THE BASAL METABOLISM OF 24 KANSAS GIRLS FROM 10 TO 12 YEARS OF AGE

by

SISTER MARY DONATA BISSETTE

B. S., Marymount College, 1939

A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

Department of Food Economics and Nutrition

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1942

TABLE OF CONTENTS

INTRODUCTION

The term metabolism, in a broad sense, involves the processes concerned with assimilation of foodstuffs within the body and excretion of body wastes. In a more limited sense, it refers to the sum total of chemical changes which take place within the body cells in growth and repair of body tissues and the release of energy. The minimum energy expenditure of a subject awake, lying quietly and comfortably relaxed, 12 to 14 hours after taking food is called basal metabolism. It must be measured under these restrictions which are known as "standard basal conditions."

Two methods are employed in measuring basal heat production: (1) direct and (2) indirect calorimetry. For the direct method, a large respiration chamber known as a calorimeter is used. The space within the respiration calorimeter allows a person to lie down, sit quietly, or move about during the experimental period which may last from a few hours to several days according to the type of machine used. In indirect calorimetry, a portable respiration apparatus of the closed-circuit type is most often employed. The subject is connected to the machine by some means, often with a rubber mouthpiece fitted between the teeth and lips so tightly that it does not permit escape of air. With this machine a noseclip with soft rubber pads is fitted firmly over the nostrils to prevent breathing through the nose. The subject then necessarily breathes through the mouth. The oxygen, supplied from a spirometer, is kept in circulation by a blower or valves and is freed from carbon dioxide as it passes through sodalime. This method is extensively used due to the availability of the portable apparatus, its ease of operation, and comparatively low cost.

The portable respiration apparatus is based upon the principle that the oxygen breathed in is regulated by the needs of the body. Oxygen is not stored; therefore, the quantity consumed is a measure of the combustion taking place within the body. Different amounts of oxygen are required to burn the various foodstuffs. This varies according to the proportion of oxygen to carbon and hydrogen in the molecule. For example, more oxygen is necessary for the combustion of 1 g of protein than for 1 g of fat or carbohydrate. The ratio of the carbon dioxide given off to the oxygen taken in is known as the respiratory quotient. It is indicative of the kind of foodstuff the body is burning. For a normal healthy person who has been without food from 12 to 14 hours the respiratory quotient is about 0.82 which is characteristic of a mixed diet.

The consumption of oxygen is recorded by means of a pen attached to the spirometer which contains the reserve oxygen. The pen marks on a special paper designed to show the amount of oxygen used and the time required to consume it. The paper is fitted to a constantly revolving cylinder calibrated to a certain speed which is in accord with the timing indicated on the record sheet. As the subject breathes the spirometer rises and falls and the pen records the rate and depth of each respiration.

Some of the factors which have been found to influence the basal metabolism of children are age, sex, climate, race, state of nutrition, rate of growth, and puberty. Apparently many of these conditions are interrelated as to their effect on heat production and they have not always produced the same effect in all children. Due to this fact many factors must be taken into consideration in the interpretation of metabolic results.

The purpose of this study was to follow intensively the basal heat production of a limited number of pre-adolescent Kansas girls over a comparatively short period, to note any trends that might be evident and to compare them with those found by other workers.

REVIEW OF LITERATURE

According to Benedict and Talbot (1921) the first respiratory experiments on infants and children were reported by two French investigators, Andral and Gavarret, in 1843. These workers employed a copper mask which was attached to the subject's face permitting the expired air to be collected in large glass globes. This air was later analyzed for carbon dioxide. Usually these tests were made in the early afternoon with the same interval after eating and with all the subjects exhibiting the same degree of muscular activity which generally involved a sitting position. Even at this early period, special emphasis was given to the influence of puberty. These workers reported a steady increase in the production of carbon dioxide between the ages of eight and 30 years with a sudden rise at the time of puberty.

Observations on children were made by Forster in Munich in 1877 (Benedict and Talbot, 1921) using the Pettenkofer and Voit method. Children from 14 days to 13 years of age were studied. The results were reported in grams of carbon dioxide excreted per hour for each 10 kg of body weight.

Speck in 1889 (Benedict and Talbot, 1921) reported observations on two girls, 10 and 13 years of age respectively, and a 13-year-old boy. He noticed that the total oxygen consumption of each of the three subjects was less than for a normal adult, but when computed on the basis of body weight it was much greater.

Studies were made in Stockholm by Sondén and Tigerstedt in 1895 (Rose, 1938) on boys and girls between the ages of eight and 15 years. These subjects were not in basal condition when studied as they were permitted to eat apples or candy while in the respiration chamber. Apparently up to this time most of the workers disregarded the influence of food and muscular activity, therefore, the values obtained were not strictly basal.

Magnus-Levy and Falk in 1899 (DuBois, 1916) supposedly made the first systematic study of normal individuals from childhood to old age. The Zuntz-Geppert apparatus was used and 25 children, 12 old men and women, and 25 others of intermediate ages including both sexes, were observed under basal conditions.

Metabolism from the modern viewpoint is believed (Talbot, 1925) to have begun in about 1898 with the work of Rubner and Heubner with infants using a modified Pettenkofer-Voit apparatus. Their data, for the most part, were not obtained under basal conditions.

An interest in metabolism studies in America began when Atwater and Rosa (1899) constructed a respiration calorimeter at Wesleyan University in Middletown, Connecticut. Improvements upon this apparatus were later made by Benedict (Atwater and Benedict, 1905) and it was then known as the Atwater-Rosa-Benedict respiration calorimeter. Murlin (1915) devised an incubator which permitted him to measure the metabolism of infants. With this, Murlin and Hoobler (1915) observed 10 hospital children between the ages of two months and one year. They found that the metabolism per square meter of surface area increased during the first few months of life.

DuBois (1916) studied the metabolism of eight normal boys 12 to 13 years of age, and compared his results with those of other workers. A Sage calorimeter was used and the results were expressed as calories per kilogram per hour and calories per square meter per hour. A high rate of metabolism was noted at these ages averaging 26 to 32 per cent higher than that of adults. This study was repeated two years later by Olmstead, Barr, and DuBois (1918) with the same subjects and under the same conditions. All boys showed a marked decrease in metabolism when the results were expressed as calories per square meter per hour. From this it was concluded that there is an increase in metabolism in the prepubescent period with a corresponding decrease after puberty has been established.

Stimulated by the introduction of a new portable apparatus by Benedict (1909, 1918) there was a sudden increase in basal metabolism studies in the United States. As more results were obtained it became necessary to have standards for comparison. Subsequently, many extensive investigations were carried out on individuals at different age levels for the purpose of setting up the needed standards.

Benedict (1919) reported a study of some 25 Boston children from one day to 16 years of age made over periods ranging from several months to three or four years. An increase in total calories per 24 hours and a decrease in calories per kilogram per 24 hours was found with increase in age. No irregularities or deviations were noted at the age of puberty. In this study, the children were not always in a strictly post-absorptive state at the time of the experiment and the tests were made while the children were asleep. A continuation of this investigation was reported by Benedict and Talbot (1921) on 108 boys and 70 girls ranging in age from birth to 15 years. Metabolism values were expressed as in the previous study and the same results were noted.

Bedale (1923) studied 45 boys and 55 girls in a boarding school in England. With heat production expressed in terms of calories per hour, calories per square meter per hour, and calories per 24 hours, an increase in metabolism was reported for subjects in the prepubscent period. A similar study was made by MacLeod (1924) with 43 girls from 11 to 14 years of age, inclusive, in a day school in New York. An increase in metabolism for the prepubertal girls was also noted when calories per 24 hours, calories per kilogram per 24 hours, calories per hour, and calories per square meter per hour were referred to age. This worker found that basal metabolism could be predicted better from body surface or height than from age or weight.

Sandiford and Harrington (1925), in a preliminary report on 157 normal school children consisting of 79 girls and 78 boys between the ages of five and 17 years, noted a decrease in calories per square meter of surface area which progressed regularly and appeared to be a straight line function for these ages.

In considering the effect of puberty on metabolism, Talbot (1925) noticed that subjects with enlarged thyroids showed a distinct rise in total metabolism. This he called a probable temporary hyperthyroidism of puberty which is not an uncommon clinical phenomenon. This worker, in summing up available evidence, concluded that the increase of metabolism at this age was probably due to rapid growth rather than to any changes associated with puberty.

