co., 1929.

Müller, W.: Die Massenverhältnisse des menschlichen Herzens, Leipzig, Leopold Voss, 1883.

Peacock, T. B.: Monthly J. M. Sc. **19**: 193, 313 and 403, 1854.

Saphir, O.: Autopsy Diagnosis and Technique, New York, Paul B. Hoeber, Inc., 1937.

Shennan [4]: Calculated from 1,020 cases of patients dying from all causes. Hearts varied in weight from 184.25 to 1,445 Gm.

Smith [1]: The ratio is slightly higher in thin persons and lower in the obese.

Thoma, R.: Untersuchungen über die Grösse und das Gewicht der anatomischen Bestandtheile des menschlichen Körpers im gesunden und kranken Zustände, Leipzig, F. C. W. Vogel, 1882.

Vierordt, K. H.: Anatomische, physiologische und physikalische Daten und Tabellen, ed. 3, Jena, Gustav Fischer, 1906.

White, P. D.: Heart Disease, ed. 2, New York, The Macmillan Company, 1937: "Enlargement up to 425 grams may exist in a large individual without clinical signs, but hypertrophy of the heart beyond that weight should be found by clinical study."

Some of the variations in the results obtained by different investigators using the heart weight/body weight ratio may be explained by the types and number of cases included in their series. Many of the

reported series of cases were so small and the variation in heart weight so great that, had the probable error of the mean been calculated, no significance could have been attached to the mean heart weight. Among the investigators using larger series of cases was H. L. Smith,[1] who studied 1,000 cases presenting none of the well recognized causes of myocardial hypertrophy. He concluded that the weight of the normal heart may be calculated from the weight of the body with an error of about 8 to 10 per cent. The ratio was higher with thin persons and lower with obese ones. He stated that this method is not so accurate for the body weight under 100 pounds (45.5 Kg.) or over 210 pounds (95 Kg.). From the results of Smith and others it seems that the heart weight/body weight ratio would be a satisfactory criterion for normal heart weight only when calculated from data on a large series of persons who are of relatively normal body weight and who present no clinical or pathologic evidence of any of the known causes of myocardial hypertrophy or atrophy and no clinical or pathologic evidence of heart disease. In addition, separate ratios should be calculated for each sex; also, age and color should be investigated as possible contributing factors. No report has been found in the literature which presents mean heart weight/body weight ratios of statistically proved reliability, with all of these factors evaluated. Aschoff's group of soldiers consisted of adults of the same sex and of similar body build and body nourishment, dying of causes not likely to affect heart weight; so his series provides a standard which should be quite accurate for males of similar body build and nourishment. In Smith's series of 1,000 cases not many were emaciated or obese. Among 532 adult males he reported 24 weighing over 190 pounds (86 Kg.) and 33 weighing less than 120 pounds (54.5 Kg.).

The method of calculating heart weight as a percentage of the body weight has certain disadvantages. Autopsies are frequently performed in laboratories, funeral parlors or other places where there are no facilities for weighing cadavers. It is much easier to provide facilities for weighing viscera than for weighing the entire body. Moreover, body weight is not stable. Variation in body weight is an integral part of the picture presented by many disease processes. It would be desirable to use only normal body weights in calculating standards for normal heart weight. But what is normal body weight? Whatever it is, it is frequently not presented at autopsy, or even clinically during the last illness, except in healthy persons dying suddenly of accidental causes. Such factors as terminal dehydration, ascites, edema, urinary retention, large "fibroids," ovarian cysts, pregnancy, loss of a limb and other causes of increase or decrease in body weight may not cause a proportional change in heart weight. In fact, many of these conditions probably do not affect heart weight at all. It would be more accurate to use the weight of the body during health, but that figure is usually not available

at autopsy, and therefore cannot be used as a basis for judging whether or not there is myocardial hypertrophy or atrophy.

