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VARIATIONS IN THE BASAL METABOLISM OF FOUR YOUNG WOMEN OF DIFFERENT RACES

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Sushela Lingaiah

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INTRODUCTION

The fundamental factors which influence the basal metabolism of individuals are age, sex, and body size. Climate and diet also may be important in causing variations in metabolism. Investigations on the basal metabolism of different races of peoples in various parts of the world have led to the concept that race may be a significant factor in determining the metabolic patterns of people. This claim was based upon the finding that the races studied had basal metabolism expenditures appreciably above or below the standards established for Americans and Europeans.

The majority of the studies on Japanese, Chinese, Indians, and Australian aborigines reported basal metabolisms below standards for Caucasians, while studies on the Eskimo and American Indian revealed a metabolism consistently above standards. However, several of the racial studies are full of inconsistencies and contradictions regarding the results obtained, or the interpretations of these results for a particular race.

Sometimes the same investigator has not obtained identical results when reporting his observations on members of the same race at another time. For instance, Heinbecker in 1928 reported the metabolism of Eskimos, who lived on a purely meat diet, to be 33 per cent above the Aub and DuBois

standard, and in 1931 he stated that the metabolism of four Eskimo women, living on a mixed diet, was similar to American standards. Hicks and colleagues in 1931 measured metabolic rates of minus 13 per cent, and minus 16 per cent of Aub and DuBois standards for male and female aborigines respectively, belonging to the Kokata tribe in South Australia, but three years later they reported that the basal metabolism of aborigines in Central Australia showed no essential departure from the published norms.

Further different investigators arriving at the same result in their studies of the same race have drawn exactly opposite conclusions. Okada et al (1926) studied the heat production of 42 male Japanese medical students and, as the average rate was 0.2 per cent below the Harris-Benedict standard, concluded that the Japanese had the same basal rate as the Americans. Baldwin and Fujisaki (1939) reported the basal metabolism of American born Japanese students in California was 3.4 per cent below the above standard. He compared his data with those of Okada et al and with the observations of Miller and Benedict (1937) on Hawaiian born Japanese students. It was concluded from these studies that a basal rate below four per cent of standards was a racial characteristic independent of environmental influences.

Similarly Mason and Benedict (1931) attributed the 17 per cent below standard basal rates found for South Indian women to be due in part to climate and in part to race. Krishnan and Vareed (1932) claimed the lowered metabolism observed in South Indian women was not due to race but to low protein diet as well as to the greater muscular relaxation possible in a tropical climate.

Conflicting results and contradictory interpretation of results are apparent in studies on the Chinese as well. MacLoed, Crofts and Benedict (1925) reported the basal metabolism of seven Chinese girls and two Japanese to be 10 per cent below the Aub and DuBois standard. These girls were studying in American colleges and, as their diet, activity and environment was similar to American college girls, the investigators believed the lowered metabolism was due to race only. In contrast to this study, Wang and Hawks (1932) observed that the basal metabolism of American born or reared Chinese children was similar to that of white American children. Benedict and Meyer (1935) observed a basal rate of 9.2 per cent below the Harris-Benedict standard for a group of American born (Boston) Chinese children. He was of the opinion that this was possibly a racial characteristic. Wang (1934) compared her data on Chicago Chinese children with those of the Boston group and found the results were alike but contradictory conclusions drawn from the two studies were due to differences in standards used for comparison.

Steggerda and Benedict (1928) studied brown men and women in Jamaica. They concluded that as the metabolism was very close to standards, the differences were not so much racial as perhaps due to the tropical climate and low protein diet of the Jamaicans. In 1932 after they had noted the increased metabolism of Maya Indians of Yucatan they declared that this difference could be mainly attributed to race.

A critical examination of the racial studies reveals thus a divergence of opinions among investigators regarding the existence of a racial factor in metabolism. The lack of uniformity noted in the metabolism of different races of people may be caused in part by various factors. One of them possibly accounting for some of the divergence in the findings, is the differences in the techniques employed for the measurement of the respiratory exchange. The Tissot gasometer, the Douglas bag and Haldane apparatus, the Krogh, the Benedict-Roth-Collins, the Jones, the Benedict Sanborn, the Benedict field apparatus all were used in basal metabolism determinations. In addition to the inherent variability in the apparatus, the few tests conducted give reasons for doubting the validity of the conclusions drawn from limited data. For instance Shattuck and Benedict (1931) made only one test on most of their Maya Indian subjects. It has been well established that an individual's metabolism varies from day to day. Blunt and Dye (1921) from their studies on Chicago University women have observed that conclusions based on one or two observations of basal metabolism tests were apt to be rather unreliable, as the basal metabolism of individuals, tested from day to day showed considerable variation. Most of the available studies on the daily variations in basal metabolism have been made on the white race.

In addition, the results of most studies have been expressed as deviations from the standards. All of these standards have been based on well nourished people in good health who took a mixed diet and lived in temperate climates. It is therefore questionable whether such standards are at all applicable to races native to the tropics and the arctic regions, where climate and dietary habits are different. Furthermore the bodily configuration of many races varies and this in turn may cause variations in the surface area. In the DuBois standard the basal metabolism was related to surface area, unless the surface area of a race in question has been shown to bear the same relationship to weight and height, as has been demonstrated for Caucasians, the results of any such comparison are questionable.

It is clear that the problem of the possible influence of race on metabolism is complex. The present investigation was undertaken to study the day to day variability of four young women, belonging to four different races, in as ideal

conditions as possible. They were all students of Michigan State College under similar climatic and environmental conditions. Studies were made during a period of three months, to investigate the range of the basal metabolism.

REVIEW OF LITERATURE

The Influence of Race on Basal Metabolism

The evidence from the numerous investigations as to whether race is a factor in determining the metabolism is full of conflict and contradictions.

Eijkman (1896) is considered to have made the initial study in this field, though the special object of his investigation was to determine the chemical heat regulation in the tropics. He reported values for the oxygen consumption of Malay and European men in Batavia, that agreed well with previously published values for men in Germany. His average figures are given below--

Europeans in Europe............250 c.c. of oxygen per minute

12 Europeans in East Indies....245.7 c.c. of oxygen per minute

11 Malays in East Indies.......251.5 c.c. of oxygen per minute

He concluded that the metabolic rates of his European and Malay subjects were similar.

Almeida's (1924) investigations were not in agreement with those of Eijkman. He found that European men in Brazil had basal metabolic rates averaging 16 per cent below American standards and the negroes had rates eight per cent higher than did the whites in Brazil.

Metabolism studies on individuals in many parts of the world followed these investigations of Eijkman and Almeida in rapid succession. The investigations of Benedict and his co-workers, working in co-operation with the Nutrition Laboratory of the Carnegie Institution of Washington, gave particular impetus to consideration of the role played by race itself. Racial studies are not reviewed below in their chronological order but are grouped according to nationality and, to some extent, by race. The basal metabolism determinations reported were made by the closed circuit type of apparatus or by analysis of respired gases by Haldane apparatus except as stated.

<u>Australian aborigines</u>. Wardlaw and Horsley (1928) determined the basal metabolic rate of eight Australian aborigines between 35 and 65 years of age, who were living under civilized conditions. The subjects were capable of complete relaxation and sometimes it was difficult to keep them awake. The average metabolism of eight full blooded male aborigines was found to be 30 per cent below Aub and DuBois standards. The investigators thought that aside from a specific racial factor, three factors might be responsible for the low values observed, namely lethargic habit of life, hot climate, and poor physical development.

Hicks, Matters and Mitchell (1931), using a Benedict portable apparatus loaned by the Carnegie Institute of

Heston, studied the metabolism of 40 aboriginals of the Kokata tribe. The results expressed as deviations from Aub and DuBois were as follows:--

23 women minus 16 per cent

17 men minus 13 per cent

These aborigines had a different bodily configuration than Caucasians.

Wardlaw and Lawrence (1932) conducted further studies on nine full blooded male aborigines, engaged in regular physical work. The subjects were between 19 and 69 years old. They were intelligent and not phelgmetic or lethargic as the previous group. They did not relax as completely as the first group and more repetitions were found necessary before consecutive measurements agreeing within five per cent of the mean were obtained. The group average was 91 per cent of the Aub and DuBois standards. The average basal metabolism of two subjects not employed was 67 per cent of the standard, a figure close to that obtained on other unemployed subjects in their first study.