A study of 46 girls in Chicago between the ages of eight and 18 years was reported by Blunt, Tilt, McLaughlin, and Gunn (1926). This work was repeated the second year with 22 of the same girls and the third year with 15 of them. No consistent changes were noted in year-to-year variations in metabolism nor did the variations show any effect due to puberty.

From observations of normal children from six to 12 years of age living in Georgia, Klugh (1926) reported very little variation for the different years which could not be accounted for by individual differences in the subjects.

Topper and Mulier (1932), working in New York, made basal metabolism tests on 28 girls and 10 boys from 10 to 16 years of age at six-month intervals over a period of one to four years. An increase in the basal metabolic rate when expressed in total calories per 24 hours was found in the prepubescent period with a subsequent decline after puberty was established. These workers believed that the increased basal rate coincided with the physiological age rather than with the chronological age and that it occurred earlier in girls than in boys, coincident with their earlier prepubescence.

Bruen (1933), in a mathematical analysis of the data in the literature, reported on the variations with age of the basal metabolic rate per unit of surface area. This author noted indications of a definite increase or an irregularity of decrease which was related to puberty. This he attributed to a cyclic acceleration which was not the effect of adolescent growth but represented an independent pubertal metabolic acceleration.

An investigation by Molitch and Cousins (1934) on 200 New

Jersey boys from nine to 18 years of age confirmed the results of DuBois, Olmstead, et al., and Topper and Mulier. Although their figures expressed as calories per square meter per hour did not show a definite increase, there was an irregularity of decrease which they believed was related to puberty.

Lewis (1936) reported a study on a group of 39 New York girls between the ages of 14 and 16 years. A Benedict-Roth apparatus with helmet was used. The purpose of this study was to investigate the relationship between the rate of growth in stature and the basic physiologic rate. The girls were grouped both chronologically and physiologically. The average rate of metabolism was expressed as calories per 24 hours, calories per kilogram per 24 hours, and calories per square meter. These values showed a slight but consistent decrease with chronological age. From a statistical analysis of the results of both groupings it was inferred that the decrease in metabolism with age is a function of chronological rather than of physiological age. Surface area was found to be a better basis than height or weight for predicting basal metabolism.

Wang, Kaucher, and Wing (1936) made basal determinations on 34 females of Cincinnati ranging in age from 11 to 30 years. Of this number, 18 were in the prepubertal group. Results showed that values for the postpubertal group as expressed in calories per 24 hours and calories per centimeter per 24 hours were decidedly higher while values in calories per kilogram per 24 hours and calories per square meter per hour were higher in the prepubertal group.

This difference, as the workers concluded, was undoubtedly due to the greater weight and surface area of the postpubertal group.

In summing up the evidence from previous metabolism studies, DuBois (1936, p. 184) made the following statements:

> It now seems to be quite well established that many individuals have some acceleration of metabolism at the time of puberty but this can be usually overlooked in large groups where at any given age some of the children are showing a rise in metabolism and others a fall. Only the study of individuals over long periods will bring out the facts clearly.

A study of 106 normal, healthy girls living in Boston by Talbot, Edwin, and Worcester (1937) showed a rise in total metabolism of about 100 Calories in some instances and none in others. A definite relationship was found between body weight and heat production. In regard to the effects of puberty upon the basal metabolism these workers concluded:

> The combined data of all observers indicate that an elevation of heat production of girls commences roughly at the age of 10 years and reaches its maximum at the establishment of catamenia. The metabolism then falls, and at the age of $15\frac{1}{2}$ years it is 5 per cent below the average trend. This so-called puberty reaction is not constant in Boston and is entirely absent in Madison, Wisc. The irregularity of its appearance may be taken to indicate that puberty per se is not the causative factor.... The evidence is strongly against the theory that the increased activity of the thyroid gland and the elevation in pulse rate are alone responsible for this rise. There is sufficient evidence to indicate that the extra growth in height is the primary factor with which the elevation of metabolism is connected.

Lewis, Kinsman, and Iliff (1937) reported a study in Denver on a large number of boys and girls from two to 12 years of age but refrained from drawing any conclusions as to the effect of puberty on metabolism. However, their results showed an increase in calories per hour when referred to weight and height and a decrease in calories per hour per square meter of surface area and in calories per hour per kilogram when both were referred to age. They did not find height to be as good a measure for comparing heat production as had been previously suggested by MacLeod (1924), and Talbot (1925) who concluded that the relationship between height and metabolism was closer for girls than any other method of comparison.

Observations were reported by Nakagawa (1937) on 24 Japanese children; 10 boys ranging in age from three years and seven months to 13 years and four months, and 14 girls from eight years and 11 months to 13 years and two months. The rate of increase in total heat production was higher for girls at the ages of 11 and 12 years than for the boys of the same age. This was believed to be due to the influence of the increase in rate of growth at puberty. The basal metabolic rate per unit of body weight or surface area showed a decrease in inverse proportion to age.

Talbot (1938) presented standards for the basal metabolism of children developed by statistical methods from data on 2,200 girls and 800 boys. He suggested that several factors should be considered in the interpretation of the metabolism of children, such as, geographic factors and variations which occur from day to day. He considered variations of -15 to +15 per cent from these standards as normal.

Other factors besides puberty which may or may not be connected with this condition have been considered by several workers as having some effect upon the variations in the heat production of children.

Cameron (1925) reported basal metabolic determinations upon 250 Winnipeg school children between the ages of six and 17 years, inclusive. He found Benedict and Talbot standards based on body weight too low for children of that climate.

MacLeod and Rose (1926) made observations upon 13 country children and 10 city children of New York. Determinations were made first in December and again in late March or early April. The city children had lower rates in the spring which was attributed to the fact that they were probably indoors during the winter months more than the country children.

Seasonal variations were also reported by Nakagawa (1935) in a study of 26 children over a period of one year. The maximum heat production occurred in January and the minimum during the month of July.

In reference to the effect of nutrition upon the metabolism of children, Wang, Kern, Frank, and Hays (1926) made studies in Chicago of nine normal girls and 32 undernourished children consisting of 14 boys and 10 girls. They found that normal children varied less from the predicted metabolism according to weight than from any other standard; while underweight children adhered more closely to the figures for age and height. They also noted that the basal rate seemed to decrease with increasing underweight when computed on the basis of height but when computed on the basis of weight it was increased over normal standards. The normal children agreed closely with predicted rates per kilogram but the underweight children were high in this respect.

Lucas and Pryor (1933) made a study on 573 San Francisco children four to 15 years of age with reference to body build as a factor in basal metabolism. They found that children of slender build had higher basal metabolic rates than broadly-built children of the same age and sex and that high rates were characteristic of the linear type. These workers claimed that differences in oxygen requirements were not determined by nutritional variations in children.

Johnston and Maroney (1936) reported a study made in Detroit on the relationship of the dietary intake to the basal metabolism of 33 children ranging from four to 15 years of age over a period of three years. All diets were carefully calculated and the nitrogen of the meals determined. A definite lowering of basal heat production with submaintenance diets was found. A maximal elevation of the basal rate occurred when a high-caloric, high-protein diet was eaten. The addition to an already adequate diet of an excessive amount of carbohydrate in one instance caused a slight decrease of basal metabolism. An abundance of fat caused a slight increase while a plethora of protein showed a marked rise in the basal metabolic rate.

Other studies have been made and others are being carried on at present in regard to the effects of altitude, climate, and nationality on normal basal metabolism. The method of selection of data also appears to be a significant factor in the results obtained.

METHOD

The subjects for this study were 24 Kansas girls ranging in age from nine years and eight months to 12 years and six months at the beginning of the observations. These girls were divided into 10-, 11-, and 12-year-old groups according to age which was taken to their nearest birthday. At the time the study was begun the 10-year group consisted of eight girls ranging from nine years and eight months to 10 years and four months of age; the 11-year group was composed of 10 girls from 10 years and eight months to 11 years and four months; and the 12-year group included six girls from 11 years and eight months to 12 years and six months of age.

Twenty-two of the subjects were Concordia grade-school children. Observations on them were made at St. Joseph's Hospital in Concordia. Two of the 11-year group were from Manhattan and their tests were made at the Nutrition Laboratory of the Department of Food Economics and Nutrition of the Kansas State College. The children were all regarded as normal in health, size, height, and weight, and were free from noticeable physical defects.

A brief case history was obtained from each subject to supply information desirable for interpretation of the results. This included type of body build, previous illnesses, the usual number of hours of sleep each day, and general living conditions. Special attention was given to dietary habits, the kinds of food eaten, and particularly the extent to which milk, fruit, vegetables, meat, and eggs were included in the daily menu. Each child's diet was scored for adequacy as shown in Table 1.

