THE BASAL METABOLISM OF OKLAHOMA COLLEGE WOMEN

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By

ZELMA PATCHIN

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APPROVED:

Gladys M. Kinsman

In Charge of Thesis

Daisy I. Purdy

Head of the Household Science Dept.

D.C. McIntosh

Dean of the Graduate School

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PREFACE

Information relating to the basal metabolism of young women between the ages of seventeen and twenty-four years, inclusive, has been rather limited in the past. However, at present, the subject has received a new impetus and studies are being conducted in many regions of the United States.

There is a great deal of discussion, among the contributors to the literature, as to the influence of such factors as age, climate, and altitude on the basal metabolism. It is the purpose of this study of the basal metabolism of Oklahoma college women to determine values of the heat production of these young women. The number of cases included in this study is not sufficient to permit dogmatic conclusions on the basal metabolism of Oklahoma college women, but the results will indicate whether there is a tendency for the basal metabolism of young women of Oklahoma to vary from the published data on heat production obtained with subjects of similar status.

Basal metabolism is an important phase of the subject of energy metabolism which was the beginning of the subject of nutrition. A review of the early development of the subject of energy metabolism seems pertinent to this paper on basal metabolism.

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HISTORICAL REVIEW*

The world's knowledge of the subject of energy metabolism before the seventeenth century consisted of the realization that, although the weight of the obvious excrements of the body was less than that of the food and liquids ingested, the weight of an adult man did not continue to increase. In 1614 Sanctorius followed the changes in his own weight, before and after meals, by means of a chair suspended from a steelyard. After many observations he concluded that processes other than the simple ingestion of sensible supplies and the elimination of body wastes occurred in the body. He advised those persons who were giving consultations on health to consider the waste that was made daily by the insensible perspiration of the body. During this same century, in 1668, Mayow added to the information on the subject of energy metabolism by stating that a substance which supported the combustion of the foodstuffs was furnished to the body by the atmosphere.

The modern era of the science of energy metabolism began in the latter part of the eighteenth century with the observations of Lavoisier, who substantiated Mayow's statement and gave the name of oxygen to the atmospheric substance which supported combustion. He declared that heat was produced by the oxidation in the body, and that

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*The information in this historical review was obtained from Du Bois (21) and Lusk (29).

oxidation was the basis of life processes. However, Lavoisier believed that a body fluid carried hydrogen and carbon to the lungs and that these two substances united with the oxygen of the air to form water and carbon dioxide. The elimination from the body of the heat produced by this process was regulated, Lavoisier stated, by perspiration. Lavoisier made observations of the respiration of man, and, although there is no record of the apparatus used, the conclusions that he made from this study still stand. He concluded that food, work and temperature determined the quantities of oxygen absorbed and carbon dioxide excreted by the body.

Magnus, in 1837, corrected the false belief that oxidation occurred only in the lungs. He found that the blood held large quantities of oxygen and carbon dioxide. This finding was to him an indication that oxidation must occur in the blood stream. Ludwig, in his later years, also believed that oxidation took place in the blood.

The results of the studies of Liebig, a German chemist and a pupil of Lavoisier, were published in 1842. Liebig is called the father of modern methods of organic analysis. From his discoveries, particularly from those on carbon compounds, the chemical compositions of foods, which he classed as proteins, carbohydrates and fats, and of urine, tissues and feces have become known. Liebig first thought that protein decomposition occurred during muscular activity and that the combustion of carbohydrates and fats was caused by oxygen. He later suggested that the nitrogen in the urine might be a measure of protein decomposition. The plausibility of the latter suggestion was established by Bidder and Schmidt in 1852. In a series of experiments in which they fed meat to dogs and cats, Bidder and Schmidt observed that the nitrogen in the feces and urine was practically equal to the nitrogen content of the food intake. They concluded:

> Almost all the nitrogen of protein and collagen is split from its combination and carries with it enough carbon, hydrogen, and oxygen to form urea; the remaining part, containing five-sixths of the total heat value of the protein, undergoes oxidation to carbon dioxid and water which are eliminated in the respiration, the calorifacient function having been fulfilled.

The work of Bidder and Schmidt was not recognized until Voit established the fact that an animal could be brought into nitrogen equilibrium. Voit conducted an experiment in which a dog was fed a quantity of meat which contained a known amount of nitrogen. The nitrogen in the urine and feces was determined. Such a small quantity of the ingested nitrogen was not accounted for in the urine and feces that Voit suggested that the total nitrogen of protein was excreted in the urine and feces. He continued the verification of his statement by conducting an experiment on the nitrogen excretion of the hair and epidermis of a dog. Voit found that the quantity of nitrogen that was excreted daily through these two channels was negligible. Later, in 1906, F. G. Benedict found that the cutaneous nitrogen excretion of man was very slight and varied with his activity; a slightly greater excretion of nitrogen in a man was produced during a period of hard work than was noted during a rest period. Benedict's observations aided in establishing Voit's suggestion concerning nitrogen excretion. Bachl, experimenting on a rabbit with a tracheal cannula, showed that after six hours of breathing through Nessler's reagent there was no trace of ammonia in the expired air. This observation indicated that the ammonia group produced during protein metabolism was not excreted through the lungs. If nitrogen was not lost in appreciable quantities in respiration or perspiration, its chief outlets were through the urine and feces as had been suggested by Voit. Since the analysis of meat protein had shown that approximately 16 per cent of its content was nitrogen, or that for every gram of nitrogen found in the excreta 6.25 grams of protein were destroyed by the body, information was available for the calculation of heat production from protein metabolism.

Voit and Pettenkofer were stimulated to study further the subject of energy metabolism. Pettenkofer, in 1866, constructed a respiration chamber, the expense of which was defrayed by King Maximilian II of Bavaria. The chamber consisted of a small, well-ventilated room in which a subject could live. It was possible to make analyses of air as it entered and escaped from the chamber. The quantities of carbon dioxide and water derived from a subject in the chamber could thus be determined. The water was removed by passing the air over calcined pumice stone soaked in sulphuric acid. The air was bubbled through baryta water to remove carbon dioxide. The volumes of the air as it entered and as it escaped from the apparatus were measured with gas meters. The apparatus was checked by the use of a burning candle and by evaporating a known weight of water within the chamber. The carbon dioxide and water produced were measurable within one per cent of error.

Experiments conducted in the respiration chamber on a starving man showed that the quantity of oxygen utilized in heat production in the body depended upon the class of foodstuffs burned by the organism. The foodstuff also determined the relationship between the amount of oxygen used and the amount of carbon dioxide excreted. The relationship between the carbon dioxide produced and the oxygen consumed was expressed as a respiratory quotient:

$$\frac{\text{Volume of Carbon Dioxide}}{\text{Volume of Oxygen}} = \text{Respiratory Quotient}$$

In the case of carbohydrates the respiratory quotient was 1.0 because carbohydrates contained in their molecules exactly enough oxygen to combine with their hydrogen to form water and, therefore, in burning they required outside oxygen only for their carbon. The respiratory quotients of protein and fat, found by Voit and Pettenkofer, were 0.781 and 0.71, respectively. Neither protein nor fat contained as much oxygen in their molecules as did carbohydrates; hence, it was necessary that more oxygen be supplied for oxidation of these two foodstuffs.

Pettenkofer observed that during the starvation period fat and protein were burned, and that more fat than protein was oxidized if the subjects were physically active. If, however, carbohydrates were consumed by the subject, the body oxidized the carbohydrates rather than the body fats to furnish the needed energy. This phenomena also occurred if fats and carbohydrates were fed simultaneously.