The investigators reported that the data presented in this and in the previous communication seemed to indicate that Australian aborigines under suitable conditions of climate, nutrition and avoidance of physical exertion were capable of leading a more lethargic existence than seemed possible to the average white European. Under such conditions their basal metabolism might fall to surprisingly low levels. But where the living conditions were similar to those of the whites, the existing evidence did not indicate the action of any racial factor independent of the effects of environment, nutrition and activity.

Hicks, Moore and Eldridge (1934) made another study of central Australian aborigines. The body shape of this group was similar to that of Westerners. Their metabolism showed no essential departure from standards.

Wardlaw, Davies and Joseph (1934) observed the metabolism of 10 male aboriginals, immediately after they had left their natural surroundings and found the average to be 16 per cent below Aub and DuBois standards. The average basal value for European white controls was minus eight per cent of the same standard.

Indians. Mason and Benedict (1931) observed the basal metabolic rate of 54 women teachers and students in Madras. The values obtained were compared with the Harris-Benedict and Aub and DuBois standards. The average deviation was minus 17.2 per cent of the Aub and DuBois, and minus 16.8 per cent of the Harris-Benedict standards. They postulated three casual factors, (1) low protein intake (2) tropical climate (3) more complete relaxation of the subjects during the test, as responsible for the low metabolic values obtained.

Mukerjee and Gupta (1931) reported a study on 18 normal Bengali Indian men. The men varied in age between 20 to 29 years. The average for the entire group was minus 13.3 per cent of Aub and DuBois standards.

Banerji (1931) tested the basal metabolism of 145 prisoners of all classes in the district jail in Lucknow. The average basal metabolism obtained was six to nine per cent below European and American standards. The investigator related his results to atmospheric temperature, humidity and pressure. He was inclined to the view that, of these factors, humidity was most important in lowering the basal metabolic rate.

Krishnan and Vareed (1932) conducted a study of college men and women in Madras, aged 18 to 25 years. The average basal metabolism per square meter per hour for males was 35 calories and for females was 31 calories. The percentage deviation from standards was as follows--

	DuBois	Harris-Benedict	Dreyer	Kroph
Men	-12	-10.8	-11.9	-8.1
Women	-16	-18	-17	-12.5

They considered the low rate to be due to the degree of muscular relaxation attainable in hot climates and to the low protein content of the diet and not to racial influence.

They also reported that in the women studied there were two rises in metabolism during the menstrual cycle, one before the onset and another after two weeks from the cessation of menstruation.

Bose and De (1934) determined the basal metabolism of 30 men and 30 women in Calcutta and indicated that the metabolic rate of healthy Indians consuming a mixed diet, did not differ essentially from the European standards. His subjects were all within five per cent of United States standards.

Mason (1934) measured the metabolism of 34 European women residents in the city of Madras, which had a mean annual temperature of 82.8 degrees Farenheit and a relative humidity of 72 per cent. The average metabolism of the 36 women was 32 calories per square meter per hour. She compared her data with her study of Indian women and reported the percentage deviations from standards of the two averages was as given below--

	Harris-Benedict	Dreyer	Aub and DuBois
European Women	-7.9	-6.3	+2.5
Indian Women	-16.9	-16.2	-17.2

The measurements of oral temperature, blood pressure and pulse rate of European women did not differ significantly from that of Indian women.

Nine of these European subjects were studied in both tropical and temperate climates. They showed a decrease of metabolism of 5.1 per cent in the tropical climate. Three Indian women were measured in Madras and later, when they were engaged in scientific pursuits in Western countries. They showed an increase in metabolism of 4.5 per cent in cold climates. Her data indicated approximately five per cent of the low metabolism previously reported for Indian women might be attributed to the effect of the tropical climate and if a five per cent correction of standards be applied, there still remained to be explained by factors other than climate, a difference between the averages of Indian women and Western women of approximately seven per cent. This difference Mason considered to be due to race.

Rajgopal (1938) noted that the metabolism of Indians, who had lived three years in the cool dry climate of the hills in Coonoor was significantly higher than that of some Indians, who had lived there only two months.

Mason and Benedict (1936) conducted an interesting study on seven women students of South India whose waking basal metabolism averaged 20.7 per cent below the Harris-Benedict standards, to determine, whether the low basal metabolism previously reported for South Indian women was the result of muscular relaxation. The metabolism was measured on 21 days when awake and when asleep. They showed a consistent decrease in oxygen consumption averaging 9.8 per cent during sleep. Two European controls also measured for eight days in a similar manner, showed a decrease of oxygen consumption amounting to 7.2 per cent during sleep.

The nearly 10 per cent decrease in oxygen consumption observed in South Indian women during sleep was of the same magnitude as that indicated for Westerners. They concluded therefore that the state of relaxation was not a causal factor in the lowering of basal metabolism of South Indian women when awake.

Khama and Manchanda (1946) determined the basal metabolism of 60 Indian men and 40 women. The average rates were lower than those reported for Westerners. The sex difference in metabolism observed in Europeans was not noticed in Indian subjects. The results also showed the metabolism of vegetarians was lower than that observed on subjects taking a mixed diet.

Chinese. MacLoed, Crofts and Benedict (1925) observed six Chinese and two Japanese women doing collegiate work in two American colleges in New York City and South Hadley, Massachusetts, under essentially similar climatic and food conditions. A careful inspection of their subjects dietary habits and general habits showed that they closely resembled those of the average woman student of the American college.

The length of time since these women had left their homes was between 15 and 52 months.

The experiments were all made in the winter months, that is between November and April. Surface areas of these women were for the most part computed from the DuBois height-weight chart, but on three subjects, surface area was also calculated from the DuBois linear formulae by making use of actual anatomical measurements. The surface areas as actually measured were uniformly three per cent greater than the areas estimated from the chart.

The blood pressure determined on three subjects was normal, the respiration rate varied from nine to eighteen respirations per minute, averaging 14. The average pulse rate for the entire group was 60 beats per minute.

Their average basal metabolism rate was 33.2 calories per square meter per hour. It was on the average 10.4 per cent below the Harris-Benedict standard and 10.2 per cent below Aub and DuBois standards. The investigators concluded since there was nothing in the physiological measurements of these women to indicate abnormality, their data showed that transplanted orientals retained their inherited low metabolism in an American environment. They believed they were justified in emphasizing the high probability that the low metabolism exhibited by their subjects might be considered as a racial characteristic.

Earle (1928) showed that the basal heat production of 31 of his Chinese subjects in Peiping was only 2.5 per cent below standards, while that of the natives of HongKong was 10 per cent below American standards. Furthermore 47 Westerners resident in HongKong and Peiping had a metabolism seven per cent below standards. It was indicated in this study that climate was an important factor in causing variations in metabolism.

Necheles (1930) was impressed with the observation that the average Chinese was more relaxed than the average Westerner. Their muscular tone seemed to be constantly lower than that of Westerners and he conjectured that this might be the reason for their lower basal. To put this hypothesis to test he used Benedict's technique of the difference in basal metabolic rate between waking and sleeping. If no difference was found between the two, it would be inferred complete relaxation already existed in the waking state.

A respiration chamber was constructed large enough to prevent feelings of oppression. The subjects slept in the chamber for the whole night, their basal was determined during and after sleep. On the eight orientals, three Chinese, three Filipinos, one Japanese and one Korean, he conducted nine experiments and on two Western controls he made two observations. Six orientals with a low basal metabolic rate did not show any appreciable drop in metabolism during sleep, while two orientals and the two controls with normal or high metabolism showed a considerable drop in rate during sleep. The averages of the two groups compared to standards was as follows--

	Sleep	Awake
2 Westerners	-0.9	+27.1
8 Orientals	-15.1	-13.1

He concluded from these data that the low basals of orientals was due in part to their greater muscular relaxation.

Necheles in a later study in 1932 tested the usefulness of the DuBois height and weight formulae for the Chinese on 65 men and 63 women. He found good agreement between height weight formulae and the linear measurement of DuBois and of Stevenson. He reported that it was not necessary to alter DuBois height and weight and linear formulae for the Chinese.

