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BODY WEIGHT IN TWO HUNDRED AND TWENTY-NINE ADULTS

WHICH STANDARD IS THE BEST?

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PROBLEM

It is rare for clinicians to recognize that medicine, as a whole, profits more by normal standards than by scattered observations of interesting pathologic cases. This is Benedict's judgment,¹ and Galton's² appears to have been much the same: "Variations of weight are the surest guides to health. . . . Dangerous illnesses may be avoided, and even life preserved." Such illnesses may be outspoken, like malnutrition in children, thyrotoxicosis and tuberculosis; also diabetes and obesity. Or the disease may be insidious, in which case the weight abnormalities are apt to be called defects without obvious cause. Such defects have been alarmingly frequent in recent military examinations. And not only frequent, but surprisingly important. For instance, if we are conservative and consider not the incidence among draftees but only the actual rejections, we find that overweight ranks second among the prominent causes of rejection, as detailed in Table 1.

TABLE 1.—PHYSICAL CAUSES OF REJECTION

Causes of Rejection in Order of Frequency	By Seven Local Boards for the Army ³	By the Navy and Marine Corps ³	By the Total Draft for the Army ⁴
	No. examined.....7,611	No. examined....82,592	No. examined...2,510,591
	Percentage of Examinees Rejected	Percentage of Examinees Rejected	Percentage of Examinees Rejected
1	Eyes..... 6.0	Eyes..... 11.4	Heart..... 4.3
2	Teeth..... 4.8	Underweight..... 6.5	Underweight..... 2.6
3	Underweight..... 4.6		
15 etc.	Overweight..... 0.4	Overweight not given	Obesity..... 0.17

The literature furnishes an embarrassing variety of standards by which to judge whether the weight of a given person is within normal

1. Benedict, F. G.: Boston M. & S. J. **181**:109, 117, 118 (July 31), 1919.

2. Galton, F.: Life History Album, London, 1884, p. 2.

3. Fisher, I., and Fisk, E. L.: How to Live, Ed. 15, New York and London, 1919, p. 400, 258.

4. Love, A. G., and Davenport, C. B.: Defects Found in Drafted Men, Printed for Senate Committee on Military Affairs, Washington, 1919, p. 71.

limits. To enable the physician or statistician to choose between these methods is the main object of this paper. The plan has been to collect measurements and actual weights on a series of normal individuals, then to predict the weights for these men by means of various standards, and finally by comparing these predicted weights with the actual weights to compute the error made by each standard.

INDIVIDUALS OBSERVED

The first series was abruptly terminated by entry into service of one of the authors, and was, therefore, reported at the time.⁵ It is summarized in Table 7, together with some new calculations based on the original data. But this earlier series comprised only twenty subjects, and so it was thought desirable to assemble a second group. This was done in the intervals between regular work in the U. S. Army Base Hospital 76, mostly in France, while the extensive computations have been carried out since leaving the service. This second series comprises 229 soldiers, all from the personnel of Base Hospital 76. They were all born in the United States, mostly in Maryland and Pennsylvania. Most of them were inducted at Fort Oglethorpe in June, 1918, and mobilized as this hospital unit at Camp Devens in July, 1919. At that time they were weighed naked, measured and examined physically by the medical officers of the unit, in the hope of excluding some on the ground of possible defects overlooked in the hastier examination at enlistment. Incidentally, the number of positive Wassermanns in 200 tests was only one. The unit sailed from New York August 31, spent about a week in England, and was on duty in Vichy, Allier, France, from the latter part of September until after the time of the second weighing in January, 1919. Some of the original members had meanwhile been separated from the unit, but all who had been weighed twice at the six months' interval are included in this report. Nobody was excluded by preconceived notions on our part as to the typical man. The series is, therefore, unselected, except that males of military age who happen not to fit the army standard are not represented. This fact constitutes a technical defect, as pointed out by Hoffman, but the advantage accrues to a method other than that championed in this paper. Accordingly, we have assumed these to be fair samples of American-born young men, and as such to be suitable controls by which to test the accuracy or error of different methods for predicting weight.

The gist of this test is that Bornhardt's standard is the most accurate, closely followed by the Army and insurance tables; while

5. Gray, H., and Gray, K. M.: *Normal Weight*, Boston M. & S. J. **177**:894 (Dec. 27) 1917.

Guthrie's, Broca's and von Noorden's give much less satisfactory results. This is shown graphically in the accompanying chart, and is detailed numerically in Table 9. The casual reader, therefore, may well omit the following minutiae as to method, and skip to the conclusions at the end of the paper.

Average error in predicting weight by different standards. Difference between predicted and actual weights, expressed as percentage of the actual weight.

DEFINITIONS

The actual weight is often represented by such terms as: net weight, weight stripped, weight without clothes. This is the criterion by which we are to choose between various standards in the literature.

The Weight of Clothes.—Nearly every standard except the medico-actuarial is expressed as net weight. In our previous observations⁵

men's clothing averaged eight pounds (3.6 kg.), and heels averaged one inch (2.5 cm.). By these values the medico-actuarial table, derived from life insurance records, has been adjusted for net weight in making the comparisons both in the earlier series and the present series. It would have been more accurate, however, for us to have subtracted not 8, but only 6 pounds (2.7 kg.) from the medico-actuarial table to find the predicted weight, because that table was based on weighings with clothes and shoes, but without coat and vest. If, now, we should correct by an increase of 2 pounds our weights predicted by that table, they would be mathematically more correct, but would make no better showing for that standard, since the predictions already run too high. In practice, when using any other than the insurance table, the average weight of house clothes and shoes for men at all ages, sizes, and seasons may be allowed for by Table 2. The figures opposite Quetelet's ⁶ name were obtained by applying his rule, that clothes average one-eighteenth of the total weight of the male body, to the average weight for the age group here considered, i. e., from 20 to 34 years inclusive (not the average weight for our own group, which is so small relatively and gives 7.8 pounds, i. e., 3.5 kg., but) as computed by us from figures given ⁹ for 130,301 men insured in the United States and Canada: 152.1 pounds (69.1 kg.) with clothes; then clothes come to $152.1/18 = 8.5$ pounds (3.8 kg.).

TABLE 2.—ALLOWANCE FOR MEN'S CLOTHES AND SHOES *

Writer	Weight of Clothes and Shoes	
	Kg.	Lbs.
Fisher and Fisk.....	3.1	6.9
Gray.....	3.6	8.0
Quetelet.....	3.8	8.5
Gaertner ⁷	4.0	8.8
Harris and Benedict ⁸	4.0	8.8

* Expressed as kilograms or pounds.

The *ideal weight* is that accompanied by the healthiest or longest life. Too few people are familiar with the insurance experience ³ that one should endeavor to keep his weight at the average for his height and for age 30, the period of full maturity.

