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THE BASAL METABOLISM OF TWENTY-SIX KANSAS WOMEN
OF THIRTY TO THIRTY-FOUR YEARS OF AGE

by

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INTRODUCTION

The basal metabolism of mid-western college women has been studied in Kansas for the past seven years as part of a regional project. The other states cooperating are: Iowa, Minnesota, Ohio, and Oklahoma. The basal rates of the subjects indicated significant state differences and, in general, were lower in the warmer climates. It is now considered desirable to extend this work beyond the college age-group to accumulate data which in time, may help to establish basal metabolism standards for all ages of women in these different localities. It is also planned to continue the investigation of the effects of age upon the basal rates.

With these objects in view this study was made on 26 Kansas women ranging in age from 30-34 years.

REVIEW OF LITERATURE

According to Du Bois (1936), the general principles of the closed-circuit metabolism apparatus were developed in 1849 by the French scientists Regnault and Reiset. Some of the first investigators in this country to contribute studies of normal metabolism, basal and otherwise, were Atwater and Benedict (1905). They made respiration calorimeters in which men could live and work for days. Also Lusk (1928), another early Ameri-

can worker who in his youth had studied calorimetry with Voit in Germany, contributed much to this subject devoting considerable time to the effects of food upon metabolism.

Until the present time probably the most-used standards for computing basal metabolic rates have been those of Harris and Benedict (1919), Aub and Du Bois (1917), and Dreyer (1920). The tables of Harris and Benedict are based upon weight and standing height, and those of Aub and Du Bois upon the law first stated by Rubner in 1883, that heat production is proportional to surface area. Dreyer's tables use trunk length, weight, and chest circumference as bases for computation. All take into consideration variations due to age and sex. The Aub-Du Bois standards as modified by Boothby and Sandiford (1929) are now much used, judging by the frequency with which they are mentioned in the literature.

Benedict (1928) in his basal metabolism studies of 33 normal women found the average deviation from the Harris and Benedict standard was -4.2 percent; from the Dreyer standard, -4.0 percent; and from the Aub-Du Bois standard, -7.3 percent. He suggested that all of these were too high for women and that they should be lowered about five percent. Stark (1933), working in Wisconsin, agreed with Benedict but recommended that the standards be modified only after many groups of data covering all ages become available for comparison. Then, according to this worker, the corrections necessary to make the standards fit the greatest number of women can be determined.

The need for specifying the standard used when reporting metabolism tests was emphasized by Jenkins (1931). He discussed the various ones in common use and suggested that too many existed. His recommendation was that the present standards should be retained but made more accurate.

Sex is one of many factors recognized as affecting basal metabolism. Hafkesbring and Collett (1924), reporting 96 experiments on one woman and 80 on another, found considerable day-to-day variation in the basal rate of these subjects. Their work was confirmed by Hitchcock and Wardell (1930) who also found day-to-day variation in the basal metabolism of most of their women subjects. In contrast to this, Benedict (1935), using himself as a subject for two periods of a month each, concluded that a healthy, normal man's basal metabolism was quite uniform from day-to-day.

This variation in the basal metabolic rate of women is believed by Hitchcock and Wardell (1930) to be due to the effects of the menstrual cycle. In 800 metabolism tests on 27 women these workers found the metabolic rate was comparatively low during the menstrual period. Stark (1935), as a result of her Wisconsin studies, agreed that the basal metabolic rate reached its lowest level during menstruation.

Harris and Benedict (1919) reported that basal metabolism throughout adult life decreased as age increased. They obtained a mean decrease in daily heat production per 24 hours per year of 7.15 Calories for men and 2.29 Calories for women.

Later, Benedict (1928) studied the effects of age upon the basal rate of three men and one woman. In this study the only variable was age as height and weight for his subjects remained fairly constant. The woman was studied between the ages of 24 to 36 years and the men from 30 to 59 years. The woman subject at the age of 24 years was 1.7 percent above the Aub-Du Bois standard and her total heat production per 24 hours was 1302 Calories. At the age of 36 years her metabolism had dropped to -5.3 percent and her Calories to 1251 per day. One of the men at 30 years was 11.3 percent above the Aub-Du Bois standard and his total basal Calories per day was 1397. At 49 years this same man had a deviation of -15.9 percent and a daily heat production of 1070 Calories. The basal rate of the second male subject at the age of 38 years was 8.5 percent above the Aub-Du Bois standard or 1371 Calories per day and at 57 years had dropped to -7.1 percent and 1563 Calories. These three subjects all showed a decrease in basal metabolism with increase in age. With the third male the decrease in basal metabolic rate was not evident, possibly because he was in poor health at the beginning of the experiment. His basal rate actually increased slightly as his health improved.

Magnus-Levy (1943), using himself as a subject, reported a decrease in his basal rate over a 50-year period. At the age of 26 years his basal metabolism was 4.0 percent below the Aub-Du Bois standard and at the age of 76 years it had dropped to -11.0 percent. The actual decrease per square meter of body

surface per hour was from 38.1 to 31.5 Calories. This agrees with Benedict's work on basal metabolism as affected by age.

According to Chaney and Ahlborn (1943) growth tends to increase the basal metabolic rate per unit of weight. This is shown during infancy, childhood, adolescence, and pregnancy. It is generally agreed that an average normal infant during the first year of life needs approximately 55 Calories per kilogram of body weight for his basal activities. In contrast to this, the average adult woman needs only about 25 Calories per kilogram of body weight. Because of the great stimulus to cellular activity in the child during growth, his basal rate is expected to be higher per unit of weight than that of the adult.

The effects of adolescence upon metabolism have been the subject of many studies. However, the results have been conflicting. Some workers have found a definite increase in metabolism before and during adolescence, while others noted no striking changes during this period.