Wang and Hawks (1932) studied 21 Chinese children, 11 boys and 10 girls between the ages five and 17. With the exception of the 17 year old girl none of the children had reached the age of puberty. All but three children, who were born in China, were born and reared in Chicago. In spite of the fact that their parents had been residents of the United States for a long time, their habit of living was little different from that of their ancestors in China. All the children were below the height and weight of American children of average size. The metabolisms were conducted on three or four consecutive Sunday mornings. The children were trained to become accustomed to the test before any experiment included in their data was conducted. The average of the two lowest values obtained was used as the basal metabolism of each child. The results were compared with Benedict and Talbot standards. With the exception of the 17 year old girl, all the children had a total heat production above the Benedict Talbot standards, with an average percentage deviation ranging from 6.8 to 16.6 for boys and from 11.5 to 20.2 for girls. In comparison with the Dreyer standards all the values were within normal limits. The results also compared well with Bailey standards. The basal metabolic rate of the 17 year old Chinese girl was consistently low.

The results of this investigation was compared with the findings in the group of American children classified as "normal in weight but not vigorous" studied by Wang et al (1926) in connection with the problems of undernourished children. The present study failed to demonstrate a definitely low basal metabolism in American born Chinese children.

Wang and Hawks concluded that the racial influence played an insignificant role in the metabolism of American born Chinese children. They stated that on account of the small number of children studied the results should not be considered conclusive.

Benedict and Meyer (1933) reported the metabolism of 18 American born Chinese girls between the ages of 12 to 22 in Boston. The average was 9.2 per cent lower than the Harris-Benedict standard and 6.1 per cent below the Aub and DuBois standards. They stated that the racial factor played a less pronounced role in the metabolism of Chinese and Japanese children. Nevertheless they believed their data indicated that the Chinese children, even though American born and subsisting in part in a modern American life, tended to have a metabolism somewhat lower than the Caucasian.

Wang (1934) vigorously refuted Benedict's and Meyer's conclusion on the American born Chinese having a lower basal metabolism than a strictly corresponding group of American children. She made a detailed comparison of the results on 12, 13, 16 and 17 year old American born Chinese children studied in Boston and in Chicago and showed that, with one exception, the Chicago girls had a slightly lower metabolism than Boston girls. The actual differences were comparatively slight and the values on the whole agreed exceptionally well. The contradictory conclusions of the two investigators undoubtedly were due to the differences in standards of reference used. When nine comparisons were made with the various standards only three of the average metabolism values for the American born Chinese girls were lower than the predicted values. Sixteen American girls studied by Wang (1934) in Cincinnati within the ages 12 to 27 years, had average basal tests below five per cent of standards for native American children. The Chinese girls showed a lower basal metabolism than the American girls in only two instances, i.e., with Harris-Benedict and the standard of Benedict and Talbot which express metabolism as total calories per 24 hours referred to age.

Further, Wang recalculated and compared the basal metabolic values of 52 American girls between the ages of 12 to 20 taken from the data published by Tilt (1930) of Florida and MacLoed (1926) of New York and compared them with nine standards together with the data for the Cincinnati girls. She demonstrated that American girls from three different sections of the country showed a greater diversity in heat production than the girls of the two races. The basal metabolism values of New York girls was slightly higher than those of the Cincinnati girls and decidedly higher than those of Florida girls. For the value given in terms of total calories per 24 hours, the difference between the two extreme groups was 17 per cent, while the difference in the values of the races was only three per cent.

From these careful comparisons she concluded that it was difficult to say that orientals had a lower basal metabolism than occidentals. The studies conducted on the two groups of American born Chinese girls had entirely failed to show any difference between the basal metabolism of these girls and the American girls of the same age range.

Turner and Benedict (1935) observed 13 oriental women six of whom were Chinese. All these young women were foreign born and were studying in the Mount Holyoke College. They had been in the United States from one to three years. The object of this investigation was to determine whether the low basal metabolism of oriental women reported in the literature was due to a deficient protein intake. Basal metabolism tests were made on five subjects and their total urinary nitrogen excretion was determined. Six Caucasian college women served as controls. The pairs lived in the same dormitory and partook of the same food. The oriental girls had adopted American modes in food, clothing and daily activities. The oriental girls had a metabolism averaging 12 per cent below standards. The general observation was that they had a lower metabolism compared with prediction standards, and with their own particular controls. The total urinary excretion of nitrogen averaged 8.3 grams per day for the Caucasians and 7.5 grams for the orientals. Hence from the point of the total urinary nitrogen excretion, the protein metabolism of the orientals was not markedly different from that of their American College mates. The orientals were not subsisting on a low protein diet. Therefore it was concluded from this study that as foreign born orientals under American environment still had a low basal metabolism, the low basal metabolism of oriental women could not be attributed to a low protein diet. Presumably the lowered metabolism was a racial characteristic.

Kilborn and Benedict (1937) observed the basal metabolism of the Miao race of Kweichow. The metabolism values of these inhabitants of the mountainous district of South China averaged 15.8 per cent above Harris-Benedict's standards. Their pulse rate averaged 55 beats per minute. This was the first high metabolism reported for a group of Chinese. A high basal was here associated with a low pulse rate.

Japanese. Takahira (1925) observed the average basal metabolism for Japanese men was 5.5 below the Sage standards, and that of the women 7.3 per cent below the same standards. There was a good deal of difference between the groups according to occupation and muscular development and Takahira did not believe there was any significant racial difference in metabolism.

Okada, Sukurai and Kameda (1926) made a study of 42 men medical students between the ages 22 to 28 and 11 nurses aged 20 to 22. Surface area was calculated according to DuBois height and weight formulae. The basal metabolism of

96 per cent of the cases showed less than 5 per cent deviation from Harris-Benedict standards. The average deviation of the metabolism was minus 0.2 per cent for males and minus 3.9 per cent for females. Average heat production in males per square meter per hour was 38.7 calories and in the females it was 36.75 calories. He concluded that the basal metabolism of healthy Japanese, was quite like that of Americans and Europeans and no racial difference existed.

Nagakawa (1934) conducted tests on 15 Japanese boys and 16 girls between the ages of three years 10 months and six years six months. Before data was collected preparatory training was given to the children to accustom them to the unfamiliar apparatus. All children tested had a basal heat production above Benedict Talbot standards. The results of this investigation were similar to those obtained by Wang and Hawks on United States Chinese children.

Hise and Ochi (1934) presented data on a study of 44 male and 50 female Japanese, within the age range of 50 to 93 years. Surface area was determined by actual measurements, modifying DuBois height and weight formulae since Japanese had a little different proportions of the body structures than the European races. Since groupings of ages were different, curves were drawn for graphic comparison with American standards. The curve on male groups almost agreed with that of Harris and Benedict in the period from 50 to

59 years, but in females it differed a little and was more nearly comparable to Aub and DuBois data. In general the curve drawn with the Japanese data resembled that of Krogh, but it showed less difference between sexes.

Baldwin and Fujisaki (1939) measured the basal metabolism of 38 American born Japanese University students attending two large universities in California. Three of the subjects were descendants of immigrants. The average metabolic rate for the entire group was 3.6 per cent below Harris-Benedict and 6.1 per cent below Aub and DuBois standards. The results of this study were in accordance with the average basal metabolic rate of 38 Hawaiian born Japanese studied by Miller and Benedict (1937). They were also in close agreement with those of Okada et al on a group of 42 medical students. The results of the three studies were shown below--

		Deviations	
		Aub and DuBois	Harris-Benedict
Okada et al	62 Japanese	-2.0	-0.2
Miller and Benedict	38 Hawaiian born Japanese	-3.9	-2.8
Present study	38 American born Japanese	-4.1	-3.4

Although there were differences in nutritional and climate factors of these three localities the final results of the average basal metabolic rates were within a range of four per cent. This fact, according to the investigators, tended to support the conception that there was a hereditary retention of racial characteristics among the Japanese as far as the basal metabolic rate was concerned.

