CLINICAL CALORIMETRY

THIRTEENTH PAPER

THE BASAL METABOLISM OF NORMAL ADULTS WITH SPECIAL REFERENCE TO SURFACE AREA*

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Since the writing of Paper 4[1] of this series an unusual amount of work has been published on the subject of the normal metabolism. It is now possible to calculate the normal baseline much more exactly than a year ago and it is therefore necessary to reconsider the whole question at this early date. The figures representing the average normal metabolism have been changed frequently since the study of the respiratory exchanges began and it may be said that the chief advance has depended on the fact that it has been possible to make the variation in the normal smaller and smaller each year. With the oldest type of large respiration chamber the range of heat production fluctuated enormously with the uncontrolled influences of muscular activity and the specific dynamic action of food. With the improved technic of Johansson and with the small apparatus of the Zuntz school these factors were eliminated, but errors due to changes in the calorific factors for O_2 and CO_2 remained. The normal variation was frequently quoted as from about 2.5 to 5.0 c.c. O_2 per kilogram and minute with a mean of about 3.5 c.c. Under these conditions a pathological departure from the average normal as great as 40 per cent. might be obscured. In 1914 Coleman and Du Bois[2] gathered 48 controls from various sources including seven studied in the Sage calorimeter and gave the figure 34.2 calories per hour as the average heat production per square meter of body surface as determined by Meeh's formula. They pointed out that the normal variation was only plus or minus 10 per cent. if the surface area were used as a standard. In Paper 4 of this series,[1] on the basis of a much larger number of controls, we selected the average

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1. Gephart and Du Bois: Clinical Calorimetry, Paper 4, The Archives Int. Med., 1915, xv, 835

2. Coleman and Du Bois: The Influence of the High Calory Diet on the Respiratory Exchanges in Typhoid Fever, The Archives Int. Med., 1914, xiv, 168.

figure of 34.7. Since then Benedict, Emmes, Roth, and Smith[3] have published the details and have discussed their experiments which were only briefly reported at the time of our last publication. They found the metabolism of vegetarians to be practically the same as that of nonvegetarians, while the athletes average 7 per cent. higher than the nonathletes used as controls. This is accounted for in part by the fact that the athletes were somewhat younger than the controls with whom they were compared. The average age of the fifteen athletes was 22⅓ years and the average heat production 40.7 calories per square meter per hour as recalculated according to the height-weight chart. This is only 2.5 per cent. higher than our standard for normal men. Benedict and his co-workers have pointed out the fact that the younger subjects show a higher metabolism and that the heat production is much lower when the subject is asleep at night than when he is awake in the day time. They have found the metabolism of women average about 6 per cent. lower than that of men. The extremes of variation in the oxygen consumption of the same man over the course of months and years are shown in a very instructive table of thirty-five subjects. Eleven show a variation less than 10 per cent., eighteen show from 10 to 20 per cent. and six a difference of 20 to 31 per cent., the average variation being 13.9 per cent. It must be remembered that this table shows the extremes, giving the percentage increase of the very highest period over the very lowest. The results in an early morning period when the subject was asleep may be contrasted with an afternoon period when he was awake and weary of experimentation. The "Universal" respiration apparatus with which these tests were made can be used only for periods of 10 to 20 minutes and with some people there may be a considerable amount of discomfort from the mouth or nose pieces. On the whole it is quite remarkable that the extremes of variation are not greater. It is to be hoped that the details of this table will be published so that we may estimate the frequency with which observations under similar conditions show results which differ materially from the average. Benedict also calls attention to the variation of the metabolism of different individuals according to body weight and surface area.

Palmer, Means and Gamble[4] have studied a considerable number of normal men and women and have found that the creatinin elimination bears a constant relationship to the basal heat production. Means[5] has

3. Benedict, Emmes, Roth and Smith: Jour. Biol. Chem., 1914, xviii, 139. Benedict and Roth: The Metabolism of Vegetarians as Compared with the Metabolism of Non-Vegetarians of Like Weight and Height, ibid, 1915, xx, 231. Benedict and Emmmes: A Comparison of the Basal Metabolism of Normal Men and Women, ibid, xx, p. 253. Benedict and Smith: The Metabolism of Athletes as Compared with Normal Individuals of Similar Height and Weight, ibid., xx, p. 243. Benedict: Factors Affecting Basal Metabolism, ibid, xx, p. 265.