In pregnancy the basal metabolic rate begins to increase slowly during the fourth month. About six weeks before the infant is born the rate has increased to an average of 23 percent above that of the fourth month. From this time until delivery some investigators have found a slight fall in the basal metabolism of the pregnant woman. However, others have reported that the basal rate remained at the maximum level until delivery, at which time the rate of the mother and of the baby equaled that of the mother before the baby was born.

Blunt (1926), McKay (1930), and Du Bois (1936) are fairly well agreed that body surface expressed as calories per square meter is the best basis for comparison of basal metabolism of persons of abnormal build. Boothby and Berkson (1936) and Du Bois (1936) also suggested that this method gives the most consistent results for all persons.

Boothby, Berkson, and Dunn (1936) made a study of an adult group of 639 males and 828 females at the Mayo Clinic in Rochester, Minnesota. The group represented persons from all parts of the country and various social conditions. These investigators obtained a mean basal rate of 35.51 Calories per square meter per hour for 54 women subjects of 30-34 years, inclusive, which is the age-group represented in the present study. This value is the mean of the first satisfactory test for these women and is high when compared with other standards. This is to be expected according to Du Bois and Chambers (1943), who reported the first test in a metabolism study is usually five to ten percent higher than the second. This would explain the high figure of Boothby, et al. (1936), who preferred to use the first test for clinical purposes.

The type of diet has been studied as a factor affecting the basal metabolism. Wang (1930) varied the daily protein intake of six normal women between the ages of 17 and 35 years. These subjects were given two grams of protein per kilogram of body weight for a period of five weeks, then 0.6 g per kilogram for one month. For a third period these women chose their

normal diet in which the protein varied but fell between that of the two controlled diets. There was little difference in the metabolic rate with these protein levels. This indicated that the specific dynamic action of protein in the quantities used did not change the basal metabolism of these subjects in the period covered by the study. Tilt and Walters (1935) in their short-time studies of Florida women, also found no consistent relationship between protein and caloric intake and basal metabolism. However, Wakeman (1932) comparing the basal rate of meat-eaters and vegetarians found some difference as a result of diet. He suggested that one would have to be a complete vegetarian for a number of years to obtain an appreciable lowering of the basal metabolism.

Gustafson and Benedict (1928) studying the effects of climate upon basal metabolism reported on 22 women attending Wellesley College. Each subject was tested once a month from October, 1926 to January, 1928. The data suggested that the basal metabolic rate was lower in winter and higher during the spring and summer. McKay (1930), working with women and girls in Ohio, also reported that basal metabolism tests tend to be low in winter and high in spring. Hitchcock and Wardell (1930) at Ohio State University agreed with these workers that a lower basal metabolic rate occurs in the winter.

Contrary to this, Hafkesbring and Collett (1924) reported a study of four months duration including 96 experiments on one subject and 80 on another. They found the basal rate was about

five percent higher in cold than in hot weather. Further conflicting evidence was presented by Tilt (1930), a Florida worker, who observed no change in the basal metabolism of her subjects with the change in season. However, seasonal changes in Florida temperature are comparatively slight.

On the other hand there have been several studies made in different states on the basal metabolism of college women which have indicated a lower rate in warm climates. Coons (1931) found the mean per square meter per hour for normal Oklahoma women was 32.6 Calories. This value was 13.2 percent lower than the Aub-Du Bois standard. Later, Coons working with Schiefelbusch (1932) attempted to find an explanation for this low metabolic rate of their Oklahoma subjects. They suggested that prolonged undernutrition was a contributing factor in many cases.

In Tilt's (1930) Florida studies mentioned above, the average metabolic rate of 52 women students between the ages of 17 and 25 years was 10.6 percent below the Aub-Du Bois standard. She suggested that women living in a southern climate may maintain a lower basal rate than those living in the northern states. Working with Walters (1935), she continued this study with 30 normal women of 17 to 26 years of age, who had lived in Florida eight years or longer. The mean deviation from the Aub-Du Bois standard for this group was -14.1 percent. A second group of women which had recently come to Florida from the North was also studied by these workers. This group was only 7.7 percent below the Aub-Du Bois standard which confirmed

their earlier work.

McCord (1939) described a study of 75 Indiana University women for whom the mean deviation was -9.0 percent from the Aub-Du Bois standard. She also recommended a lowering of these standards for women.

Pittman, et al. (1943) reported basal metabolism studies on 576 college women from Iowa, Kansas, Minnesota, Ohio, and Oklahoma. The subjects ranged in age from 17 to 24 years, inclusive. They concluded:

The basal rates for subjects from the different states were significantly different. Something more than temperature in the geographical region represented is needed to explain the differences in basal rates although it would seem to have some influence. In general the rates were lower in warmer climates.

Similar metabolism studies by Rogers (1939) of Connecticut College women showed an average deviation from the Aub-Du Bois standard of only -2.3 percent. This is considerably higher than the metabolic rate of the Florida and Oklahoma subjects and suggested that those living in colder climates have a higher basal metabolic rate than those from warmer regions.

In Wyoming, McKittrick (1935) obtained for 100 college women, who had lived in Wyoming ten years or longer, a basal rate only 3.18 percent below the Aub-Du Bois standard. She suggested the higher basal metabolism of Wyoming compared with that of Florida and Oklahoma subjects might be due to the higher altitude rather than lower temperature. Crile and Quiring (1939) in an altitude study on one white male reported that the

mean of five tests at an altitude of 8100 ft. was -7.5 percent. This same subject at an altitude of 800 ft. showed a deviation of ten percent below the standard. These results indicated a higher metabolic rate at a higher altitude.

Contrary to this, Lewis, et al. (1943) presented a study made with five women and two men in which metabolism tests were made at Denver, Colorado with an altitude of 5280 ft., Stillwater, Oklahoma at 910 ft., and Eldora, Colorado at 8720 ft. The subjects remained at each altitude long enough to become acclimated and basal tests were taken daily. They found little change in the basal metabolism of their subjects and believed that change in altitude below 9000 ft. does not affect the basal metabolic rate.