Table 1. Method of scoring adequacy of diet.

Rating of diet	Foods included daily			
	Milk	Fruit	Vegetables besides potatoes	Meat, eggs, or fish
	cups	servings	servings	servings
Good	3-4	2	2	2
Fair	2-3	1-2	1-2	1-2
Poor	1-2	1	1	1
Very poor	less than 1	less than 1	less than 1	less than 1

The number of meals eaten each day and the frequency of between-meal eating were also noted.

The study covered a period of five months. Observations were begun the latter part of August, 1941, and were continued until the last of January, 1942. It was planned originally to to make tests on each individual at two-week intervals but this was not always possible. If the subjects had bad colds, coughs, or if a temperature were evident, the determinations were not made as the results obtained would not have represented basal conditions. Because of these occasional interruptions, the observations on each child varied from eight to 11 in number. A total of 239 determinations were made on the entire group.

Before beginning the metabolism study, each girl was instructed as to the procedure to be followed and the necessary requirements for a good basal test. A copy of the directions was given to each child (Form I). Appointments were made in advance to permit her to make the required preparation. All tests were made between 7:00 and 8:30 a.m. Usually two subjects were observed each morning. The children who lived near the hospital walked slowly to the laboratory; those who lived several blocks away were brought by car. After the girls arrived at the hospital they were required to lie quietly with enough covering to be comfortably warm for at least 30 minutes before the test was begun. At the end of the rest period, oral temperature, respiration, and pulse rate were taken.

A closed-circuit Sanborn waterless metabolism apparatus, 1939 model, with motor driven circulation was used for making all the determinations on the Concordia children (Fig. 1). The "short-test" method was employed. This permitted the omission of calculated corrections for barometric pressure and temperature because these corrections were made automatically by means of a guage when a measured volume of oxygen, $1\frac{1}{4}$ l. was released from the cylinder into an inner pressure chamber. The directions of the Sanborn Company (1939) were followed carefully

FORM I

Directions for basal appointments

1. Be sure to have at least eight hours of sleep or rest in bed the night before the test is to be made.

2. Take no food (except water) after the evening meal the night before the test is given.

3. Allow enough time to dress leisurely in the morning before the test.

4. Come to the hospital in a car or taxi if possible. If it can be arranged you may stay at the hospital the night before the test is to be made.

5. Breakfast will be served after the test.

6. The test cannot be made if you are excited, nervous, worried, or show any rise in temperature.

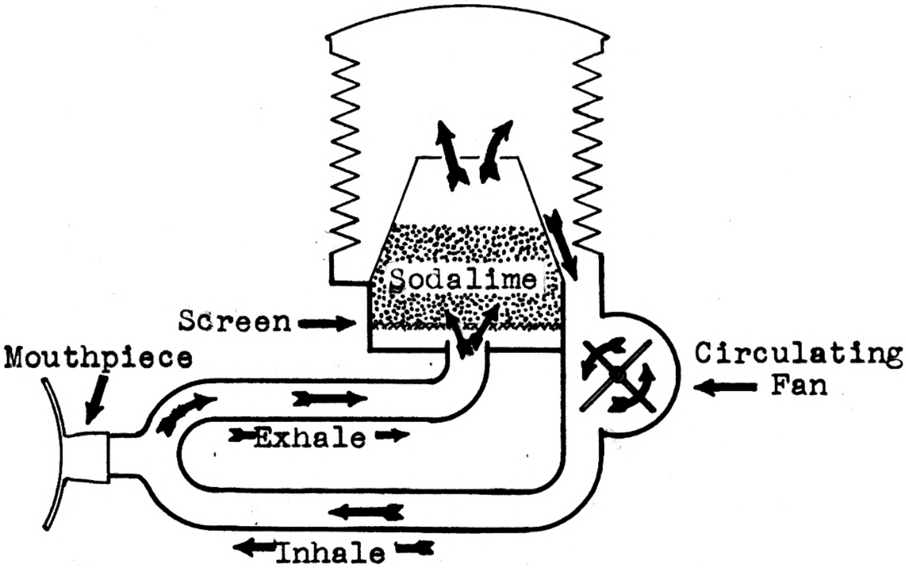

Fig. 1. Schematic diagram of Sanborn waterless metabolism apparatus. Courtesy of Sanborn Co., Cambridge, Mass.

for preparation of the apparatus and performance of the test. The mouthpiece and noseclip were checked by observation several times during a determination in order to detect any possible leakage. Valves were also checked and the tracings on the chart were watched for any marked deviation from the normal upward slope which would denote possible leakage. The sodalime was changed regularly at the end of 60 determinations unless it became exhausted beforehand as was shown by increased rapidity and irregularity of the subject's respiration. Any marked restlessness on the part of a child was noted by the observer and used in evaluating the determinations. If, according to the judgment of the operator, standard conditions were not secured the results were discarded.

After each observation the child was weighed without shoes but with the other clothing ordinarily worn indoors. The height was then taken, also without shoes. Age was recorded to the nearest birthday. Each subject was questioned as to the amount of rest in bed secured during the preceding night, if any food were taken since the evening before, if she hurried in dressing or in coming to the laboratory, and if she felt comfortable during the test. If these requirements were not fulfilled the conditions were not standard and the determination was discarded. Usually two tests were made on each girl during an observation period. If she appeared unduly fatigued at the end of the first test or if she were late for her appointment, a second one was omitted. Occasionally the time available did not permit a second test. All determinations apparently free from technical errors and in which basal conditions were believed to have been met were used in this investigation.

The results of each test, as calculated from the individual charts, were expressed as cubic centimeters of oxygen consumed per minute. This was converted into Calories per hour by dividing by 3.454 as directed by the Sanborn Company (personal communication). This factor is based on a respiratory quotient of 0.82 and the calorific value of oxygen which is 4.825 Calories per liter (Sanborn Metabolism Tables, p. 27) when the subjects have been consuming a mixed diet as was the case with these children.

The same procedure was followed for the Manhattan girls. A Benedict-Roth closed-circuit respiration apparatus was used and two six-minute tests were made at each observation. With this type of machine the oxygen consumption was expressed directly in Calories per hour. The heat equivalent of the oxygen consumed is one Calorie per hour per millimeter fall of the spirometer bell. This is based upon the following data: The spirometer bell has a volume of 20.73 cc of oxygen per millimeter of height and 1 l. of oxygen has a heat equivalent of 4.825 Calories under ordinary conditions which assume the subject consumes a mixed diet. A fall of 1 mm in six minutes was equivalent to 20.73 cc of oxygen or 207.3 cc per hour or 0.2073 l. per hour; 0.2073 x 4.825 = 1 Calorie per hour per millimeter fall in the spirometer bell. These figures were corrected for temperature and barometric pressure.

The basal heat production of each subject was expressed in total calories per 24 hours, calories per kilogram per 24 hours, calories per centimeter per 24 hours, calories per square meter per 24 hours, calories per hour, and calories per square meter per hour. The standard used in this study was that of Aub-DuBois as modified by Boothby and Sandiford (1929). The percentage deviation from this standard on the basis of calories per hour was calculated. From the individual means of the above mentioned values, the means, standard deviations from the means, and coefficients of variation were calculated for each age group.

DISCUSSION OF RESULTS

The data for each girl were tabulated as shown for subject E. D. (Table 2). An increase was noted in height and weight with corresponding increase in body surface in all children over the experimental period of approximately five months. For subject E. D. (Table 2), increases of 3.5 cm in height and 1.8 kg in weight were noted. The maximum increase observed was 3.2 cm in height and 4.6 kg in weight for subject L. L., 12 years of age; whereas the minimum was only 1.3 cm and 0.5 kg for subject B. W. of the 11-year group.