4. Palmer, Means and Gamble: The Basal Metabolism and Creatinin Elimination, Jour. Biol. Chem., 1914, xix, 239.

5. Means: Basal Metabolism and Body Surface, ibid, 1915, xxi, 263.

calculated out the metabolism of these same subjects according to square meters of body surface as determined by Meeh's formula and by the new linear formula described in Paper 5 of this series. The average figure for men according to Meeh's formula was 33.2 calories per hour, according to the "Linear Formula" 39.6. The averages for women were lower, Meeh's formula 29.9, "Linear Formula" 38.2. The greatest variation from the average was 12.3 per cent. according to Meeh's formula and 7.9 per cent. according to the linear, the mean variations were 4.8 per cent and 4 per cent., respectively. Means[6] has also shown that the apparent depression of metabolism in obesity in most cases was due to the large plus error in Meeh's formula, and that according to the linear formula his two very stout subjects came within normal limits.

In Papers 5 and 9 in this series attention has been called to the variable plus error in Meeh's formula, which averages about 15 per cent., and a formula based on linear measurements has been described. In Paper 10 a "Height-Weight" formula is given which makes it possible to determine the approximate surface area of subjects described in publications in which the height and weight are stated. Results expressed in terms of square meters of surface area are comparable if either the linear formula or "Height-Weight Formula" be used, but are about 15 per cent. higher than if Meeh's formula be applied. This necessitates the use of two different sets of figures to represent the average metabolism of men between the ages of 20 and 50—39.7 calories per square meter per hour according to the linear formula, 34.7 calories according to Meeh's formula. In Paper 11 it is shown that the metabolism is slightly lower in the semireclining posture than flat in bed. In Paper 12 the increase in metabolism during the period of growth is discussed in detail.

METHODS AND SUBJECTS

The methods described in Paper 4 of this series were followed in the present work. Many of the subjects have been reported in previous papers.

Morris S., former typhoid patient, is reported in Paper 6 where the history and experimental data are given. At the date of the experiments here discussed he was in perfect health. Dec. 17, 1914, a basal determination was made and the next day between 8:40 and 9:20 a. m. he ate the protein meal, consisting of 110 gm. egg white, 21 gm. egg yolk, 600 c.c. fat-free milk, 150 gm. pot cheese and 10 gm. lactose. This according to analysis of the cheese and milk contained 9.6 gm. nitrogen. He was quiet throughout the experiment and during the third hour slept for forty minutes. The metabolism was much lower during this hour and it should be excluded from the averages.

Albert G. Normal control whose history is given in Paper 12. Dec. 30, 1914, he was given 79 gm. olive oil at 10:15 a.m. During the first and second periods

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

he slept fourteen and ten minutes, respectively. Jan. 4, 1915, at 10:13 a.m. he was given 115 gm. commercial glucose, the equivalent of 100 gm. pure dextrose. He slept most of the first period. In the third period the CO_2 and O_2 measurements were lost. The experiment was repeated two days later.

A. P. C., normal control, male, 24 years old, 179.4 cm. tall; medical student in good health.

Jan. 21, 1915, after having been on a low nitrogen diet for several days a basal determination was made.

R. H. S. history in Paper 12.

E. F. B. D. history in Papers 4 and 12.

Emma W., normal control. History in Paper 9. She was in unusually good health and was able to take violent exercise. Her menses were regular and not profuse. On examination of the heart there was a marked respiratory allorrhythmia and also an ocasional premature systole. Several electrocardiographic plates were taken but no abnormal beats photographed, although it was possible to see the typical large diphasic swing of the shadow several times. The first experiment was made May 13, which was the second day of the catamenia. To control this factor a second basal determination was made May 17, the third day after the flow had ceased. She was almost motionless both days while in the calorimeter.

AVERAGE BASAL METABOLISM OF MEN

In Paper 4 the results of respiration experiments on 96 men were considered. To this group may be added the nine men of Palmer, Means and Gamble and the four men studied in the Sage calorimeter, Morris S., Albert G., R. H. S., and A. F. C. If we tabulate the results according to the surface area as determined by Meeh's formula there is no need to change the conclusions expressed in Paper 4. The average of the new cases is 33.6 calories per square meter per hour as opposed to the former figure of 34.7. It does not seem necessary to change the base line again. The greatest variation from the mean is 12.3 per cent. as mentioned previously.