However, McCrery, et al. (1943), working with 124 Texas women of 18-38 years, inclusive, reported a deviation of -10.5 percent from the Aub-Du Bois standard for their subjects. They suggested that the differences could not be attributed to altitude or temperature. Rather, these investigators believed the variations could result from lack of agreement in techniques and interpretation of data.

Many studies have been made on race as a factor affecting basal metabolism. Most of the investigators have found that the Orientals have a low basal rate. MacLeod, Crofts, and Benedict (1925) studied nine normal Oriental women who had been transplanted to an American climate and conditions of living. They still showed a deviation of -10.4 percent from the stand-

ard, suggesting that the Orientals retain their low basal rate when moved to other climates. Mason (1934) measured the basal metabolism of 34 European women living in India and found it low compared with that of European women living in their native environment. However, it was higher than that of native Indian women. This investigator concluded that something more than climate was necessary to explain the differences found in the two groups. She suggested that only about five percent of the low metabolism of the Indian women could be credited to the effects of a tropical climate. In her estimation, race was the important factor in the differences obtained.

Crile and Quiring (1939) reported on the basal rates of the Indian and Eskimo peoples of Canada. They found the male Indians averaged 18 percent above the Aub-Du Bois standard while the mean for the Indian women was 18.5 percent. Similar high rates were obtained for Eskimo men and women. These investigators believed these high results were probably due to a combination of the factors of race and climate.

It is agreed that sleep causes a lowering of the basal metabolic rate. Some workers have suggested that the Orientals in basal conditions were relaxed as much when awake as is an average Westerner during sleep. Benedict and Mason (1934), studying the effects of sleep upon the basal metabolism of South Indian women and western women living in India, reported a fall in the basal rate of both groups. The amount of decrease was approximately the same for the South Indian women as for the

western ones. Thus it would seem from this work that the state of relaxation of the body could not account for the differences noted while the subjects were awake. This is contrary to the belief that the Orientals are more relaxed when awake than members of the white race.

Barnes (1943) presented a study of more than 1000 basal metabolism records of women in which many subnormal temperatures were noted. With these subjects the body temperature was never up to normal unless some type of infection was present.

Dill, Edwards, and Forbes (1934) found it of interest to study the effects of cigarette smoking on basal metabolism. Their subjects rested 90 minutes in a fasting state, then smoked a cigarette and rested 45 minutes longer before the test was made. These investigators noted that smoking one cigarette produced an increase of five to 15 percent in the basal metabolic rate of some subjects. However, this was not uniformly true.

Later, Goddard and Voss (1942) also reported inconsistency in the effects of cigarette smoking upon the basal rates of university men and women. In some cases the basal rate was higher and in others lower after smoking three-fourths of a cigarette.

The effects of coffee upon the basal metabolism of young women was investigated by Hackett (1931). She found that coffee drinkers had an average basal rate some six percent higher than that of the non-coffee drinkers.

Numerous basal metabolism studies have been made at Kansas State College in Manhattan. Working with 24 Kansas girls of 10-12 years, inclusive, Sister Mary Donata Bissette (1942) found the mean basal rate for this group was 0.2 percent above the Aub-Du Bois standard. Osbourne (1940) obtained an average of -8.8 percent for 25 Kansas girls of 16-18 years, inclusive. The higher rate might be expected for the younger girls as they were in the early stages of adolescence while those in the second study were approaching adulthood.

In the college group Shinkle (1937) noted that 54 freshmen women, averaging 19.7 years of age and coming from all over the state, showed a deviation of -7.8 percent from the Aub-Du Bois standard. Those living in Kansas at least eight years previous to the experiment were 9.0 percent below the standard which suggested a low rate for Kansans of long standing. The findings of Pittman, et al. (1943) for a somewhat older group of 182 Kansas State College women of 20-22 years, inclusive, indicated a mean basal rate of -10.84 percent.

Richardson (1939), considering the age-group of 25-30 years, inclusive, obtained a mean basal rate of -11.88 percent for 25 Kansas women. These studies suggest a fall in basal metabolism with increase in age.

The object of the present study was to extend the above work to include 26 Kansas women of 30-34 years of age, inclusive.

PROCEDURE

The metabolism apparatus used in this investigation was a 1935 Benedict-Roth closed-circuit model of portable type in which the air was kept in circulation by flutter valves. These valves directed the flow of air in such a manner that the subject inhaled oxygen from the spirometer bell and the exhaled air was returned through soda lime into the spirometer chamber. The soda lime removed carbon dioxide and most of the water vapor from the exhaled air. To prevent leakage of oxygen from the spirometer bell, a water seal was used. Also the bell was carefully balanced so that it would rise and fall with each respiration without friction. A graphic ink-record was made by means of a specially designed pen and a calibrated kymograph paper. The subject was connected with the breathing tubes by a soft rubber mouthpiece. By placing a clamp on the nose, breathing through the mouth was secured and a closed circuit insured.

To obtain standard basal metabolism conditions for a determination the subject was given the following directions in advance of a test: (1) have at least eight hours of sleep the night before the test, (2) eat a light supper, (3) eat no food (except water) after supper and postpone breakfast until after the test, (4) do not smoke in the morning before the test, (5) allow enough time to dress leisurely in the morning, (6) take a taxi or ride in a car to the laboratory for the test, and (7)

avoid a test within four or five days before or after a menstrual period.

The subject upon arrival at the laboratory was requested to rest in a reclining position at a comfortable room temperature for at least 30 minutes before beginning the determination. Thus the standard conditions for a basal metabolism test were obtained, i.e., a postabsorptive state, lying quietly in a relaxed condition both physically and mentally, awake, and comfortably warm.