6. Quetelet, L. A. J.: *Sur l'homme*, Paris, 1835, 2:44, or in the first English translation, *A Treatise on Man*, Edinburgh, 1842, p. 64.

7. Gaertner, G.: *Diätetische Entfettungskuren*, Leipzig, 1913, pp. 154, 158, 160; or in English translation, *Reducing Weight Comfortably*, Philadelphia, 1914, pp. 278, 286, 291.

8. Harris, J. A., and Benedict, F. G.: *A Biometric Study of Basal Metabolism in Man*, Carnegie Institute, Washington, Publication No. 279, 1919, pp. v, 2, 3, 4, 7, 21, 26, 163, 164, 228.

9. *Medico-Actuarial Mortality Investigation*, Vol. I, *Statistics of Height and Weight of Insured Persons*, published by Assn. Life Ins. Directors and Actuarial Soc. of America, N. Y., 1912, pp. 13, 16, 18, 38, 67, 105, 109.

The *average weight*, or usual weight, is the familiar arithmetic mean weight, of subjects grouped by age, height, or other more complex methods. In the medico-actuarial investigation the average weight agreed closely with the central weight (also technically called the mode, the most frequent or the typical weight), thus showing the reliability of using the average.

The *correct weight* may signify either the ideal or the average weight, hence unfortunately it leads to ambiguity.

The *normal weight* also may be interpreted as either the ideal or the average weight. For children Holt¹⁰ says that "the average is not to be confused with the normal. There are considerable variations on either side of the average which should be regarded as within the range of normal. The normal is a zone, not a line." Benedict,¹ too, believes that "for the growing child a gross error has been committed in . . . accepting the average . . . as normal." For adults the insurance committee makes a like statement: "Normal weight for any age and height may vary considerably from the average."

Normal Zone Weight.—This term might be used for the healthy range called "standard lives" by the insurance committee, "the norm of weight" by Gaertner, and more recently emphasized by Holt in the words cited above. The phrase is suitable to express any weight within acceptable limits, but yet not the ideal nor the exact average. The lower boundary of this zone, i. e., the minimal permissible figure beneath which the person is judged underweight, is given by Emerson¹¹ as 7 per cent., and by Holt as 10 per cent., both for children. For adults, figures which we have calculated from the 1916 printing of the Army standard give 9 per cent. (ranging from 6 to 13 per cent. according to height), and from the 1919 edition 13 per cent. (ranging from 8 per cent. acceptable below the standard weight for 60 inches, up to 19 per cent. below the standard weight for 74 inches); while the insurance companies regarded lives as standard even down to 15 per cent. underweight.

The *standard weight* may mean the ideal, or the average, or the zone.

A *weight standard* is any method, whether table or formula, for predicting weight, as in the title to this paper.

Pathologic Weight, Underweight, Overweight.—Whatever term be used, whatever standard be selected, whatever variation above and beneath the average be accepted as healthy, nearly every writer on obesity or malnutrition starts his reckoning from the predicted weight.

10. Holt, L. E.: Am. J. Dis. Child. **16**:359 (Dec.) 1918.

11. Emerson, W. R. P.: Am. J. Dis. Child. **17**:251 (April) 1919; Boston M. & S. J. **181**:139 (July 31) 1919.

Predicted weight, calculated weight, estimated weight, expected weight, theoretical weight. This value may be derived from a variety of tables and formulae, of which six are analyzed. It usually corresponds to the average weight.

STANDARDS COMPARED

While the average weight is affected by various factors, e. g., age, sex, country and locality of birth, height, chest-girth, individual variation or sampling; the weight has in nearly every standard offered been considered in connection with one of the following four periods of life: Birth, preschool age, school age, or adult life. The borders of these four groups, except of course the first, vary somewhat according to different writers, but this is of no concern here. For each of the first three age-groups one table was chosen and reproduced in a previous paper;⁵ while for the last or adult age group six standards were quoted: Two tables and four formulas. They were Bornhardt's, the Army's, the medico-actuarial, Guthrie's, Broca's and von Noorden's.

Bornhardt's formula was used in the shape given by Fröhlich,¹² Vierordt,¹³ Gaertner,⁷ Baer,¹⁴ Barker¹⁵ and Vedder,¹⁶ namely: If H be the height without heels in centimeters, C the mean chest girth in centimeters as measured over the nipples, W the net weight in kilograms, then the expected weight for the adult of average constitution is: $W = H \times C/240$.

*The Army Table*¹⁷ used in our earlier paper⁵ has been adhered to in the present study, for the sake of uniformity. The editions of "the physical examination standards . . . are . . . all together seven in number,"¹⁸ from G. O. 66, A. G. O., April 18, 1910, to the latest and larger table authorized Nov. 8, 1918, and published in Washington, 1919. The changes have been slight.

*The Navy Table*¹⁹ gives the same weights for the same heights, i. e., from 64 to 73 inches inclusive, as in the edition of the Army table used here.

12. Fröhlich, H.: Allgem. medic. Central. Zeitg. **64**:8 (Jan. 2) 1895.

13. Vierordt, H.: Tabellen für Mediziner, Ed. 3, Jena, 1906, p. 97.

14. Baer, J.: Fettsucht (Obesity), in L. Mohr and R. Staehelin's Handbuch der inneren Medizin, Berlin **4**:650, 1912.

15. Barker, L. F.: Clinical Diagnosis of Internal Dis., New York and London **3**:794, 1916; or Monographic Medicine **4**:794, 1916.

16. Vedder, E. B.: Sanitation for Medical Officers, Medical War Manual No. 1, Ed. 2, Philadelphia, 1918, p. 74.

17. McCain, H. P., Adjutant General, War Department, U. S. A. Recruiting Circular No. 2, Washington, Nov. 1, 1916, i. e., G. O. 66 W. D.

18. Hoffmann, F. L.: Army Anthropometry, Prudential Press, Newark, N. J. **34**:46, 1918.

19. Bureau of Navigation, U. S. Navy, Circular Relating to the Enlistment of Men, July 20, 1912, also Circular N. M. S. 126,480, October, 1916; also Manual for the Medical Department, U. S. Navy, 1917, par. 2082.

The *Medico-Actuarial Table* is not reproduced, being very long and available elsewhere.^{5, 9, 20}

Broca's Formula, so-called,¹⁵ has also been credited to Quetelet²¹ by some,²² to Allaire²³ and to Robert²⁴ by others,^{7, 25} and cited without credit by still others.²⁶ We have not succeeded in finding the original, despite search of the supposed sources. The formula is uniformly expressed as: $W \text{ (in kg.)} = H \text{ (in cm.)} \text{ minus } 100$. Bouchard believes the rule to be approximately true for heights between 168 and 175 cm.; but we find, from applying the rule to the 116 men of our series who fall within this restricted range, that the prediction error, without regard to sign, averages 14 per cent. This is not materially better than the average for our whole series which will be seen in Table 8.

