THE BASAL METABOLISM IN OBESITY *

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A year ago I reported some observations of the gaseous metabolism in four cases of obesity and one of acromegaly.¹ At present I wish to discuss the findings in these cases somewhat further, and at the same time to report observations on eight new cases.²

The object in view has been to determine whether any gross disturbances in the metabolism as shown by the basal gas exchange occur in obesity.

The method has been described in the previous paper and consists, briefly, in the determination of the gas exchange in the *nüchtern* subject, lying prone, in a moderately warm room, and the calculation of the heat production by indirect calorimetry from the oxygen absorption and the calorific value of oxygen for the respiratory quotient obtained.³

In judging of the normality of any given metabolism the body surface is unquestionably a better criterion than the body weight. This has been discussed in previous papers.^{1, 4}

It was also pointed out that the DuBois linear formula⁵ is far more accurate than Meeh's, particularly when one is dealing with obese subjects. Consequently in the present research, as well as in

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1. Means, J. H.: Studies of the Basal Metabolism in Obesity and Pituitary Disease, Jour. Med. Research, 1915, xxvii, 121.

2. I shall take this opportunity to correct three errors in the previous paper. In the first place Mrs. McK.'s height was incorrectly given. It should have been 144.5 cm. In Table 5, page 133, a cipher should be added to the figures for alveolar ventilation. Lastly, an error was made in measuring N. K. This was called to my attention by Dr. DuBois. The subject was not available so I could not remeasure him, but I have calculated his probable area as shown in Table 2 of the present paper. This correction lowers the figure for his metabolism from 43.1 to 36.4 calories per square meter and hour.

3. When the respiratory quotient was below 0.70 the calorific value for 0.70 was used.

4. Means, J. H.: Basal Metabolism and Body Surface, Jour. Biol. Chem., 1915, xxi, 263. In the latter paper, Dr. F. G. Benedict has kindly called my attention to a slight error. The surface area of P. H. P. (page 264, Table 1), by Meeh's formula, should be 2.230 instead of 2.179 square meters.

5. DuBois, D., and E. F.: Measurement of the Surface Area of Man, THE ARCHIVES INT. MED., 1915, xv, 868.

the former, the area of all the subjects has been determined by the linear formula.⁶

In the following tables the metabolism is given both as per kilogram of body weight and as per square meter of body surface.

In order to get a rough idea of the degree of obesity of the various subjects, I have estimated the proper weight for their height from some insurance tables and expressed their excess weight as a percentage. Thus a patient weighing twice as much as he should is considered 100 per cent. overweight.

In my first paper the metabolism was compared with an average figure of 34.7 calories per square meter and hour, which was based on a large series from the literature in which the Meeh formula was used for surface area. At that time I knew that in obese subjects the Meeh formula gave a higher figure than the linear, but did not appreciate that this was likewise true, though to a lesser extent, in persons of normal build. It would have been more accurate had I used as a standard 38.8 calories per square meter and hour, which is the figure I subsequently obtained in a series of normal men and women when using the linear formula.⁴ Even this figure is not entirely satisfactory for it does not take into account changes due to age and sex. In a recent paper DuBois⁷ has discussed the basal metabolism at various ages, and has plotted a curve of the same, based on a large series of cases of his own and from the literature, the areas being determined by Meeh's formula. This curve shows the metabolism to be highest between the ages of 3 and 6 years, after that to fall fairly rapidly up to 18 or 20, and then to fall slowly through the remaining decades. As my cases of obesity vary considerably in age it will obviously be unfair to compare them all with the same normal figure. In regard to sex also, Benedict⁸ has shown that the metabolism of normal men is somewhat higher than that of women of the same height and weight. Bearing the sex and age difference in mind, and starting with my average of 39.6 for normal men between 20 and 30 years of age, I

6. In measuring obese subjects the results obtained by the linear formula are undoubtedly less accurate than in persons of normal build. On Feb. 9, 1916, Dr. F. G. Benedict and I both measured Mrs. McK. Dr. Benedict's measurements gave an area of 2.37 square meters; mine, 2.12 square meters. She weighed at that time 99 kg. The difficulty lies in making the same amount of traction in taking the circumferences, and in locating some of the bony landmarks. Nevertheless the linear formula is more accurate than any other method available, except the actual measurement of casts or molds of the body.