The basal metabolic rate for each child throughout the study usually varied more or less from test to test. Subject E. D. (Table 2) showed extremes of deviation from the Aub-DuBois standard as modified by Boothby and Sandiford ranging from -10.3 to +2.1 per cent. The maximum deviation noted was for subject E. W., 12 years of age, whose basal rate fluctuated during the

Table 2. Basal metabolism data for subject E. D., age 11 years.[1]

Date of test	Ht. cm	Wt. kg	Body temp.[2] °F.	Pulse min.	Respiration min.	Sleep hrs.	Surface area sq m	Calories: Per 24 hrs. Total	Per cm	Per sq m	Per kg	Per hr. Per sq m	Actual	Predicted	Deviation[3] per cent
8/23/41	147.3	40.0	97.9	60	22	9.0	1.28	1228.8	8.3	960.0	30.7	40.0	51.2	57.7	-10.3
9/5 /41	148.6	40.2	97.4	68	20	8.5	1.29	1274.4	8.6	988.0	31.7	41.2	53.1	57.5	- 7.7
9/19/41	148.6	40.2	97.9	66	22	8.5	1.29	1248.0	8.4	967.4	31.0	45.3	52.0	57.4	- 9.5
9/30/41	149.2	40.5	98.0	64	22	8.5	1.30	1348.8	9.0	1037.5	33.3	43.2	56.2	57.9	- 2.9
10/17/41	148.8	40.0	97.4	72	22	10.0	1.29	1309.2	8.8	1014.9	32.8	42.3	54.6	57.4	- 5.0
10/31/41	149.2	40.9	97.6	80	20	9.0	1.30	1354.8	9.1	1042.2	33.2	43.4	56.5	57.7	- 2.2
11/14/41	149.2	40.9	98.0	70	20	8.5	1.30	1341.6	9.0	1032.0	32.8	43.0	55.9	57.7	- 2.2
12/2 /41	150.2	41.8	97.8	70	22	9.0	1.32	1296.0	8.6	981.9	31.0	40.9	54.0	58.5	- 7.7
12/12/41	150.2	40.9	98.0	72	18	8.5	1.31	1389.6	9.3	1060.8	34.0	44.2	57.9	58.0	- 0.2
1/9 /42	150.8	41.4	96.8	68	18	8.0	1.32	1411.2	9.4	1069.1	34.1	44.5	58.8	58.3	+ 0.9
1/23/42	150.8	41.8	98.4	72	22	9.0	1.32	1425.6	9.5	1080.0	34.1	45.0	59.4	58.2	+ 2.1
Mean	149.4	40.8	97.7	69.3	20.7	8.8	1.30	1329.8	8.9	1021.3	32.6	43.0	55.4	57.8	- 4.1

[1] Sample of data collected for each subject.
[2] Oral.
[3] Aub-DuBois standard as modified by Boothby and Sandiford.

study from -23.6 to +16.6 per cent of the standard. The minimum variation, ranging from -5.6 to -0.3 per cent, was observed for subject F. S. of the 11-year group in a total of eight tests. The differences between determinations on the same subject were probably due to unrecognized factors existing under conditions believed to be basal. It is probable that the same degree of physical and mental relaxation was not attained in all observations although no outward manifestations were evident which would permit discarding irregular results.

The mean data for each subject were tabulated according to age (Tables 3, 4, and 5). From these data the group means, standard deviations from the means, and coefficients of variation were calculated as indicated. Considerable individual variation was noted in all factors within each age group. Coefficients of variation indicated that the greatest variability for the three ages was in weight (Table 6), which ranged from 12.4 per cent for the 10-year-old group to 17.6 per cent for the 12-year-old subjects. The least variability for the three years was for height, from 2.7 to 5.7 per cent. The variability for basal metabolism, expressed as calories per square meter, was also low. This was probably to be expected because the girls composing each group varied a good deal in height, weight, and body build.

A comparison of the mean results (Table 6) showed an increase from year to year in height, weight, surface area, and heat production when expressed in total calories per 24 hours

Table 3. Mean data on 10-year-old group.

Subject	No. obs.	Ht. cm	Wt. kg	Body temp.[1] °F.	Pulse per min.	Respiration per min.	Sleep hrs.	Surface area sq m	Calories: Per 24 hrs.: Total	Per cm	Per sq m	Per kg	Per hr.: Per sq m	Actual	Predicted	Deviation[2] per cent
M. A. D.	10	148.3	34.1	98.0	72.5	19.7	8.8	1.21	1254.0	8.7	1066.0	37.5	44.1	53.3	54.9	- 2.9
D. S.	10	131.8	26.2	98.6	89.4	20.0	9.7	0.98	1241.0	9.4	1264.0	47.4	52.3	51.7	44.9	+ 15.1
A. R. B.	11	145.5	31.9	98.2	80.2	19.5	8.3	1.16	1256.0	8.6	1087.0	39.4	45.3	52.3	52.7	- 0.7
B. A. P.	10	138.3	29.3	98.0	77.2	21.3	10.0	1.07	1124.0	8.2	1051.0	38.3	43.8	46.8	48.2	- 2.9
A. L. B.	10	132.9	26.0	97.9	72.8	21.6	9.5	0.98	1048.0	7.9	1069.0	40.4	44.4	43.7	44.7	- 2.2
J. F.	10	133.7	22.1	99.1	77.8	20.1	10.4	0.93	1063.0	8.0	1147.0	48.0	47.8	44.3	42.7	+ 3.7
E. B.	9	136.8	27.1	98.2	69.8	19.5	9.7	1.03	1210.0	8.8	1180.0	44.7	49.2	50.4	47.1	+ 7.0
P. B.	8	131.1	28.9	98.4	80.0	19.4	10.2	1.02	1071.0	8.2	1050.0	37.1	43.8	44.6	45.7	- 2.4
Mean	9.75	137.3	28.2	98.3	77.5	20.1	9.6	1.05	1158.0	8.5	1114.0	41.6	46.3	48.4	47.6	+ 1.7
Standard deviation		± 6.0	± 3.5	± 0.4	± 5.7	± 0.8	± 0.7	± 0.10	± 85.3	± 0.5	± 71.7	± 4.2	± 2.9	± 3.7	± 3.9	± 6.0
Coefficient of variation		4.4	12.4	0.4	7.4	4.0	7.3	9.80	7.4	5.9	6.4	10.1	6.3	7.6	8.2	---

[1]Oral.
[2]Aub-DuBois standard as modified by Boothby and Sandiford.

Table 4. Mean data on 11-year-old group.

Subject	No. obs.	Ht. cm	Wt. kg	Body temp.[1] °F.	Pulse per min.	Respiration per min.	Sleep hrs.	Surface area sq m	Calories							Deviation[2] per cent
									Per 24 hrs.				Per hr.			
									Total	Per cm	Per sq m	Per kg	Per sq m	Actual	Predicted	
C. B.	10	139.9	29.2	97.6	73.0	19.0	9.9	1.07	1081.0	7.7	1007.0	37.1	42.0	45.1	47.3	- 4.6
N. W.	10	147.4	32.4	98.2	73.2	18.0	10.6	1.17	1257.0	8.6	1071.0	38.9	44.7	52.4	52.3	+ 0.2
M. G.	11	129.4	26.1	98.4	65.8	20.7	9.2	0.97	1070.0	8.3	1105.0	41.1	46.1	44.6	43.2	+ 3.2
M. P.	10	135.5	28.7	98.7	86.9	20.0	9.3	1.04	1121.0	8.3	1076.0	39.1	44.9	46.7	46.6	+ 0.2
M. T. J.	11	158.9	42.5	98.3	83.0	19.5	9.0	1.40	1394.0	8.8	1007.0	32.8	42.0	58.1	61.0	- 4.8
D. H.	11	138.9	37.5	98.2	80.2	20.7	10.0	1.20	1198.0	8.6	1001.0	32.0	41.7	49.9	53.0	- 5.8
E. D.	11	149.4	40.8	97.7	69.3	20.7	8.8	1.30	1330.0	8.9	1021.0	32.6	43.0	55.4	57.8	- 4.2
B. W.	9	133.8	28.8	98.7	79.3	17.8	10.0	1.04	1132.0	8.5	1091.0	39.3	45.5	47.2	46.2	+ 2.2
F. S.	8	141.1	29.4	98.2	62.9	21.2	10.6	1.09	1133.0	8.0	1041.0	38.5	43.4	47.2	48.6	- 2.5
J. I.	8	143.5	29.9	98.3	82.0	13.9	10.4	1.11	1131.0	7.9	1019.0	37.8	42.5	47.1	50.1	- 6.0
Mean	9.9	141.8	32.5	98.2	75.6	19.2	9.8	1.14	1185.0	8.4	1044.0	36.9	43.6	49.4	50.6	- 2.2
Standard deviation		± 8.1	± 5.4	± 0.3	± 7.5	± 2.1	± 0.6	± 0.1	± 103.3	± 0.4	± 36.7	± 3.1	± 1.6	± 4.3	± 5.2	± 3.2
Coefficient of variation		5.7	16.6	0.3	9.9	15.6	6.1	8.8	8.7	4.8	3.5	8.4	3.7	8.7	10.3	---

[1] Oral.