After resting for 30 minutes or longer the body temperature was taken by mouth, two half-minute counts were made of the pulse, and without the subject's knowledge the respiration was counted for a one-minute period. These results were recorded for future reference.

The machine was filled with oxygen until the pen came within two inches of the bottom of the kymograph paper. The apparatus was moved conveniently near the subject and the spirometer rebalanced if necessary. The sterile mouthpiece was attached to the two-way valve connection of the breathing tubes. These tubes were held in place by an adjustable flexible arm. The position of the mouthpiece was explained to the subject and that she would breathe room-air until the valve was turned, at which time she would breathe the oxygen from the machine. The nose clamp was applied, the mouthpiece inserted, the kymograph drum started, and after a few seconds the valve turned so that the subject was breathing the oxygen from the spirometer bell.

No discomfort was observed under these conditions.

The temperature of the spirometer bell was read at the beginning and again at the end of each eight-minute test. If the rise or fall in temperature was one degree Centigrade or more an additive or subtractive correction was made of 0.5 cc of oxygen for each degree of change. Lesser changes were ignored.

Two tests were made on a subject on each of two mornings, scheduled as close together as possible. Four observations were thus obtained on each subject and the mean of the four was used as the basal metabolic rate for that person.

Each determination was of eight minutes duration but only six minutes were used for the calculations. During the fourth minute a "leak tester" (a 50 g weight) was placed on top of the spirometer bell and left in position for one minute. If the connections were air-tight a slight rise would be noticed in the tracings of the pen which would drop back in line again when the weight was removed. In case of a leak, this added weight caused the oxygen to escape faster and the subject's respirations would assume a steeper angle as evidenced by the graphic record on the kymograph paper. When a leak was apparent, the test was stopped and the nose-clamp, mouthpiece, and connections were tightened. Then a new test was made.

After the first eight-minute determination was finished the subject was allowed to rest five minutes before starting the second one. During this time the following information was obtained: (1) the number of hours of sleep or rest in bed obtain-

ed the night before, (2) the number of cigarettes smoked the day before the test, (3) the number of cups of coffee consumed the previous day, (4) the date of the last menstrual period, (5) the date of birth, and (6) the number of years the subject had lived in Kansas.

The spirometer bell was again filled with oxygen and the second eight-minute observation was made in the same manner as the first. At the close of the second test the subject's height was taken in centimeters and her weight in kilograms. Also the barometric pressure was read. Before she left the laboratory the subject was served a light breakfast consisting of an orange, a graham cracker, and a glass of milk.

From the slope of the respirations recorded on the kymograph paper it was possible to calculate the amount of oxygen consumed over a six-minute period. The size of the spirometer bell was such that it contained exactly 20.73 cc of oxygen per millimeter of height. One liter of oxygen has a heat equivalent of 4.825 Calories under the conditions of this test which assumes that the subject has been consuming a mixed diet. A fall of the bell of one millimeter in six minutes is equivalent to 20.73 cc of oxygen used in six minutes. This is the same as 207.3 cc or 0.2073 l of oxygen per hour. Therefore, 0.2073×4.825 equals one Calorie per hour per millimeter of fall in the spirometer bell. Corrections for barometric pressure and temperature, taken during the basal metabolism test, were necessary to reduce the consumption of oxygen to

standard conditions of 760 mm at 0° C.

RESULTS

The basal metabolism data for 26 Kansas women of 30-34 years, inclusive, appear in Table 1. These are computed on the basis of age, height, weight, and surface area. They indicate for each subject, respectively, the total calories, calories per centimeter, and calories per kilogram for 24 hours, and the calories per square meter per hour. Also the percentage deviation from the basal rate predicted from the Aub-Du Bois standard as modified by Boothby and Sandiford (1929) is shown. In the calculation of the means the data from all four basal metabolism tests of each subject were used whether or not they checked within the conventional five percent frequently recommended. Young, et al. (1943) found little difference in reporting mean basal metabolism computed by using all data or only that which checked within five percent. According to these workers, any selection of data would bias the variance and eliminate nearly 50 percent of the observations. Consequently all data were used in this study.

Table 1. Basal metabolism data for 26 Kansas women.