7. DuBois, E. F.: *The Respiration Calorimeter in Clinical Medicine*, Harvey Lecture, Nov. 27, 1915.

8. Benedict and Emmes: *Comparison of the Metabolism of Normal Men and Women*, *Jour. Biol. Chem.*, 1915, xx, 253.

have adopted the following standards with which to compare the metabolism of my fat subjects.

Age, Years	Male	Female
13	46	....
15	43.5	....
20-30	39.0	37.0
30-40	38.0	36.0
40-50	36.0	34.0
50-60	35.0	33.0

These standards while to a certain extent arbitrary, are, I believe, fairly near the real average. In choosing them I used DuBois' age

TABLE 1.—METABOLISM DATA—

Subject	Date	Age	Weight. Kg.	Height, Cm.	Surface Area Square Meters (Linear Formula)	Per- centage "Over- weight"	CO ₂ per Minute, c.c.*	O ₂ per Minute, c.c.*
Mrs. L. L.	8/ 4/15	36	145.3	163.5	2.79	105	227	324
	10/ 6/15	..	144.5	.....	2.78†	...	230	343
	10/11/15	..	141.5	.....	2.75†	...	226	326
	10/16/15	..	139.0	.....	2.73†	...	219	301.5
	10/17/15	..	139.0	.....	2.73†	...	209	314
	10/18/15	..	138.0	.....	2.72†	...	203	305
	10/20/15	..	137.5	.....	2.71†	...	205	309
	11/13/15	..	133.8	.....	2.68†	...	217.5	298.5
	11/20/15	..	132.0	.....	2.66†	90	213	294
Subject's aver. ...	.....	..	.....	.....	.....	...	.....	.....
Mrs. McI.	1/ 7/16	46	127.0	157.5	2.29	95	203	299
Mrs. Sha.	11/ 4/15	30	113.0	155	2.21	80	184	283
	11/14/15	..	107.5	.....	2.15†	...	190	249
	11/26/15	..	106.5	.....	2.14†	...	195	254
	12/17/15	..	102.0	.....	2.10†	60	168	250
Subject's aver. ...	.....	..	.....	.....	.....	...	.....	.....
Miss P. M.	11/ 1/15	..	99	172	2.11	45	209	245
Mr. Z.	12/ 1/15	30	98	167.5	1.99	50	272	278
H. S. (boy).....	9/ 2/15	13	57.6	146.5	1.47	50	189	236
Mr. P. A. M.	10/13/15	24	95	172.5	2.13	40	253	317
Mr. Ch.	9/16/15	54	102	178.5	2.145	30	.....	282

* The figures for CO₂ and O₂ are in all cases the average of three consecutive ten-minute periods on the Benedict apparatus.

† Corrected from original determination on basis of 0.01 sq. m. per kg.

curve, assuming that changes in the metabolism due to age, expressed in terms of Meeh's area, would run parallel with those expressed in terms of the linear formula area.

The clinical data on the new subjects are as follows:

CASE 1.—Mrs. L. L., aged 36. Has had pneumonia twice. Five pregnancies, four of them ending in miscarriage. Positive Wassermann now. Left ovary removed eight years ago, since then there have been neither pregnancies nor catamenia. Her attitude toward sexual matters is normal. She is nearly always thirsty and has a definite polyuria. Some dyspnea on exertion. Her appetite, she says, is very good. She leads a sedentary life. Has always been fat. At 15 years she weighed 190 pounds; at 20, 200 pounds; at 35, 375 pounds. Physical Examination: Enormous obesity, slightly irregular pupils, knee jerks

