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Prediction of lean body mass from height and weight

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SYNOPSIS Lean body mass, calculated from the measurement of total body water using antipyrine space, was estimated in 29 males and 27 females. It was found that the lean body mass could be predicted from the height and weight, and formulae for both males and females have been produced with multiple correlation coefficients (r) of 0·96 and 0·83 respectively.

In 1956 Allen, Peng, Chen, Huang, Chang, and Fang showed that the circulating total blood volume was closely related to a combination of body weight and cube of height. In 1962 Nadler, Hidalgo, and Bloch improved on this formula by adding a computer correction factor. Since the red cell volume is directly related to the lean body mass or fat-free body weight (Muldowney, 1957), and since the red cell volume derived from the height-cubed body weight formula of Nadler, Hidalgo, and Bloch correlates closely with the red cell volume derived from the lean body mass relationship (Hume and Goldberg, 1964), it seemed likely that the lean body mass could be predicted from height and weight. In 1965, Steinkamp, Cohen, Goffey, McKey, Bron, Siri, Sargent, and Isaacs showed from an extensive study of the problem that fat weight could be accurately predicted from body parameters other than height and weight. This paper presents evidence which confirms the practicability of predicting lean body mass from height and weight.

METHODS

CLINICAL CASES Fifty-six subjects were studied (29 males and 27 females). They comprised four main clinical groups: those with no apparent disorder, those suffering from polycythaemia vera, those with chronic bronchitis, and those suffering from obesity (Table I). Many of the subjects had formed part of a previous study on the polycythaemic states (Hume and Goldberg, 1964). None had clinical evidence of fluid retention or malnutrition, conditions known to influence the relationship between total body weight and total body water. The ages of the males ranged from 40 years to 77 years with a mean of 61 years. The ages of the females ranged from 37 years to 80 years with a mean of 60·0 years.

TABLE I

GENERAL DESCRIPTION OF SUBJECTS STUDIED

Group	*Males*		*Females*	
	No. of Subjects	*Mean Age (yr.)*	*No. of Subjects*	*Mean Age (yr.)*
Normal	8	61	11	63
Chronic bronchitis	9	62	2	49
Polycythaemia vera	9	59	8	64
Obesity	3	67	6	53
Total	29	61·0	27	60·0

HEIGHT AND WEIGHT (Tables II and III) The standing height in centimetres was measured without shoes.

TABLE II

RESULTS IN MALES

Case No.	*Age (yr.)*	*Height (cm.)*	*Total Body Weight (kg.)*	*Lean Body Mass[1] (kg.)*
1	50	182·9	82·4	59·8
2	55	176·5	66·3	56·8
3	77	167·6	66·0	52·5
4	54	162·6	59·9	43·0
5	77	173·0	75·1	53·6
6	54	172·7	73·1	53·7
7	58	168·3	58·3	48·3
8	69	171·5	81·9	55·0
9	76	168·9	113·5	63·0
10	65	173·4	132·8	72·5
11	61	167·6	107·1	60·0
12	40	178·4	81·0	53·0
13	56	172·7	87·6	58·4
14	49	177·8	68·3	50·0
15	63	160·0	77·1	52·0
16	73	163·8	75·1	56·0
17	59	151·1	63·1	43·0
18	68	162·6	80·0	52·0
19	64	163·8	83·0	52·0
20	42	168·9	60·8	50·4
21	57	177·8	70·9	56·0
22	70	157·5	56·3	39·1
23	46	187·9	75·6	54·8
24	72	167·6	77·4	49·3
25	69	171·5	75·0	48·5
26	66	188·0	80·5	66·8
27	54	175·3	80·0	56·7
28	57	157·5	45·4	41·0
29	69	152·4	42·9	36·0

[1]Lean body mass derived from measurement of total body water

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TABLE III

RESULTS IN FEMALES

Case No.	Age (yr.)	Height (cm.)	Total Body Weight (kg.)	Lean Body Mass[1] (kg.)
1	48	160·0	64·4	37·0
2	56	139·7	54·0	32·2
3	65	161·3	63·1	48·2
4	58	160·0	67·2	39·5
5	80	152·4	48·6	43·9
6	69	152·4	59·4	41·9
7	70	152·4	67·2	31·3
8	66	160·0	56·7	28·4
9	69	152·4	69·4	41·8
10	55	156·2	59·0	34·0
11	59	160·0	81·2	46·8
12	37	158·8	115·5	59·3
13	62	157·5	106·2	55·3
14	55	152·4	97·6	50·9
15	52	154·9	92·6	43·4
16	52	155·6	97·6	54·8
17	51	144·8	45·8	38·0
18	54	172·8	83·0	51·0
19	62	160·0	48·3	38·2
20	67	151·0	47·0	31·0
21	65	160·0	63·5	47·0
22	71	147·3	56·3	35·2
23	64	154·9	65·8	44·6
24	69	157·5	52·2	34·8
25	60	182·9	69·9	62·5
26	48	162·6	71·4	41·6
27	57	139·7	44·7	29·1

[1]Lean body mass derived from measurement of total body water

Patients with a spinal deformity were excluded. The total body weight in kilograms was estimated after outdoor clothes only had been removed in order to make the procedure readily applicable to out-patients.