Some investigators have estimated the normal weight for a given body from the height, sex and age, using insurance tables as their standard, and have used this estimated body weight in calculating the normal heart weight/body weight ratio. However, these reported series of cases included emaciated and obese persons, as well as normally nourished ones. If emaciation and obesity affect heart weight, the hearts of these persons were not suitable material for calculating standards for normal heart weight, even though a corrected body weight was used in the ratio. The quantitative effect of emaciation and of obesity on the heart weight/body weight ratio has not been determined. The reports on this subject present conflicting points of view. Results from experiments on small series of experimental animals range from no loss in heart weight with loss in body weight to a percentage loss in heart weight greater than the percentage loss in body weight. Van Liere and Sleeth,[11] after working with 33 guinea pigs, concluded: "In prolonged inanition, the heart loses slightly more weight than does the body." The percentage loss in their animals was so slight as to be within the range of experimental error. In man the heart weight/body weight ratio seems to increase slightly with emaciation and decrease with obesity (table 1: Jackson; Smith). Since obesity and emaciation are parts of various disease conditions it seems advisable to consider tentatively, at least, that variations in heart weight associated with these changes in the state of body nourishment are departures from normal in heart weight.

Many attempts have been made to diagnose degrees of myocardial hypertrophy by methods not requiring the use of heart weight, the most common method being clinical determination of heart size by roentgen examination or by percussion. Although much knowledge concerning variation in heart size has been acquired by these methods, it must be remembered that "size" thus measured means dimensions and is not synonymous or even directly correlated with heart weight. A dilated heart is a large heart, but its weight may not be increased in proportion to its increase in dimensions. Increase in dimensions is not an accurate criterion of myocardial hypertrophy, which is an increase in the size of the heart muscle cells and thus an increase in muscle bulk. Increase in cardiac dimensions may be an increase only in the size of the heart's cavities with little or no increase in muscle bulk or in heart weight. Other factors which may cause variations in heart weight, such as fluid, fibrous tissue and inflammatory exudates, probably produce changes in weight too small to be differentiated at present from variations in normal heart weight. At present there is no clinical method by which heart weight can be accurately determined or predicted.

11. Van Liere, E. J., and Sleeth, C. K.: Am. J. Physiol. **116**:635, 1936.

In summarizing methods of calculating heart weight standards and in diagnosing departures from normal in heart weight, the best method in present use seems to be the heart weight/body weight ratio method but, as has been pointed out, this method is often inaccurate, impracticable and sometimes impossible to use.

Height, or body length, as measured at autopsy, occasionally has been considered a possible factor in estimating heart weight. In a group of healthy persons considerable differences in body weight can be expected to be associated with differences in height. Variations in body weight to the degrees commonly designated as emaciation and obesity are not accompanied by comparable changes in height. In other words, variation in body weight not due to pathologic conditions is directly correlated with variation in height when the factors age and sex remain constant (Dorst,[12] citing tables of the Medico-Actuarial Mortality Investigation). Therefore, it seems reasonable that any variation in heart weight with body weight which is not part of a pathologic condition would be also a variation with height.

Height is a much more stable factor in body "build" than is weight and is much less influenced by disease processes. At autopsy it is much easier to obtain an accurate measurement of body length than of body weight.

A search through the available literature revealed many suggestions of possible correlation between height and heart weight. In 1878 Beneke [13] studied the "volume of the heart substance from the standpoint of body length." Smith included in his report a graph showing the close correlation between heart weight and height—but he dismissed it with the remark that "the height affects the heart weight only as the height effects the body weight." In 1930 Kirsch [14a] traced through youth the parallelism between increase in the breadth and the length of the heart and increase in body height. In 1931 Bedford and Treadgold [2] used Eyster's [15] formula to predict the normal transverse diameter of the heart as seen in roentgenograms of the living subject. This formula includes factors for both height and weight of the body. He concluded that TD (transverse diameter) can be predicted from body weight alone in those of average height for weight, but that in others both height and weight must be taken into account to obtain an equally successful prediction.