Guthrie's Formula, worked out on patients in Professor Barker's clinic,¹⁵ is: $\text{Wt. in pounds} = 110 + (5.5 \times [\text{ht. in inches minus } 60])$.

Von Noorden's Formula is given by Barker as: $\text{Wt in kg.} = \text{ht in cm.} \times 430 \text{ to } 480$. If from this statement the constant factor for average weight be inferred to correspond to the mean between these two values we get: $\text{Wt in kg.} = \text{ht in cm.} \times 455$. This interpretation has been applied both in the earlier paper and in this. The results cause regret that we have not been able to see Von Noorden's original statement of his rule.

OBSERVATIONS

The method of recording measurements was as follows: Weight to the nearest half-kilogram (or pound), height and chest-girth to the nearest centimeter, and age to the nearest year.^{8, 9, 17, 19, 27} Harris and Benedict⁸ point out that "A measurement of stature to the nearest centimeter is about the limit of accuracy. To retain tenths of kilograms is . . . a degree of refinement . . . Finally, when individuals are recorded to the nearest year of age we may remember that they are on the average a quarter of a year older or younger than the age to which they are assigned." Our technic also conformed in many respects to the recommendations of the Committee on Anthropology of the National Research Council.¹⁸ For height a tape 150 by 1.5 cm. ($59 \times \frac{5}{8}$ in.) was tacked to the wall so that the lower end was 100 cm.

20. Joslin, E. P.: *Diabetic Manual*, Ed. 2, Philadelphia, 1919, p. 115.

21. Quetelet, L. A. J.: *Anthropométrie*, Bruxelles, 1871, p. 178, and elsewhere.

22. Sahli, H.: *Diagnostic Methods*, trans. from German Ed. 5, by N. B. Potter, Ed. 2, Philadelphia, 1911, p. 28. Heckel, F.: *Grandes et Petites Obésités*, Paris, 1911, p. 105.

23. Allaire: *Recueil de mémoires de médecine milit.*, III e S. **10**:161, 1863.

24. Robert: *Recueil de mémoires de médecine milit.*, III e S. **10**:171, 1863.

25. Fröhlich, H.: *Körpergewicht*, in *Real-Encyclopädie der ges. Heilk.*, Ed. A. Eulenburg, Vienna, 1887, **11**:199.

26. Bouchard, C.: *Traité de Pathologie Générale*, Paris, **3**:183, 1900.

27. Treasury Dept., Bureau of War Risk Insurance Form 2A.

above the floor. The subject stood in bare feet, touching the wall with heels, hips, shoulders and head; and a block with square end was pressed down firmly on the scalp. For chest-girth a similar tape was applied on a level with the nipples and read at full inspiration and full expiration; midway between these two readings was taken as the mean chest-girth. The above technic is somewhat more precise than that considered adequate by the Medico-Actuarial Committee:²⁸ height to the nearest inch. Incidentally, if inches be preferred to centimeters, the inch may well be divided, not into eighths (binary fractions) as in ordinary rules, but into tenths. Similarly, fractions of pounds are better noted as tenths than as sixteenths (ounces). These decimal fractions occupy less space in the chart, are more quickly written down, and are better adapted for averaging and other statistical manipulation, as pointed out by Roberts²⁸ long ago.

The basal data obtained by our measurements are reported in Table 3, with the subjects arranged according to their actual weights, the lightest first.

METHODS OF STATISTICAL ANALYSIS OR CALCULATIONS

The importance of giving attention to methods considered fussy by some, has been urged by Harris and Benedict in these words: "Data must be . . . interpreted as the statistical constants . . . indicate without any regard to opinions heretofore expressed. In the past, data have been treated almost exclusively by the simple method of averages and graphic representation. . . . By means of the biometric formulas . . . during the past two decades instances of the demonstration of law and order in processes hitherto apparently chaotic have been rapidly multiplying. The reader who is interested in end-results rather than in methods should pass over these features, just as the general biologist must pass over the details of method. . . . in a paper by an organic chemist, realizing that they are essential to the technical development of the subject."

Pearl²⁹ more recently wrote a paper "to illustrate by a concrete example, not only the importance, but indeed the absolute necessity of mathematical tests of the validity of results and conclusions, if medicine is ever to measure up the standards of scientific logic and accuracy which prevail in some, at least, of the other branches of biologic and physical science. Many, indeed most, of the problems of practical

28. Roberts, C.: *Manual of Anthropometry*. London, 1878, p. 26. For example, see Reference 5 in which Table 2 reproduces the American Medical Association's table for children (first published by Crum) with the common fractions translated by us into decimals.

29. Pearl, R.: A Statistical Discussion of the Relative Efficacy of Different Methods of Treating Pneumonia, *Arch. Int. Med.* **24**:398 (Oct.) 1919.