Some of the incorrect conclusions which had appeared in the literature on energy metabolism were corrected by Voit and Pettenkofer's series of experiments in the respiration calorimeter. The belief of scientists that physical exercise increased the protein metabolism of the body was not verified by these observations. The above workers stated that physical work did not increase protein metabolism and that the energy metabolism of the body was not proportional to the oxygen supply. They also observed that the absorption of oxygen did not initiate metabolism, but that the rate of energy metabolism determined the amount of oxygen to be utilized in heat production. Lossen, a pupil of Voit, and Pflueger concluded that the volume of carbon dioxide formed was independent of the ventilation of the lungs except as forced breathing increased muscular activity of the body tissues and, consequently, increased the amount of carbon dioxide formed. From experiments on men and rabbits, these workers showed that the ratio of carbon dioxide to oxygen in the blood regulates the rate of respiration.

Laplace and Lavoisier in 1780 were the first to realize that body heat was derived from oxidation and to conduct experiments to verify their belief. A known quantity of carbon was burned in an ice-chamber and the amount of ice which was melted was noted. A guinea pig was also placed in an ice-chamber and the quantity of ice melted by the heat of his body was recorded for a ten-hour period. Computations from the data showed that the animal yielded 31.82 calories of heat to the ice-chamber. The analysis of the respiratory gases in the ice chamber showed that 25.408 calories could have been derived by the burning of carbon in the body. Lavoisier realized that the difference between the two determinations of the heat produced, one direct and the other indirect, was caused by errors in his work. The respiratory gases were collected at various temperatures and no corrections were made for the differences. An error in the calculations was also due to the addition of water vapor to the melted ice. Lavoisier concluded that oxidation in the body was the sole source of body heat.

In 1823, Depretz and Dulong, working separately, calculated the amount of heat which should have been produced in the body by the oxidation of the carbon that was exhaled as carbon dioxide. This predicted value of heat production was compared with the amount of heat given off by the animal measured directly by means of a calorimeter. Because of the technics used in the determinations of heat, Depretz found that the amount of heat calculated by the indirect method of calorimetry was from 74 to 90 per cent of the amount determined by the direct method. Each of the workers concluded that although oxidation was the chief source of body heat, it was not sufficient to explain the total production of heat. Depretz stated that the food eaten, the motion of the blood, and friction yielded the heat for which he was unable to account.

In later years, the recognition of certain natural laws, such as the law of the conservation of energy and the mechanical equivalent of heat, called attention to the errors in the work of Depretz and Dulong. Joule, in 1842, established the mechanical equivalent of heat. The law of the conservation of energy was laid down by Mayer in 1845 and again in 1847 by Helmholtz. It is of interest to note that the leading German scientific journal of that period rejected these laws.

Upon the suggestion of Voit, Schurmann, in 1878 and 1879, conducted experiments to find in what way carbohydrates and fats were interchangeable in nutrition. The experiments, which were incomplete at the time of Schurmann's death, were continued by Rubner. The isodynamic law resulted from the series of observations. This law stated that the foodstuffs, i. e., proteins, fats and carbohydrates, under given conditions may replace each other in accordance with their heat-producing value. Rubner gave the following quantities of foodstuffs as isodynamic:

100 grams fat,
232 grams starch,
234 grams cane-sugar,
243 grams dried meat.

Rubner also reported that the oxidation of starch and fat produced the same quantities of heat in the body as were produced in the calorimeter. Whether burned in the body or in the calorimeter, the end products of fats and starch were found to be the same. The fuel value of protein oxidized in the body differed from the heat value obtained by the calorimeter because the end-products were not the same. In the body, the products of the oxidation of protein were excreted in the urine, feces and exhaled air. In determining the heat value of protein to the body, the latent heat lost in the urine and feces were deducted from the heat value of protein determined in the calorimeter. Rubner emphasized the need of considering the heat value of all excretions and not just that of urea in the determination of the fuel value of protein to the body. Rubner applied his findings on energy metabolism to the date of the fasting man of Pettenkofer and Voit and to other human subjects. He concluded that the energy metabolism of the resting individual expressed in calories was proportional to the surface area of the body.

Rubner calculated the calorific values of one gram portions of each of the foodstuffs, i. e., carbohydrates, fats and proteins. His values are still used extensively in calculating the average fuel value of a mixed diet. The standard values are:

1 gram of protein..................	4.1 Calories.
1 gram of fat......................	9.3 Calories.
1 gram of carbohydrate.............	4.1 Calories.

An apparatus which made it possible to measure accurately by direct and indirect calorimetry the heat production of a small animal was devised by Rubner in 1894.

Rubner's observations of animals placed in the calorimeter verified his former calculations and also the method which was originated by Pettenkofer and Voit to determine total energy metabolism.

A calorimeter similar to the one constructed by Rubner was devised by Atwater and Rosa in 1897. The cost of the calorimeter was borne by the United States Government. The calorimeter was sufficiently large to permit the study of the heat production of man while he effected various bodily motions. Experiments conducted in the apparatus confirmed the work done by Rubner on animals.

The first closed respiration system in which oxygen was measured directly, was constructed by Regnault and Reiset in 1850. Using small animals for experimentation, they placed the subject in a glass case containing a known amount of oxygen. This apparatus was improved by Rubner, in 1894, as has been mentioned.

Atwater, Rosa and Benedict in 1915, applying the principles represented in the first respiration apparatus, constructed a respiration calorimeter to determine the heat production of man. The apparatus included two functional parts, one for measuring the gaseous exchange, the other for measuring the heat production of the subject. The determination of the source of the heat produced by the subject was based on the theory of respiratory quotients. Analyses of the nitrogen content of the urine and feces determined the amount of protein oxidation, and from this information the carbon dioxide derived from protein could be calculated.

The carbon dioxide derived from protein oxidation was deducted from the total quantity of carbon dioxide eliminated by the lungs, and the remainder represented the carbon dioxide which could be attributed to the oxidation of carbohydrate and fat. The validity of the indirect method of determining the heat production of man or animals was checked by comparing the values obtained by this method with those obtained at the same time by the method of direct calorimetry. The comparison offered by Atwater and Benedict showed only 0.2 per cent difference.

Benedict, in 1909, devised a unit respiration apparatus for determining heat production of man from the amount of oxygen used. Its simple construction and ease of operation have made the apparatus a valuable addition to the clinical laboratory. With the advent of this apparatus, energy metabolism studies became numerous.

REVIEW OF THE LITERATURE

In this review of the literature on the basal metabolism of young women, only the publications which include in the data information on women who were from seventeen to twenty-five years of age, inclusive, are considered.

A study of the basal metabolism of college women was made by Blunt and Dye (8) in 1921. To determine the influence of the menstrual cycle on heat production, these workers conducted a series of tests on seventeen women whose ages ranged from twenty-one to forty-four years, inclusive. A second series of tests was carried on by Blunt, Tilt and McLaughlin (9) in 1926 on girls ranging in age from eight to eighteen years, inclusive. From ten to eighteen subjects were observed in each age group from nine through thirteen years, and in each of the other five age groups only two or three subjects were included. Four hours before the test, the subject was given a light breakfast from which meat, eggs and coffee were excluded, and she was permitted to attend school during the morning. The basal metabolism test was made at 11:00 o'clock in the morning, after the subject had rested one-half hour. According to Blunt (10), who had previously observed with her co-worker, Bauer, the influence of a light breakfast on the energy metabolism of children, the above treatment of the subjects did not affect the basal metabolic rates. Three forms of the Benedict portable respiration apparatus were used, a Sanborn, a Collins and during the last year a Roth. Tests were made with each subject on two consecutive days, and, if the two tests agreed within five per cent, the average of the two was called the basal metabolism. If the two tests did not agree, a new series was conducted at a later date.