LEAN BODY MASS (Tables II and III) Antipyrine space was measured by the method described by Muldowney (1957). 'Lean body mass' was calculated from the antipyrine space by the equation of Pace and Rathbun (1945).

RESULTS

MALES (29) The linear regression of lean body mass (L.B.M.) in kg. on weight (W) in kg. and on height (H) in cm. is:—

$$\text{L.B.M.} = 0{\cdot}32810\ W + 0{\cdot}33929\ H - 29{\cdot}5336 \quad \text{(equation 1)}$$

The correlation coefficient (r) between H and W was 0·3744 and between H and L.B.M. was 0·6719 and between W and L.B.M. was 0·8840, yielding a multiple correlation coefficient (r) between L.B.M. and H and W of 0·957. The standard deviation of deviations from regression is 2·307 kg.

Using $(H)^3$ instead of H gave the following linear regression:—

$$\text{L.B.M.} = 0{\cdot}33103\ W + 0{\cdot}0000039726\ (H)^3 \quad \text{(equation 2)}$$

which gave the following coefficients: $(H)^3$ and W, r = 0·3477, $(H)^3$ and L.B.M., r = 0·6660, W and L.B.M., r = 0·8840. The first two correlations in equation 2 are slightly inferior to the correlations of equation 1 and therefore for the range of heights, weights, and lean body masses in the present study equation 1 is the more suitable.

FEMALES (27) The linear regression of L.B.M. (kg.) on weight (W) in kg. and on height (H) in cm. is:—

$$\text{L.B.M.} = 0{\cdot}29569\ W + 0{\cdot}41813\ H - 43{\cdot}2933 \quad \text{(equation 1)}$$

The correlation coefficients (r) between H and W was 0·3098 and between H and L.B.M. was 0·5877 and between W and L.B.M. was 0·7390, yielding a multiple correlation coefficient r between L.B.M. and H and W of 0·8298. The standard deviation of deviations from regression is 5·372 kg.

Using $(H)^3$ instead of H gave the following linear regression:—

$$\text{L.B.M.} = 0{\cdot}29873\ W + 0{\cdot}0000056477\ (H)^3 + 0{\cdot}08 \quad \text{(equation 2)}$$

which gave the following coefficients: $(H)^3$ and W, r = 0·2815 and $(H)^3$ and L.B.M., r = 0·5886. As with the males, equation 2, using height cubed, has no advantage over equation 1.

DISCUSSION

Analysis shows that the lean body mass or fat-free body weight obtained by measuring total body water bears a close correlation with height and weight in both males (r = 0·96) and females (r = 0·83). Since the cube of height makes a greater contribution than height alone to the prediction of total blood volume (Allen *et al.*, 1956; Nadler *et al.*, 1962) and since red cell volume is clearly related to lean body mass (Muldowney, 1957), it is of interest that analysis failed to show any advantage in using height cubed in the prediction of lean body mass.

Tables for easy calculation of the lean body mass from height and weight are produced (Tables IV and V). The standard deviation of deviations from regression for the males is 2·3 kg. which is an acceptable margin of error in making a prediction of lean body mass. In female subjects, the standard deviation of deviations from regression of 5·4 kg. may be a little large for individual prediction but it is satisfactory when comparing groups of individuals. Moore, Olesen, McMurray, Parker, Ball, and Boyden (1963) have shown that the total body water contributed less to the total body weight of men over the age of 60 than to those between 16 and 60 years of age. Although a number of the men studied were over the age of 60 years there seems no benefit in introducing another variable in the analysis since the correlation of lean body mass to height and weight is so close to unity (r = 0·96). Therefore the formula is applicable to males over the age of 16 years. Moore *et al.* have also shown that in females over 30 age has no

TABLE IV

TABLE OF PREDICTED LEAN BODY MASS IN MEN

Weight (kg.)	*Height (cm.)*							
	150	*155*	*160*	*165*	*170*	*175*	*180*	*185*
45	36·12	37·82	39·52	41·21	42·91	44·61	46·30	48·00
50	37·76	39·46	41·16	42·85	44·55	46·25	47·94	49·64
55	39·40	41·10	42·80	44·49	46·19	47·89	49·58	51·28
60	41·05	42·75	44·45	46·14	47·84	49·54	51·23	52·93
65	42·69	44·39	46·09	47·78	49·48	51·18	52·87	54·57
70	44·33	46·03	47·73	49·42	51·12	52·82	54·51	56·21
75	45·97	47·67	49·37	51·06	52·76	54·46	56·15	57·85
80	47·61	49·31	51·01	52·70	54·40	56·10	57·79	59·49
85	49·25	50·95	52·65	54·34	56·04	57·74	59·43	61·13
90	50·89	52·59	54·29	55·98	57·68	59·38	61·07	62·77
95	52·53	54·23	55·93	57·62	59·32	61·02	62·71	64·41
100	54·17	56·17	57·57	59·26	60·96	62·66	64·35	66·05
105	55·81	57·81	59·21	60·90	62·60	64·30	65·99	67·69
110	57·45	59·45	60·85	62·54	64·24	65·94	67·63	69·33
115	59·09	61·09	62·49	64·18	65·88	67·58	69·27	70·97
120	60·73	62·73	64·13	65·82	67·52	69·22	70·91	72·61
125	62·37	64·37	65·77	67·46	69·16	70·86	72·55	74·25
130	64·01	66·01	67·41	69·10	70·80	72·50	74·19	75·89
135	65·65	67·65	69·05	70·74	72·44	74·14	75·83	77·53
140	67·29	69·29	70·69	72·38	74·08	75·78	77·47	79·17