TABLE 3.—OBSERVED DATA

Number	Name	Age at Nearest Birth- lay, in Years	Height Without Shoes		Chest Girth at Nipple, Mean, in Cm.	Actual Weight, Stripped		
			In.	Cm.		July, 1918, Lbs.	Jan., 1919, in Lbs.	Per Cent. Gain (+) or Loss (—)
1	2	3	4	5	6	7	8	9
1	P. A. N.	25	60	152	88	105	120	+14
2	J. N. N.	22	66	168	83	107	105	— 2
3	J. M. W.	31	65	165	84	109	110	+10
4	P. J. S.	23	65	165	84	109	136	+25
5	M. L.	24	62	157	80	110	117	+ 6
6	S. S.	25	66	168	82	110	117	+ 6
7	M. K.	22	62	157	83	112	112	0
8	J. K. T.	22	61	155	83	113	126	+12
9	G. W.	30	65	165	89	114	126	+11
10	T. W. S.	23	64	163	88	116	122	+ 5
11	P. C. F.	25	63	160	84	116	124	+ 7
12	A. J. D.	22	62	157	86	116	125	+ 8
13	W. L. D.	28	65	165	86	116	139	+20
14	F. W.	22	64	163	90	117	129	+10
15	J. H. M.	28	63	160	84	118	120	+ 2
16	W. C. W.	28	63	160	89	118	126	+ 7
17	S. A.	27	62	157	85	119	125	+ 5
18	J. S.	26	65	165	88	120	120	0
19	M. J.	24	65	165	90	120	121	+ 1
20	S. Y.	28	64	163	86	121	129	+ 7
21	H. D.	25	68	173	90	121	129	+ 7
22	W. S.	26	58	147	89	122	118	— 3
23	J. P. V.	26	65	165	89	122	122	0
24	J. P. D.	27	63	160	90	122	122	0
25	L. W.	27	64	163	90	122	122	0
26	G. D. W.	33	66	168	80	122	126	+ 3
27	J. J. M.	23	66	168	88	122	133	+ 9
28	A. L. M.	28	71	180	85	122	135	+11
29	J. C. T.	27	66	168	90	123	127	+ 3
30	W. W. W.	27	69	175	90	123	130	+ 6
31	C. O. N.	27	68	173	84	123	137	+11
32	W. J. W.	23	62	157	91	123	140	+14
33	J. F. M.	33	69	175	85	124	129	+ 4
34	M. E. J.	19	69	175	86	124	133	+ 7
35	P. W. E.	26	67	170	81	124	139	+12
36	J. A. F.	24	67	170	88	124	146	+18
37	J. O.	21	65	165	89	125	132	+ 6
38	J. A. W.	25	66	168	93	125	132	+ 6
39	L. S.	22	65	165	90	125	136	+ 9
40	L. C. B.	26	65	165	85	125	144	+15
41	D. E. F.	24	62	157	89	126	128	+ 2
42	L. H. W.	27	66	168	90	126	131	+ 4
43	R. T. F.	23	69	175	89	126	134	+ 6
44	P. S. H.	24	69	175	83	126	137	+ 9
45	A. F. S.	26	65	165	89	128	132	+ 3
46	J. W.	29	68	173	90	128	134	+ 5
47	J. B. R.	23	67	170	80	128	136	+ 6
48	L. L. H.	25	68	173	84	128	141	+10
49	J. K.	23	64	163	86	128	141	+10
50	F. A. C.	30	69	175	90	128	141	+10
51	A. E. B.	31	69	175	86	128	143	+12
52	L. G. M.	23	65	165	88	128	146	+14
53	P. P. L.	32	69	175	85	130	142	+10
54	J. M. D.	23	69	175	85	129	145	+12
55	B. L. F.	23	64	163	89	129	150	+16
56	A. B. R.	28	67	170	91	130	130	0
57	P. J. S.	23	63	160	85	130	131	+ 1
58	R. M.	23	69	175	88	130	135	+ 4
59	O. L. O.	22	63	160	88	130	138	+ 6
60	E. S.	28	66	168	88	130	139	+ 7
61	F. J. F.	30	65	165	88	130	140	+ 8
62	P. R. C.	25	68	173	93	130	150	+15
63	A. B. B.	34	70	178	88	130	154	+18
64	F. S.	24	66	168	86	131	134	+ 2
65	C. M. A.	24	63	160	88	131	135	+ 3
66	V. P. B.	31	71	180	88	131	140	+ 7
67	J. E. J.	26	62	157	90	131	142	+ 8
68	G. F. M.	26	70	178	88	131	144	+10
69	W. S.	22	66	165	90	131	146	+11
70	O. C. M.	25	66	168	84	132	142	+ 8
71	J. F.	29	66	168	86	132	151	+14
72	H. R. S.	21	67	170	87	132	152	+15
73	M. W.	27	68	173	91	133	133	0
74	V. S. D.	29	66	168	86	133	134	+ 1
75	W. D. J.	23	69	175	89	133	135	+ 2
76	F. W. F.	23	67	170	91	133	140	+ 5
77	W. S.	28	65	165	93	133	142	+ 7

TABLE 3.—OBSERVED DATA—Continued

Number	Name	Age at Nearest Birth- day, in Years	Height Without Shoes		Chest Girth at Nipple, Mean, in Cm.	Actual Weight, Stripped		
			In.	Cm.		July, 1918, in Lbs.	Jan., 1919, in Lbs.	Per Cent. Gain (+) or Loss (—)
1	2	3	4	5	6	7	8	9
78	W. C. B.	23	68	173	93	133	142	+ 7
79	L. P. A.	26	58	160	91	133	145	+ 9
80	A. B. C.	23	71	180	92	133	150	+13
81	C. L. V.	28	68	173	85	134	144	+ 7
82	M. M.	27	67	170	87	134	145	+ 8
83	L. G.	23	66	168	85	134	148	+10
84	J. L. B.	25	71	180	85	134	148	+10
85	F. M. S.	23	65	165	89	134	152	+13
86	H. W. D.	31	67	170	89	135	133	— 2
87	F. K.	22	68	173	89	135	135	0
88	F. J. D.	27	67	170	89	135	137	+ 2
89	J. M. T.	22	67	170	82	135	139	+ 3
90	M. R. D.	30	64	163	91	135	139	+ 3
91	L. S.	27	66	168	86	135	141	+ 4
92	F. J. C.	32	67	170	91	135	141	+ 4
93	W. J. M.	23	70	178	90	135	148	+10
94	H. A. U.	24	70	178	91	135	148	+10
95	F. N. B.	27	68	173	88	135	150	+11
96	B. J. S.	27	64	163	93	135	150	+11
97	E. H. W.	22	67	170	87	135	152	+13
98	R. O. G.	26	71	180	85	135	153	+13
99	J. S.	30	65	165	88	136	133	— 2
100	J. P. M.	29	67	170	93	136	144	+ 6
101	W. E. W.	28	65	165	88	136	145	+ 7
102	J. A. B.	33	67	170	90	136	149	+10
103	G. S. S.	25	68	173	89	136	152	+12
104	O. E. T.	23	69	175	90	136	152	+12
105	F. J. S.	25	69	175	86	136	153	+13
106	C. J. A.	27	68	173	90	136	156	+15
107	G. D.	28	66	168	89	136	157	+15
108	A. Z.	26	65	165	93	137	148	+ 8
109	S. J. H.	24	69	175	97	137	152	+11
110	J. B.	25	69	175	86	137	161	+18
111	F. J. F.	25	68	173	90	138	151	—12
112	S. J. H.	25	67	170	94	138	139	+ 1
113	J. R. K.	23	67	170	91	138	146	+ 6
114	J. W. B.	23	71	180	85	138	150	+ 9
115	E. S.	25	66	168	94	138	152	+10
116	W. J.	25	66	168	94	138	152	+10
117	C. F. S.	23	68	173	87	138	157	+14
118	E. R. W.	25	68	173	88	139	140	+ 1
119	J. A. A.	25	67	170	89	139	144	+ 4
120	P. H. O.	25	68	173	88	139	146	+ 5
121	J. M. C.	21	72	183	94	139	152	+ 9
122	H. H.	28	68	173	83	140	132	— 6
123	D. K. T.	18	68	173	86	140	137	— 2
124	R. E. M.	24	70	178	91	140	140	0
125	R. E. H.	21	69	175	86	140	145	+ 4
126	A. C. W.	28	70	178	87	140	142	+ 9
127	W. N. S.	26	70	178	88	140	154	+10
128	A. F. S.	26	67	170	92	140	174	+24
129	Z. F. C.	31	72	183	89	141	152	+ 8
130	G. W. K.	24	71	180	91	141	158	+12
131	J. N.	24	68	173	90	141	168	+19
132	J. A.	28	65	165	91	142	135	— 5
133	C. T.	28	71	180	91	142	142	0
134	P. K.	26	69	175	91	142	144	+ 2
135	H. E. G.	24	63	160	94	142	144	+ 2
136	L. A. M.	21	72	183	90	142	153	+ 8
137	F. R. P.	28	72	183	91	142	153	+ 8
138	M. J. R.	28	68	173	86	143	138	— 3
139	J. S.	27	67	170	90	143	142	— 1
140	W. C. S.	30	66	168	83	143	150	+ 5
141	J. J. L.	22	70	178	91	143	151	+ 6
142	A. W. H.	28	72	183	91	143	152	+ 6
143	P. F.	28	75	191	94	143	155	+ 8
144	L. A. D.	28	71	180	91	143	157	+10
145	G. H. S.	23	64	163	90	144	143	— 1
146	J. W. T.	31	69	175	98	144	144	0
147	K. R.	23	66	168	98	144	156	+ 8
148	W. H. M.	23	71	180	90	144	164	+14
149	J. C. M.	25	71	180	86	144	165	+15
150	V. V.	26	68	160	99	145	146	+ 1
151	L. D. O.	25	70	178	91	145	147	+ 1
152	C. H. F.	23	69	175	90	145	159	+10
153	J. W.	24	69	175	94	145	179	+23
154	W. G. L.	23	67	170	93	146	161	+10