In Paper 4 of this series the results in five cases are given in terms of calories per square meter as determined by the new "Linear Formula." Adding the four new cases of this paper we have a total of nine normal men whose surface area has been accurately measured. The average basal metabolism is 39.7 calories per square meter per hour ("Linear Formula"). The extremes of variation from the average are + 4 per cent. and — 6 per cent. John L., who was 44 years old, could not be found and measured. His results would probably have been further from the average. Means,[5] who measured his nine subjects by the same method, obtained an average figure of 39.6. Until we have a larger number of subjects measured in this manner the figure 39.7, given above, will be considered the standard with which all results are to be compared.

The results obtained by Benedict, Emmes, Roth and Smith may also be recalculated by means of the new "Height-Weight" chart. If we take the seventy-nine men between the ages of 20 and 50, who were of average body shape, and calculate the calories per square meter per

TABLE 1.—Data of—

Subject, Date, Weight, Surface Area, Linear Formula	Period	End of Period	Carbon Dioxid, Gm.	Oxygen, Gm.	R. Q.	Water, Gm.	Urine N per Hour, Gm.	Indirect Calorimetry, Cal.	Heat Eliminated, Cal.
Albert G. 12/30/14 64.91 Kg. 1.657 Sq. M.	Prelim.	11:15	.....	.....	.....	.....	.....	......	.....
	1	12:15	23.94	21.20	0.821	30.81	0.418	70.78	74.34
	2	1:15	22.70	20.31	0.813	29.14	0.418	67.63	73.41
	3	2:15	25.40	21.21	0.871	30.47	0.380	71.81	73.78
	4	3:15	24.37	22.30	0.795	30.84	0.380	74.07	74.99
								284.19	
Albert G. 1/4/15 65.64 Kg. 1.665 Sq. M.	Prelim.	11:12	.....	.....	.....	.....	.....	......	.....
	1	12:13	29.97	23.79	0.916	31.69	0.445	81.53	81.87
	2	1:12	29.29	20.73	1.03	29.44	0.445	72.45	77.98
								153.98	
Albert G. 1/6/15 66.16 Kg. 1.671 Sq. M.	Prelim.	11:11	.....	.....	.....	.....	.....	......	.....
	1	12:11	32.55	22.59	1.05	30.38	0.509	79.19	77.67
	2	1:11	30.64	22.69	0.982	35.28	0.509	78.72	85.06
	3	2:11	29.03	21.73	0.972	33.60	0.509	75.20	77.68
	4	3:11	24.90	22.03	0.822	34.77	0.509	73.54	81.22
								306.65	
A. F. C. 1/21/15 69.22 Kg. 1.792 Sq. M.	Prelim.	8:48	.....	.....	.....	.....	.....	......	.....
	1	9:48	24.17	21.28	0.826	27.28	0.261	71.51	73.07
	2	10.48	23.19	20.33	0.830	27.49	0.261	68.44	72.90
								139.95	
Emma W. 5/13/15 57.38 Kg. 1.64 Sq. M.	Prelim.	10.41	.....	.....	.....	.....	.....	......	.....
	1	11:41	18.22	16.44	0.806	31.75	0.402	54.60	59.93
	2	12:41	18.41	16.18	0.827	29.11	0.402	53.94	56.21
								108.54	
Emma W. 5/17/15 57.26 Kg. 1.64 Sq. M.	Prelim.	11:00	.....	.....	.....	.....	.....	......	.....
	1	12:00	18.55	16.06	0.840	29.15	0.214	54.18	50.86
	2	1:00	18.86	16.77	0.818	27.93	0.214	56.21	52.26
								110.39	

hour, we obtain the figure 38.9. While this figure is slightly lower than ours, it must be remembered that it was obtained by means of the Benedict apparatus with periods only fifteen to twenty minutes long. For these periods the subjects can remain absolutely motionless, something impossible in calorimeter experiments two to four hours long. It seems preferable to use the average normal obtained in the calorimeter as a standard for pathological cases studied in the same apparatus.