Subject No.	Age yr.	Years in Kansas	Married or single	Cigarettes per day	Cups of coffee per day	Body temperature ° F.	Pulse rate per minute	Respirations per minute	Height cm	Weight kg	Surface area sq m	Mean Calories per 24 hrs.			Calories per sq m per hr.	Deviation from standard** percent
				number	number		minute	minute	cm	kg	sq m	total	cm	kg	per hr.	percent
1	30	30	M	0	2	97.8	51	14	174.0	66.4	1.78	1327.3	7.6	20.0	31.1	-14.2
2	30	29	M	0	0	97.6	67	16	173.5	69.2	1.82	1376.0	7.9	19.9	31.5	-13.0
3	30	8	M	10	4	98.4	65	15	164.0	49.1	1.51	1380.3	8.4	28.1	38.1	+ 5.2
4	30	25	M	0	0	98.0	60	20	170.0	63.6	1.72	1279.9	7.5	20.1	31.3	-14.3
5	30	7	M	0	2	98.2	61	14	173.5	51.8	1.61	1268.5	7.3	24.5	32.8	- 9.3
6	31	31	M	0	4	98.4	69	16	170.0	56.6	1.64	1332.0	7.8	23.5	33.8	- 6.5
7	31	7	S	0	3	97.2	70	23	165.0	55.6	1.60	1139.3	6.9	20.5	29.7	-18.0
8	31	31	M	0	4	98.0	70	16	159.0	55.9	1.56	1395.7	8.8	25.0	37.3	+ 3.0
9	31	31	S	0	0	98.0	67	15	166.8	61.3	1.68	1370.8	8.2	22.4	34.1	- 5.5
10	31	31	S	0	1	97.8	61	15	158.8	64.2	1.65	1257.4	7.9	19.6	31.8	-12.3
11	32	32	M	0	2	97.8	61	12	158.5	48.3	1.46	1033.5	6.5	21.4	29.5	-18.5
12	32	32	M	0	2	98.2	71	12	169.5	64.9	1.74	1349.0	8.0	20.8	32.4	-10.5
13	32	32	S	0	3	98.4	72	12	164.5	64.2	1.69	1337.0	8.1	20.9	33.0	- 9.0
14	32	32	M	0	1	98.0	51	15	164.6	53.6	1.57	1161.2	7.1	21.7	30.8	-14.9
15	32	32	M	0	1	98.4	60	13	160.8	53.1	1.54	1206.7	7.5	22.7	32.8	- 9.5
16	33	33	S	0	1	98.2	56	15	169.5	58.0	1.66	1168.3	6.9	20.0	29.2	-19.2
17	33	33	S	0	1	97.8	63	14	169.5	52.9	1.60	1232.7	7.3	23.5	32.1	-11.3
18	33	33	S	10	4	98.4	68	14	160.0	59.2	1.61	1289.1	8.1	21.7	33.4	- 7.7
19	33	32	S	0	2	97.6	60	15	164.0	65.5	1.70	1296.4	7.9	19.8	31.8	-12.2
20	33	30	S	0	1	98.4	61	15	170.5	96.9	2.08	1786.1	10.5	18.4	35.9	- 4.7
21	33	33	M	0	2	98.4	61	16	160.0	66.0	1.68	1582.7	9.9	24.0	39.3	+ 8.4
22	34	7	M	0	0	98.2	54	14	166.5	57.6	1.63	1241.5	7.5	21.6	31.7	-12.0
23	34	7	S	0	2	97.8	61	13	168.5	65.9	1.75	1311.8	7.8	19.9	31.2	-13.7
24	34	34	M	0	3	97.8	62	16	166.0	71.4	1.78	1267.7	7.6	17.8	29.7	-18.0
25	34	34	M	0	0	98.2	54	11	166.0	56.9	1.62	1158.5	7.0	20.4	29.8	-17.7
26	34	34	S	0	0	97.4	65	16	169.5	69.3	1.79	1257.7	7.4	18.1	29.3	-19.1
Median							61.0	15.0	166.3	60.3	1.66	1284.5	7.7	20.9	31.8	-12.1
Mean		26.9				98.0	62.3	14.9	166.2	61.4	1.67	1300.3	7.8	21.4	32.4	-10.6
Standard error							1.20	0.054	0.96	2.0	0.002	24.0	0.176	0.440	0.520	1.44

*M = married; S = single.

**Aub-Du Bois as modified by Boothby and Sandiford (1929).

The mean basal metabolic rate of the 26 subjects expressed as percentage deviation from the modified Aub-Du Bois standard was -10.6 (Table 1). This was higher than the findings for a slightly younger group studied by Richardson (1939) who reported that the basal rate of 25 Kansas women of 25-30 years, inclusive, showed a -11.88 percent deviation. However, in the present study 54 percent (14 subjects) had a mean basal rate of -15.5 percent. This was considerably lower than that indicated by Richardson (1939) and suggests that a lowered rate was evident for the majority of these older subjects.

Many workers including Harris and Benedict (1919) have agreed that as age increases the basal metabolic rate decreases. Later, Benedict (1928) modified this statement by reporting that the basal rate remains fairly constant between the ages of 20-40 years. He, therefore, assumed that the effects of age are less at this particular time of life. When more subjects in these two age-groups are studied the above mean basal metabolic rates may be expected to be modified to some extent. It will then be of interest to note if the basal metabolism for 30-34 year old Kansas women will be lower than that of the 25-30 year women.

In grouping the subjects according to the number of years they had lived in Kansas, it was found that 81 percent (21 women) had made their home in this state 25 years or longer. The remaining 19 percent had resided in this region only seven or eight years. The first group was 10.8 percent and the second

9.6 percent below the modified Aub-Du Bois standard. The subjects living in Kansas for many years apparently had a somewhat lower basal rate than those living here for a comparatively short time. This raises the question of geographical location as a possible factor affecting basal metabolism. Tilt and Walters (1935) and Pittman, et al. (1943) have suggested that it may account for significant differences in results.

Of the women in this study, 58 percent (15 subjects) were married. For them, the mean basal rate was -9.5 percent. The 11 unmarried subjects had a somewhat lower basal metabolism averaging 12.1 percent below the modified Aub-Du Bois standard. Possible explanations for the higher basal metabolism of the married women may be their home responsibilities, the care and management of their children, and perhaps the effects of their sexual life. However, many studies need to be made involving more subjects before any conclusions can be drawn concerning the effects of this factor upon basal metabolism.

The mean body temperature for the 26 subjects was 98.0° F. In no case was the so-called normal temperature of 98.6° F. observed. The mean for this study is identical with that reported by Barnes (1943) for more than 1000 women in whom he found that body temperature was never up to normal. Temperatures taken in the early morning, as these were, may be expected to be lower than they would be at the end of the day. Barnes (1943) believed women have a more variable and lower body temperature than men. Certainly the temperature was low in these

tests and Pittman, et al. (1943) noted a similar mean temperature of 97.9° F. for 379 Kansas subjects. Barnes (1943) has indicated that a low basal rate tends to accompany a low body temperature. He also suggested that it may be used by physicians as indicative of a need for thyroid therapy.

Hackett (1931) observed that habitual coffee drinkers had a higher basal metabolism than non-coffee drinkers. In the present study 77 percent (20) subjects were coffee drinkers and their mean basal rate was -9.3 percent. The remaining six subjects who were non-coffee drinkers maintained a definitely lower basal metabolism averaging -13.6 percent. Of the coffee drinkers, four women consumed at least four cups of coffee daily and they had a decidedly higher rate being only 1.5 percent below the modified Aub-Du Bois standard. These are interesting observations but more studies with greatly increased numbers are needed before any conclusive statements can be made.