TABLE 3.—OBSERVED DATA—Continued

Number	Name	Age at Nearest Birth- day, in Years	Height Without Shoes		Chest Girth at Nipple, Mean, in Cm.	Actual Weight, Stripped		
			In.	Cm.		July 1918, in Lbs.	Jan., 1919, in Lbs.	Per Cent. Gain (+) or Loss (—)
1	2	3	4	5	6	7	8	9
155	J. J. K.	26	66	168	93	147	148	+ 1
156	H. W. T.	29	71	180	91	147	157	+ 7
157	C. D. K.	24	71	180	91	147	164	+12
158	J. P. G.	29	66	168	91	148	155	+ 5
159	G. S.	23	67	170	91	148	148	0
160	W. D. L.	26	71	180	91	148	149	+ 1
161	P. J. M.	23	67	170	89	148	157	+ 6
162	M. N. K.	23	69	175	86	148	170	+15
163	G. E. K.	30	67	170	98	148	170	+15
164	J. B. R.	24	69	175	88	148	178	+20
165	R. L. P.	25	70	178	91	149	155	+ 4
166	C. W. S.	25	68	173	89	149	162	+ 9
167	W. S.	25	63	160	94	150	159	+ 6
168	J. S.	30	69	175	95	150	168	+12
169	P. S. W.	25	70	178	94	150	157	+ 5
170	D. L. H.	31	71	180	90	150	157	+ 5
171	C. J. M.	31	68	173	95	150	164	+ 9
172	J. S.	28	70	178	85	150	142	— 5
173	H. O. W.	29	67	170	95	150	169	+13
174	S. W.	28	68	173	94	151	168	+11
175	A. J. S.	26	68	173	95	151	177	+17
176	R. T.	22	62	157	92	152	155	+ 2
177	F. P. A.	29	70	178	94	152	162	+ 7
178	C. A. E.	23	70	178	89	152	165	+ 9
179	H. S. F.	29	70	178	91	152	169	+11
180	H. S.	24	68	173	97	152	169	+11
181	E. E. P.	25	70	178	93	153	165	+ 8
182	F. D. S.	25	70	178	91	153	171	+12
183	L. R.	29	66	168	97	154	170	+10
184	C. M.	22	64	163	97	155	157	+ 1
185	M. A. M.	24	74	188	88	155	159	+ 3
186	H. A. T.	25	68	173	89	155	164	+ 6
187	E. H. B.	28	71	180	90	156	157	+ 1
188	D. W. E.	24	71	180	89	156	160	+ 3
189	T. J. C.	31	64	163	95	156	166	+ 6
190	J. H. C.	31	71	180	98	156	170	+ 9
191	F. S. T.	23	69	175	89	156	171	+10
192	E. A. B.	24	69	175	93	156	176	+13
193	R. M.	28	67	170	96	158	146	— 8
194	D. E. R.	28	70	178	86	158	160	+ 1
195	J. B. M.	27	70	178	95	158	161	+ 2
196	W. B. W.	20	68	173	94	158	165	+ 4
197	J. J. K.	29	68	173	94	158	172	+ 9
198	J. B. O.	29	68	173	99	158	174	+10
199	J. C. T.	28	72	183	85	160	153	— 4
200	R. E. S.	23	68	173	95	160	155	— 3
201	O. H. W.	31	66	168	95	160	175	+ 9
202	W. M. G.	27	69	175	95	160	175	+ 9
203	W. S.	24	71	180	95	161	179	+11
204	J. D. G.	23	72	183	94	161	194	+20
205	F. E. C.	23	69	175	101	162	173	+ 7
206	A. S. S.	28	68	173	84	163	152	— 7
207	W. M. B.	27	73	185	93	163	168	+ 3
208	P. S. K.	25	68	173	96	164	170	+ 4
209	V. P. N.	26	74	188	91	164	183	+12
210	G. J. S.	28	68	173	87	165	162	—18
211	S. P. M.	26	69	175	95	166	183	+10
212	W. F. R.	25	71	180	95	167	168	+ 1
213	T. J. D.	29	69	175	91	167	170	+ 2
214	H. C. L.	27	67	170	95	168	177	+ 5
215	C. E. B.	26	67	170	94	168	179	+ 7
216	A. A. R.	24	67	170	96	169	166	— 2
217	J. K. Z.	28	72	183	101	170	186	+ 9
218	S. E. S.	23	71	180	106	171	183	+ 7
219	W. C. R.	29	70	178	102	172	168	— 2
220	M. W. H.	27	69	175	102	173	173	0
221	I. L.	31	65	165	99	174	180	+ 3
222	E. S.	22	68	173	70	175	162	— 7
223	T. J. D.	29	69	175	99	175	176	+ 1
224	A. L. A.	30	72	183	98	175	190	+ 9
225	J. C. M.	25	72	183	95	176	185	+ 5
226	W. F. S.	30	65	165	96	179	184	+ 3
227	F. J. R.	30	71	180	95	180	174	— 3
228	E. E. W.	30	71	180	93	190	185	— 3
229	L. A. T.	24	75	191	102	193	236	+22
	Average	26	67	171	90	141	150	+ 7

medicine in a broad sense are either essentially statistical problems, or their statistical phase is a vitally important one in reaching correct conclusions."

Dreyer,³⁰ and others,³¹ have also recently urged greater care as to the method of collecting and presenting facts.