—ON ALL NEW SUBJECTS

R. Q.‡	Pulse	Calories per Sq. M. and Hour (Linear Formula)	Calories per Kg. and 24 Hrs.	Total Calories per 24 Hours (Basal)	Standard Basal Metabolism for Age and Sex Calories per Sq. M. and Hour	Percentage Deviation from Standard	Remarks
0.70	79	32.6	15.0	2,185	36	— 9.4	
0.69	74	34.7	16.0	2,315	..	— 3.6	
0.69	73	33.3	15.5	2,200	..	— 7.5	
0.70	66	31.0	14.6	2,035	..	—13.9	Started a complete fast today.
0.67	70	32.3	15.2	2,120	..	—10.3§	Second day of complete fast
0.67	70	31.5	14.9	2,060	..	—12.5§	Third day of complete fast
0.66	73	32.0	15.2	2,085	..	—11.1§	
0.73	68	31.5	15.2	2,030	..	—12.5§	Has been on thyroid extract for last 5 days. Started at 3 grains and increased gradually to 12 grains per day
0.72	67	31.1	15.1	1,990	..	—13.6§	Has been on pituitary substance (B. W. & C.) for last 5 days.
0.69	..	32.7	15.3	.....	..	— 9.2	Started at 8 grains and increased to 24 grains per day
0.68	65	36.7	15.9	2,020	34	+ 7.9	
0.65	68	36.1	16.9	1,910	36.5	— 1.1	
0.76	68	33.0	15.8	1,705	....	— 9.6	
0.77	68	33.9	16.3	1,740	....	— 7.1§	Has been on thyroid extract for last 5 days. Started at 1½ grain per day and increased up to 7½ grains per day
0.67	66	33.5	16.4	1,685	....	— 8.2§	No food for 48 hours. Has been on ovarian extract (Armour) for last 5 days. Started at 2 grains, worked up to 16 grains per day
0.705	..	34.5	16.3	.....	....	— 5.5	
0.85	65	33.9	17.3	1,715	37	— 8.4	
0.98	..	40.7	20.5	2,010	38.5	+ 5.7	
0.80	..	46.2	28.3	1,630	46	+ 0.8	
0.80	..	42.9	23.1	2,190	39	+10	
....	..	37.9	19.1	1,950	35	+ 8.3	

‡ It will be noted that in the case of Mrs. L. L., Mrs. I. and Mrs. Sha. the R. Q. is very low. This is undoubtedly due to the fact that these patients were on a very low carbohydrate intake.
§ Not included in averages.

absent, and a large ventral hernia; otherwise negative. Blood, urine, pulse and blood pressure normal. Sugar tolerance: no reduction after 150 gm. levulose; very slight reduction after 200 gm. of levulose. Roentgen-ray Examination: Sella turcica normal.

CASE 2.—Mrs. McL., aged 46. Nothing remarkable about history or physical examination. Normal save for obesity. Had always been stout. Weighed 250 pounds when she was 16 years old. She has always been a heavy eater and is particularly fond of sweets. Has led a sedentary life. At the present time she is passing through the menopause.

CASE 3.—Mrs. Sha., aged 30. Has had two miscarriages and five pelvic operations. The last operation five years ago, at which time all the pelvic organs were removed; there have been no catamenia since. Before that she had been quite thin but following this last operation gained weight rapidly and steadily to the present time. She says that she is not a heavy eater. Leads a fairly active life. Physical Examination: Negative save for obesity. Sugar tolerance: sugar appeared after 150 gm. of levulose.

CASE 4.—Miss P. M. Has been stout since the age of 15, at which time she had a "goiter" without symptoms of hyperthyroidism; neck at that time measured 16 inches. Following this, had some sort of medication by mouth for two years and neck went down to 14 inches. Eats very little, and leads a very active life, yet gains weight steadily. Catamenia started at 13 and have always been regular. Skin is rather dry, but she perspires normally; hair has been falling and getting brittle. Does not feel the cold particularly and is neither nervous nor abnormally placid. Physical Examination: Unimportant except for the obesity.

CASE 5.—Mr. Z. Perfectly healthy medical student of 30; has been gaining weight for the last five years. Says he does not overeat.

CASE 6.—H. S., boy, aged 13. Always has been very fat, as have all his family. Has been well save for numerous upper respiratory tract infections. Eats large quantities of carbohydrate food, and eats continually between meals. Physical Examination: Shows marked obesity; small genitalia (though patient says erection and ejaculation occur); female type of breast; no pubic or axillary hair. Eye grounds and visual fields normal. Roentgen-ray Examination: Sella turcica normal.

CASE 7.—Mr. P. A. M., a normal man of 24. Has been stout since boyhood. Is a fairly heavy eater and takes little exercise.

CASE 8.—Mr. Ch., man of 54. Has been very stout for years; more so five years ago than at present. History and physical examination not remarkable. When first seen had a slight glucosuria which cleared up readily on slight restriction in carbohydrates.

The experimental data on the new subjects are all given in Table 1.

In Table 2 the subjects previously reported are compared with the new standards so that they may be used in the discussion of the whole series.