12. Dorst, S. E., in Piersol, G. M.; Bortz, E. L., and others: Cyclopedia of Medicine, Philadelphia, F. A. Davis Company, 1931, vol. 2, p. 534.

13. Beneke, F. W.: Die anatomischen Grundlagen der Constitutionsanomalieen des Menschen, Marburg, N. G. Elwert, 1878.

14. Kirsch, O.: (*a*) Klin. Wchnschr. **9**:881, 1930; (*b*) Jahrb. f. Kinderh. **137**: 185, 1932.

15. Eyster, J. A. E.: Radiology **8**:300, 1927; Arch. Int. Med. **41**:667, 1928; Tr. A. Am. Physicians **43**:18, 1928

In 1932 Kirsch [14b] again mentioned body length as one of the factors to be considered in evaluating the size of the heart. During that year Moritz [16] also correlated body length with heart size, but he used, not the weight, but the breadth and the length of the heart as measurements of size. In 1934 Bray [17] included height in a list of external dimensions which he sought to correlate with heart weight, but unfortunately must have included some diseased hearts, since they varied in weight from 102 to 480 Gm. In 1939 Comeau and White [8] studied the body build and heart size of twins. They stated that body weight and surface area were more important than height in determining heart size as seen by roentgenograms. In 1940 Fray [18] described his cardiomensurator, an instrument for the detection of cardiac enlargement in roentgen films, and he made use of "the direct correlation of transverse diameter of the heart with body weight and height."

PRESENT INVESTIGATION

In order to determine the possible relationship between height and heart weight, and also to learn more about factors related to heart weight, the present study was begun. From the autopsy records of the Cincinnati General Hospital a series of 933 cases was collected in which the hearts had been considered relatively normal both clinically and pathologically and in which none of the well recognized causes of myocardial hypertrophy were present.

The criteria for the inclusion of cases in this series were as follows:

(1) No gross or microscopic lesions in the heart or the pericardium except
  (*a*) toxic changes, such as edema or cloudy swelling, and
  (*b*) relatively unimportant minor departures from normal, such as "slight fibrosis," "milk patch in the epicardium" or "slight atheroma of valves."

(2) No clinical evidence of cardiac disease except terminal acute cardiac dilatation.

(3) No gross or microscopic evidence of lesions causing increased peripheral resistance in any considerable extent of the peripheral vascular bed, such as extensive fibrosis of an organ or constricting lesions in arterioles.

(4) No recorded systolic blood pressure exceeding 140 or diastolic pressure exceeding 90.

(5) No deforming lesions which may have affected height, such as scoliosis.

(6) All persons 21 years of age or older.

An examination of the records of 9,676 consecutive cases in which autopsy was done at the Cincinnati General Hospital from 1924 to 1940, inclusive, revealed only 933 cases which fulfilled the foregoing criteria.

16. Moritz, F.: Deutsches Arch. f. klin. Med. **174**:330, 1932.
17. Bray, E.: Arch. ital. di anat. e di embriol. **32**:257, 1934.
18. Fray, W. W.: Am. Heart J. **19**:417, 1940.

In order to rule out arteriolosclerosis as having a possible effect on the heart weight, microscopic sections of heart, pancreas, kidney, liver, spleen and adrenal were searched for this lesion in each case. Cases which fulfilled all of the stated criteria except for the presence of arteriolosclerosis (and which therefore were excluded from this series) will be dealt with in a subsequent report.

In the pathologic laboratory of the Cincinnati General Hospital, where in each of these cases autopsy was done, it is customary to measure the body length along the flat surface on which the body is supine. The heart is weighed after its great vessels have been severed near their pericardial attachments and after the heart has been opened and the clots removed. The body weights are not recorded.