American Indians. Williams and Benedict (1928) presented data on a study of 32 Maya male Indians of Yucatan. They were found to have a metabolism averaging 5.2 per cent above Harris-Benedict standards and an average pulse rate of 55 per minute. The sub-tropical climate was expected to lower rather than raise the metabolism of Mayas. Measurements of the metabolism of white men of the expedition and of white men and women, who had lived in Yucatan for several months showed no lowered metabolism. The sub-tropical climate had no effect on their metabolism. It was evident that some other factor, presumably racial had asserted itself. However, it was difficult to assess to what extent the increased metabolism was due to racial characteristics, to habits of diet or living conditions. Besides the Mayas had a slightly different body build than Westerners, but this difference was not conspicuous.

Shattuck and Benedict (1931) made a further study of the basal metabolism of Maya Indians in Yucatan. They measured 26 male Mayas. In nine instances the subjects were the same as those of Williams and Benedict. There was reason to doubt the age statements made by the men as the age records of the nine common subjects varied in the two studies. Their pulse rate was low, an average 56 per minute and their blood pressures also were low. In most instances only one measurement was taken. Eight cases of 26 showed lower oxygen consumption in the second test. The basal metabolism average of this group was 5.8 per cent above Harris-Benedict standards. Benedict and his colleague stated that as several of the age statements were not reliable and in some instances ages were guessed by the appearance of the subjects, and since comparison of standards of Harris and Benedict depended upon true and known ages, the age factor was a real one, and any uncertainity as to age vitiated final comparisons.

Steggerda and Benedict (1932) confirmed the previous observations on Maya Indians of Yucatan concerning their high basal metabolism and low pulse rate. Their observations were on 30 Maya males. They had a heat production which averaged eight per cent above Harris-Benedict standards. The build of this group was stocky without any obvious body disproportion. They seemed well nourished. They concluded that the high metabolism of the Maya might be in part attributed to environment, but the major part must be considered as indicative of a real racial effect.

Pi-Suner (1933) studied the basal metabolism of 45 Mapuche Indians of Chile, 31 men and 14 women served as subjects. He also noticed a high basal metabolic rate associated with low pulse rate in his subjects. The average values were 9.8 per cent above Harris-Benedict standards for men and 14.8 per cent above for women. Triplicate tests were taken on 40 subjects and on five, duplicate tests were taken. In 22 cases the determinations were repeated on two different days. No significant differences were noted between the observations of the first and second day. The oxygen intake was slightly higher in eight cases on the first day.

Shaw (1933) presented data on a study of five American Indian girls between the ages of 18 and 20 years. They were selected after examination of physical and medical records which indicated normal health. The subjects lived in school dormitories. Six girls of European stock were used as controls. All were natives of South Dakota. Tests were made in duplicate on two consecutive days. Only those results that checked within five per cent were used for final calculations. The deviations from standards between the two groups were given as follows--

	Aub and DuBois	Harris-Benedict	Dreyer
White girls	-0.76	-0.68	-0.62
Indian girls	+1.0	+6.9	+3.9

The basal rate of the American Indian girls was higher than that of the white South Dakota girls.

Crile and Quiring (1939) tested the metabolism of six male and seven female Chippewa Indians. A short preliminary test was made for practice and the next test was recorded. The average metabolic rate was 18 per cent above the Mayo standards for males and 13.5 per cent above this standard for females. The pulse rate and the blood pressure appeared lower than that recorded for Maya Indians of Yucatan.

Crile and Quiring (1939) reported data on the metabolism of Maya Quiche Indians of Guatemala, Central America. Basal estimates were made on 35 male subjects, 164 tests being conducted. They also had a high basal metabolism, the average was 8.2 per cent above the Mayo Clinic standards. Tests on one male white control gave a value of 10 per cent below Mayo standards.

Eskimos. Heinbecker (1928) measured the basal metabolism of three subjects, one male aged 28 years, two females, 25 and 26 years old. After three days of fasting the average of all three subjects was 33 per cent above Aub and DuBois standards. However, in 1931 he reported that 4 Eskimo women on a mixed diet had metabolism similar to standards.

Rabinowitch and Smith (1936) studied 10 Eskimo subjects, seven male and three female. They reported a deviation of the average metabolism of 26 per cent above Aub and DuBois standards for the whole group. They considered the high basal rate of Eskimos to be due to the high protein diet and the cold climate, which increased muscular tone.

Crile and Quiring (1939) reported a study on the metabolism of 30 Eskimo males and 32 females. The average basal rate of male Eskimos was 14.5 per cent above Mayo standards for males and 21.1 per cent above the same standard for females. Pulse rate was normal. The blood pressure was slightly lower than that of whites of corresponding age.

Filipinos. Ocampo Cordero and Concepcion (1930) conducted metabolism observations on 104 healthy subjects. Duplicate tests were taken on one, two and three days. The average test for 88 males was minus 7.8 per cent and for 16 females, minus 10 per cent of Aub and DuBois standards.

Syrians. Turner and Aboushadid (1930) reported a study on 28 Syrian women and seven white Caucasian subjects. Metabolic tests were taken with Krogh's metabolimeter. The basal metabolism of the Syrian subjects averaged 13.3 below Aub and DuBois standards and that of the controls was six per cent below the Aub and DuBois standards. The pulse rate and blood pressure of both groups was normal. They concluded that the low metabolic level noticed in their subjects was possibly an inherited racial characteristic, independent, to a certain extent, of environmental influences.

Jamaicans. Steggerda and Benedict (1928) studied the metabolism of 37 brown men and five brown women. They were a peculiarly homogeneous group in so far as age, nutritive state and living conditions were concerned. The ages of the men were between 19 to 22 years and women 23 to 30 years, one was 60 years old. Many of the subjects were mildly infected with hook worm. In most cases two tests were taken on separate days. The average deviation of the actual from the predicted metabolic rate was, in the case of the males minus 5.4 per cent, and, in the females, minus three per cent of Harris-Benedict standards. Eight full blooded male blacks had a deviation of two per cent of the standard. The investigators stated that if allowances could be made for the low protein intake of the subjects, and for the high temperature and humidity of the environment, the racial element as such might disappear in the evaluation of metabolism of people.

American Negroes. Maxwell and Wakeham (1945) observed the basal metabolism of 27 healthy negro women aged 17 to 35 years. The DuBois height and weight formulae was used to determine surface area. The average of 182 tests showed that the negro women gave a lower basal metabolic rate than the value reported for white women of North America. The average deviation from DuBois standards as modified by Boothby and Sandiford was minus 14.6 per cent. Observations on 14 men subjects gave a deviation of minus 12.4 per cent.

No conclusions were drawn as to presence of a racial difference in metabolism.

Variation in Basal Metabolism in Men and Women of European Races

Hafkesbring and Borgstrom (1926) reported a study in New Orleans on seven men and two women engaged in student or teaching work. The average deviation from standard was as follows--

Aub and DuBois	Harris-Benedict	Dreyer
-18 per cent	-16 per cent	-11 per cent

Hindmarsh (1927) observed the basal metabolism of 76 white Australian subjects, 26 women and 50 men between the ages of 19 and 23. All subjects except one were born in Australia. Using Aub and DuBois standard for comparison, he found the average basal metabolic rate was 10.5 per cent lower in women and nine per cent lower in men. He suggested that the lowered basal metabolism might be due to climatic effect. Very probably acclimatization to high temperatures took place and the body had the power of reducing its fundamental or basal metabolism to a lower level, thus facilitating the regulation of body temperature where heat loss was difficult. He believed the ready muscular relaxation of subjects in warmer climates might be another factor in lowering metabolism.

Several studies on American college women in various sections of the country reported basal rates consistently lower than the standards. Subjects from southern states showed lower basal rates than those from the northern states.

Gustafson and Benedict (1928) reported the basal metabolism of 20 young women of Wellesley College to be 1.8 per cent below the Harris-Benedict standard.

Tilt (1930) reported the metabolism of 52 Florida college women to be minus 13 per cent of the Aub and DuBois standard.

Coons and Schiefelbusch (1931) observed the basal metabolism rate of 17 Oklahoma College women to be 13.2 per cent below the Aub and DuBois standard. The investigators concluded that the lowered basal metabolism was possibly related in part to unsatisfactory nutrition and in part to the climate.

McCord (1939) reported the basal metabolism of 19 Indiana women to be minus nine per cent in comparison with the Aub and DuBois standard. High temperature and humidity were listed as factors responsible for lowering basal metabolism.