(L.B.M. = 0·32810 W + 0·33929 H − 29·5336)

TABLE V

TABLE OF PREDICTED LEAN BODY MASS IN WOMEN

Weight (kg.)	*Height (cm.)*							
	145	*150*	*155*	*160*	*165*	*170*	*175*	*180*
35	27·69	29·78	31·87	33·96	36·05	38·14	40·23	42·32
40	29·17	31·26	33·35	35·44	37·53	39·62	41·71	43·80
45	30·65	32·74	34·83	36·92	39·01	41·10	43·19	45·28
50	32·12	34·21	36·30	38·39	40·48	42·57	44·66	46·75
55	33·60	35·69	37·78	39·87	41·96	44·05	46·14	48·23
60	35·08	37·17	39·26	41·35	43·44	45·53	47·62	49·71
65	36·56	38·65	40·74	42·83	44·92	47·01	49·10	51·19
70	38·04	40·13	42·22	44·31	46·40	48·49	50·58	52·67
75	39·52	41·61	43·70	45·79	47·88	49·97	52·06	54·15
80	41·00	43·09	45·18	47·27	49·36	51·45	53·54	55·63
85	42·47	44·56	46·65	48·74	50·83	52·92	55·01	57·10
90	43·95	46·04	48·13	50·22	52·31	54·40	56·49	58·58
95	45·43	47·52	49·61	51·70	53·79	55·88	57·97	60·06
100	46·91	49·00	51·09	53·18	55·27	57·36	59·45	61·54
105	48·39	50·48	52·57	54·66	56·75	58·84	60·93	63·02
110	49·87	51·96	54·05	56·14	58·23	60·32	62·41	64·50
115	51·34	53·43	55·52	57·61	59·70	61·79	63·88	65·97
120	52·82	54·91	57·00	59·09	61·18	63·27	65·36	67·45
125	54·30	56·39	58·48	60·57	62·66	64·75	66·84	68·93
130	55·78	57·87	59·96	62·05	64·14	66·23	68·32	70·41

(L.B.M. = 0·29569 W + 0·41813 H − 43·2933)

effect in relation to total body water although it does have in those below 30. Since the youngest woman studied in this series was 37, it is suggested that the formula is probably only applicable to those over the age of 30 years.

Although many of the subjects studied were selected because of particular clinical problems (Table I), nevertheless they were unselected with regard to height and, with the exception of nine obese patients, to weight. They may therefore in all probability be regarded as a random sample of a hospital population and it is suggested that the formulae are applicable to hospital patients. It is recognized that this recommendation is contrary to the opinion of Edwards and Whyte (1962), who concluded from their own observations and after reviewing the literature, that there was no method for estimating at all accurately the fat mass (calculated from total body water) from simple accessible bodily measurements. But, in the construction of their formulae, they failed to differentiate between the sexes. This may well have been important since not only is age a factor but total body water related to body weight is different between the sexes (Moore *et al.*, 1963).

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REFERENCES

Allen, T. H., Peng, M. T., Chen, K. P., Huang, T. F., Chang, C., and Fang, H. S. (1956). *Metabolism*, **5**, 328.
Edwards, K. D. G., and Whyte, H. M. (1962). *Clin. Sci.*, **22**, 347.
Hume, R., and Goldberg, A. (1964). *Ibid.*, **26**, 499.
Moore, F. D., Olesen, K. H., McMurray, J. D., Parker, H. V., Ball, M. R., and Boyden, C. M. (1963). *The Body Cell Mass and Its Supporting Environment*. Saunders, Philadelphia, London.
Muldowney, F. P. (1957). *Clin. Sci.*, **16**, 163.
Nadler, S. B., Hidalgo, J. U., and Bloch, T. (1962). *Surgery*, **51**, 224.
Pace, N., and Rathbun, E. H. (1945). *J. biol. Chem.*, **158**, 685.
Steinkamp, R. C., Cohen, N. L., Goffey, W. R., McKey, T., Bron, G., Siri, W. E., Sargent, T. W., and Isaacs, E. (1965). *J. chron. Dis.*, **18**, 1291.