The factors chosen for investigation as possibly having an effect on heart weight were sex, color, age and state of body nourishment. In all cases used, both the autopsy and the clinical records contained descriptions of the state of nourishment. After dividing the cases into two groups according to sex, we redivided them according to race. Three males and four females were designated mulattoes in the records; so their cases were dropped from this series, leaving 926 cases for further study. It is understood that in this series there probably were others who were not as pure white or Negro as the records would indicate. This probability must be remembered when evaluating the racial factor in this report.

The race-sex groups were then subdivided as follows: (1) cases in which the body was described as "emaciated," "wasted" or "cachectic;" (2) cases in which the body was described as "obese"; (3) cases in which the body was described as "powerfully developed muscularly"; (4) cases not included in the above categories, classed as cases in which the body was normally nourished.

It is fully realized that group 4 may contain some cases belonging in one of the other groups, but since most of the cases were described by two or more independent observers, errors of this type are probably not numerous.

Table 2 indicates that in this series of 926 cases no significant difference in heart weight was found between white persons and Negroes. The female hearts were significantly lighter in weight than the male hearts in each category. Hearts from emaciated persons were significantly lighter in weight than hearts from better nourished persons of the same sex. Hearts from obese persons and from those of unusually powerful muscular development were heavier than those from persons in a more nearly average state of nutrition and muscular development. Although only 12 persons of unusually powerful muscular development were studied, all males, 8 of them had hearts weighing 375 Gm. or more, the largest being 425 Gm.

Therefore, sex, state of nourishment and probably muscular development of unusual degree must be considered in calculating standards for normal heart weight.

TABLE 2.—*Effect of Sex, Race and State of Body Nourishment on Heart Weight*

		Males					Females				
Race	Physical Classification	Number	Mean Heart Weight, Gm.	Probable Error of Mean, Gm.	Standard Deviation, Gm.	Coefficient of Variation, per Cent	Number	Mean Heart Weight, Gm.	Probable Error of Mean, Gm.	Standard Deviation, Gm.	Coefficient of Variation, per Cent
Negroes	Emaciated	71	267.5	3.9	49.0	18.3	63	220.4	3.1	36.0	16.3
	Normally nourished	141	326.4	2.3	40.8	12.5	94	263.7	2.8	41.0	15.5
	Obese	8	357.5	9.2	38.2	10.7	25	289.2	3.3	29.2	10.1
	Muscular	5	367.0	12.1	39.3	10.7	.....	.....	.....	.....	.....
	Total	225	310.5	2.4	52.8	17.0	182	252.2	2.4	47.4	18.8
White persons	Emaciated	65	261.0	3.7	44.3	17.0	58	216.0	3.1	35.2	16.3
	Normally nourished	216	325.8	1.9	41.1	12.6	130	261.1	2.2	37.1	14.2
	Obese	10	354.0	10.0	46.0	13.0	33	289.7	4.9	34.9	12.1
	Muscular	7	379.3	5.2	19.5	5.3	.....	.....	.....	.....	.....
	Total	298	313.5	2.0	51.8	16.5	221	253.5	1.9	41.4	16.3
Total	Emaciated	136	264.9	2.7	47.0	17.7	121	218.3	2.4	38.4	17.6
	Normally nourished	357	319.3	1.3	40.9	12.8	224	262.2	1.4	30.2	11.5
	Obese	18	355.6	6.8	42.8	12.0	58	289.5	2.9	32.6	11.3
	Muscular	12	374.2	5.8	30.0	8.0	.....	.....	.....	.....	.....
	Total	523	312.0	1.7	52.0	16.6	403	252.9	1.6	46.4	18.3

TABLE 3.—*Age and Heart Weight in Normally Nourished Cadavers*

	Males			Females		
Age, Yr.	Number	Mean Heart Weight, Gm.	Probable Error of Mean, Gm.	Number	Mean Heart Weight, Gm.	Probable Error of Mean, Gm.
21-29	99	315.8	2.7	100	254.9	2.7
30-39	111	322.3	2.6	78	263.3	3.3
40-49	90	318.3	2.8	36	276.0	4.6
50-59	39	319.5	4.3	6 *	295.0	.....
60-69	15	318.7	6.9	4 *	248.8	.....
70-79	3 *	350.0	.....	.....	.....	.....