Gustafson and Benedict (22), in 1928, made a study of the influence of seasonal variation on the basal metabolism of college women. The ages of the subjects were from eighteen years to twenty-two years, inclusive. The subjects were described by the authors as unusually healthy young women who engaged in athletic sports and general outdoor activities. Each subject slept in the laboratory the night before the test, and, before rising the following morning, was given a basal metabolism test. A Benedict portable form of respiration apparatus was used to record two 10-minute periods. The mean of the values of the whole group was 1.8 per cent below the Harris-Benedict prediction standards. The percentage deviation of the actual from the predicted heat production ranged from -21.1 to +12.3.

From 1930 to 1935, Tilt (36) collected data on the basal metabolic rates of fifty-two college women between the ages of seventeen and twenty-five years, inclusive. Most of the subjects were native Floridans and had records of normal health. The determinations of the basal metabolism were made in the laboratory between seven and seven-thirty in the morning. The subjects had not eaten for from twelve to thirteen hours and had rested at least one-half hour before the tests were made. Two successive periods of from eight to ten minutes each were used to measure the heat production. The Sanborn-Benedict apparatus, which was used, was tested for leaks by placing a twenty-gram weight on the spirometer during the last four or five minutes of each period. Any period which showed a change in slope, indicating a leak, was discarded. Tests were made with thirty-one of the subjects on two consecutive days and with the other twenty-one subjects on from three to eight days, which were scattered over a period of several months. Only observations which agreed within ten centimeters on the kymograph were reported. The mean of the tests which agreed was taken as the value for the basal metabolic rate. The average heat production of the subjects was 1236 calories per twenty-four hours. This value was lower than that (1396 calories per twenty-four hours) of the group reported by Gustafson and Benedict (22). The values reported by Tilt were 9.9 per cent lower than the Harris-Benedict standards and 10.6 per cent lower than the Aub-Du Bois standards. Tilt offered this study as evidence that the basal metabolism of southern young women had a tendency to be lower than that of northern women of the same age. The range of variation of the values obtained in this study was from -18.5 per cent to a +1.8 per cent from the Harris-Benedict standard, and from -21.5 per cent to +2.7 per cent from the Aub-Du Bois standard. The average value of the basal metabolic rates of eight of the subjects who were physical education majors agreed closely with the average of the group. There did not seem to be an increase in heat production with increased activity as had been suggested previously by Gustafson and Benedict (22).

In 1930 McKay (30), using college girls and members of Girl Scout Troops as subjects, sought to find the difference in basal metabolic rates of normal, overweight and underweight girls. All subjects who were within a range of ten per cent above or below the Baldwin-Wood height-weight-age standards were considered normal. Ninety-one girls were observed. Of this number, sixty-three were classified as normal, twenty-eight as overweight, and nine as underweight. The subjects came to the laboratory without breakfast and rested for from thirty to forty minutes. The Benedict-Roth respiration apparatus which was used was tested for leaks by placing a weight on the spirometer and observing the slant of the excursions of the pen. Two 10-minute observations were made and if these agreed within five per cent, the lowest value was taken as the basal metabolic rate for that day. The tests were made a second and sometimes a third time on different days, and the lowest values observed were averaged with the lowest value of the first day. Consequently, the final values reported represented the mean of the lowest values obtained on each day. McKay's results indicated that there was only a small difference in the average number of calories produced per twenty-four hours by the members of the various age groups.

A pronounced relationship seemed to exist between each of the factors, height, weight, and surface area and basal metabolism. The total caloric production, 1262 calories, of the underweight subjects was lower than the total heat production of the overweight subjects, 1474 calories, and of the normal weight subjects, 1346 calories. However, the calories per kilogram of body weight produced by the underweight subjects were greater, and those of the overweight subjects were less than the calories per kilogram of body weight produced by the subjects of normal weight. An increase in height, according to McKay, increased total heat production regularly and decreased heat production per kilogram of body weight. Heat production per square meter of body surface also decreased, but only slightly, as the height of the subjects increased. On the basis of surface area, heat production decreased with an increase in age. The mean values for the basal metabolism of the fourteen and eighteen-year-old groups were 37.7 and 34.8 calories per square meter of body surface per hour, respectively. McKay, by means of a study with five women, also showed that there were noticeable fluctuations in basal metabolism from day to day. The greatest variation of any individual test from the average of all of the tests was 337 calories or 28.8 per cent and the smallest variation was 171 calories or 13 per cent. However, the intra-variations were not as great as the inter-variations. The deviations from the means for each subject was 2, 2, 3, and 4 per cent when the basal metabolism was expressed as calories per hour per square meter of body surface.

Conklin and McClendon (16), in 1930, published results of a study which was undertaken to determine the correlation between basal metabolism and the menstrual cycle. A Benedict-Roth apparatus was used and "all the necessary precautions were observed in making the determinations." The ten subjects of the study were normal college women who did not suffer with menstrual pain. Tests were made almost daily during the complete menstrual cycle. In order to eliminate any influence of diet and muscular activity, one subject served as a control. Each day the subject ate a weighed diet and did an almost invariable amount of routine work. However, this diet, which contained 1200 calories, was insufficient to maintain her weight and resulted in a loss of nine pounds by the subject during the experimental period of two months. The decrease in the metabolic rate and the decrease in the duration of menstruation which were observed during the experimental period were, according to these authors, an indication that a deficient diet influenced metabolic and menstrual processes. The mean metabolic rate for the entire menstrual cycle, which was calculated from the records of all of the subjects, was 32.37 calories per square meter of body surface per hour. The heat production for the various periods of the cycle were: premenstrual, 35.50 calories per square meter per hour; menstrual, 32.37 calories per square meter per hour; postmenstrual, 32.22 calories per square meter per hour; and intermenstrual, 32.86 calories per square meter per hour.

Remington and Culp (33), 1931, offered more extensive data on the basal heat production of young women than did the studies previously mentioned. Nurses and medical students, many of whom were of college age, served as subjects. The nurses had been examined upon admission to the hospital for training, and their minor physical defects had been remedied. Of the ninety women included in this series of tests, fifty-two were classed as underweight and thirty-eight as overweight. The tests were made with a Benedict-Roth apparatus. Five alcohol checks of the apparatus resulted in an average of 99.72 per cent of the theoretical amount of heat evolved. The authors stated that they adhered closely to the standard procedure for the preparation and handling of their subjects. One determination on each of three successive days was made on each subject. The data were divided into groups according to the ages of the subjects, that is, eighteen years, nineteen to twenty-four years, inclusive, twenty-five to twenty-nine years, inclusive, and thirty to thirty-four years, inclusive. The mean of all of the tests in each age group was compared with the mean of the lowest values obtained on each subject in each age group and to the Aub-Du Bois standard. The two means, for the total values and for the lowest values, of the eighteen year old group were 36.9 and 35.0 calories per square meter per hour, respectively. There was less variation in the results reported on the subjects between the ages of nineteen to twenty-four years, inclusive, than in those reported for the subjects of the eighteen-year-old group. The means of the tests for this group were 34.4 and 33.0 calories per square meter of body surface per hour for all values and for the lowest values, respectively. The deviation from the Aub-Du Bois standard for the group of ninety subjects, if all tests were included, was -6.6 per cent. If only the lowest values were considered, the deviation was -10.4 per cent.