Prediction Error.—When the weight of an individual is predicted by any method the value may be identical with the observed weight, but in general deviates or errs somewhat from it. This error may be either above or below the actual weight, i. e., either positive or negative in sign; and in consequence it tells us whether the predictions made by a given method are on the whole too large or too small. Since we are in this case testing methods of prediction against actual observation we have taken the differences: calculated weight less actual weight, or $PW - W = D$. This difference D is then reduced from pounds or kilograms to its percentage of the actual weight, plus or minus, i. e., above or below that actual weight; or $\frac{(PW - W) 100}{W} = \frac{100 D}{W} = \%$ prediction error = E . This percentage prediction error is our common unit on which all further discussion is based hereafter. For example, in Table 4, Bornhardt's method applied to Case 1 gives: $PW = 55.9$ kg. (123 pounds), $W = 47.7$ kg. (105 pounds), hence $D = 8.2$ kg. (18 pounds), from which by substitution in the above formula we find the prediction error is $8.2/47.7 = 17$ per cent., or $18/105 = 17$ per cent. In other words, this value E will be the same no matter whether our observed data have been recorded in metric or customary units, though ordinarily of course all one's data are recorded in the same unit. The error for each individual has been calculated only to the nearest integral, while the average error for each standard is given to about 1 per cent.

The reasons for this percentile manner of expression are:

1. When comparing the varying errors obtained by applying the same formula to the 229 different subjects, percentage errors are always comparable, whereas kilogram or pound errors are often not comparable owing to the subjects' varying weights.
2. When comparing the average of these 229 errors by one formula with the average of the errors by a second formula on the same 229 cases, percentage errors are always comparable, whereas kilogram or pound errors are often not comparable because the two formulas are expressed in different units: one metric, the second English.

30. Dreyer, G., and Walker, E. W. A.: *Iatro-mathematics*, in *Contributions to Medical and Biological Research*, Dedicated to Sir William Osler, New York, 1:40, 1919.

31. Editorial, J. A. M. A. **73**:1531 (Nov. 15) 1919; also, Kilgore, E. S.: J. A. M. A. **75**:86 (July 10) 1920.

3. Furthermore, as will be clearer further on, the expression of the errors as percentages automatically determines limits of the class intervals convenient for tabulating the frequency of each of the different sized errors, for reckoning the average of the 229 errors, or their standard-deviation, or their coefficient of variation.

Analysis of the error, to determine the relative precision of prediction by different methods, is carried out by the application of the following criteria or constants:

1. The frequency distribution of error.
2. The average error with regard to sign, i. e., the algebraic mean.
3. The average error without regard to sign, i. e., the arithmetical mean.
4. The standard error, i. e., the square root of the sum of the squares of the errors.
5. The range between the maximum error and the minimum error.
6. The standard deviation of the average error, i. e., the square root of the sum of the squares of the deviations of each of the 229 errors from the average error.
7. The coefficient of variation.

The next step is to summarize the errors in the predictions by each method, as given in Table 4, into a frequency-distribution table, Table 5, in conformity with the dictum: "In all cases of published work the figures of the frequency-distribution should be given; they are absolutely fundamental."³²

Calculation of the Mean Error.—Method I (Yule³²): From frequency distribution Table 5.

Let A = an arbitrary value or guess at approximate mean.

Let M = true mean.

Let d = difference between approximate and the true mean = M-A = Sum f. z/N.

Then by substitution of figures from Table 5.

$$d = \frac{\text{Sum (f.z)}}{N} = \frac{+453-452}{229} = \frac{+1}{229} = 0.0044 \text{ class-intervals.}$$

Now in making the frequency Table 5, each class-interval was taken as = 1 per cent. error.

$$\therefore d = 0.0044 \text{ per cent.}$$

$$M = A + d = 6 + 0.0044 = 6.0044 \text{ per cent.}$$

Method II (Harris and Benedict): From basal Table 3.

$$M = \frac{\text{Sum E}}{N} = \frac{1374}{229} = 6.00 \text{ per cent.}$$

32. Yule, G. U.: *Introduction to the Theory of Statistics*, Ed. 5, London, 1919, pp. 79, 112, 133, 141, 144, 153.

TABLE 4.—METHOD OF COMPUTING PREDICTION ERROR; WITH EXAMPLES FROM THE APPLICATION OF BORNHARDT'S STANDARD TO THE SERIES OF 229 MALES

	Case Number	Prediction (Standard: Bornhardt's Formula)			
		Predicted Weight	Difference of Predicted Weight from Actual Weight, Too High (+) Too Low (—)	Percentile Prediction Error, Prediction Error, or Simply Error	Error Squared
		PW	$PW - W = D$	$\frac{D}{W} = E$	E^2
		Kg. or Lbs.	Kg. or Lbs.	Per Cent. of Actual Weight W	
	1	55.9	+ 8.2	+17	289
	2	127	+20	+19	361
	229	179	—14	— 7	49
Arithmetic sum.....				1,374	14,283
Mean error.....				6.0%	62.37
Root-mean-square error..					7.89%
Range of error.....			0 to +20 and —64 lbs.	0 to +19 and —36%	0 to 1,296
Standard deviation.....				5.14%	

TABLE 5.—SUMMARY OF PREDICTION ERRORS IN COLUMN E OF ORIGINAL TABLE 4, TO SHOW FREQUENCY-DISTRIBUTION, AVERAGE ERROR AND STANDARD-DEVIATION. STANDARD: BORNHARDT'S. SERIES: 229 SOLDIERS

1	2	3	4	5	6
Percentage Prediction Error	Frequency	Deviation from Arbitrary Value A	Product Column 2 × Column 3	Deviation Squared	Product Column 2 × Column 5
E	f	z	f.z	z ²	f.z ²
0	9	— 6	— 54	36	324
1	33	— 5	—165	25	825
2	27	— 4	—108	16	432
3	25	— 3	— 75	9	225
4	16	— 2	— 32	4	64
5	18	— 1	— 18	1	18
6	24	0	— — — — — 452		
7	8	1	8	1	8
8	11	2	22	4	44
9	5	3	15	9	45
10	7	4	28	16	112
11	12	5	60	25	300
12	7	6	42	36	252
13	6	7	42	49	294
14	4	8	32	64	256
15	5	9	45	81	405
16	1	10	10	100	100
17	4	11	44	121	484
18	3	12	36	144	432
19	3	13	39	169	507
36	1	30	30	900	900
			— — — — — +453		
Sum.....	229		+1	...	6,027
Mean.....	...		+0.0044	...	26.3

Calculation of the Standard Deviation.