Pittman et al (1943) presented data on an extensive study of mid-western college women. A total of 1179 determinations were made on 576 different subjects, belonging to five states, Iowa, Kansas, Minnesota, Ohio, and Oklahoma. Oklahoma women apparently had the lowest basal rates. Statistically significant differences existed between states.

A mean basal rate expressed as calories per square meter per hour was not calculated for each state, as statistically significant basal rates existed between age groups. The means for one group between the ages of 20 to 22 years for four states are given below--

State	Number of Subjects	Calories per Square Meter per Hour
Iowa	140	35.8
Ohio	63	34.4
Minnesota	146	33.7
Kansas	182	32.9

Analysis of variance showed Oklahoma subjects were significantly different at 20 years, and after this age the numbers were too few to give reliable results. Therefore no general mean was computed for the age group 20 to 22 years for this state. Kansas definitely and Oklahoma apparently had lower basal rates than those of colder regions. However, Minnesota, the coldest state, did not have the highest rate. The investigators suggested the possibility of differences in thyroid activity in different localities probably should be considered as a possible explanation for these discrepencies. Minnesota was in an iodine-deficient region. Some of the subjects of the Minnesota group may have had lowered thyroid activity due to lack of iodine and this might explain to some extent the somewhat low rate of Minnesota students, which was evident in spite of the cold climate.

Pittman et al (1946) observed the basal metabolic rates of ten midwestern college women, distributed by states as follows: Iowa, 2; Kansas, 2; Minnesota, 2; Ohio, 3; and Oklahoma, 1. Each was studied from 20 to 104 weeks. Duplicate determinations were made in the morning of a test, and the mean of these was used as the basal rate for the subject for that particular day. The individual tests, ranging in number from 17 to 55, showed a good deal of variation for the same subject over the period of investigation. An analysis of variance indicated a significant interstate difference.

Season was apparently a significant factor affecting basal rate for six of the ten subjects. Pulse, respiration, body temperature, outside temperature, humidity, and hours of sunshine were seemingly minor factors in influencing basal metabolism in this study.

Summary

DuBois (1936) reviewed the racial studies on metabolic level up to the year 1936 and in his summary stated that it seemed clear from the results of the investigations that there were distinct racial differences in metabolism apart from the effects of climate, but no satisfactory explanation had been offered to explain such divergencies. In 1930 DuBois did not place so much stress upon the racial factor. He had then stated that after all one got the impression that racial differences were so slight that they were almost entirely obscured by the factors of repose, physical training and nutrition.

Wilson (1945) made a concise survey of the literature on racial factors in metabolism and in her summary stated that it was apparent that so many different factors may play concurrent roles in affecting the basal metabolism that it was impossible at the present time to say whether different patterns of basal metabolism noted with various races thus far studied were reflections of a racial characteristic alone or were the results of a combination of some or all the factors such as climatic factors, diet, physical activity, muscular relaxation, bodily configuration or even of factors thus far unsuspected.

The Influence of Menstruation on Basal Metabolism

The literature on the effect of the menstrual cycle on basal metabolism yields conflicting evidence.

Zuntz (1906) observed the carbon-dioxide output, and for part of the time, the oxygen consumption of two women for 97 days, including three menstrual cycles. He found no regularity of the variation of metabolism due to menstruation.

Cephart, and DuBois (1916) conducted four tests on one woman on two days. They made duplicate basal metabolism tests on the second day of the catamenia and four days later. The values obtained on those two different days were similar.

Snell, Ford and Rowntree (1920) found that a rather constant rise occurred during menstruation, or in the pre-menstrual period, the rise being followed by a post-menstrual fall. Their work was on 10 subjects, eight of whom showed constant rises. Among them, two showed rises varying from four per cent to 16 per cent, the average being 10 per cent, while in two a drop in rate was encountered.

Blunt and Dye (1921) reported a series of 216 basal observations on 17 faculty members or students of the University of Chicago, aged 21 to 44 years, to find out whether there was any regular periodic variation in the metabolism of normal women during menstruation. One to three complete

periods were studied with pre and inter menstrual observations on each of the 14 subjects and on three subjects only intermenstrual observations were recorded. Four women experienced absolutely no discomfort or disturbance during menstruation, while others experienced more or less fatigue or lassitude. They found the average metabolism of menstrual days was only 1.6 per cent lower than on other days, and this lowering they considered was within the range of variation that might occur at any time. They concluded that their data gave no indication of a rhythmic periodic variation in metabolism.

Wiltshire (1921) studied the basal metabolism of five subjects, on each day of menstruation as far as possible and three or four times between these periods. She said that the variations during phases of the sexual cycle were so small that they could not be regarded as showing any marked effect due to menstruation. The fluctuations, which normally occurred were often greater than these variations.

Wakeham (1923) performed 98 basal determinations on 24 cases, 20 of whom were nurses in training with little variation in mode of life, and daily routine. He analysed his data, as well as the data by Blunt and Dye, and noted that there was a distinct fall in basal metabolism during or immediately after menstruation. His data also indicated a premenstrual rise in basal metabolism.

Wafkesbring and Collet (1926) also recorded a rise before menstruation with a sharp drop during menstruation, from their careful investigations on two subjects tested daily for a period of four months. They did 96 tests on one subject and 80 on another. They concluded there was a definite tendency towards a rise before each period and a sharp drop on the first or second day of menstruation, the difference between the high and low levels of metabolism amounting to five percent.

Hitchcock and Wardell (1929) conducted 800 tests on 27 women, following at least two complete menstrual cycles. All tests were made in duplicate and only the lower one was used. This was done on the assumption that many things might happen to a subject that would increase her metabolic rate, but that aside from sleep nothing could happen to her that would decrease it. Their final compilation of data was on 20 women only. Of these 20 women, 14 showed a lowering of basal metabolism during the menstrual period, one had no change, and five showed a slight but insignificant rise. For the group of 10 women whose fall in metabolism was of statistical importance the average drop was 5.16 per cent. A second low point in the metabolic rate averaging 5.03 per cent occurred about the middle of the menstrual cycle.

Gustafson and Benedict (1928) conducted a basal metabolism study on 20 young women of Wellesley College primarily to determine the influence of seasons on metabolism. They secured occasional observations on menstrual days, as they made monthly tests on the subjects for a year except during the summer months. Although there was a wide variability in the results obtained on these days there was a hint in some observations of depression in metabolism during menstruation.

Benedict and Finn (1928) studied an extraordinarily placid and normally functioning artist's model without the complicating factor of pain during menstruation. Intermittent observations were recorded on her, for over 12 years. They noticed that deviations of the measured from the predicted Harris-Benedict standard, averaged minus 4.5 per cent for 89 intermenstrual days, and minus 7.5 per cent for 32 menstrual days. The difference of three per cent suggested that menstruation might lower metabolism and this was further emphasized by the preponderance of deviations, greater than minus 10 per cent, occurring on menstrual days.

To study the influence of this factor in greater detail, an extensive series of practically consecutive daily measurements extending over two months and including three menstrual cycles, were made on the subject mentioned above. Because of her unusually placid temperament and good health, and because she experienced no pain or discomfort as a result of this physiological function, it was believed insofar as possible, the menstrual factor alone was involved in this study. Their evidence indicated that with a normal woman, whose menstruation was physiologically normal, there was a distinct tendency for the lowest metabolism to occur during the menstrual days and for a high metabolism to appear a week after the last day of menstruation.

Griffith et al (1929) observed three women aged 30, 19, and 24 for two years and presented their data as averages of the determinations made during the periods and during the first, second, third, and fourth week following. No determinations were included in which the subject suffered pain since pain was thought to raise heat production. Total metabolism whether measured by oxygen consumption or carbon-dioxide excretion was highest during the third or the fourth week following the menstrual period. In two cases, metabolism was lowered during menstruation and in the third no such lowering was observed. The point of lowest metabolism in the cycle was different for each of the subjects studied.

Conklin and McClendon (1930) made daily determinations on 10 women, who were without the complicating factor of menstrual pain, through one or more menstrual cycles. They divided the cycle into four periods, menstrual, post menstrual, intermenstrual and premenstrual, and expressed their results as calories per square meter per hour. They treated their data statistically. One woman out of the 10 had the highest basal metabolism during menstruation. Their conclusion was that the basal metabolic rate tended to reach its lowest value following menstruation and its highest value preceding menstruation.