Coons (17), in 1931, studied the basal metabolism of 101 college women ranging in age from seventeen to thirty-six years, inclusive. The weights of all of the subjects fell within plus or minus ten per cent of the "Wood Standards", and their physical examinations did not show any abnormality likely to affect basal metabolism. The subjects were tested before breakfast and after a rest period of from one-half to three-fourths of an hour. From two to four 6-minute tests were made during each observation period by means of a Benedict-Roth kymographic apparatus. Computations were based on the two lowest concordant values obtained. The author concluded that the averages for the age groups were lower than the averages obtained in other studies of college women. The average deviations for all of the age groups were -13.2 per cent from the Aub-Du Bois standard and -10.1 per cent from the Dreyer and the Harris-Benedict standard. It was interesting to note that, by tabulating the data so that students of nutrition were compared with other students of the same ages (from twenty to twenty-nine years) and with the same variation in weight, the students of nutrition showed slightly, but consistently, higher averages than the members of the other group. The average for all of the tests on students of nutrition was 33.2 calories per square meter of body surface per hour and the average for the other subjects was 32.4 calories per square meter per hour.

Because of the low values for the basal metabolism of college women obtained in the above work, Coons (18) made a study of the basal metabolism with girls of abnormal weights. Tests were made on thirty-eight overweight and eighty underweight college women in an attempt to establish the relationship between basal metabolism and undernutrition. Coons concluded that there was a tendency for the average heat production, expressed as calories per hour per square meter, to be above normal in the overweight subject and below normal in the underweight subject.

In 1932 Coons and Schiefelbusch (19) continued the study of the basal metabolism and dietary habits of college women. Eighteen women, mostly upperclassmen, served as subjects. Their food, which consisted of the usual self chosen diet, was analysed for nitrogen, calcium, phosphorus and caloric content. The determinations of basal metabolism preceded the studies of the dietary habits. The mean basal heat production observed in this group of subjects was 1193 calories per twenty-four hours, a value which was 12 per cent below the Du Bois prediction standard. The average total caloric intake, 1990 calories, was in excess by 67 per cent of the actual basal metabolism and by 50 per cent of the basal heat production predicted by the Harris-Benedict standard. Coons stated that from 2000 to 2500 calories daily, or at least 1000 calories in excess of the basal metabolism, was a desirable intake for the average college woman. This statement was based upon a dietary study of three women conducted at the same time as that during which the above data were collected.

In 1932 Hetler, Killinger and Plant (25) reported a study of the relationship between the protein intake and the basal metabolism of college women. The tests were made by means of a Benedict-Roth apparatus, with eighty-five college women who had been subjected to the usual preliminary treatment. The mean deviation of the basal metabolism of this group from the Harris-Benedict prediction standards was -7.1 per cent, and the mean total heat production for the group was 1260 calories per twenty-four hours. The average protein intake of the subjects was 0.94 grams per kilogram of body weight. This value was slightly less than Sherman's standard of one gram per kilogram of body weight. The authors concluded that it was impossible to assign any definite relationship between levels of protein intake and basal metabolism.

Starks (33), 1933, published a table of prediction values of the basal metabolism of young women between the ages of seventeen and twenty-one years, inclusive. Data were collected on ninety-seven college women who had a grading of A in their medical and physical examinations. There were twenty-five subjects in each of the seventeen, eighteen and twenty-year-old groups and twenty-two subjects who were nineteen years old. The two determinations of the basal metabolism of thirty-five of the subjects were made at intervals of three weeks. An interval of from seven to fifty-five days separated the two determinations of each of the other subjects. Only the first test of each individual, if it was satisfactory, was used in establishing the prediction standards. The Benedict portable apparatus, which was used for the determinations, was checked for leaks by placing a weight on the spirometer chamber midway through the period. The subject was tested before breakfast, and after at least a thirty-minute rest period. The average heat production of the group was 1296 calories per twenty-four hours or 34.01 calories per square meter per hour. The mean deviation from the Aub-Du Bois standards was -11.9 per cent and from the Harris-Benedict prediction table -7.6 per cent. The average calories per square meter per hour for the seventeen to eighteen-year-old group was 34.4 which was a slightly higher value than the 33.54 calories per square meter per hour obtained for the nineteen to twenty-year-old group.

Talbot, Wilson and Worcester (34), 1935, published a prediction table of basal metabolic rates, in which the heat production was expressed as the total calories for height and the total calories for weight. According to Talbot, fewer errors in diagnosis occurred and a more accurate clinical picture was obtained, if the metabolic rates of children were compared to this type of standard rather than to one in which the heat production was expressed as calories per hour per square meter of body surface. Two groups of girls were used as subjects. The younger group was the same as that used by Benedict and Talbot (6) in an earlier experiment. The members of this group were from the less fortunate part of the population but were within -9 and 20 per cent of the Baldwin-Wood height-weight-age standards. The members of the older group, composed of eighty-seven girls between ten and twenty years of age, inclusive, were enrolled in a private school which was patronized by the economically fortunate members of the population. As in the younger group only data were collected on those subjects who fell within the range of -9 and +20 per cent of the Baldwin-Wood height-weight-age standards. The data were treated statistically, and the results were published as a prediction table. Talbot recommended this table for use in clinical diagnosis of cases of abnormal physical development.

In 1936 Boothby, Dunn and Berkson (15) published a prediction table which was derived from data collected from studies on 639 men and 828 women subjects. The individuals included in the study comprised two main groups. The members of the first group were from six to seventeen years old, inclusive, and were mostly Rochester, Minnesota school children who had been rated as normal by the school physician. The second group included subjects who had been selected from the clientele of the basal metabolism laboratory of the Mayo Clinic. The calculations for the basal energy production were based on the first determination made with the individual, unless for some reason it was deemed unsatisfactory. The test was made on the subject before breakfast by the open circuit method. The prediction table included the mean calories per square meter and the standard deviation of each age group for men and women. The authors suggested that, since the subjects represented a cross-section of the population, the prediction table was appropriate for use in studing the influence of factors such as race and climate upon basal metabolism.

In 1936 McKittrick (30) published data including the basal metabolic rates of one hundred young women enrolled in the university of Wyoming. The subjects were rated as normal by the college physician. Only students who had lived in Wyoming at least six months previous to the test period served as subjects. The purpose of the tests was to determine if the high altitude of 7,148 feet above sea level influenced the heat production of the residents. The subjects were tested before breakfast, and after a thirty to forty-five minute rest period. Three 6-minute tests were usually made by means of a Benedict-Roth kymographic apparatus. If the first two tests were very regular and checked exactly, the third test was omitted. The mean of the energy production values obtained deviated -3.18 per cent and -2.54 per cent from the Boothby and Sandiford modification of the Aub-Du Bois standards and from the Harris-Benedict standards, respectively. Because the deviations from the standards were much smaller than those obtained by Coons (14) and Tilt (35) at lower altitudes, McKittrick concluded that high altitude increased heat production.

The results of the studies mentioned in the preceding review of the literature are summarized in Table 1. Whenever it was possible, the data reported were compared with the Boothby and Sandiford modification of the Aub-Du Bois standards.