—Calorimeter Experiments

Direct Calorimetry (Rectal Temp.), Cal.	Rectal Temp., C.	Average Pulse	Work-Adder, Cm.	Non-protein R. Q.	Per Cent. Calories from			Calories per Hour		Remarks
					Protein	Fat	Carbohyd.	Per Kg.	Per Sq. M. (Meeh)	
......	37.00	..	..	....	..	..	..	.....	.....	Olive oil, 79 gm. 10:15 a. m.
69.29	36.91	57	12	0.82	16	52	32	1.090	35.59	Asleep 10 min.
79.53	37.03	61	7	0.81	16	54	30	1.042	34.00	Asleep 10 min.
61.51	36.83	64	10	0.88	14	35	51	1.106	36.10	Awake
74.68	36.84	62	13	0.79	13	62	25	1.141	37.24	Awake
285.01										
......	36.88	..	..	....	..	..	..	.....	.....	Commer. glucose, 115 gm.; water, 200 c.c., 10:13 a.m.
94.63	37.12	65	7	0.94	15	17	68	1.242	40.73	Asleep
72.76	37.03	59	17	1.08	16	0	84	1.104	36.35	Awake
167.39										
......	36.94	..	..	....	..	..	..	.....	.....	Com. glu., 115 gm.; lemon juice, 10 c.c.; water, 125 c.c. at 10:11 a. m.
74.57	36.89	66	11	1.11	17	0	83	1.197	39.32	Quiet
84.19	36.88	64	29	1.02	17	0	83	1.190	39.09	Quiet
75.70	36.85	..	30	1.01	18	0	82	1.137	37.34	Restless
72.69	36.70	57	15	0.83	18	47	35	1.112	36.51	Fairly quiet
307.15										
......	36.89	..	..	....	..	..	..	.....	.....	Basal; low nitrogen diet
61.25	36.69	68	30	0.83	10	52	38	1.033	34.45	Restless
60.55	36.48	74	20	0.84	10	70	20	0.989	32.97	Restless
121.80										
......	37.04	..	..	....	..	..	..	.....	.....	Basal; 2d day of catamenia
54.38	36.93	60	2	0.81	20	52	28	0.952	29.80	Almost motionless
49.73	36.80	58	6	0.83	20	46	34	0.940	29.44	Almost motionless
104.11										
......	36.91	..	..	....	..	..	..	.....	.....	Basal
46.26	36.82	57	4	0.85	10	46	44	0.946	29.61	Almost motionless
55.75	36.90	55	4	0.82	10	55	35	0.982	30.72	Almost motionless
102.01										

If we apply the "Height-Weight Formula" to the averages of the 68 women given by Benedict and Emmes[7] on page 256, we find that the approximate surface area for the average weight of 54.5 kg. and average height of 162 cm. is 1.57 sq. meters. This would make their average heat production per hour 35.9 calories per sq. meter, and if

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

TABLE 2.—Summary of Results with Normal Subjects (all men except Emma W.)

Name	Age, Years	Average Weight, Kg.	Height, Cm.	Sq. M. Surface Area		According to Meeh's Formula		According to Linear Formula	
				Meeh's Formula	Linear Formula or Measured	Cal. per Sq. M. per Hour	Variation from Average, per Cent.	Cal. per Sq. M. per Hour	Variation from Average, per Cent.
Morris S.	22	61.21	164.3	1.912	1.644	35.2	+1	41.2	+ 4
Albert G.	24	65.90	162.2	2.009	1.667	34.3	—1	41.2	+ 4
R. H. S.*.....	21½	64.36	184.2	1.977	1.830	34.6	—0	37.4	— 6
E..F. D. B. ..	33	74.64	179.2	2.183	1.906	32.9	—6	37.7	— 5
A. F. C.	24	69 22	179.4	2.076	1.792	33.7	—3	39.1	— 2
Emma W.*...	26	57.32	164.8	1.831	1.642	29.9	—8	33.3	—10
Average for men						34.7	...	39.7	
Average for women						32.3	...	37.0	

* Unusually quiet subjects.