* Here there are too few cases to be useful. Pearl [19] stated that when a mean is based on less than fifteen observations, special methods must be used to determine its reliability.

In order to determine whether age has any direct influence on heart weight, table 3 was constructed.

Using the simple theorem in probability which states that the probable error of the difference between two independent quantities is equal to the square root of the sum of the squares of the probable errors of the quantities entering into the differences (Pearl [19]), and realizing

19. Pearl, R.: Introduction to Medical Biometry and Statistics, ed. 2. Philadelphia, W. B. Saunders Company, 1930.

also that a difference between two quantities, to be significant, must be four or more times its probable error, I used the following formula to test the significances of the differences between the various mean heart weights in table 3.

$$\frac{\text{Mean}_A - \text{Mean}_B}{(\text{P.E.}_A)^2 + (\text{P.E.}_B)^2}$$

TABLE 4.—*Heart Weight and Body Length in Normally Nourished Males*

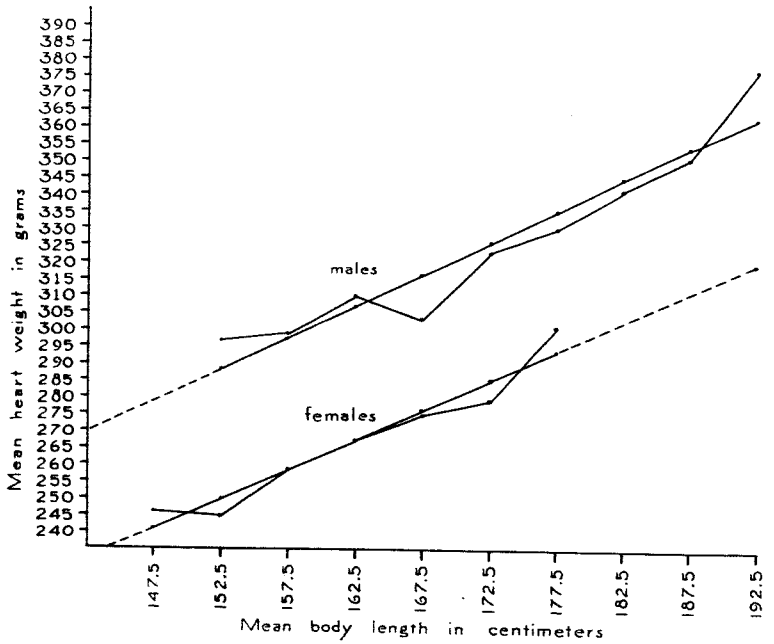
Heart Weight, Gm.	Cases	Mean Body Length, Cm.	Probable Error of Mean, Cm.	Standard Deviation, Cm.	Coefficient of Variation, per Cent	Body Length, Cm.	Cases	Mean Heart Weight, Gm.	Probable Error of Mean, Gm.	Standard Deviation, Gm.	Coefficient of Variation, per Cent
200-224	3	165.7	1.3	3.3	2.0	140-144	1	250	.....	.....	.....
225-249	11	168.0	0.9	4.5	2.7	145-149	0	.....	.....	.....	.....
250-274	29	168.2	1.2	9.7	5.8	150-154	6	296.7	10.0	36.5	13.7
275-299	49	167.3	0.6	6.7	4.0	155-159	11	298.1	4.7	23.3	7.8
300-324	89	170.6	0.5	7.2	4.2	160-164	51	309.8	3.0	32.0	10.3
325-349	64	170.4	0.6	6.7	3.9	165-169	84	303.2	2.5	37.7	12.4
350-374	76	171.7	0.4	5.7	3.3	170-174	99	322.8	2.4	34.8	10.8
375-399	23	174.1	0.9	6.4	3.7	175-179	62	330.4	2.5	40.9	12.4
400-424	13	186.0	1.3	6.7	3.6	180-184	31	341.8	4.9	40.7	11.9
						185-189	8	351.3	12.0	49.8	14.2
						190-194	3	376.7	15.7	40.3	10.7
						195-199	0	.....	.....	.....	.....
						200-204	1	240.0	.....	.....	.....
Total	357						357	319.3	1.5	40.9	12.8