Sandiford, Wheeler and Boothby (1931) made 336 tests on one subject during 14 different menstrual periods. They averaged all the tests for the 14 menstrual periods for the weeks preceding menstruation, the week of menstruation and for each of the following weeks. They noticed a decided tendency toward a slightly lowered heat production during the menstrual period preceded by a rise in the premenstrual period. The variations of the average values for each of these weeks were quite small. They did not consider these variations significant as they were within the range produced by variation in the degree of physical or mental relaxation. They emphasized that variations of this magnitude could be readily due to varying degrees of mental relaxation dependent on the mental status and the physical discomfort of the subject, the time relationship of these factors to the menstrual period as well as their intensity could readily vary in different subjects. Consequently they concluded that menstruation in a normal woman did not cause any significant alteration in the intensity of the oxidation processes going on in the body.

Wible (1931) conducted basal experiments on 22 women students of the Department of Physiology, Nebraska University.

Three to 12 menstrual cycles were studied for each individual. Tests included a total of 118 menstrual cycles. Each cycle involved five tests distributed as follows--

> Two tests during menstruation, the first one made on the first or second day.
>
> One test each in 1 to 4 days before menstruation, 5 to 8 days after cessation of menstruation and two weeks after cessation of menstruation.

With the exception of one subject the results indicated a low oxygen consumption during menstruation. The exception showed the highest oxygen consumption during menstruation. A similar contradictory case had been reported by Conkin and McClendon (1930). About one half of the subjects had one or two menstrual periods in which oxygen consumption during menstruation had a tendency to rise above the premenstrual consumption. Their values did not indicate any premenstrual rise. The period of highest oxygen consumption seemed to be two weeks after cessation of menses.

Maxwell and Wakeham (1945) studied 27 Negro subjects aged 15 to 40 years. They made three to 26 tests per person, and on two subjects daily tests were taken, the rest were tested before, during, and after menstruation with an average interval of seven days. The results of their work were to suggest the presence of a premenstrual rise, with a lowering of the metabolism during actual menstruation and in the immediately post-menstrual period.

EXPERIMENTAL PROCEDURE

A series of basal metabolic tests were conducted on four young women belonging to different races. The period of observation was from January to the second week of April. With few exceptions a weekly test was taken on each subject. On two subjects tests were terminated in March. In general, two observations were made on a testing day, with an interval of five to ten minutes between tests. The determinations were all conducted in the metabolism room of the Foods and Nutrition Department.

Measurement of Oxygen consumption. The oxygen consumptions were recorded using the Benedict-Roth portable apparatus with nose clip and the mouth piece attachments. Oxygen temperatures were recorded with the aid of the thermometer attached to the apparatus. Barometric pressure readings were taken from an Anaeroid Barometer. By placing the leak-tester weight on the top of the oxygen bell, the equipment was periodically checked for air-tightness.

Special instructions were given to the subjects to be followed in preparing for a test. They were requested to get eight hours of sleep on the night before the test. If this were not possible, they were asked to make a note of the hours they had sleep. Further they were instructed not to take food or fluid except water after dinner on the night previous to the test, nor in the morning of the test. They were forbidden from smoking or taking any medicine or exercise (except as noted) on the morning of a test.

Tests were taken on all subjects from eight to ten o'clock in the morning. Three subjects walked approximately a half mile to the metabolism room. They were instructed to walk slowly and not to rush. One subject came by bus to the door of the Home Economics building. Soon after a subject arrived for a test her shoes and outer warps were removed, and she was made comfortable on a bed and allowed to rest for 30 minutes. Then her oral temperature was recorded. The nose clip was clamped in place and by inserting the mouth piece she was connected to the apparatus. After allowing the subject to breath the room air for a few minutes, the valve was closed and the test was started. Actual determinations were made for six minute periods after one or two minutes of adjustment. While the pen traced the graphic record of the respirations, on the Kymograph chart, the pulse was taken and the number of respirations per minute were noted. At the end of the six minute period test, the nose clip was removed and the subject detached from the apparatus and allowed to rest for five to ten minutes. After the rest, in a similar manner to the first test, a second observation of the metabolic rate was conducted. Soon after testing was completed, the subject's weight was taken and her height measured. As all the subjects were past the growing period, and as the height measurements did not alter from test to test, they were discontinued after four or five observations. Weights of the subjects were recorded with the subjects fully clothed but without shoes or any heavy outer garments.

Subjects. The subjects were selected for the study because each represented a different race. They were all between the ages of 30 and 33 years. All the subjects were given a physical examination.[1]

Subject I was Chinese by race. Her home was in KongChow, China. She came to the United States in the Fall of 1943, and was since enrolled as a graduate student in Michigan State College, majoring in Chemistry. Her parents were living and she had one sister. Her build was light with smooth contours. She was of average height. Her disposition was that of a very stable relaxed young woman. Her weight fluctuated little from week to week. Her medical history was negative. She was unmarried. During menstruation she occasionally suffered from cramps on the first day, otherwise she felt no discomfort on these days.

Subject II was Indian of Caucasian stock. She was married and was a home-maker. She was from Bombay, India and came to Michigan State College in May 1948, and was taking courses in the college as a special student. Her parents

[1]The courtesy of the medical staff of the College Hospital is acknowledged.

were living, she was one of six children. Her husband was employed in Bombay. She was medium-sized and overweight. She was easy going by temperment. Her medical history and physical examination indicated that she was a suitable subject for the study of metabolism.

Subject III was a Hollander. She was enrolled as a special student of Michigan State College since the fall of 1949. Her home was in Baarn, Netherlands. Her mother was living and she had two sisters and two brothers. By disposition she was intense. During the second world war, she had suffered from severe undernutrition from the year 1944 to 1945, as a result of which menstruation ceased during that time. She was somewhat underweight though not seriously so. Since her arrival in the United States she had made rapid recovery from past undernutrition. At the time of study, menstrual periods were regular and she suffered no pain during menstruation, but felt rather low spirited during these days. Vitamin B_{12} shots were given by the physician in charge during the study, however, any injection of this Vitamin was recorded and no such injections were taken either on the day previous to the test or on the test day.

Subject IV was an American Negro. She was a southerner from Arkansas. She was married and by profession a teacher. She had no children. Her parents and her husband were living. She had two sisters and one brother. She had been a graduate

student of the college since the fall of 1949. She was a very tall well built woman, slightly underweight. She was uneven by temperment, but good natured. Her medical history showed that she had a healthy past. During menstruation she continued routine work without experiencing pain or discomfort.

Anthropometric measurements. The anthropometric measurements of the subjects were taken to evaluate their body proportions.

Activity records. The subjects kept a record of their activities during the day previous to each testing day. The activities were recorded in the form given in the appendix. The day's activities were summarized into classifications in the form also given in the appendix. However, it was felt that the records on the whole gave a fairly satisfactory idea of the subjects activities. The energy expended per day was estimated from each activity record by using Sherman's (1946) list of factors.

Food records. Food records were recorded by subjects for the day before each testing day. The food values of food records were calculated by the short method of dietary analysis using the Donelson and Leichsenring (1945) table; Taylor's (1942) food tables were used, when foods were included, which did not come under the classifications of the above table.

Selection of data. All observations of the basal metabolic rates of the subjects were recorded with the following exceptions: in the case of all the subjects the first day tests were discarded as they were considered practice tests and as it was felt that unfamiliarity with the testing situation could result in the failure to relax. In addition to these days, a total of nine other tests on the four subjects were discarded due to irregularities at the testing period, which seemed to invalidate the results even though some of the values were within the range of tests reported.

RESULTS

The physiologic measurements such as pulse rate, respiration, body temperature, blood pressure, and hemoglobin of subjects are presented in Table I. The average pulse is slightly above 60 beats per minute for two subjects, and slightly below this for two others. The respiration rates per minute were greater in Subjects II and IV than in Subjects I and III. The body temperature showed little variation during the period of study. Mean values were 97.8° F., 97.7° F., 97.8° F., and 97.9° F., for the four subjects. The blood pressure was somewhat high and the hemoglobin low for Subject IV, while these two measurements were satisfactory for the other subjects.