[2] Aub-DuBois standard as modified by Boothby and Sandiford.

Table 5. Mean data on 12-year-old group.

Subject	No. obs.	Ht. cm	Wt. kg	Body temp.[1] °F.	Pulse per min.	Respiration per min.	Sleep hrs.	Surface area sq m	Calories							Deviation[2] per cent
									Per 24 hrs.				Per hr.			
									Total	Per cm	Per sq m	Per kg	Per sq m	Actual	Predicted	
M. R. S.	10	140.5	31.4	97.7	72.8	18.2	9.7	1.12	1239.0	8.9	1111.0	39.5	46.3	51.7	47.6	+ 8.6
L. L.	10	145.5	38.3	98.2	68.4	19.3	10.2	1.25	1385.0	9.6	1116.0	36.8	46.5	57.9	53.2	+ 8.8
E. W.	11	153.6	46.5	97.8	78.3	22.5	9.1	1.41	1438.0	9.4	1023.0	31.0	42.6	59.9	61.4	- 2.4
M. L. V.	10	143.4	30.7	98.1	79.4	18.1	8.6	1.12	1149.0	8.0	1025.0	37.4	42.7	47.9	47.7	+ 0.4
M. L. V.	10	144.5	32.9	98.5	79.8	17.8	8.5	1.17	1197.0	8.3	1022.0	36.1	42.9	49.9	49.6	+ 0.6
J. F.	10	145.1	28.4	98.8	77.0	20.0	10.0	1.09	1153.0	8.0	1059.0	40.7	44.1	48.1	47.5	+ 1.3
Mean	10.2	145.4	34.7	98.2	76.0	19.3	9.4	1.19	1260.0	8.7	1059.0	36.9	44.2	52.6	51.2	+ 2.7
Standard deviation		± 4.0	± 6.1	± 0.4	± 4.1	± 1.6	± 0.7	± 0.10	± 112.2	± 0.6	± 40.4	± 3.1	± 1.6	± 4.7	± 5.0	---
Coefficient of variation		2.7	17.6	0.4	5.4	8.3	7.4	8.4	8.8	6.9	3.8	8.4	3.6	8.9	9.8	---

[1]Oral.

[2]Aub-DuBois standard as modified by Boothby and Sandiford.

or calories per hour. Increase in growth was greatest between the 10- and 11-year groups while the greatest increase in total heat production occurred between 11 and 12 years of age. The increases noted (Table 6) were as follows:

	10 to 11 yrs.	11 to 12 yrs.
Height	4.5 cm	3.6 cm
Weight	4.3 kg	2.2 kg
Surface area	0.09 sq m	0.05 sq m
Cal. per 24 hrs.	27	75
Cal. per hr	1	3.2

These findings do not agree completely with those of Nakagawa (1937), who observed the greatest increase in growth as well as in heat production between the ages of 11 and 12 years in Japanese girls who were studied over a period of one year. Possibly in the present study the increase in total basal heat production between the ages of 11 and 12 years was not due entirely to obvious growth. This may indicate that the effects of spproaching puberty had some influence on heat production in this group of girls.

With basal metabolism expressed in terms of Calories per square meter of body surface, a decrease of 70 Calories per 24 hours or 2.7 Calories per hour was observed between the ages of 10 and 11 years (Table 6); whereas a slight increase of 15 Calories per 24 hours or 0.6 Calorie per hour was noted between 11 and 12 years of age. This difference for the latter group per unit of body surface may be regarded as negligible. On the other hand it possibly confirms the tendency already suggested toward a slight upward trend in basal heat production at this age or it

Table 6. Comparison of the basal metabolism of the different age groups.

Data	10-year group (8 subjects)			11-year group (10 subjects)			12-year group (6 subjects)		
	Mean	S. D.[1]	V.[2]	Mean	S. D.[1]	V.[2]	Mean	S. D.[1]	V.[2]
Height in cm	137.30	± 6.0	4.4	141.80	± 8.1	5.7	145.40	± 4.0	2.7
Weight in kg	28.20	± 3.5	12.4	32.50	± 5.4	16.6	34.70	± 6.1	17.6
Surface area in sq m	1.05	± 0.1	9.5	1.14	± 0.1	8.8	1.19	± 0.1	8.4
Cal./24 hrs.	1158.00	± 85.3	7.4	1185.00	±103.3	8.7	1260.00	±112.2	8.8
Cal./sq m /24 hrs.	1114.00	± 71.7	6.4	1044.00	± 36.7	3.5	1059.00	± 40.4	3.8
Cal./kg /24 hrs.	41.60	± 4.2	10.1	36.90	± 3.1	8.4	36.90	± 3.1	8.4
Cal./cm /24 hrs.	8.50	± 0.5	5.9	8.40	± 0.4	4.8	8.70	± 0.6	6.9
Cal./sq m /hr.	46.30	± 2.9	6.3	43.60	± 1.6	3.7	42.20	± 1.6	3.6
Cal./hr.	48.40	± 3.7	7.6	49.40	± 4.3	8.7	52.60	± 4.7	8.9

[1]Standard deviation.
[2]Coefficient of variation.

may mean an irregularity in decrease such as was observed by Bruen (1933) and Molitch and Cousins (1934).

On the basis of weight, a mean decrease from 41.6 to 36.9 Calories per kilogram per 24 hours, a difference of 4.7 Calories, was noted from 10 to 11 years (Table 6); while the mean values for the 12-year group were the same as for the 11-year-old girls remaining at 36.9 Calories per kilogram. It is thus apparent that the younger children, although having a lower total basal metabolism, had a higher rate per unit of weight amounting to 11.3 per cent. Per unit of body surface it was only 6.2 per cent higher than that of the older children. This is in accord with the generally accepted rule that basal metabolism per unit of weight decreases with age. It also emphasizes that basal metabolism is more nearly proportional to body surface than to weight. The failure of the basal metabolism to decrease per kilogram from 11 to 12 years is further evidence of some special stimulus that was not due to increase in weight.

The mean values expressed in terms of Calories per centimeter of height per 24 hours showed a decrease of 0.1 Calorie per centimeter between 10 and 11 years of age (Table 6) and an increase of 0.3 Calorie between the ages of 11 and 12 years. These small differences suggest that Calories per centimeter may be the most uniform way of expressing basal rates of any of the measures used for the subjects followed in this study.

In summarizing each child's history (Table 7) and attempting to associate the data with the results of her basal

Table 7. Summary of case histories.

Subject	Age yrs.	Body build type	Sleep hrs.	Previous illnesses	Living conditions	Diet
P. B.	10	Lateral	9-11	Measles, flu	Favorable	Good
A. L. B.	10	Linear	9-10	Measles, flu, colds	Favorable	Good
D. S.	10	Linear	9-11	Measles, flu	Unfavorable	Fair
J. F.	10	Linear	10-12	Tonsilitis, flu, measles	Unfavorable	Very poor
E. B.	10	Medium	9-11	None	Favorable	Fair
B. A. P.	10	Linear	9-11	Flu	Favorable	Good
A. R. B.	10	Linear	8-9	Measles, flu	Favorable	Fair
M. A. D.	10	Linear	8-9	None	Favorable	Fair
M. G.	11	Medium	9-10	Pneumonia, measles, chicken pox	Moderately favorable	Fair
B. W.	11	Medium	9-10	Chicken pox, whooping cough	Unfavorable	Very poor
M. P.	11	Medium	9-10	Chicken pox, flu, measles, mumps	Favorable	Good
E. D.	11	Lateral	8-9	Measles, chicken pox, whooping cough	Unfavorable	Poor
D. H.	11	Lateral	9-11	Measles, chicken pox, appendicitis	Moderately favorable	Fair
C. B.	11	Medium	8-10	Measles, whooping cough, chicken pox	Favorable	Good
F. S.	11	Medium	10-11	Measles, mumps, whooping cough	Favorable	Good
J. I.	11	Linear	10-11	Chicken pox, mumps	Favorable	Good
N. W.	11	Linear	10-11	Pneumonia, flu, measles	Favorable	Good
M. T. J.	11	Lateral	9-10	Whooping cough, measles	Favorable	Fair
M. R. S.	12	Linear	9-10	None	Unfavorable	Fair
M. L. V.	12	Medium	8-10	Colds, flu	Favorable	Good
M. L. V.	12	Medium	9-10	Colds, flu	Favorable	Good
J. F.	12	Medium	9-10	Colds, flu	Unfavorable	Very poor
L. L.	12	Medium	9-10	Measles, whooping cough, chicken pox	Favorable	Fair
E. W.	12	Lateral	8-10	Chicken pox, measles	Favorable	Good

metabolism test, neither dietary habits nor living conditions appeared to exert any particularly noticeable influence upon the basal rate. However, a somewhat lower rate per unit of weight was noted for the children who received a good diet than for those on very poor or fair diets. Again such factors as variations in body build and too few subjects prevented the drawing of any definite conclusions regarding this point, but these findings possibly suggest that the children on good diets have less actively metabolizing tissue in their bodies per unit of weight. This in turn indicates the presence of more body fat as would be expected with a good diet.