Only two subjects in this study smoked and there was a wide range between their basal rates. More data for women who smoke cigarettes should be studied before drawing conclusions concerning the effects of cigarette smoking upon basal metabolism.

Wide variation was observed for each measurement as shown in Table 2. For example, the percentage deviations from the standard for the entire group ranged from a low of -19.2 to a high of 8.4. The Calories per square meter per hour varied from 29.2 to 39.3, and total Calories per 24 hours from 1033.5 to 1736.1. This tendency to vary was also true when each year

Table 2. Analysis of basal metabolism data.

Subjects age yr.	Limits and number	Pulse/min.	Respirations/min.	Height cm	Weight kg	Surface area sq m	Calories per 24 hrs.			Cal./sq m/hr.	Deviation from standard* percent
							total	per cm	per kg		
All											
30-34	26	Limits: 51-72 Mean: 62.3	11-23 14.9	158.5-174.0 166.2	48.6-96.9 61.4	1.46-2.08 1.67	1033.5-1786.1 1300.3	6.5-10.5 7.8	17.8-28.1 21.4	29.2-39.3 32.4	-19.2 to + 8.4 -10.6
Grouped according to age											
30	5	Limits: 51-67 Mean: 60.8	14-20 15.8	164.0-174.0 171.0	49.1-69.2 60.0	1.51-1.82 1.69	1268.5-1380.3 1326.4	7.3-8.4 7.8	19.9-28.1 22.5	31.1-38.1 33.0	-14.3 to + 5.2 - 9.1
31	5	Limits: 61-70 Mean: 67.4	15-23 17.0	158.8-170.0 163.9	55.6-64.2 58.7	1.56-1.68 1.63	1139.3-1370.8 1299.0	6.9-8.8 7.9	19.6-25.0 22.2	29.7-34.1 33.3	-18.0 to + 3.0 - 7.9
32	5	Limits: 51-72 Mean: 63.0	12-15 12.8	153.5-169.5 163.6	48.3-64.9 56.8	1.46-1.74 1.60	1033.5-1349.0 1217.5	6.5-8.1 7.4	20.8-22.7 21.5	29.5-33.0 31.7	-18.5 to - 9.0 -12.5
33	6	Limits: 56-68 Mean: 61.5	14-16 14.8	160.0-169.5 165.6	52.9-96.9 66.4	1.60-2.08 1.72	1168.3-1786.1 1392.6	6.9-10.5 8.4	18.4-24.0 21.2	29.2-39.3 33.6	-19.2 to + 8.4 - 7.8
34	5	Limits: 54-65 Mean: 59.2	11-16 14.0	166.0-169.5 167.3	56.9-71.4 64.2	1.62-1.79 1.71	1158.5-1311.8 1247.4	7.0-7.8 7.5	17.8-21.6 19.6	29.3-31.7 30.3	-19.1 to -12.0 -16.1

*Aub-Du Bois as modified by Boothby and Sandiford (1929).

of age was studied separately. No uniform rise or fall could be observed. However, there was a tendency for the mean of the above measurements in the 34-year group to be lower than those for 30 years, indicating a fall with increased age. The mean weight and surface area were higher in the 34-year group which might be expected as people over 30 years of age are inclined to "put on weight." But these factors of weight and surface area, which determine the size of an individual, also affect the basal rate. So with numbers so few and the factor of size entering in, it is not possible to say that the basal rate declined from 30 to 34 years, although there appears to be a tendency in this direction.

It was of interest to find the range limits of the measurements for the majority of the subjects. In order to exclude the extremes, the middle 54 percent (14 subjects) of the women were chosen for this analysis. These limits are compared with the mean and median for the entire group in Table 3. For this limited group the Calories per square meter of body surface per hour ranged from 30.8 to 33.4 while those for the mean subject were 32.4 and the median, 31.8. The basal rate varied from -14.9 to -7.7 per cent from the modified Aub-Du Bois standard, while the percentage deviation for the mean and median were -10.6 and -12.1, respectively. The weight of this middle group ranged from 55.6 to 65.9 kg. The mean weight was 61.4 and the median 60.3 kg. The standard weight for women adopted by the Food and Nutrition Board of the National Research Council is

Table 3. The range limits for middle 54 percent of the subjects compared with the mean and median for the group.

	Height cm	Weight kg	Surface area sq m	Calories per 24 hrs.			Cal./sq m/hr.	Deviation from standard* percent
				total	per cm	per kg		
Limits for middle 54 percent	164.0-169.5	55.6-65.9	1.60-1.74	1232.7-1349.0	7.3-8.1	19.9-22.7	30.8-33.4	-14.9 to -7.7
Mean**	166.2	61.4	1.67	1300.3	7.8	21.4	32.4	-10.6
Median**	166.3	60.3	1.66	1284.5	7.7	20.9	31.8	-12.1

*Aub-Du Bois as modified by Boothby and Sandiford (1929).

**For entire group.

56 kg. This weight has been widely used for many years for the average woman of moderate activity. It was observed that 69 percent of the entire group (18 subjects) were above this standard, showing that these Kansas women of 30-34 years of age tended to be heavier than the standard accepted for women. Again, larger numbers are needed to prove the point which is indicated in this analysis.

To study the effects of size upon basal metabolism (Table 4) the factors of surface area, weight, and height were considered. The extremes for each of these measurements were selected, five subjects for each. It was noted that the five largest women based on surface area and the five heaviest based on weight were the same subjects. Three of these same five were also found in the tallest group. There were fewer duplicates in the "smallest," "lightest," and "shortest" groups. From the standpoint of surface area or weight the smallest subjects used fewer total calories and calories per centimeter of height, but consumed more calories per kilogram and per square meter of body surface. Also they had a lower percent of deviation when compared with the modified Aub-Du Bois standard which indicated a higher basal metabolism. On the basis of height the same tendencies are evident except the calories per centimeter were identical.