Method I (Yule): From the frequency distribution Table 5.

$$\begin{aligned}
 \text{S. D.} &= \sqrt{\frac{\text{Sum } f \cdot z^2}{N} - d^2} \\
 &= \sqrt{\frac{6027}{229} - (0.0044)^2} \\
 &= \sqrt{26.3 - 0.000019} \\
 &= \sqrt{26.299981} \\
 &= \sqrt{26.3} \\
 &= 5.13\%
 \end{aligned}$$

Method II (Harris and Benedict²⁸): From Tables 3 and 4.

$$\begin{aligned}
 \text{S. D.} &= \sqrt{\frac{\text{Sum } E^2}{N} - \left[\frac{\text{Sum } E}{N} \right]^2} \\
 &= \sqrt{\frac{\text{Sum } E^2}{N} - (M)^2} \\
 &= \sqrt{\frac{14283}{229} - (6.00)^2} \\
 &= \sqrt{62.37 - 36.00} \\
 &= \sqrt{26.37} \\
 &= 5.14\%
 \end{aligned}$$

Average Error with Regard to Sign, Algebraic Mean.—When a given prediction method gives results which are on the average too high, the mean error with regard to sign will have the positive sign.⁸ When it is too low, it will have the negative sign. Dividing the sum of the errors with regard to sign by the total number of individuals in the series in hand we have a measure of the average error in the direction of too high or too low prediction. This value is given in Tables 7, 8, 9. It is liable to give a factitious appearance of accuracy because the plus and minus errors tend to cancel, and the algebraic mean is therefore only mentioned in passing, while great attention is given to the arithmetic mean discussed below. Before passing to that however, another measure of the direction of the error may be presented in Table 6.

TABLE 6.—PREDICTION ERROR TOO HIGH OR TOO LOW

	Number of Times				Percentage of Times			
	Too Low	Too High	Correct	Total	Too Low	Too High	Correct	Total
Bornhardt's.....	89	131	9	229	39	57	4	100
Army.....	82	111	9	202	41	55	4	100
Medico-Actuarial..	79	144	5	228	35	63	2	100
Guthrie's.....	46	175	8	229	20	76	4	100
Broca's.....	27	201	1	229	12	87	1	100
von Noorden's.....	4	223	2	229	2	97	1	100

Average Error Without Regard to Sign, Arithmetic Mean.—But the question, however, as to whether a given prediction method yields on the whole too high or too low values is not the only one to be answered. One wishes to know the extent of errors, either above or below the actual weight, in the case of each of the methods used. This

extent may be reckoned (1) by ignoring the signs and simply regarding a difference between observed and predicted body weight as an error of a given magnitude in kilograms, or better as an error of the equivalent percentage of the actual weight; then dividing the sum of these errors by the number of individuals in the series, the formula is: $\text{Sum } E/N = M$. Another method (2) for obtaining the mean, useful as a confirmation of the above briefer method, is seen in Table 5.

This mean error sometimes proves identical for two methods under comparison, so that further analysis by other constants is necessary. Furthermore, these other constants may be of service even in cases where they are not made absolutely necessary by similarity of means. For the arithmetical mean has two disadvantages.⁸ First, it does violence to sound mathematical usage with regard to signs. Second, it gives errors importance only proportional to their magnitudes, while one may consider, in a comparative test like the present, that very great errors should be given proportionally more weight than very slight deviations. Both of these drawbacks may be avoided by figuring the standard error.

Standard Error, or Root-Mean-Square Error.—In this paper this term is used in another sense than that usual among statisticians. Here, the above mentioned magnitudes of the deviations or of the percent errors may be logically weighted and the transgression against the law of signs avoided by squaring the errors, summing the squares, obtaining their mean and extracting its squares.

Range.—The error made by Bornhardt's or any other method is of course variable, and for this variation, technically called dispersion, "the simplest possible measure . . . is the actual *range*, i. e., the difference between the greatest and least values observed. While this is frequently quoted, it is as a rule the worst of all possible measures for any serious purpose."³² A better measure is the standard deviation, and better still, the coefficient of variation.

Standard Deviation.—Yule³² states that "The standard deviation should always be used as the measure of dispersion, unless there is some very definite reason for preferring another measure, just as the arithmetic mean should be used as the measure of position." The standard deviation is the square root of the average of the squares of all deviations as measured from the arithmetic mean of the observations; and therefore is called the root-mean-square deviation from the mean. To square all the deviations may seem artificial, but such root-mean-square quantities frequently occur in other branches of science. The computation may be made either from the frequency Table 5, modeled on Yule, or from the briefer formula of Harris applied to figures in Table 4.^{8, 33}

33. Harris, J. A.: *Am. Naturalist* **44**:693, 1910.

Coefficient of Variation.—Standard deviations are not comparable when the respective means are of different size, hence the need of translating the former from absolute to percentage values, thus securing the coefficients of variation. The formula is $100 \text{ S.D./M.} = \text{C. V.}$

DATA COMPUTED AND ANALYZED

Error in Relation to the Six Standards.—Our findings are summarized for the first series in Table 7, for the second or present group in Table 8, and for the two groups consolidated in Table 9. In each table note the lower values across the first row, as compared with successive rows down the page.

TABLE 7.—ERROR IN RELATION TO STANDARDS. SUMMARY OF PREDICTION ERRORS
COMPUTED FROM ORIGINAL OF TABLE 4. STANDARDS: ALL SIX.
SERIES: TWENTY MALES

Rank in Order of Accu- racy	Standards Compared	Num- ber of Sub- jects	Average or Mean Error		Root-Mean- Square Error or Standard Error	Standard- Deviation of Mean Error	Coeffi- cient of Variation of Mean Error
			Sum E				
			N				
			Algebraic Mean	Arithmetic Mean			
			Average With Regard to Sign	Average Without Regard to Sign	$\sqrt{\frac{\text{Sum } (E^2)}{N}}$	$\sqrt{\frac{\text{Sum } (E^2)}{N} - M^2}$	100 SD M
		N	A	M	S.E.	S.D.	C.V.
1	2	3	4	5	6	7	8
1	Bornhardt's.....	20	— 2.7	5.6 ± 0.542	6.6	3.6	64.3
2	Army.....	18	+ 2.6	7.3 ± 1.03	9.8	6.5	89.0
3	Medico-Actua- rial.....	20	+ 3.1	7.4 ± 0.77	8.9	5.1	68.9
4	Guthrie's.....	20	+ 8.8	9.5 ± 1.22	12.5	8.1	85.3
5	Broca's.....	20	+13.1	13.1 ± 1.37	15.9	9.1	69.5
6	v. Noorden's....	20	+19.8	19.9 ± 1.84	23.4	12.2	61.3