The children were classified according to type of body build (Table 8) as linear, medium, and lateral. In comparing the mean results of the basal metabolism tests from each group, it was observed that the linear children had the highest rates when expressed as calories per kilogram per 24 hours and calories per square meter per hour and the lateral group was lowest as to these values although somewhat higher in total calories. Calories per centimeter per 24 hours were about the same for the three groups. These findings agree with those of other workers who have found that the linear type apparently exhibits a higher rate of metabolism per unit of weight, and to a lesser degree, of body surface whereas the lateral type, which tends to be heavy, may have a higher total metabolism although it will be lower per unit of weight and per unit of body surface.

When the results of this study were compared with those of other workers (Table 9), it appeared that the total calories

Table 8. Comparison of the mean metabolism of children of linear, medium, and lateral types of body build.

Subject	Age yrs.	Calories: Per 24 hrs. Total	Per kg	Per cm	Per hr. Per sq m	Deviation[1] per cent
Linear						
D. S.	10	1241	47.4	9.4	52.3	+ 15.1
A. L. B.	10	1048	40.4	7.9	44.4	- 2.2
J. F.	10	1063	48.0	8.0	47.8	+ 3.7
B. A. P.	10	1124	38.3	8.2	43.8	- 2.9
M. A. D.	10	1254	37.5	8.7	44.1	- 2.9
A. R. B.	10	1256	39.4	8.6	45.3	- 0.7
N. W.	11	1257	38.9	8.6	44.7	+ 0.2
J. I.	11	1131	37.8	7.9	42.5	- 6.0
M. R. S.	12	1239	39.5	8.9	46.8	+ 8.6
Mean	--	1178	40.8	8.5	45.7	+ 1.4
Medium						
E. B.	10	1210	44.7	8.8	49.2	+ 7.0
C. B.	11	1081	37.1	7.7	42.0	- 4.6
M. G.	11	1070	41.1	8.3	46.1	+ 3.2
M. P.	11	1121	39.1	8.3	44.9	+ 0.2
F. S.	11	1133	38.5	8.0	43.4	- 2.5
B. W.	11	1132	39.3	8.5	45.5	+ 2.2
M. L. V.	12	1149	37.4	8.0	42.7	+ 0.4
M. L. V.	12	1197	36.1	8.3	42.9	+ 0.6
J. F.	12	1153	40.7	8.0	44.1	+ 1.3
L. L.	12	1385	36.8	9.6	46.5	+ 8.8
Mean	--	1163	39.1	8.4	44.7	+ 1.7
Lateral						
P. B.	10	1071	37.1	8.2	43.8	- 2.4
D. H.	11	1198	32.0	8.6	41.7	- 5.8
E. D.	11	1330	32.6	8.9	43.0	- 4.2
M. T. J.	11	1394	32.8	8.8	42.0	- 4.8
E. W.	12	1438	31.0	9.4	42.6	- 2.4
Mean	--	1286	33.1	8.8	42.6	- 3.9

[1]Aub-DuBois standard as modified by Boothby and Sandiford.

reported by Bedale for her subjects, who were English children, were lower than those of the 10-year group and higher than those of the 11- and 12-year-old girls used in this investigation. These findings were in close agreement in regard to total calories with those reported by MacLeod on New York girls and those of Blunt et al. on Chicago girls. MacLeod did not include 10-year-old subjects in her investigation but her values expressed in total calories for the 11- and 12-year groups were only slightly higher than those of this study. Blunt et al. also found slightly higher values in total calories and calories per hour but these differences were slight when compared with those of Bedale (Fig. 2).

Comparing the results on the basis of weight, both MacLeod's and Blunt's findings were lower than those of the present study (Table 9). This seems to indicate that the Kansas children may have been lighter in weight than the subjects used by MacLeod and Blunt living in New York and Chicago respectively. The highest rate in calories per kilogram occurred in the 10-year-old group both in this study and in Blunt's. MacLeod obtained a higher rate per kilogram for 12- than for 11-year-old children; Blunt's results showed a lower rate for 12- than for 11-year-old girls, whereas in this study the values for these ages were identical.

With heat production expressed in calories per centimeter per 24 hours, the values reported by Blunt et al. were practically the same as those observed for the Kansas children; while those of MacLeod were slightly lower (Table 9). The work of

Table 9. Results of some earlier investigations compared with those of the present study.

	Investigator															Present study		
	Bedale (1923)			MacLeod (1924)			Blunt et al. (1926)			Boothby and Sandiford (1929)			Boothby, Berkson, and Dunn (1936)					
Subjects Age	10	11	12	10	11	12	10	11	12	10	11	12	10	11	12	10	11	12
No.	2	3	10	0	4	18	11	13	18	-	-	-	20	26	27	8	10	6
Total Cal. per 24 hrs.	988.00	1498.00	1402.00	-	1191.00	1295.00	1165.00	1188.00	1309.00	-	-	-	-	-	-	1158.00	1185.00	1260.00
Cal. per kg per 24 hrs.	- --	- --	- --	-	29.20	32.30	37.20	33.70	32.40	-	-	-	-	-	-	41.60	36.90	36.90
Cal. per cm per 24 hrs.	- --	- --	- --	-	7.90	8.61	8.53	8.32	8.74	-	-	-	-	-	-	8.50	8.40	8.70
Cal. per hr.	41.15	62.40	58.41	-	49.60	54.00	48.50	49.50	54.50	-	-	-	-	-	-	48.40	49.40	52.60
Cal. per sq m per hr.	40.90	47.73	43.89	-	37.50	41.30	44.20	41.50	42.30	45.80	44.60	43.40	45.92	46.07	43.98	46.30	43.60	44.20

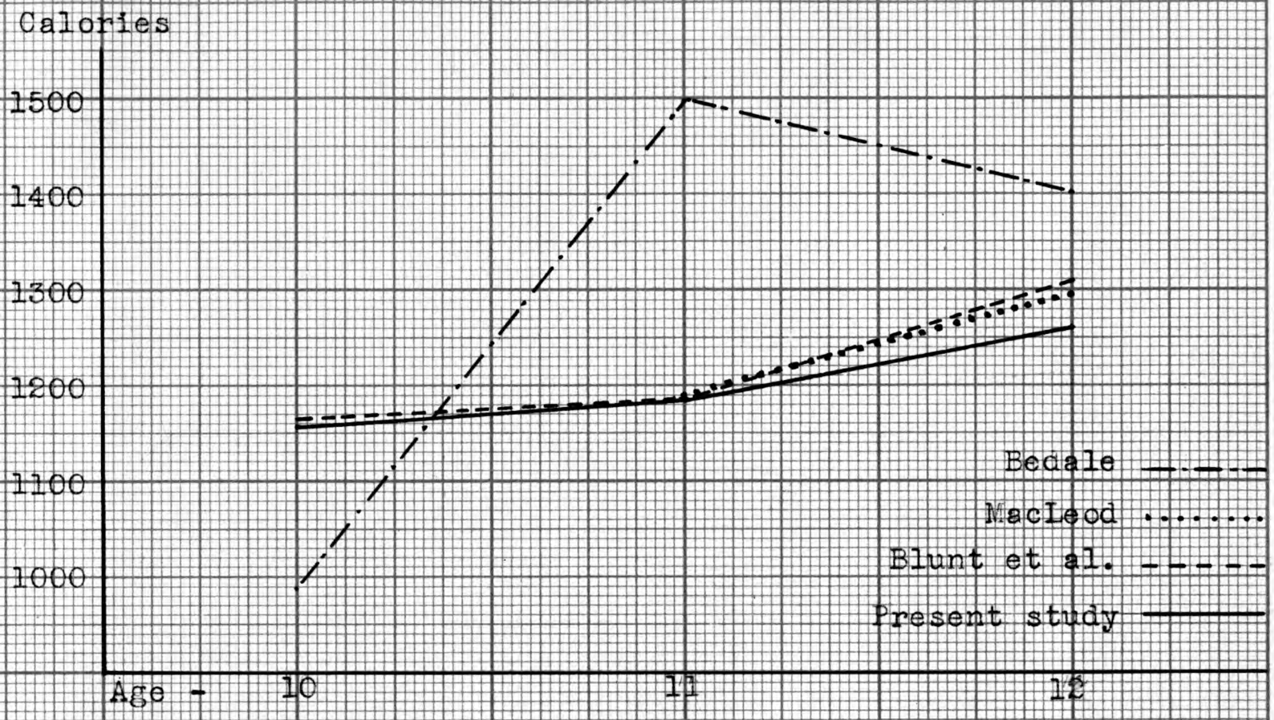

Fig. 2. Calories per 24 hours referred to age.