The Anthropometric measurements are given in Table II. The body proportions of all the subjects came within the average reported for Americans of European stock by Donelson et al (1940). Consequently, the use of the DuBois nomograph to compute the surface areas of subjects with the aid of height and weight measurements was justified. The height, actual weights, and predicted weights and the surface areas based on these measurements are recorded in Table III. The predicted weights were judgments by Dr. Ohlson, based upon measurements of the bony size and the contour and depth of the fat pads. The predicted weights of Subjects I, III, and IV are almost the same as the actual

TABLE I

PULSE, RESPIRATION, BODY TEMPERATURE, BLOOD PRESSURE AND HEMOGLOBIN OF FOUR WOMEN

Subject	no. obs.	Pulse per minute	no. obs.	Respiration per minute	no. obs.	Body Temperature Degrees Fahrenheit	no. obs.	Blood Pressure	no. obs.	Hemo-globin
I	21	63 (53-72)	42	10 (7-12)	11	97.8 (97.4-98.0)	1	104/58	1	15.4
II	26	57 (52-63)	52	13 (10-15)	13	97.7 (97.4-98.4)	1	114/74	1	12.0
III	22	56 (50-65)	44	10 (5-15)	12	97.8 (97.4-98.2)	1	116/74	1	12.1
IV	16	61 (57-70)	32	16 (9-22)	9	97.9 (97.4-98.6)	1	124/85	1	10.5

Figures in parenthesis denote the range.

TABLE II

ANTHROPOMETRIC MEASUREMENTS OF FOUR WOMEN

Body Parts	I	II	III	IV
Chest Breadth, cm.	23.0	24.5	24.8	24.2
Chest Depth, cm.	15.8	19.2	17.2	18.0
Biliac, cm.	24.6	26.3	27.5	28.0
Bitrochanter, cm.	23.4	31.6	31.5	27.0
Arm, Right, cm.	35.0	26.3	27.0	26.8
Arm, Left, cm.	35.0	28.8	26.5	32.2
Leg, cm.	32.8	35.2	36.0	36.5
Grip, Right, kg.	26.1	25.0	35.0	45.0
Grip, Left, kg.	27.5	30.0	30.0	30.0
Fat pads	Average	Heavy	Very small	Very small

TABLE III

HEIGHT, ACTUAL AND PREDICTED WEIGHT AND SURFACE AREA OF FOUR WOMEN

Subject	Height cms.	Weight, kg. Actual	Weight, kg. Predicted	Surface Area, sq. meter Actual Weight	Surface Area, sq. meter Predicted Weight
I	160	49.3 (48.0-49.9)	49.5	1.49 (1.48-1.50)	1.50
II	159	62.9 (62.1-63.4)	53.0	1.64 (1.63-1.65)	1.53
III	171	61.1 (60.1-62.7)	65.0	1.71 (1.70-1.73)	1.76
IV	167	63.8 (62.8-64.7)	65.0	1.71 (1.70-1.73)	1.74

Figures in parenthesis denote the range.

weights, while the predicted weight of Subject II, was much lower than the actual weight. The actual weight of Subject I was essentially constant during the period of study. The actual weight for Subject II was 63 kg.. at the beginning and at the close of the study but she gained slightly and then lost weight during three months of study. Subject III gained weight slowly from an initial weight of 60 kg.. to 62 kg.. at the close of the study. Subject IV consistently lost weight from week to week. She was 64 kg.. at the beginning of the study and 63 kg.. at the close.

A careful inspection of the activity records of the four young women revealed that all were moderately active. The average energy expenditure per day as estimated from the activity records were for Subject I, 1594 calories; Subject II, 2037 calories; Subject III, 2237 calories; and Subject IV, 2136 calories. These energy expenditures seemed high in comparison with the average caloric intakes of the Subjects.

The caloric evaluation and comparison of specific nutrients were based on the food records kept by the subjects.

As estimated, the average caloric intake and the intake of eight other nutrients are presented in Table IV. The caloric intake as well as the intake of several nutrients are below National Research Council's recommendations for women of this age group. In particular, the intake of

TABLE IV

CONSUMPTION OF CALORIES AND EIGHT NUTRIENTS BY FOUR WOMEN

Nutrients	Subjects							
	I		II		III		IV	
	no. obs.		no. obs.		no. obs.		no. obs.	
Calories	8	1290 (770-1580)	9	1425 (1156-1715)	9	1673 (1100-2360)	8	1160 (930-1560)
Proteins, gms.	8	53.2 (39.3-90.3)	9	55.0 (37.0-95.0	9	50.0 (28.0-59.0)	8	41.2 (31.9-53.5)
Calcium, gms.	8	.31 (.11-.43)	9	1.2 (.84-1.6)	9	.80 (.30-1.31)	8	.30 (.14-.40)
Iron, mgs.	8	4.9 (3.8-17.0)	9	5.9 (4.6-8.8)	9	7.4 (4.1-9.0)	8	7.2 (4.6-9.0)
Vitamin A, I U.	8	7220 (335-19390)	9	3068 (1310-5190)	9	5164 (1030-13060)	8	6558 (1520-11170)
Thiamin, mgs.	8	.97 (.26-1.63	9	.70 (.42-.98)	9	.91 (.39-1.7)	8	.88 (.38-1.37)
Riboflavan, mgs.	8	1.4 (.14-1.7)	9	1.8 (1.3-2.27)	9	1.3 (.64-2.4)	8	.91 (.54-1.38)
Niacin, mgs.	8	5.2 (1.7-13.8)	9	2.8 (1.3-4.2)	9	4.2 (1.3-5.9)	8	4.9 (3.4-7.4)
Vitamin C, mgs.	8	75 (14-123)	9	53 (21-136)	9	58 (20-116)	8	45 (16-34)
Estimated daily energy expenditure	8	1584 (1521-1662)	9	2087 (1860-2432)	9	2237 (1841-2818)	8	2163 (1581-2466)

Figures in parenthesis denote the range.

calories, protein, calcium, and niacin are very low in Subject IV who is a large woman. However, she lost weight steadily during the study although total losses were not great. The nourishment of the other three subjects seemed fairly satisfactory; but Subject I, who disliked milk, had very low calcium intake with an average of 0.3 gm. per day.

The average daily heat production in calories per hour, per 24 hours, and calories per hour per square meter, based on actual weight and predicted weight are presented in Table V, with the deviation from the Aub and DuBois standards. The basal metabolism of all the subjects is below the standard.

The day to day variation in metabolism, expressed in calories per hour and per square meter per hour according to predicted weight and actual weight, are given for each subject separately in Tables VIII, IX, X and XI in the appendix. The data on heat production per square meter per hour, based on predicted weight, was subjected to an analysis of variance to determine variation from day to day, compared with the variance within one day of testing. The F values obtained are given in Table VI with the predicted chances of significance.

The variations of the basal metabolism as related to the menstrual cycle are presented in Table VII as averages of determinations for the week before menstruation, the days

TABLE V

BASAL METABOLIC STUDIES FOR FOUR SUBJECTS

Subject	Dates Tested	No. Tests	Calories Measured: Per 24 hours	Calories Measured: Per square meter per hour, Actual weight	Calories Measured: Per square meter per hour, Predicted weight	Deviation from Aub-DuBois Standard
I	1-19 to 3-29[1]	21	1162 (1116-1247)	32.40 (29.15-34.37)	32.27 (29.15-34.64)	-9.2
II	1-21 to 4-8	26	1373 (1177-1501)	35.09 (29.90-40.41)	37.39 (32.05-43.05)	-2.7
III	1-26 to 4-11	22	1396 (1270-1477)	33.54 (30.76-36.22)	32.66 (30.06-35.19)	-5.8
IV	1-26 to 3-18	16	1249 (1131-1300)	30.34 (29.47-33.61)	29.90 (28.28-33.03)	-15.0

[1] All tests were made during the winter of 1950.
Figures in parenthesis denote the range.

TABLE VI

VARIANCE OF THE BASAL METABOLISM FROM DAY TO DAY COMPARED WITH VARIANCE ON ONE DAY OF TESTING

Subject	F Values Obtained	Predicted F Values*	
		1 chance in 20	1 chance in 100
I	3.30	2.86	4.54
II	1.74	2.60	3.96
III	1.76	2.72	4.22
IV	1.14	3.50	6.19

* Required for a significant result.