TABLE 8.—ERROR IN RELATION TO STANDARDS. STANDARDS: ALL SIX.
SERIES: 229 SOLDIERS

Rank in Order of Merit	Standards Compared	Number of Cases	Average or Mean Error		Stand- ard Error	Stand- ard Deviation	Coeffi- cient of Variation
			N	A			
1	Bornhardt's.....	229		+ 1.4	6.0 ± 0.228	7.9	5.1
2	Army.....	202		+ 2.0	8.4 ± 0.318	10.7	6.7
3	Medico-Actuarial.....	228		+ 3.5	8.7 ± 0.291	10.9	6.5
4	Guthrie's.....	229		+ 8.7	11.7 ± 0.374	14.4	8.4
5	Broca's.....	229		+13.0	14.7 ± 0.418	17.4	9.4
6	v. Noorden's.....	229		+23.6	23.7 ± 0.504	26.3	11.3

Error in Relation to Age.—The question may be raised, do prediction errors vary proportionately with age, actual weight, height, or chest-girth (either directly, inversely, or at the extremes from the average)? The age ranged from 18 to 34 years, with an average of

25.9 years. The mode, i. e., the most frequent or typical age, was 23 years. Eighty-six per cent. of the men were in their twenties. Ninety per cent. were 23 or over, "the age when the average man has attained his full stature and bulk," according to Quetelet,⁶ Dawson, Aitkin and Beddoe.²¹ It should be remembered that this age is taken from the nearest, not the last, birthday. The frequency distribution shows that the error is least at the average age, i. e., 26, runs high at isolated ages, but does not tend to be greater over the younger or indeed over any significant period. The errors for the extreme age groups are bracketed, as being unreliable, owing to the small number of cases in each of those classes (Table 10).

TABLE 9.—ERROR IN RELATION TO STANDARDS.
SERIES: 20 + 229 = 249 MALES

Rank in Order of Merit	Standards Compared	Number of Subjects	Average or Mean Error		Standard Error	Standard Deviation	Coefficient of Variation
			A	M			
1	Bornhardt's.....	249	+ 1.1	6.0 ± 0.213	7.8	5.0	83.3
2	Army.....	220	+ 2.0	8.3 ± 0.304	10.7	6.7	80.7
3	Medico-Actuarial.....	248	+ 3.5	8.6 ± 0.274	10.7	6.4	74.4
4	Guthrie's.....	249	+ 8.7	11.5 ± 0.358	14.3	8.4	73.0
5	Broca's.....	249	+13.0	14.6 ± 0.396	17.3	9.3	63.7
6	v. Noorden's.....	249	+23.2	23.4 ± 0.485	26.0	11.4	48.7

TABLE 10.—DISTRIBUTION OF ERROR ACCORDING TO AGE
STANDARD: BORNHARDT'S. SERIES: 229 MALES

	Nearest Age																	Sum
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
Class-frequencies, i. e., number of cases in each class.....	1	1	1	5	15	38	23	31	19	20	30	15	12	12	2	3	1	229
Average error at each age.....	(2	11	5	6)	9	5	5	6	4	6	7	5	9	7	(6	5	11)	

Error in Relation to Actual Weight.—The weight varied from 47.6-87.5 kg. (105-193 lbs.), with a mean of 64.1 kg. (141 lbs.), and a mode of 61.2 kg. (135 lbs.). The frequency distribution is summarized in Table 11. In choosing the magnitude of the class-interval, the frequency distribution unit of 1 pound each would have given 88 classes which would have been unwieldy and would have included too few figures in each class; units of one kilogram each with 40 classes, would have the same drawbacks; 2 kilogram intervals would have given the very desirable number of classes,³² but would still have had a rather small number of cases in each. The size chosen also has the advantage of keeping both kilos and pounds as integers. Even with only eight classes the last covers only two cases, and must be ignored in the inter-

pretation. The error is seen to be least for the groups including the central weights, as would be expected, and to increase toward the extremes.

Error in Relation to Height.—The stature in bare feet averaged 171 cm. (67 inches), ranging from 147-191 cm. (58-75 inches). No correlation is seen in Table 12.

TABLE 11.—DISTRIBUTION OF ERROR ACCORDING TO WEIGHT *
STANDARD: BORNHARDT'S. SERIES: 229 MALES

Weight.....	{ Kg. Lbs.	48 and under 53 106 up	53— 117—	58— 128—	63— 139—	68— 150—	73— 161—	78— 172—	83— 183—	47.6-87.5 105-193
Number of cases.....		13	31	73	49	36	16	9	2	229
Average error for each weight class.....		12	9	5	4	5	7	13	(13)	

* Each class-interval = 5 kg. = 11 lbs.

TABLE 12.—DISTRIBUTION OF ERROR ACCORDING TO HEIGHT *
STANDARD: BORNHARDT'S. SERIES: 229 MALES

Height....	{ Cm. In.	147 and under 152 58 up	152— 60—	157— 62—	162— 64—	167— 66—	172— 68—	177— 70—	182— 72—	187— 74—	147-191 58-75
No. of cases.....		1	2	19	33	51	65	43	11	4	229
Average error for each class..		(2)	11)	5	8	5	6	5	6	(7)	

* Each class interval = 5 cm. = 2 inches.

TABLE 13.—DISTRIBUTION OF ERROR ACCORDING TO CHEST-GIRTH *
STANDARD: BORNHARDT'S. SERIES: 229 SOLDIERS

Chest girth	{ In.	70 28	{ 79 and under 81.5 31 up	81.5—	84—	86.5—	89—	91.5—	94—	96.5—	99—	101.5—	104—	70-106		
				32—	33—	34—	35—	36—	37—	38—	39—	40—	41—	28-42		
No. of cases.....				1	4	9	40	29	79	15	33	9	6	3	1	229
Average error for each class..				36	3	8	6	5	6	7	6	5	4	5	2	

* Class interval = 2.5 cm. = 1 inch.

Error in Relation to Chest-Girth.—The perimeter of the thorax, at the level of the mammillae, midway between inspiration and expiration, varied from 70 to 106 cm. (from 28 to 42 inches) with an average of 90 cm. (35 inches). No correlation is evident (Table 13).

CONCLUSIONS

The normal weight for an American man may be predicted somewhat more accurately by Bornhardt's formula than by the Army and Navy table, the Medico-Actuarial, Guthrie's, Broca's, or Von Noorden's standard. This was true for a series of 249 native-born men, aged 18 to 34 years, inclusive. Whether it would also hold true for other men, for women and for children, we cannot state. Bornhardt's standard did not vary in accuracy at varying ages, weights, heights and chest-girths. Though other writers have urged the value of routinely recording the chest perimeter as well as height, nobody has incorporated it into a formula as simple as Bornhardt's. And, just as his rule (based on height and chest-girth) as a rough measure of surface seems both theoretically and empirically the best guide so far offered for guessing weight, so we expect that experiment would discover an even better rule (based on height, chest and a third factor) expressing a rough measure of volume. For fundamentally weight must be proportional, not to length nor surface, but to cubic mass.

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