TABLE 1

Compilation of the Data Reported in the Review of Literature

Observer	Age	No. of	Calories	Calories	Deviation from Standards		
	Years	Cases	per 24 hrs	per sq. m. per hr.	Aub-Du Bois %	Aub-Du Bois (Boothby & Sandiford) %	Harris and Benedict %
Blunt and Dye (1921)	21 to 44	17	1337	--	-6.5	--	--
Blunt, Tilt, McLaughlin, Gunn (1926)	17	3	1543	34.8	--	-9.6	--
	18	3	1406	36.7	--	-1.6	--
Gustafson & Benedict (1928)	18	5	1352	34.6	--	-7.2	-3.5
	19	5	1396	36.6	--	-1.6	-0.1
	20	5	1431	36.1	--	-2.2	+0.02
	21	3	1396	35.7	--	-3.2	-1.4
Mean	18 to 22	20	1396	35.9	--	--	--
Tilt (1930)	College Stu.	29	1235	33.4	-11.6	--	-10.0
Mean	17 to 25	52	1236	--	-10.6	--	-9.9
McKay (1930)	17	32	1381	36.6	--	-2.1	--
	18	15	1365	34.8	--	-6.7	--
Mean	14 to 18	91	1364	36.4	--	--	--

TABLE 1 CONTINUED

Compilation of the Data Reported in the
Review of Literature

Observer	Age Years	No. of Cases	Calories per 24 hrs	Calories per sq. m. per hr.	Deviation from Standards		
					Aub-Du Bois %	Aub-Du Bois (Boothby & Sandiford) %	Harris and Benedict %
Conklin and Mc-Clendon (1930)	20	3	--	32.3	-12.6	-12.5	--
	21	1	--	37.2	+ 0.5	+ 0.8	--
	22	3	--	32.6	-11.9	-11.6	--
	23	2	--	32.4	-12.6	-12.2	--
Mean	20 to 23	9	--	33.6	-9.2	-8.9	--
Remington and Culp (1931)	18	9	--	36.0	-2.9	-3.5	--
	19	20	--	34.8	-7.5	-6.4	--
Mean	19 to 24	74	--	34.4	-7.0	-6.8	--
Coons (1931)	17	6	1226	33.7	-15.5	-9.9	-10.0
	18	14	1265	32.8	-13.7	-12.1	-10.6
	19	15	1235	32.5	-14.4	-12.6	-11.1
	21 to 24	39	1248	32.6	-11.9	-11.6	-10.5
Mean	17 to 39	101	1245	32.6	-13.2	--	-10.1
Coons (1932)	Jr. & Sr.	17	1193	--	-12.0		
Hetler, Killinger and Plant (1932)							-7.1

TABLE 1 CONTINUED

Compilation of the Data Reported in the Review of Literature

Observer	Age Years	No. of Cases	Calories per 24 hrs	Calories per sq. m. per hr.	Deviation from Standards		
					Aub-Du Bois %	Aub-Du Bois (Boothby & Sandiford) %	Harris and Benedict %
Stark (1933)	17 to 18	50	1313	34.4	--	-7.9	--
	19 to 20	47	1280	33.5	--	-9.4	--
	17 to 20	97	1296	34.0	-11.9	--	--
Boothby, Dunn, & Berkson (1936)	17	4	--	37.35	--	-0.13	--
	18	9	--	37.33	--	+0.08	--
	19	30	--	35.7	--	-4.0	--
	20	18	--	36.7	--	-0.54	--
	21	23	--	36.3	--	-1.63	--
	22	29	--	35.7	--	-3.2	--
	23	23	--	36.2	--	-1.9	--
	24	19	--	35.8	--	-3.0	--
Mean	17 to 24	155	--	36.4	--	--	--
McKittrich (1936)	17	6	1349	34.72	--	-7.4	-6.3
	18	7	1654	35.97	--	-3.5	-1.8
	19	20	1340	35.99	--	-3.8	-3.4
	20	24	1371	35.22	--	-2.1	-2.1
	21	13	1379	35.76	--	-3.0	-2.7
	22	11	1337	35.39	--	-4.2	-3.7
	23	8	1429	36.76	--	+0.5	+1.6
	24	6	1400	36.69	--	-0.6	+1.0

EXPERIMENTAL PROCEDURE

Subjects:

The twenty-five women who served as subjects for this study ranged in age from seventeen years to twenty-three years, inclusive. Of the twenty-five subjects, nineteen were native Oklahomans, four had been residents of Oklahoma for at least a period of eight years, and two resided in adjoining states. All were registered as freshmen in the Oklahoma A. and M. College and appeared to be in good health. Twenty-three of the subjects lived in Murray Hall, a college dormitory which houses the majority of freshmen women, and two subjects lived in private homes.

Apparatus:

A Benedict-Roth kymographic apparatus was used to determine the basal metabolism of the subjects. The apparatus furnished an indirect method of obtaining the heat production by measuring the amount of oxygen consumed by the subject over a given period of time. The subject was attached to the apparatus by means of a rubber mouthpiece. Breathing through the nasal passages was prevented by the use of a nose clamp. The inhaled and exhaled air were directed by flutter valves. Wilson's soda lime was used as the carbon dioxide absorbent. The rise and fall of the spirometer, occurring with each respiration, was recorded on a kymograph by means of a pen. The fall of the spirometer, as the oxygen was used by the subject, was measured in millimeters on the kymograph. For each millimeter of height the spirometer bell had a volume of 20.73 cubic centimeters. Therefore, for each millimeter fall of the spirometer during the six minute test period the subject used 20.73 cubic centimeters of oxygen. During a period of one hour the subject would have used ten times this amount, 207.3 cubic centimeters or 0.2073 liters of oxygen. The volume of oxygen which was used was changed to standard temperature and pressure conditions by correcting the observed volume for the temperature of the spirometer, the barometric pressure and the tension of water vapor. Assuming the non-protein respiratory quotient to be 0.82, each liter of dry oxygen at standard temperature and pressure had a heat value of 4.825 calories (21). Therefore, each corrected millimeter of fall of the bell in a six minute period represented one calorie per hour.

The Benedict-Roth apparatus was checked for accuracy by means of a Jones alcohol check apparatus (27). The Jones apparatus burned a measured amount of absolute ethyl alcohol in a closed chamber to which the metabolism apparatus was connected. It was the purpose of the test to determine whether the amount of oxygen removed from the spirometer chamber of the metabolism apparatus was the chemical equivalent of the amount of alcohol burned. The concentration of the alcohol, determined by measuring the specific gravity, was 100 per cent. The pipette which was used in measuring the alcohol was calibrated with water. The percentage error observed on eight determinations made from January 6 to January 11, were +1.38,

-1.48, +0.38, -0.50, +1.68, -0.07, +0.41, and -1.11, with a mean of +0.08.

Technic:

Each of the twenty-five subjects reported to the laboratory on two days for the determination of basal metabolism. Eighteen of the subjects reported on two consecutive days but in seven cases this was impossible. However, four days was the greatest length of time which expired between any two series of tests on one subject. To insure accurate determinations of basal metabolism, instructions were given each subject on the day previous to the first test. The eating of food was not permitted after the usual six o'clock dinner, and the subject came to the laboratory the following morning before breakfast and after at least eight hours of sleep. The short walk to the laboratory was executed in a leisurely fashion and was followed by a thirty-minute rest period. During the last ten minutes of the rest period, the subject's temperature and pulse were recorded and the metabolism apparatus was prepared for use. Simple, short explanations of the procedure were offered as the nose and mouth pieces were adjusted to the subject. Three 8-minute test periods were recorded on each morning. The first two minutes of each test were discarded and the values of heat production were based upon the last six minutes of each test. The subject's weight and height and the beginning of the last menstrual period were recorded.