DISCUSSION OF RESULTS

The basal metabolism of each subject has been compared with an appropriate standard for his or her age and sex, and the percentage variation from that standard noted. Table 3 shows the average metabolism of all the subjects in Tables 1 and 2 divided into two groups, one group including the subjects less than 60 per cent. over-

weight, and the other the subjects more than 60 per cent. overweight. In the former group the actual metabolism is only 0.3 per cent. below the average of the standards for the same subjects, and in the latter group the actual is 2.3 per cent. below the standard average.

Taking the series as a whole, then, we may certainly say that there is no characteristic change whatsoever in the basal metabolism even in very extreme cases of obesity. Or, to put it more concisely, extreme obesity may occur in persons with a normal heat production per unit of surface area.

TABLE 2.—DATA ON CASES PREVIOUSLY REPORTED

Subject	Age	Weight, Kg.	Height, Cm.	Surface Area Square Meters (Linear Formula)	Per-centage Over-weight	R. Q.	Calo-ries per Sq. M. and Hour	Calo-ries per Kg. and 24 Hours	Standard Basal Metabolism for Age and Sex. Calories per Sq. M. and Hour	Per-centage Devia-tion from Stan-dard
Mrs. B.	44	179.0	163.0	2.95	160	0.78	35.4	14.0	34	+ 4.1
Mrs. McK.	48	103.0	144.5*	1.86§	120	0.75	34.8	15.0	34	+ 2.3
N. K. ♂	15	94.0	165.0	2.11†	55	0.76	36.4*	19.6	43.5	-16.3
Mrs. M.	28	87.0	161.0	2.01	30	0.75	31.1	17.2	36	-13.6

* Values corrected since appearance of first paper as explained in text.

† Obtained from area of Mrs. M., a subject of nearly same weight and height, by equation, Area by Meeh of A : Area of A by linear formula = Area by Meeh of B : Area of B by linear formula.

§ This area was obtained by direct measurement of casts of the body as described in DuBois' paper on body surface determination (Note 5). It was for a weight of 93 kg. For 103 kg., 1.96 would be more nearly correct. However, the conclusions regarding the normality of the metabolism would hold in either event.

TABLE 3.—AVERAGE METABOLISM OF ALL CASES IN TABLES 1 AND 2

Group	Number of Subjects	Calories per Sq. M. and Hour, as Determined Group Average	Calories per Sq. M. and Hour. Average of "Standards" of Individual Members of Group	Variation of Group Average Metabolism Observed, from "Standard" Average
Subjects more than 60% overweight.....	5	34.8	34.9	-0.3%
Subjects between 30% and 60% overweight	7	38.4	39.8	-2.3%

So much in regard to the series as a whole. Individually we can pick several cases that seem to have an abnormal metabolism. Following the Sage Institute investigators I shall consider a metabolism more than 10 per cent. from its appropriate standard as of questionable normality. On looking over the series we find that N. K. and Mrs. M. (Table 2) both have a metabolism more than 10 per cent. below the normal. Reference to the clinical histories of these cases will show

that they both presented some evidence of hypopituitarism. H. S. (Table 1), however, who likewise was thought to be hypopituitary, had a normal metabolism. Mrs. L. L., whose metabolism was sometimes below 10 per cent., also presented some evidence of hypopituitarism in that her sugar tolerance was increased. From all of this we may say that out of a series of twelve obese subjects three showed a slight reduction in basal metabolism, and that all of these three showed some clinical evidence of disturbed internal secretion.

CONCLUSIONS

1. The majority of obese subjects show no alteration in the basal metabolism, as expressed in terms of their surface area, even though the obesity is of a most extreme type.

2. Occasionally a slight reduction occurs and in such cases clinical evidence of disturbed internal secretion is present.

My sincere thanks are due to Dr. D. L. Edsall, Dr. E. F. DuBois, and Dr. F. G. Benedict, all of whom were good enough to read the original manuscript and make many valuable suggestions and criticisms.

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CORRECTION

In the article by Drs. I. H. Levy and J. L. Kantor, entitled "A Clinical Study of Delayed Gastric Emptying," *THE ARCHIVES OF INTERNAL MEDICINE*, April, 1916, p. 476, in the section on Tone of Stomach, p. 479, the second sentence should read: "This so-called peristolic function of Stiller is impaired in muscular weakness (atony or myasthenia gastrica)."