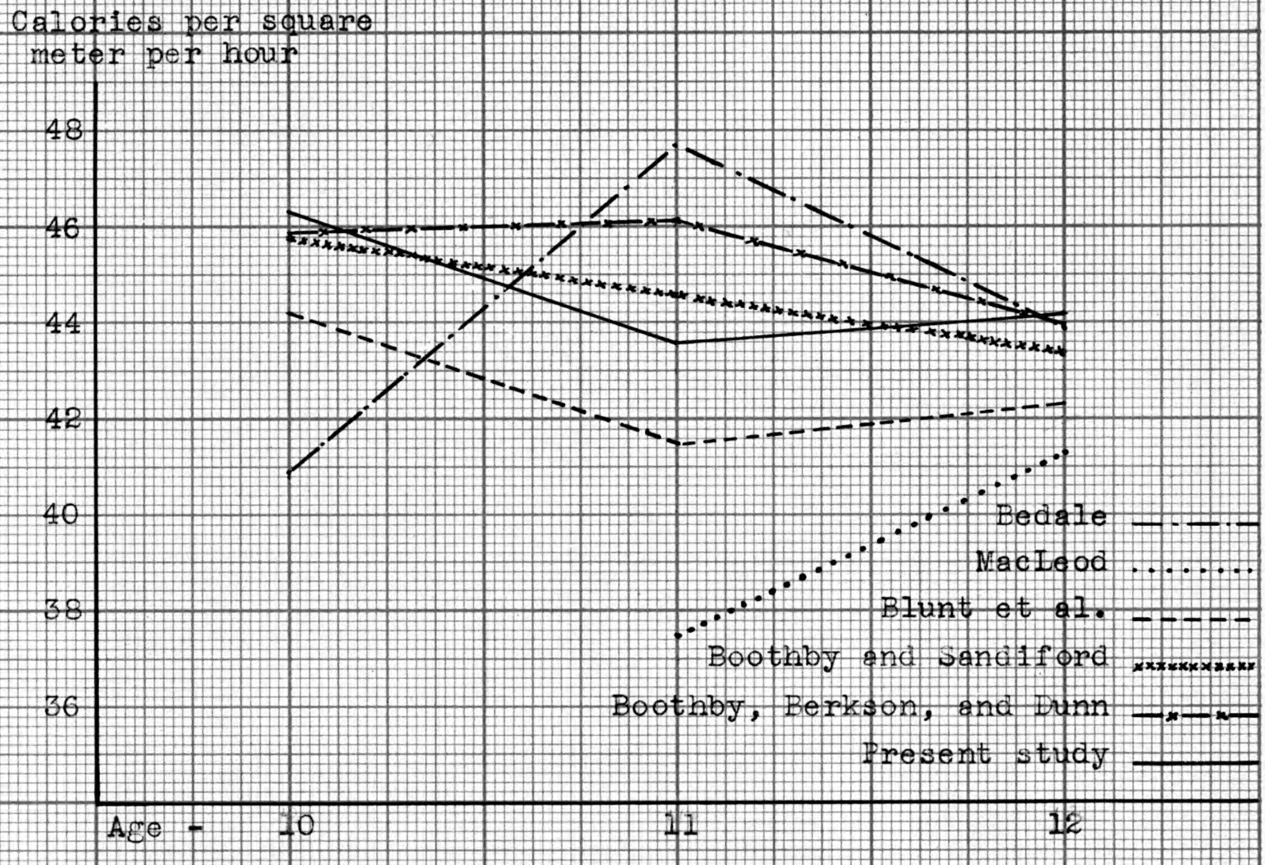

Fig. 3. Calories per square meter per hour referred to age.

these two investigators as well as Talbot's findings (1925) appear to confirm calories per unit of height as the most uniform way to express the basal metabolism for girls of these ages.

In a comparison of the results in terms of calories per square meter per hour (Table 9), differences were noticed in trends between workers as well as in actual values for the different ages (Fig. 3). The trend noted in the present study is in the same direction as that reported by Blunt et al. although their actual values are consistently lower as may be seen in Fig. 3. The inconsistencies in trends among these studies have been noted also by other workers (Benedict and Talbot, 1921), (Sandiford and Harrington, 1925), and (Topper and Mulier, 1932). In comparing the actual values on this same basis (Table 9), the results reported in these six studies were in very close agreement for the 12-year-old group ranging from 41.3 to 44.2 Calories per square meter per hour. A fairly close agreement was noted for the 10-year-old girls, with extremes of 40.9 and 46.3 Calories. A wide deviation was observed at 11 years of age varying from 37.5 to 47.7 Calories. The greater range noted at this age, may indicate greater variation in the rate of growth at 11 years and shows that factors which influence the basal metabolism of children do not produce the same effects at certain ages.

The total mean heat production of these subjects was compared with standards of Talbot on the basis of height and weight (Table 10). It was necessary to interpolate the figures given

Table 10. Total metabolism on basis of height and weight compared with results of Talbot (1938).

Ht.	Cal. per 24 hrs.		Wt.	Cal. per 24 hrs.	
cm	Talbot	This study	kg	Talbot	This study
129	978*	1070	22	898	1063
131	1001*	1071	26	984	1120
132	1015*	1241	27	1005*	1210
133	1029*	1048	28	1025	1153
134	1043*	1098	29	1044*	1110
136	1072*	1121	30	1063	1140
137	1086*	1210	32	1101	1257
138	1101*	1124	33	1119*	1197
139	1115*	1198	--	--	--
140	1130	1081	34	1137	1254
141	1146*	1186	38	1207	1292
143	1177*	1149	41	1258*	1330
144	1192*	1131	43	1290*	1394
145	1208	1175	46	1338	1438
146	1225*	1321	--	--	--
147	1242*	1257	--	--	--
148	1259*	1254	--	--	--
149	1276*	1330	--	--	--
154	1368*	1438	--	--	--
158	1441*	1394	--	--	--

*Values derived by interpolation.

by Talbot in some cases for certain of the values desired for this comparison. The subjects were classified according to height and weight and the mean values in terms of total calories per 24 hours for the given heights and weights were used. Results of this study agreed more closely for height than for weight, 14 of the means being higher than Talbot's figures for a given height, five lower, and eight were approximately the same. On the basis of weight all caloric values of this study were decidedly higher than those reported by Talbot for the same weights. In general the basal heat production per unit of weight was higher for the Kansas girls than for the Boston ones.

No definite conclusions can be drawn in regard to the effects of puberty on basal metabolism. To determine this it would be desirable to continue this study over a long period of time using a larger number of subjects. Great individual variations were noted between subjects and in the same subject from period to period but the mean values indicated a rise in total heat production at the twelfth year that did not appear to be related entirely to growth in height and weight. Whether this was due to pubertal development was not established but would seem to be indicated.

SUMMARY

The basal metabolism of 24 Kansas girls ranging from 10 to 12 years of age, inclusive, was determined at two-week intervals over a five-month period. The children were divided according to age into 10-, 11-, and 12-year-old groups. From eight to 11 determinations were made on each child or a total of 239 for the entire group. Case histories were obtained from each subject as an aid in interpretation of results.

The basal heat production of each individual was expressed in total calories per 24 hours, calories per hour, calories per kilogram per 24 hours, calories per centimeter per 24 hours, calories per square meter per 24 hours, and calories per square meter per hour. The percentage deviation from the Aub-DuBois standard as modified by Boothby and Sandiford was determined for each test. Means, standard deviations from the means, and coefficients of variation were computed for each age group.