RESULTS AND DISCUSSION

The twenty-five subjects observed for this study comprised four age groups, i. e., three subjects were seventeen years old, ten were eighteen years old, eight were nineteen years old and four were from twenty to twenty-three years old. The age, pulse, temperature, height, weight and surface area in square meters of each of the subjects are recorded in Table 2. The body surface expressed in square meters was obtained from the nomogram prepared by Boothby and Sandiford (21) from the Du Bois height-weight formula. Values for the basal metabolism for the six observation periods of each subject are recorded in Table 3. These values are reported as calories per hour per square meter of body surface. The means of the six tests for each subject are presented in Table 4. The basal metabolism for each of the four age groups are listed in Table 5.

Table 5 has included in it the standard deviation from the mean and the coefficient of variation of each age group. The formula which was used in obtaining the standard deviation from the mean is as follows:

$$\text{Standard Deviation} = \sqrt{\frac{\Sigma X^2}{N} - m^2}$$

$\underline{\Sigma X^2}$ equals the sum of the squares of the mean values of each individual, $\underline{N}$ equals the number of subjects, and $\underline{m}^2$ equals the square of the mean for that age group. The standard deviation was used as a measure of the

TABLE 2

Age, Pulse, Body Temperature, Height, Weight and Body Surface Area of the Individual Subjects, College Women

Subject	Age	Pulse	Body Temp.	Height cm.	Weight kg.	Surface Area square meters
A. T.	17	82	98.2	161.0	45.39	1.45
L. Mo.	17	72	98.3	165.1	73.48	1.79
L. Ma.	17	71	98.0	165.5	55.22	1.60
A. S.	18	63	98.4	158.0	50.92	1.50
B. R.	18	66	98.0	161.5	53.98	1.55
L. W.	18	76	98.6	163.0	56.12	1.59
V. E.	18	75	98.2	165.5	52.68	1.56
N. P.	18	74	97.7	165.5	58.51	1.63
V. H.	18	56	97.4	166.5	62.60	1.69
M. J.	18	75	98.2	167.5	50.28	1.55
M. L.	18	69	98.2	168.2	70.99	1.79
B. W.	18	64	98.4	170.5	50.88	1.64
J. S.	18	63	98.5	173.0	100.00	2.13
G. P.	19	60	98.0	152.4	57.55	1.53
K. W.	19	67	98.3	157.5	53.07	1.52
L. B.	19	61	97.6	159.0	60.32	1.61
M. F.	19	74	98.1	160.5	60.49	1.62
M. S.	19	82	98.2	163.0	46.33	1.46
F. S.	19	72	98.1	168.2	61.23	1.69
C. H.	19	63	97.7	170.0	70.70	1.81
L. L.	19	61	97.8	176.0	75.82	1.88
C. B.	20	73	98.1	170.5	61.12	1.69
M. D.	20	66	98.5	171.5	57.34	1.66
D. K.	21	70	97.2	164.4	62.03	1.64
A. H.	23	58	98.5	174.5	62.82	1.74
Average		69	98.1	165.5	60.31	1.65

TABLE 3

The Individual Six-minute Determinations of the Basal Metabolism of College Women

Subject	Age	Tests for the First Day (1)	(2)	(3)	Tests for the Second Day (1)	(2)	(3)
A. T.	17	35.2	36.9	36.4	36.4	33.2	34.7
L. Mo.	17	34.1	36.5	34.1	36.3	33.8	35.2
L. Ma.	17	36.3	34.4	35.8	36.8	35.9	35.7
Average	17	35.2	35.9	35.4	36.5	34.3	35.2
A. S.	18	33.1	33.1	31.7	33.7	32.6	33.9
B. R.	18	36.6	38.2	37.6	37.0	37.0	37.2
L. W.	18	41.9	35.7	36.7	42.3	33.0	38.3
V. E.	18	39.2	37.9	36.5	37.2	36.3	37.4
N. P.	18	34.3	34.8	33.9	35.5	36.7	35.9
V. H.	18	32.1	31.8	32.6	30.4	31.3	32.1
M. J.	18	34.5	36.3	33.3	37.0	34.5	36.5
M. L.	18	37.1	35.1	37.1	35.9	36.3	34.9
B. W.	18	32.6	32.6	31.5	34.6	33.5	33.5
J. S.	18	35.5	34.9	34.2	36.3	35.9	35.1
Average	18	35.7	35.0	34.5	36.0	34.7	35.3
G. P.	19	35.5	34.2	36.3	32.7	34.4	33.8
K. W.	19	34.4	35.0	34.4	35.7	35.7	36.9
L. B.	19	36.2	34.2	33.4	36.6	33.3	33.8
M. F.	19	32.3	34.2	30.5	34.1	33.6	36.2
M. S.	19	37.9	38.3	37.5	37.6	35.4	33.1
F. S.	19	37.3	37.8	37.5	38.8	36.3	37.6
C. H.	19	32.3	33.7	32.7	34.8	34.3	32.3
L. L.	19	33.4	33.8	33.6	31.9	31.1	34.3
Average	19	34.9	35.2	34.5	35.27	34.26	34.75
C. B	20	36.6	40.1	39.2	36.3	31.7	34.7
M. D.	20	33.9	31.7	33.3	33.4	33.4	32.8
D. K.	21	34.2	34.0	34.7	33.7	32.1	34.3
A. H.	23	31.0	29.2	29.4	29.9	30.1	30.1
Average		35.3	35.9	36.3	34.9	32.5	33.7
Average of four groups		35.3	35.5	35.2	35.7	34.0	34.7

TABLE 4

The Basal Metabolism of Freshmen Women Calculated from Specific Six-minute Observation Periods

Subject	Age	Cal. per hour	Calories per square meter per hour			
		(all tests)	(all tests)	(checks)*	(Lowest)	(2 Lowest)
A. T.	17	51.4	35.5	36.2	33.2	34.0
L. Mo.	17	62.7	35.0	34.3	33.8	34.0
L. Ma.	17	57.2	35.8	36.1	34.4	35.0
Average	17	57.1	35.4	35.5	33.8	34.3
A. S.	18	49.4	33.0	33.5	31.7	32.2
B. R.	18	57.8	37.3	37.3	36.6	36.8
L. W.	18	60.4	38.0	36.2	33.0	34.4
V. E.	18	58.4	37.4	37.1	36.3	36.4
N. P.	18	57.3	35.2	35.1	33.9	34.1
V. H.	18	53.6	31.7	31.7	30.4	30.8
M. J.	18	54.8	35.3	34.1	34.5	34.5
M. L.	18	64.5	36.1	38.8	34.9	35.0
B. W.	18	53.7	32.7	32.1	31.5	31.5
J. S.	18	75.0	35.3	35.3	34.2	34.6
Average	18	58.5	35.2	35.1	33.7	34.0
G. P.	19	52.8	34.5	34.7	32.7	33.2
K. W.	19	53.7	35.3	35.0	34.4	34.4
L. B.	19	55.5	34.6	33.7	33.3	33.4
M. F.	19	54.3	33.5	33.0	30.5	31.4
M. S.	19	53.7	36.6	37.8	33.1	34.2
F. S.	19	63.5	37.5	37.3	36.3	36.8
C. H.	19	60.2	33.3	32.8	32.3	32.3
L. L.	19	62.0	33.0	33.8	31.1	31.5
Average	19	57.0	34.8	34.7	33.0	33.5
C. B.	20	62.0	36.4	35.5	31.7	33.0
M. D.	20	54.9	32.9	32.9	31.7	32.2
D. K.	21	55.5	33.8	34.2	32.1	32.9
A. H.	23	52.1	29.9	29.7	29.2	29.3
Average		56.1	33.2	33.1	31.2	31.8
Average of group		57.4	34.8	34.7	33.1	33.5