TABLE 3.—The Basal Metabolism Determination of Average Normal for Men Between Ages of 20 and 50 *

Name	Details Published in Paper	Average Calories per Sq. M. per Hour, Linear Formula
G. L.	4	40.7
E. F. D. B.	4 and 11	39.4†
R. H. H.	4	40.9
L. C. M.	4	40.5
F. C. G.	4	37.7
Morris S.	7	41.2
Albert G.	11 and 13	41.2
R. H. S.	11	37.4
A. F. C.	13	39.1
Average, Sage normal controls		39.7
Average, Means' normal controls		39.6
Average, Benedict s normal controls		38.9

* Average calories per square meter per hour, acording to the "Linear Formula," of men examined in Sage calorimeter. It has been impossible to find John L. and measure his surface area.

† Average of four basal experiments, Paper 4, first experiment Paper 11.

we add to the group the seven women studied by Means[5] the average for the whole would be 36.9 calories, a figure which may be adopted as the standard for normal women. This shows that the metabolism of women is about 7 per cent. lower than that of men, a figure in agreement with the conclusions of Benedict and Emmes.

TABLE 4.—A Comparison of the Metabolism of Fat and Thin Subjects Taken Largely from the Work of Benedict, Emmes, Roth and Smith

Name	Per Cent. Deviation from Normal Average, 34.7 Meeh's Formula	39.7 Height-Weight Formula	Calories per Kg. per 24 Hours	Name	Per Cent. Deviation from Normal Average, 32.3 Meeh's Formula	36.9 Height-Weight Formula	Calories per Kg. per 24 Hours
Fat Men—				Fat Women—			
W. S.	— 1.2	+ 5.0	22.8	Dr. M. D.	—11.2	— 1.0	18.9
O. F. M.	— 8.6	— 0.5	21.3	O. A.	— 9.6	0.0	19.5
Prof. C.	—15.1	—12.0	19.9	H. H.	—17.0	— 7.0	18.0
F. E. M.	— 6.9	— 4.0	22.7	H. D.	—10.3	+ 1.0	20.1
F. A. R.	— 6.1	— 3.0	22.9	F. M. R.*	— 6.8	+ 7.0	21.0
				D. L.*	—13.5	+ 1.0	19.7
				L. F. W.*	—16.9	0.0	18.6
Average	— 7.6	— 4.0	21.9	Average	—12.2	0.0	19.4
Thin Men—				Thin Women—			
R. A. C.	+11.3	— 2.0	29.7	J. T.	+12.5	+ 2.0	31.7
B. N. C.	+ 7.2	— 6.0	29.8	A. A.	+ 9.6	— 5.0	32.0
L. E. A.	+ 7.6	— 2.0	29.5	E. W.	—12.2	+ 7.0	31.5
A. F. G.	— 0.8	—10.0	27.0	A. C.	— 0.5	— 8.0	27.4
				J.	— 2.1	— 7.0	26.9
				L. B.	— 6.7	—13.0	24.9
Average	+ 6.4	— 5.0	29.0	Average	+ 4.2	— 4.0	29.1

* Means' subjects.

A COMPARISON OF FAT AND THIN SUBJECTS

In Paper 4 of this series attention was called to the fact that in the case of fat individuals Meeh's formula would give a figure for the calories per square meter which would be very much too low. It might have been added that in the case of thin subjects the figure would be very much too high. The male subjects of Benedict and co-workers were plotted in our previous paper according to height and weight, and on account of the above mentioned errors six fat men and two thin ones were excluded from the averages. Now that it is possible to correct the error in Meeh's formula it has seemed advisable to compare the metabolism of the fat and thin groups. A table compiled by the insurance companies showing the average weight of the male applicants between the ages of 25 and 29 years for different heights was taken as a standard. Those subjects whose weight departed more than 20 per cent. from this standard were considered either fat or thin. H. F. was excluded on account of old age, two more thin men, L. E. A. and A. F. G., were included in the new list. The fat and thin women were tabulated and three stout subjects of Means[5] added to the list. The results given in Table 4 are expressed in terms of variation from the averages for all normal controls, 39.7 calories per sq. meter per hour "Linear Formula" for the men and 36.9 for the women. According to body weight the fat and thin groups show a difference of 41 per cent.; according to Meeh's formula 15 per cent., according to the "Linear Formula" 3 per cent. This shows that Rubner's law that metabolism is proportional to surface area holds for fat and thin subjects and that we can safely use our new baseline for hospital patients whether they be fat or thin.