Considerable variation in the basal rate was noted among the subjects of each age group and for the same child from test to test. These deviations between subjects were probably due in part to variations in size and body build of the children within each group.

The greatest increase in height and weight occurred between the ages of 10 and 11 years and the greatest increase in total heat production between the 11- and 12-year-old girls. Apparently the increase in total metabolism between 11 and 12

years was not due entirely to obvious growth. This may indicate that approaching puberty was possibly a factor in the rise noted in this group of girls.

A decrease in calories per kilogram per 24 hours was indicated between the ages of 10 and 11 years while the value for the 12-year-old subjects was the same as that of the 11-year group. This failure to drop with increase in age is further evidence of some special stimulus acting on the 12-year-old children.

Per unit of body surface, a decrease in calories per square meter was observed from 10 to 11 years of age with a slight increase between the ages of 11 and 12 years. This again suggests an increase in metabolism at 12 years in these subjects that was not proportional to increase in size.

Expressed in terms of calories per centimeter per 24 hours, the results were approximately the same for the three groups. This indicated that height is the best basis from which to predict basal metabolism for girls of these ages.

The children were classified according to body build as linear, medium, and lateral and the metabolism compared for each group. The linear group exhibited the highest basal metabolic rate per unit of weight and body surface; while the lateral group was lowest in these values but highest in total heat production. These findings are in accord with those of other workers.

The children who received good diets exhibited a lower basal heat production per unit of weight than those on fair or very poor diets. This was attributed to the presence of more body fat with less actively metabolizing tissue per kilogram in the children on good diets.

The total heat production of these subjects was similar to that of Chicago and New York children as reported by other workers. On the basis of body weight, higher values were obtained in this study which suggests that the Kansas children weighed less than those of corresponding age from New York and Chicago. In regard to calories per square meter of body surface, differences were noted among the various studies in tendencies to increase or decrease with increasing age. This indicated that the same factors do not always produce the same effects in the basal rate of children at these ages.

It would be necessary to study a larger number of subjects for a longer time in order to draw more definite conclusions.

ACKNOWLEDGMENT

Appreciation is expressed to Dr. Martha S. Pittman, major instructor, for her interest and guidance during the preparation of this material, to those who served as subjects for this study, and especially to the Community of the Sisters of St. Joseph, Concordia, Kansas, through whom the privilege of graduate work has been made possible.

LITERATURE CITED

Atwater, W. O. and Benedict, F. G.
A respiration calorimeter with appliances for the direct determination of oxygen. Carnegie Inst. Wash., Pub. 42. 193 p. 1905.

Atwater, W. O. and Rosa, E. B.
Description of a new respiration calorimeter. U. S. Expt. Sta., Expt. Sta. Rec. 63. 94 p. 1899.

Bedale, E. M.
Energy expenditure and food requirements of children at school. Roy. Soc. London Proc., Ser. B. 94: 368-404. 1923.

Benedict, F. G.
An apparatus for studying the respiratory exchange. Amer. Jour. Physiol. 24: 345-374. 1909.

________ A portable respiration apparatus for clinical use. Boston Med. and Surg. Jour. 178: 667-678. 1918.

________ Energy requirements of children from birth to puberty. Boston Med. and Surg. Jour. 181: 107-139. 1919.

Benedict, F. G. and Talbot, F. B.
Metabolism and growth from birth to puberty. Carnegie Inst. Wash., Pub. 302. 213 p. 1921.

Blunt, K., Tilt, J., McLaughlin, L. and Gunn, K.
The basal metabolism of girls. Jour. Biol. Chem. 67: 491-503. 1926.

Boothby, W. M., Berkson, J. and Dunn, H. L.
Studies of energy metabolism of normal individuals: a standard for basal metabolism with a nomogram for clinical application. Amer. Jour. Physiol. 116: 468-484. 1936.

Boothby, W. M. and Sandiford, Irene.
Normal values of basal or standard metabolism. A modification of DuBois standards. Abs. Amer. Jour. Physiol. 90: 290-291. 1929.

Bruen, Curtis.
Variation of basal metabolic rate per unit surface with age. II. The pubertal acceleration. Jour. Nutr. 6: 383-395. 1933.

Cameron, A. T.
Basal metabolic determinations on 250 Winnipeg school children. Canad. Med. Assoc. Jour. Rpt. 15: 1022-1025. 11 p. 1925.

DuBois, Eugene F.
Clin. Cal. 12. The metabolism of boys 12 and 13 years old compared with the metabolism at other ages. Arch. Int. Med. 17: 887-901. 1916.

____
Basal metabolism in health and disease, ed. 3. Philadelphia. Lea and Febiger. 494 p. 1936.

Johnston, Joseph A. and Maroney, John W.
Relationship of basal metabolism to dietary intake. Amer. Jour. Dis. Children. 51: 1039-1051. 1936.

Klugh, George F.
Basal metabolism in normal children from 6 to 12 years of age. Abs. Jour. Amer. Med. Assoc. 91: 202. 1928.

Lewis, Carolyn A.
Relation between basal metabolism and adolescent growth. Amer. Jour. Dis. Children. 51: 1014-1038. 1936.

Lewis, R. C., Kinsman, G. M. and Iliff, A.
The basal metabolism of normal boys and girls from two to twelve years old, inclusive. Amer. Jour. Dis. Children. 53: 348-428. 1937.

Lucas, William P. and Pryor, Helen B.
The body build factor in the basal metabolism of children. Amer. Jour. Dis. Children. 46: 941-948. 1933.

MacLeod, Grace.
Studies of the normal basal energy requirements. Dissertation, Columbia University. New York. 37 p. 1924.

MacLeod, Grace and Rose, Mary Swartz.
Factors influencing the basal metabolism of children. Jour. Biol. Chem. 67: XIX-XX. 1926.

Molitch, Matthew and Cousins, Richard F.
Variation of basal metabolic rate per unit surface area with age. Jour. Nutr. 8: 247-251. 1934.

Murlin, John R.
A respiration incubator for the study of energy metabolism of infants. Amer. Jour. Dis. Children. 9: 43-58. 1915.

Murlin, John R. and Hoobler, B. Raymond.
The energy metabolism of ten hospital children between the ages of two months and one year. Amer. Jour. Dis. Children. 9: 81-119. 1915.

Nakagawa, Itsiro.
Growth and basal metabolism. IV. Changes in the basal metabolism of children during a year. Amer. Jour. Dis. Children. 49: 1232-1239. 1935.

________ Growth and basal metabolism. VI. Changes in the basal metabolism of children during puberty. Amer. Jour. Dis. Children. 53: 991-999. 1937.

Olmstead, William H., Barr, David, P. and DuBois, Eugene F.
Clin. Cal. 27. Metabolism of boys 12 and 14 years old. Arch. Int. Med. 21: 621-626. 1918.

Rose, Mary Swartz.
The foundations of nutrition, ed. 3. New York. Macmillan. 625 p. 1938.

Sanborn Metabolism Service.
Instruction booklet for use and care of the various models of Sanborn metabolism testers. Sanborn Company, 39 Osborn St., Cambridge, Mass. 1939.

Tables of conversion for metabolism calculations. Sanborn Tech. Bul. 21: 10. 1941.

Metabolism tables to find the result of a test. Sanborn Company, 39 Osborn St., Cambridge, Mass. 27 p. 1939.

Sandiford, Irene and Harrington, Ethel R.
Preliminary report on the basal metabolism of 157 normal school children between the ages of five and seventeen years. Jour. Biol. Chem. 63: XXV-XXXVII. 1925.

Talbot, F. B.
Basal metabolism of children. Physiol. Revs. 5: 477-517. 1925.

________ Basal metabolism standards for children. Amer. Jour. Dis. Children. 55: 455-459. 1938.

Talbot, F. B., Wilson, E. B. and Worcester, J.
Basal metabolism of girls physiologic background and application of standards. Amer. Jour. Dis. Children. 53: 273-347. 1937.

Topper, Anne and Mulier, Hannah.
Basal metabolism of normal children. The puberty reaction. Amer. Jour. Dis. Children. 43: 327-336. 1932.

Wang, C. C., Kaucher, M. and Wing, M.
Metabolism of adolescent girls. I. Basal metabolism and energy exchange. Amer. Jour. Dis. Children. 51: 801-816. 1936.

Wang, C. C., Kern, R., Frank, M. and Hays, B. B.
Metabolism of undernourished children. Amer. Jour. Dis. Children. 32: 350-359. 1926.