Body surface expressed as calories per square meter per hour is considered the method that agrees best for all individuals in expressing basal metabolism according to Blunt (1926), McKay (1930), Boothby, Berkson, and Dunn (1936), and Du Bois

Table 4. Effects of size upon mean basal metabolism.

Subjects: number	Size	Surface area sq m	Calories per 24 hrs.			Cal./sq m/hr.	Deviation from standard* percent
			total	per cm	per kg		

On basis of surface area

5	:Smallest:	1.53	: 1235.5	: 7.7	: 23.8	: 33.7	: - 7.0
5	:Largest :	1.85	: 1403.0	: 8.2	: 18.8	: 31.5	: -13.8

On basis of weight

5	:Lightest:	1.54	: 1224.3	: 7.4	: 24.0	: 33.1	: - 8.7
5	:Heaviest:	1.85	: 1403.0	: 8.2	: 18.8	: 31.5	: -13.8

On basis of height

5	:Shortest:	1.59	: 1311.7	: 8.2	: 22.3	: 34.3	: - 5.4
5	:Tallest :	1.79	: 1418.0	: 8.2	: 21.3	: 33.0	: - 9.5

*Aub-Du Bois as modified by Boothby and Sandiford (1929).

(1936). However, this study suggests that calories per centimeter per 24 hours give more consistent results as there was closer agreement when the data of these women were compared on the basis of height than on that of surface area or weight.

Among the women in this study there were two of the same weight (Subjects 10 and 13). In comparing their basal metabolism it was noted that the taller person had a larger surface area, consumed more total calories, and had higher caloric needs per centimeter, per kilogram, and per square meter. She also had a higher basal metabolic rate as indicated by a smaller deviation from the standard. This agrees with Du Bois (1936) who stated that heat production is proportional to surface area.

Table 5 shows the effects of age upon the basal metabolism of Kansas women. The mean basal metabolic rates taken from the available studies of Kansas subjects 16-34 years of age shows a decrease in basal metabolism as age increases. This agrees with the findings of Harris and Benedict (1919), Benedict (1928), and Du Bois (1936). The Kansas subjects of 16 years consumed 35.0 Calories per square meter per hour while the women of 34 years used only 30.3 Calories. In contrast to these figures, the Aub-Du Bois standard as modified by Boothby and Sandiford (1929) for these years is 38.5 and 36.2 Calories, respectively. This not only shows the effects of age upon the basal rate but emphasizes that these standards are too high for Kansas women.

This difference between Kansas subjects and the modified Aub-Du Bois standard is developed further in Fig. 1. Mean basal

Table 5. Mean basal metabolism of Kansas women 16-34 years of age compared with standard.¹

Age yr.	Subjects: number	Cal./sq m/hr.	Standard ¹ Cal./sq m/hr.	Deviation from standard ^{1,2} percent
16 ³	13	35.0	38.5	- 9.09
17 ⁴	38	35.0	37.4	- 5.61
18 ⁴	58	33.6	37.3	- 8.28
19 ⁴	77	33.2	37.2	-11.02
20-24 ⁴	206	32.8	36.9	- 9.48
25-29 ⁵	25	32.2	36.6	-12.00
30-34 ⁶	26	32.4	36.2	-10.49

¹Aub-Du Bois as modified by Boothby and Sandiford (1929).

²Calculated from Aub-Du Bois standard as modified by Boothby and Sandiford (1929).

³Osbourne (1940).

⁴Pittman, et al. (1943).

⁵Richardson (1939).

⁶Present study.