TABLE 5.—*Heart Weight and Body Length in Normally Nourished Females*

Heart Weight, Gm.	Cases	Mean Body Length, Cm.	Probable Error of Mean, Cm.	Standard Deviation, Cm.	Coefficient of Variation, per Cent	Body Length, Cm.	Cases	Mean Heart Weight, Gm.	Probable Error of Mean, Gm.	Standard Deviation, Gm.	Coefficient of Variation, per Cent
150-174	3	153.7	0.5	1.3	0.8	135-139	1	250.0	.....	.....	.....
175-199	6	152.2	1.0	3.5	2.3	140-144	1	240.0	.....	.....	.....
200-224	25	157.7	0.9	7.0	4.4	145-149	15	246.3	6.6	38.1	15.5
225-249	42	157.4	0.7	7.2	4.6	150-154	43	244.9	4.3	41.6	17.0
250-274	55	159.6	0.7	7.4	4.6	155-159	53	259.3	3.6	38.7	14.9
275-299	41	160.9	0.7	6.9	4.3	160-164	61	267.0	3.5	41.3	15.5
300-324	30	161.3	0.8	6.3	3.9	165-169	29	274.5	4.6	36.4	13.3
325-349	15	161.5	1.4	8.2	5.1	170-174	13	278.5	8.1	43.2	15.5
350-374	7	166.6	1.5	5.8	3.5	175-179	8	300.6	8.6	35.6	11.8
Totals	224						224	262.2	1.4	30.2	11.3

Since within each sex group the difference between the largest and the smallest mean heart weight (of age groups including 15 or more cases) was less than four times its probable error, the conclusion is that changes in age between 21 and 69 years in males and between 21 and 49 years in females have no direct effect on heart weight. More cases in the older age groups must be studied before further conclusions are justifiable.

Since age and race were not found to exert any influence on heart weight, all of the males and females were grouped, respectively, in two frequency distribution tables according to body length and heart weight (tables 4 and 5). The mean, the probable error of the mean, the standard deviation and the coefficient of variation were calculated for each heart weight class and for each body length class.



Heart weight and body length.

In the males, as heart weight increased from 200 to 424 Gm. there was an increase in mean body length from 165.7 to 186 cm. As body length increased from 150 to 194 cm., there was an increase in mean heart weight from 296.7 to 376.7 Gm. The coefficient of correlation between heart weight and body length in these 357 normally nourished males was 0.33 ± 0.03. This figure indicates definite but imperfect correlation.

In the female group, as the heart weight increased from 150 to 374 Gm., there was an increase in mean body length from 153.7 to 166.6 cm. As the body length increased from 145 to 179 cm., there was an increase in mean heart weight from 246.3 to 300.6 Gm. The coefficient of correlation between the heart weight and the body length in these 224 normally nourished females was 0.29 ± 0.04. This figure also indicates definite but imperfect correlation.

In order to check further the possible effect of race on heart weight, the data were rearranged in such a way as to keep the body length and sex factors constant. No significant difference in mean heart weight between white persons and Negroes was found in any of the body length groups. For example, 29 white males measuring 160 to 164 cm. had a mean heart weight of 309 Gm., while 22 Negro males of that body length group had a mean heart weight of 310 Gm. Among females with body lengths of 150 to 154 cm. the mean heart weight of 35 white females was 242, and that of 23 Negro females was 247 Gm. A similar rearrangement of data for the effect of age on heart weight, the body length and sex factors being kept constant, showed no significant difference in heart weight between the various decade age groups.