*"Checks" include all six-minute observations that agreed within five per cent.

dispersion of the basal metabolic rates of the subjects included in the age group, i. e., the basal metabolism of 68.3 per cent of all normal individuals should fall within plus and minus one standard deviation, 95.5 per cent within plus and minus two standard deviations and 99.7 per cent within plus and minus three standard deviations. Normal variation is usually considered that represented by plus and minus two standard deviations. The coefficient of variation was used in a manner similar to that of the standard deviation. The formula for the coefficient of variation is as follows:

$$\text{Coefficient of Variation} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$$

The means of the basal metabolism of the subjects of the seventeen, eighteen and nineteen-year-old groups obtained in this study show little variation from one age group to the next. The variation between the seventeen and eighteen-year-old groups was 0.2 of a calorie when the basal metabolism was expressed as calories per hour per square meter of body surface and between the eighteen and nineteen-year-old groups the difference was 0.4 of a calorie. In order that the significance of the differences between the seventeen and eighteen and the eighteen and nineteen-year-old groups might be determined, the following formula was used:

Standard Error of the Difference Between Two Means =

$$\sqrt{\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_2}}$$

TABLE 5

The Results of Statistical Analysis of 150 Basal Metabolism Tests on 25 Oklahoma College Women

Subjects Age Group	No. Subj.	Mean Cal. per hr. per sq. m.	Standard Deviation From the Mean	Coefficient of Variation %
17	3	35.4	1.57	4.44
18	10	35.2	2.03	5.77
19	8	34.8	1.18	3.39
20-23	4	33.2	2.95	8.88
Average	25	34.8	1.62	4.66

TABLE 6

Comparison of the Values of the Basal Metabolism of Eighteen and Nineteen-Year-Old Women, Obtained by Various Observers, With the Values Obtained in This Study

Observer	No. Subj.	Calories per hour per sq. m. of 18 yr. old age group	Dev. from the mean of this study	No. Subj.	Calories per hour per sq. m. of 19 yr. old age group	Dev. from the mean of this study
Blunt, Gunn, Tilt and McLaughlin	3	36.7	+ 4.3	-	--	--
Gustafson and Benedict	5	34.6	-1.7	5	36.6	+ 5.2
McKay	15	34.8	-1.1	--	--	--
Remington and Culp	9	36.0	+2.6	20	34.8	0.0
Coons	14	32.8	-6.8	15	32.5	-6.6
Boothby, Berkson and Dunn	9	37.3	+6.1	30	35.7	+2.5
McKittrick	7	35.9	+2.2	20	35.9	+3.4
Average	62	35.4	+0.8	90	35.1	+3.5

σ_1^2 equals the standard deviation of the first group squared, σ_2^2 equals the standard deviation of the second group squared, and N_1 and N_2 equal the number of cases in the first and second groups, respectively. The standard error of the difference between the means for the seventeen and eighteen-year-old groups was 1.11 calories per hour per square meter of body surface. To be significant the difference between the means of the age groups would have to be three times the standard error or 3.33 calories per hour per square meter of body surface. The actual difference between the seventeen and eighteen-year-old groups was only 0.2 calories per hour per square meter of body surface and, therefore, was not significant. The standard error of the difference between the eighteen and nineteen-year-old groups was 0.242 calories per hour per square meter of body surface. The actual difference which was 0.4 calories per square meter per hour was not significant, because it was less than three times the standard error of the difference. In the seventeen, eighteen and nineteen-year-old groups of this study, the difference in age was not an influencing factor in the basal metabolism. However, it should be kept in mind that the number of subjects in each age group was small.

The mean values for the basal metabolism obtained for the eighteen and nineteen-year-old groups are compared in Table 6 to the values reported by the observers quoted in the review of literature. A comparison of the values of the seventeen and of the twenty to twenty-three-year-old groups with these data was omitted because of the few subjects observed in each of these two age groups. The percentage of deviation of the basal metabolic rates cited in the review of literature from the values observed in this study depended a great deal on which one of the six-minute test periods was used to represent the basal metabolism of the subjects. Blunt, Tilt and McLaughlin (9) and Boothby, Dunn and Berkson (15) used the mean of the first six-minute periods of their subjects. The value of the eighteen-year-old group of the first study deviated +4.3 per cent and the latter +6.1 per cent from the mean, calculated from all of the six-minute tests, obtained in this study. The value reported by McKay (30) was the mean of the lowest basal metabolic rates of the subjects of this age group. Coons (17) used the two lowest concordant values of each subject in calculating the mean of the various age groups. The mean value of the eighteen-year-old group obtained by McKay deviated -1.1 per cent and that of Coons -6.8 per cent from the mean value of heat production obtained in this study. In the reports made by Gustafson and Benedict (22), McKittrick (31) and Remington and Culp (33), the mean of all six-minute test periods of each subject was considered the basal metabolism. The values reported for the eighteen-year-old groups deviated -1.7 per cent, +2.2 per cent and +2.6 per cent, respectively, from the author's value. The average of the deviations of the seven eighteen-year-old groups from the value observed in this study was +0.8 per cent which was within the standard deviation of 2.03. The basal metabolism of the nineteen-year-old groups reported deviated from the mean of this age group obtained by the author in the same manner as did the eighteen-year-old groups. The variations in the values obtained in these studies emphasizes the logic of employing in the laboratory a technic which is similar to the one used in determining the values in the standard table which is selected for comparison.

In the above comparative study, it was noted that Coons (17) obtained the lowest values of the basal metabolism of the eighteen and nineteen-year-old groups reported. The study made by Coons was of especial interest to the writer because it was also conducted on the campus of Oklahoma A. and M. College. That it should vary the greatest from the writer's values needs some explanation. In Table 4 the means of the heat production values for the twenty-five subjects studied have been calculated from the two lowest values of each subject. Coons used the two lowest concordant values in determining basal metabolism of her subjects. The average basal metabolic rate of the 101 subjects observed by Coons was 32.6 calories per hour per square meter of body surface which gave a deviation of -2.6 per cent from the author's value of 33.5 calories per hour per square meter of body surface, if the value is determined from the two lowest tests of each subject. This comparison indicates that the variation in the results of the two studies is due principally to the difference in the selection of data for the calculation of the values of the heat production.

Likewise, closer agreement is found with the Boothby, Dunn and Berkson (15) standards, if these are compared with the writer's values obtained with selected data from the present study, i. e., only first acceptable tests are considered in both studies. The mean of all of the values reported in Table 3 for the first test periods of each day was 35.5 calories per hour per square meter of body surface. The rate of basal metabolism obtained by Boothby, Dunn and Berkson for the same age groups was 36.4 calories per hour per square meter. The latter figure deviates +2.5 per cent from the writer's figure based on the above selection of data. However, the variation is +4.6 if the Boothby, Dunn and Berkson standards are compared with values based on all of the six-minute periods, and is +8.0 per cent if compared with the values based on the two lowest concordant periods of the present study. These comparisons illustrate the point previously mentioned, that in the drawing of conclusions concerning the relative basal metabolic rates of any two studies, the selection of data and the technics employed should be carefully analysed.