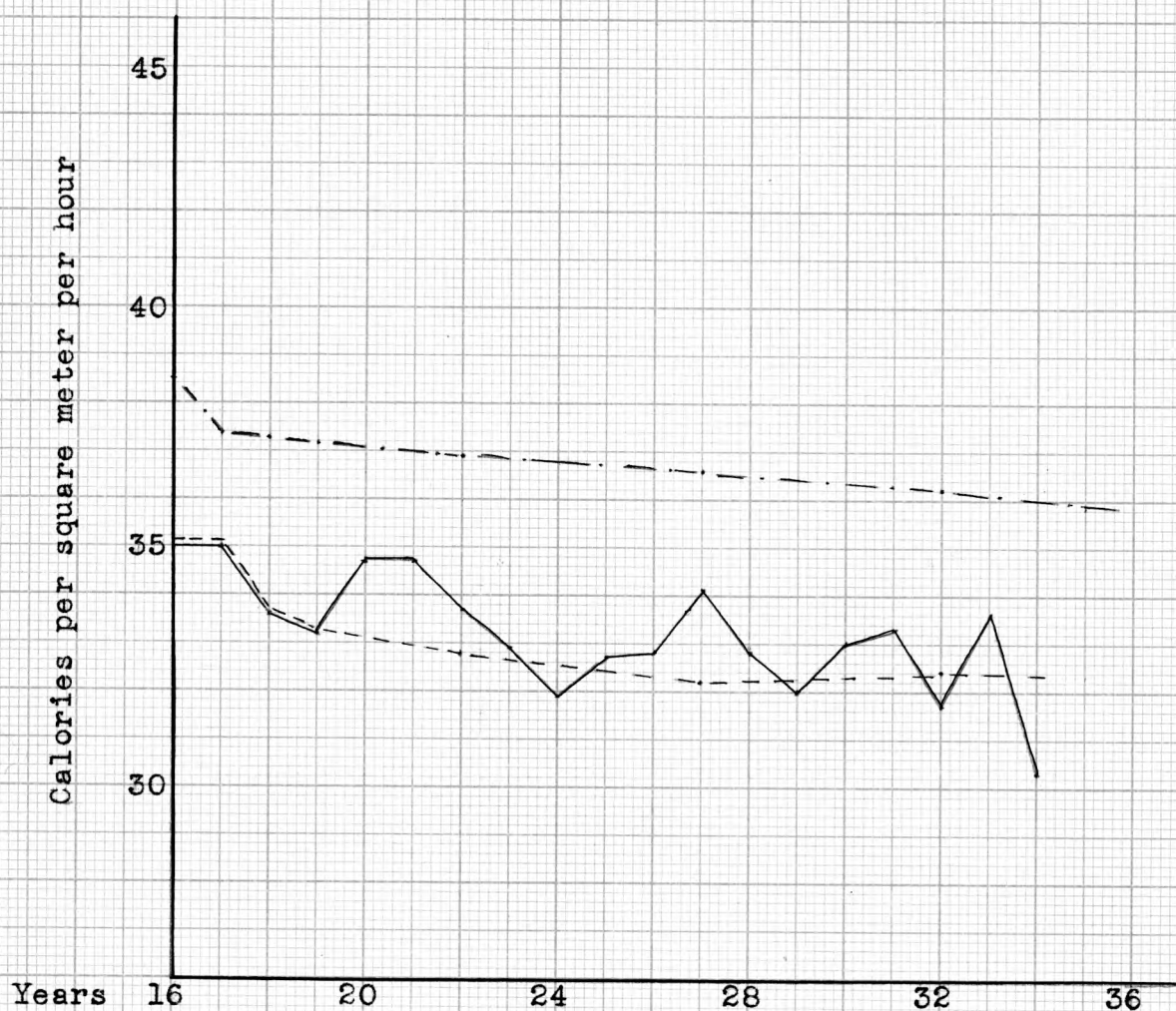


Fig. 1. Showing the mean calories per square meter per hour consumed by Kansas women of 16-34 years of age compared with the Aub-Du Bois standard as modified by Boothby and Sandiford (1929).

- Kansas women according to year.
- - - - Kansas women according to the grouping of standard.
- . - . - Aub Du-Bois standard as modified by Boothby and Sandiford (1929).

metabolic rates of the Kansas subjects, expressed as calories per square meter per hour, showed considerable variation when the individual years were studied. Variations in the basal metabolism of women from day-to-day and year-to-year may be expected according to Hafkesbring and Collett (1924), and Hitchcock and Wardell (1930). However, when the comparison is made with the same grouping of years used by Aub-Du Bois the irregularities are less evident and the decrease in calories is practically the same so the graph lines are fairly parallel. The calories per square meter per hour consumed by the Kansas subjects are undoubtedly lower than the Aub-Du Bois standard as modified by Boothby and Sandiford (1929). This agrees with Benedict (1928), Stark (1933), and McCord (1939) who reported that these standards are too high for women.

Numerous studies have been reported on the basal metabolism of college women in various states but few investigators have carried the work beyond the college age to include women of 30-34 years. Table 6 shows the mean calories per square meter per hour and the mean outside temperature for four states reporting on this older group. As the temperature increased the calories per square meter per hour decreased, showing that the basal rate tended to be lower in the warm climates. This agrees with the findings of Tilt (1930), Coons (1931), Rogers (1939), and Pittman, et al. (1943).

The altitudes of the cities where the above reports were made are: Rochester, Minnesota, 988 ft.; Columbus, Ohio,

744 ft.; Manhattan, Kansas, 1002 ft.; and Stillwater, Oklahoma, 870 ft. According to McKittrick (1936) the higher basal rates of women in Laramie, Wyoming may be due to altitude (7148 ft.). Contrary to this, Lewis (1943) suggested that altitude is not an important factor in basal metabolism until a height of 9000 ft. is reached. The difference in altitude of the four midwestern cities mentioned above is not sufficient to cause changes in basal rates.

Table 6. Mean basal metabolism for women of 30-34 years related to temperature.

State	Mean temperature ^{5,6} for state ° F.	Subjects: number	Cal./sq m/hr.	Deviation from standard ⁷ percent
Minnesota ¹	41.7	54	35.5	- 1.9
Ohio ²	51.2	18	34.0	- 6.1
Kansas ³	57.0	26	32.4	-10.6
Oklahoma ⁴	59.3	9	31.3	-14.3

¹Boothby, Berkson, and Dunn (1936).

²McKay (1930).

³Present study.

⁴Coons (1931).

⁵U. S. Weather Bureau Climatological Data (1941).

⁶Minnesota, 1891-1941; Ohio, 1883-1941; Kansas, 1887-1941; Oklahoma, 1892-1941.

⁷Aub-Du Bois as modified by Boothby and Sandiford (1929).

SUMMARY

The mean basal metabolic rate for 26 Kansas women of 30-34 years, inclusive, was 10.6 percent below the modified Aub-Du Bois standard. For subjects living in Kansas at least 25 years the deviation was -10.8, while those living in this state only seven or eight years averaged -9.6 percent below the standard. This work suggests that subjects living in Kansas for many years have a somewhat lower basal rate than those residing in the state for a shorter time.

Considerable individual variation was observed for subjects of the same age but there appears to be some tendency for the basal metabolic rate to decrease from 30 to 34 years of age. A more marked decrease in basal metabolism is indicated when all the studies available for Kansas women of 16-34 years, inclusive, are considered.

In all subjects the body temperature was below the so-called normal of 98.6° F.

From the standpoint of surface area or weight the smaller subjects had a higher basal rate and used more calories per kilogram and per square meter of body surface but consumed fewer total calories and calories per centimeter.

As the mean temperature of Kansas is higher and the basal metabolism of these subjects is lower than that obtained by investigators in some other states, the results of this work

suggest that the basal rate of women tends to be low in Kansas.

More data based on larger numbers are needed to determine new standards and to make conclusive statements regarding basal metabolism of women.

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