In the figure the mean heart weights for males and females are plotted against the variations in body length. In order to discount the fluctuations due to accidents of random sampling, the data were subjected to the mathematical process called curve fitting, the method of least squares being used. The straight line for each sex thus evolved has also been plotted in the figure. Any point on this line represents the most probable normal heart weight for a body of the length indicated at that point. However, it must be remembered that there can be deviations within the normal from any point on this line equal to the standard deviations given in tables 4 and 5. For example, a normal heart from a normally nourished female body measuring 150 cm. in length will most probably weigh 245 Gm. but may weigh any amount between 215 and 275 Gm. (245 ± 30) and still be considered of normal weight.

The equation to a straight line, $y = a + bx$, was used, letting $x =$ the middle point of each of the body length groups in tables 4 and 5, and y, the corresponding mean heart weights. Then, with the normal equations for fitting a straight line, which have been worked out by the principles of differential calculus, the equation $y = a + bx$ was solved for the values of a and b. Thus the following formulas were derived:

(1) For normally nourished adult males, the heart weight in grams equals 1.9 times the body length in centimeters minus 2.1 plus or minus 40.

$$\text{H.W.} = 1.9\ \text{B.L.} - 2.1 \pm 40$$

(2) For normally nourished adult females,

$$\text{H.W.} = 1.78\ \text{B.L.} - 21.58 \pm 30$$

With these formulas the heart weights for bodies of various lengths were calculated (table 6). This table provides a standard for judging whether or not a given heart in a given body is within normal weight limits. Furthermore, groups of cases with the same body length can be compared in order to determine whether or not there is any significant difference in heart weight between the groups. It is well to remember that to be significant a difference must be four or more times its probable error.

SUMMARY

Statistical analysis of the weights of hearts from 926 adult bodies in which was found no clinical or pathologic evidence of heart disease or of any commonly recognized cause of myocardial hypertrophy revealed the following factors to have an effect on heart weight; sex, body length and state of body nourishment. No effect of age or race on heart weight was demonstrated.

TABLE 6.—*Normal Heart Weights*

Body Length, Cm.	Heart Weight, Gm. Males $\sigma = \pm 40$	Heart Weight, Gm. Females $\sigma = \pm 30$	Body Length Cm.	Heart Weight, Gm. Males $\sigma = \pm 40$	Heart Weight, Gm. Females $\sigma = \pm 30$
135	254	219	168	317	277
136	256	220	169	319	279
137	258	222	170	321	281
138	260	224	171	323	283
139	262	226	172	325	284
140	264	227	173	327	286
141	266	229	174	329	288
142	268	231	175	330	290
143	270	233	176	332	291
144	272	235	177	334	293
145	273	236	178	336	295
146	275	238	179	338	297
147	277	240	180	340	299
148	279	242	181	342	300
149	281	243	182	344	302
150	283	245	183	346	304
151	285	247	184	348	306
152	287	249	185	349	307
153	289	251	186	351	309
154	291	252	187	353	311
155	292	254	188	355	313
156	294	256	189	357	315
157	296	258	190	359	316
158	298	259	191	361	318
159	300	261	192	363	320
160	302	263	193	365	322
161	304	265	194	367	323
162	306	267	195	368	325
163	308	268	196	370	327
164	310	270	197	372	329
165	311	272	198	374	331
166	313	274	199	376	332
167	315	275	200	378	334

σ = standard deviation.

In relatively normally nourished males the weight in grams of a normal heart was found to be 1.9 B. L. — 2.1 ± 40, B. L. being the body length in centimeters. The normal heart weight in normally nourished females was found to be 1.78 B. L. — 21.58 ± 30. Since emaciation and obesity are parts of pathologic processes, the variations in heart weights found to be associated with these conditions were considered departures from normal. Therefore, bodies presenting these conditions were not included in the series used for the determination of standards for normal heart weight. These standards based on body length were found to be more accurate and more useful than the commonly employed standards related to body weight.