TABLE 5.—Basal Metabolism of Normal Men and Women 40 to 60 Years Old, Recalculated in Terms of Surface Area by the "Height-Weight" Formula

Subject	Investigators	Age, Years	Per Cent. Deviation from Average Cal. per Sq. M. per Hr. (20-50 Yrs.)
Men			Av. 39.7
A. L.	B. E. R. and S.	40	— 2.0
F. G. B.	B. E. R. and S.	41	— 8.0
Dr. P. R.	B. E. R. and S.	41	—12.0
Dr. S.	B. E. R. and S.	43	—20.0
Prof. Z.	M-L. and F.	43	— 5.0
John L.	G. and D. B.	44	—12.0
G. L.	G. and D. B.	47	+ 3.0
W.	M-L. and F.	56	— 5.0
E. J. W.	B. E. R. and S.	58	—17.0
Women			Av. 36.9
B. K.	M-L. and F.	40	+10.0
Mrs. H. D.	B. E. R. and S.	42	+ 1.0
Dr. M. D.	B. E. R. and S.	44	— 1.0
Mrs. S. C.	B. E. R. and S.	52	—12.0
Mrs. E. B.	B. E. R. and S.	53	— 1.0
Average, men and women		40 to 50	— 4.3
Average, men and women		50 to 60	—11.3

INFLUENCE OF AGE

In Table 5 are grouped the corrected results for the normal controls between 40 and 60 years of age. In Paper 4 the subjects between the ages of 20 and 50 were grouped together, but it is apparent that the average metabolism between the ages of 40 and 50 is 4.3 per cent. lower than that of the whole group, while those between 50 and 60 are 11.3 per cent. lower. It is necessary to use a lower figure for the baseline after the age of 50, and perhaps advisable to make the change at the age of 40.

VARIATIONS IN METABOLISM

We have already spoken of the extremes in the oxygen consumption of the same individual during the course of months and years as reported by Benedict. Only a few of the subjects here reported have been studied over long enough periods to give much evidence on the question. The basal metabolism of E. F. D. B. was 35.91 calories per square meter per hour on March 13, 1913, the first time he was in the calorimeter, when he was somewhat restless. In May, 1913, it was 33.29; in March, 1914, 34.09; May, 1914, 32.97; May, 1915, 32.86. The extreme range was 9 per cent., and, excluding the first experiment, 3.7 per cent. Albert G. showed a variation of 6.4 per cent., the metabolism being unusually low on December 28, when he dozed during the two-hour experiment. In Paper 7 it will be noted that the curves representing the metabolism of the typhoid patients are very uniform.

INFLUENCE OF FOOD

In a footnote to Paper 4 it was stated that Morris S. showed a rise of 6.5 per cent. in metabolism two to six hours after a meal containing 9.6 gm. nitrogen. On recalculation the rise during the period turns out to be 7.4 per cent., and if we exclude the third period when he slept forty minutes, 11.9 per cent. This corresponds with the rise of 12 per cent. found in the case of E. F. D. B. after a similar meal containing 10.5 gm. nitrogen. Albert G. on January 6, one to four hours after 115 gm. of commercial glucose, the equivalent of 100 gm. dextrose, showed an average metabolism 11 per cent. higher than the basal determination two days later. This corresponds with the average of 9 per cent. obtained with G. L. and E. F. D. B. in the previous investigation. The one experiment on Albert G. one to five hours after 79 gm. olive oil showed little increase in metabolism. Fat exerts its chief specific dynamic action in the period immediately succeeding the hours studied. The glucose experiment on Albert G. January 4 was too short to be of value.