At the present, the most widely used clinical standards of basal metabolism for young women are the following three: first, the Boothby and Sandiford (14) modification of the Aub and Du Bois (1) standards which are based on heat production per unit of surface area; second, the Harris and Benedict (23) prediction tables which are based on a statistical study of data available at the time they were established; third, Dreyer's (20) prediction table which was based on studies of normal subjects reported by Magnus and Levy, Benedict and Du Bois. The value and accuracy of these three standards have been questioned and analyzed in recent years in an attempt to erect normal prediction standards and deviations which will be of clinical use.

The original Aub and Du Bois standards were presented in 1917. In the Aub and Du Bois table, the basal metabolism rates for ages from sixteen to sixty-nine years, inclusive, are predicted. These values were determined from studies made on normal subjects and are referred to surface area of the body. The formula used to calculate surface area was the Du Bois and Du Bois formula (21):

$$A = (Wt.^{0.425}) \ (Ht.^{0.725}) \ (71.84)$$

In this formula, A equals area in square centimeters. The Aub and Du Bois standards were modified in 1929 by Boothby and Sandiford (14). On the basis of larger numbers of normal controls, values for the basal metabolism for years from five to nineteen, inclusive, and for five yearly intervals between twenty and seventy-nine years, inclusive, were given.

In 1919, Harris and Benedict (23), made a statistical study of all available data for the basal metabolism of normal women. Multiple prediction equations were used to calculate the total heat production per twenty-four hours, and tables including each yearly age group were formulated.

The equations were:

$$\text{For men, } H = 66.4730 - 13.7516W - 5.0033S - 6.7550A$$

$$\text{For women, } H = 655.0955 - 9.5634W - 1.8496S - 4.6756A.$$

In the formulas, H equals total heat production per twenty-four hours, W equals weight in kilograms, S equals stature in centimeters, and A equals age in years. The Harris and Benedict standards averaged 3 to 4 per cent lower than the Aub and Du Bois standards. Benedict (4) recommended that the Harris and Benedict standards for women be lowered 5 per cent.

The third standard for the prediction of basal metabolism was formulated by Dreyer (20) who devised the following formulas for predicting the normal heat production:

$$\text{For women, } D = \frac{\sqrt{W}}{0.1127A^{0.1333}}$$

(For men, 0.1127A is replaced by 0.1015A in the formula.)

In the formula D equals total calories per 24 hours, W equals body weight in grams, and A equals the age in years. Dreyer used the theoretical weight computed from the sitting height and chest circumference rather than actual weight. These standards are more successful than the other two types for predicting the basal metabolism of individuals of unusual configuration, according to Hawk and Bergeim (24).

From critical studies made by Boothby and Sandiford (11) and by Krogh (24) the concensus of opinion seems to be that the Harris and Benedict predictions are the most reliable for average normal subjects; that the Du Bois standards give results in average normal cases which are about four per cent high; that in all cases, including those of exceptional build and age, the Du Bois standards show less deviation than any of the others.

The controversies, concerning which of the above three standards is more nearly accurate, have led to a great many studies of basal metabolism in recent years. Data which have been collected in the past four years, but as yet have not been published, would lead to the conclusion that the standards just mentioned are high for the women of the age groups considered in this paper. The data, presented in Table 7, indicate that the basal metabolism of Oklahoma college women does not vary greatly from the basal metabolism of young women of other regions. The mean of the basal metabolic rates of 106 eighteen-year-old college women, who served as subjects in Minnesota, Ohio, Iowa and Kansa, was 34.5 calories per square meter per hour. If this value is compared with the value obtained with ten Oklahoma college women of the same age, the deviation is -2.0 per cent. Basal metabolic rates were also determined with 131 college women who were nineteen years of age. The mean of all of the test periods for the group was 34.1 calories per square meter per hour which deviates by -2.0 per cent from the mean of the heat production values determined with eight Oklahoma college women of the same age. In the same four states, the mean of the basal metabolic rates of 384 college women, whose ages ranged from

TABLE 7

Basal Metabolism of College Women in Four States, Minnesota, Ohio, Iowa and Kansas

Age Group:	Minnesota		Ohio		Iowa		Kansas		Average	
Years	No. Cases	Cal. per sq.m. per hr.	No. Cases	Cal. per sq.m. per hr.	No. Cases	Cal. per sq.m. per hr.	No. Cases	Cal. per sq.m. per hr.	Total No. Cases	Cal. per sq.m. per hr.
17	3	36.4	2	33.1	17	35.9	4	35.5	26	35.2
18	23	35.8	25	33.0	25	34.9	33	34.2	106	34.5
19	39	34.7	13	33.4	40	35.0	39	33.1	131	34.1
20	9	35.8	7	35.4	29	35.4	18	34.7	63	35.3
21	7	33.2	4	35.0	12	35.6	9	34.9	32	34.7
22	4	36.2	1	33.6	7	34.8	6	33.7	18	34.6
23	1	33.0	1	30.9	5	35.2	1	32.9	8	33.0
Total: No. Cases:	86		53		135		110		384	
Average		35.0		33.5		35.3		34.1		34.5

seventeen to twenty-three years, inclusive, was 34.5 calories per square meter per hour. If compared to the value of heat production, 34.8 calories per square meter per hour, obtained from 150 determinations made with twenty-five Oklahoma college women of the same age range, the deviation is -0.9 per cent. As stated above, the values of basal metabolism obtained in this study do not vary greatly from the basal metabolism of young women of other regions. If the present tendency continues toward the accumulation of data, which are based on the observations of many subjects of each age group, the results will be, in all probability, more reliable standards for the calculation of basal metabolic rates.

SUMMARY AND CONCLUSIONS

1. The results of 150 basal metabolism tests on twenty-five Oklahoma college women are presented in this paper. The tests were made by means of a Benedict-Roth respiration apparatus which was checked by the Jones alcohol check apparatus. The women were enrolled as freshmen in the Oklahoma A. and M. College and appeared to be in good health. The subjects were divided into four age groups, i. e., seventeen, eighteen, nineteen, and from twenty to twenty-three-year-old groups.
2. The values for the heat production of the various groups were: seventeen-year-old group, 35.5 calories per square meter per hour; eighteen-year-old group, 35.2 calories per square meter per hour; nineteen-year-old group, 34.8 calories per square meter per hour; and twenty to twenty-three-year-old group, 33.2 calories per square meter per hour. The mean of the values for heat production for the twenty-five subjects was 34.8 calories per square meter per hour. The standard deviation from the mean of the whole group was 1.62 when the basal metabolism was expressed as calories per square meter per hour. Similarly, the coefficient of variation was 4.66 per cent.

3. The difference in age between the seventeen and eighteen and the eighteen and nineteen-year-old groups of this study did not influence the basal metabolism. However, it should be kept in mind that the number of subjects in each age group was small.

4. Comparisons of the basal metabolism of the studies cited in the review of the literature are made with the values obtained in this study. The conclusion was drawn that the differences in the basal metabolic rates revealed by this comparison were due principally to the selection of data from which the values of basal metabolism were determined. The suggestion was made that in the drawing of conclusions, concerning the relative basal metabolic rates of any two studies and particularly in clinical diagnosis, the selection of data and the technics employed should be carefully considered.

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Charlene Hyer

Zelma Patchin