TABLE 6.—Water Elimination Through Skin and Lungs. Normal Controls in Calorimeter. Basal Metabolism Experiments

Name and Date	Average H_2O Gm. per Hr.	Average Calories per Hr. Dir. Cal.	Per Cent. Cal. Lost through Vaporization	Per Cent. Deviation from Mean 23.9%
G. L. 3/11/13	37.44*	80.88	27.3*	+14
E. F. D. B. 3/13/13	27.22	75.20	21.1	—12
5/17/13	32.30	71.44	26.4	+10
3/30/14	30.52	75.78	23.5	— 2
5/18/14	28.06	68.69	23.9	± 0
5/ 6/15	32.21	72.71	25.9	+ 8
F. C. G. 3/17/13	19.45	57.19	19.9	—17
4/22/13	27.44	60.72	26.4	+10
R. H. H. 3/19/13	28.41	69.77	23.8	— 0
Louis M. 3/26/13	27.15	67.40	23.6	— 1
John L. 3/26/14	24.78	61.10	23.7	— 1
L. C M. 5/ 4/14	27.80	70.21	23.1	— 3
Albert G. 12/21/14	31.58	71.68	25.7	+ 7
12/28/14	26.12	71.20	21.4	—10
1/ 8/15	29.37	69.82	24.6	+ 3
R. H. S. 4/19/15	26.27	72.03	21.3	—11
Morris S. 12/17/14	27.06	70.33	22.5	— 6
A. F. C. 1/21/15	27.39	60.90	26.3	+10
Av. 18 experiments on men..................	28.4	.....	23.9	....
Emma W. 5/13/15	30.43	52.06	34.1	+42
5/17/15	28.54	51.01	32.6	+36

* Much more warmly dressed than the other subjects.

WATER ELIMINATION

In Table 6 the water elimination from skin and lungs is given for the twenty basal experiments on normal adults. The first column expresses the averages for each experiment in grams per hour. Each gram vaporized at 23 C. represents the loss of 0.584 calories. The second column gives the average calories produced per hour as measured by the method of direct calorimetry. The third represents the percentage of calories lost through vaporization. It will be seen that normal men dressed in underwear and pajamas in a well ventilated box at 23 C. give off between 19 and 32 gm. of water per hour, dissipating in this manner between 20 and 27 per cent. of the total heat produced. The average figures are 28.4 gm. per hour and 23.9 per cent. of the calories. Eighty-three per cent. of the eighteen experiments come within 10 per cent. of this last figure.

There are many factors which influence the amounts of water given off by skin and lungs, the most important being the amount of water previously ingested, the amount of clothing, the temperature and humidity of the air and the rise or fall of body temperature. The amounts eliminated in consecutive hours may vary greatly and even transient emotions may cause sweating. The subject is too complicated to be treated in this short paper and is reserved for later discussion.

TABLE 7.—Standards of Normal Metabolism. Average Calories Per Hour Per Square Meter of Body Surface

Subjects, Age in Years	According to Meeh's Formula	According to Linear and Height-Weight Formulas
Boys, 12 to 13	45.7	49.9
Men, 20 to 50	34.7	39.7
Women, 20 to 50	32.3	36.9
Men, 50 to 60	30.8	35.2
Women, 50 to 60	28.7	32.7

SUMMARY AND CONCLUSION

The basal metabolism of four normal men and one woman has been determined and experiments have been made on the specific dynamic action of protein and glucose. A study of the new controls, together with those reported in the literature since our last publication, supports the views previously expressed. There is no reason to change the statement made in our previous paper, that if a given subject's basal metabolism is more than 10 per cent. from the average, it may be regarded as abnormal, but cannot be proved abnormal unless the departure from the average is at least 15 per cent. The average basal metabolism of normal men is 34.7 calories per square meter per hour as determined by Meeh's formula. On account of the average plus error of about 15 per cent. in Meeh's formula the average figure is 39.7 calories, or in round numbers 40 calories, when the more exact "Linear Formula" or the new "Height-Weight Formula" is used to determine surface area.

The average metabolism of fat and thin subjects is the same according to surface area when the surface area is correctly measured. The metabolism of women averages 37.0 calories, or 6.8 per cent. lower than that of men. A group of men and women between the ages of 40 and 50 gave figures 4.3 per cent. below, and a group 50 to 60 years old 11.3 per cent. below the average for the larger group between the ages of 20 and 50.

Under the atmospheric conditions of the calorimeter experiments the average water elimination by normal men through skin and lungs is 28.4 gm. an hour. About 24 per cent. of the heat produced is dissipated in the vaporization of water.

The figures for the specific dynamic action of protein and glucose previously obtained are confirmed. A table of normal standards is given.