TABLE VII

VARIATION OF BASAL METABOLISM DURING PHASES OF THE MENSTRUAL CYCLE OF FOUR WOMEN (CALORIES PER SQUARE METER PER HOUR)

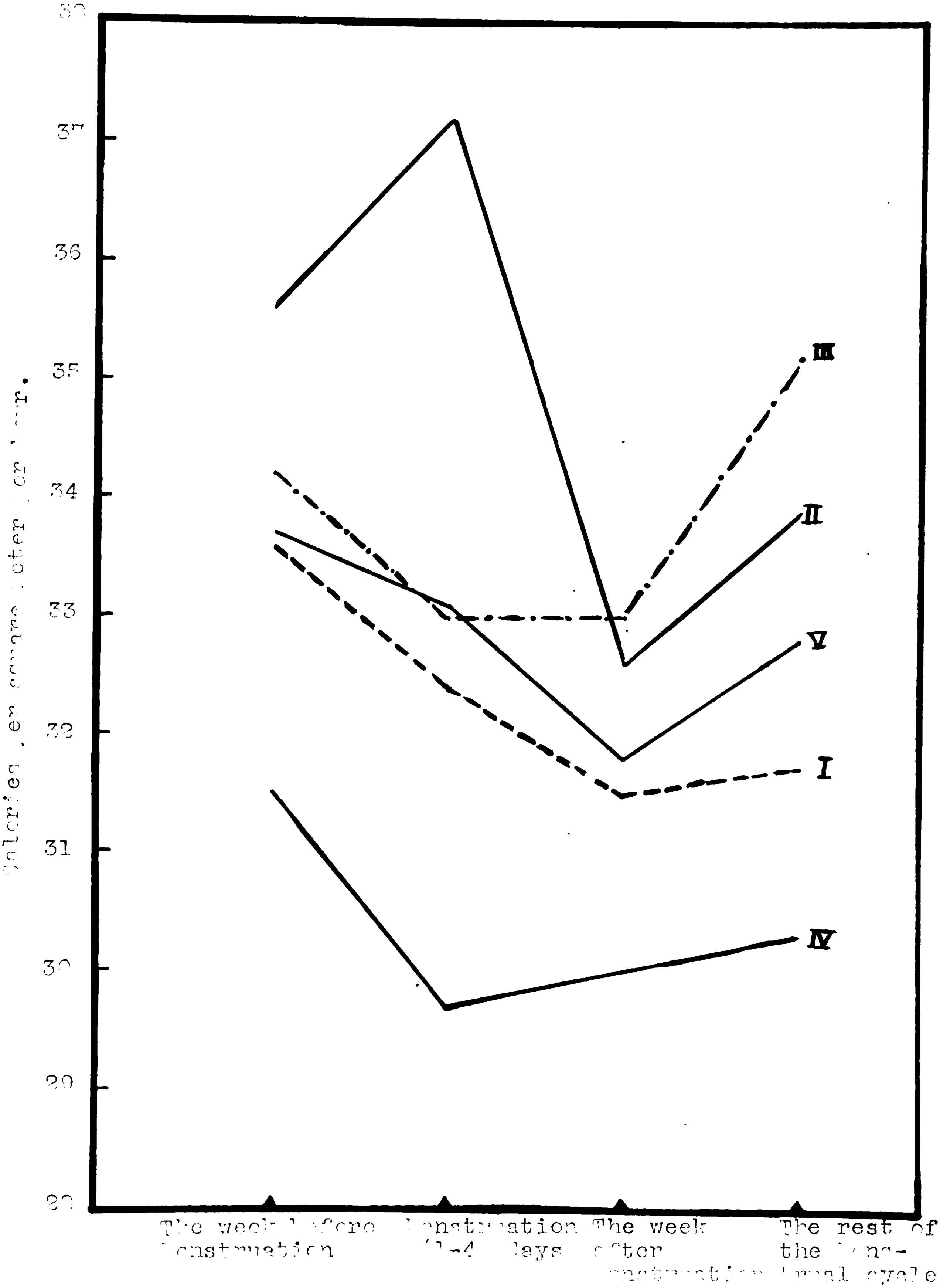
Subject	One week before menstruation		Menstruation (1-4) days		One week after menstruation		The rest of the menstrual cycle	
	no. obs.		no. obs.		no. obs.		no. obs.	
I	7	33.38	4	32.44	6	34.19	4	31.70
II	6	35.55	8	37.16	8	32.64	4	33.91
III	4	34.19	8	33.03	7	33.02	3	35.23
IV	4	31.47	4	29.67	4	29.95	2	30.25
Averages	21	33.70	24	33.08	25	31.77	13	32.77

of menstruation (one to four), the week immediately after the cessation of menstruation, and for the remainder of the menstrual cycle. The averages for all periods on four women indicate a pre-menstrual rise, a lowering of metabolism during menstruation, a post-menstrual drop, and a gradual increase of metabolism between the week after and the week before menstruation. The individual rhythms varied somewhat from this general trend except in Subject I. In Subject IV the post-menstrual drop is not evident, but otherwise the pattern is the same. In Subject II the peak of the rise in metabolism is reached during menstruation and thereafter lowering and rise of metabolism are recorded in the periods following menstruation. In Subject III, after the menstrual drop, the metabolism reaches a plateau during the post-menstrual week. In the third period the metabolism rises very rapidly, followed by a slight lowering in the pre-menstrual week. The different patterns of variance of metabolism of the four subjects during the menstrual cycle are clearly depicted in Figure I.

[illegible]

VARIATIONS IN THE BASAL METABOLISM OF FOUR SUBJECTS IN RELATION TO THE MENSTRUAL CYCLE.

I Subject I Average of 2 menstrual cycles.
II Subject II Average of 3 menstrual cycles.
III Subject III Average of 3 menstrual cycles.
IV Subject IV Average of 2 menstrual cycles.
V Average of all cycles for all women.


37
36
34
33
31
III
II
V
I
IV
The week
The rest of

DISCUSSION

The subjects of the study were healthy individuals as proved by the absence of disease and by their ability to carry successfully a full time college schedule. Also their pulse rate, respiration, body temperature, blood pressure and hemoglobin were within the range for normal women. All of them were moderately active individuals subject alike to the strains of a college life.

They were under similar climatic conditions. Subject III was accustomed to a temperate climate, the rest were from tropical or sub-tropical regions, unused to the rigors of a hard winter. Subject IV was American but she came from Arkansas which has a warm climate. All of them had a short period to adjust themselves to the very changeable Michigan weather.

A question arises, concerning the satisfactory nutrition of the subjects because of the discrepancy noted between the energy expenditure as estimated from the activity records and the caloric intake as evaluated from food records. The average energy expenditure per day for all the subjects was much greater than the average caloric intake. As stated before the day's activities of a subject were summarized and according to the judgment of the investigator, best fitted into some of the categories of activities for which Sherman (1946) has listed factors. The total expenditure of calories per day was calculated from the summary by use of Sherman's table.

The calorie intakes were based on food records kept by the participants and evaluated with the help of food tables. It is possible owing to lack of precise information on the recipes or size of portions of food eaten the caloric intake of food records may have been under estimated. However low caloric intakes have been reported previously in surveys on non-emaciated normal women. Patterson and McHenry (1941) reported an average of 1930 calories per person in Toronto families. Milam (1942) reported 1577 calories for white women and 1443 calories for Negro women in North Carolina. Winters and Leslie (1943, 1944) observed the average calories for American women of low or moderate income in the United States to be 1452 calories. Moreover the unpublished data in this laboratory[1] suggest the energy values of weighed diets determined by the bomb calorimeter were close to caloric estimates, calculated from food records. Keys (1950) stated that there was no evidence or valid argument that the caloric intake data from surveys were generally or even frequently under estimates. Since clinical under nutrition with regard to calories was not characteristic of the persons studied in these surveys, it must be concluded that the

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[1] By courtesy of Dr. Margaret Ohlson

recorded caloric intakes were, on the average at least, equal to all caloric expenditures. The above statement is applicable to caloric intake and outgo of subjects I, II, III, who maintained or increased in weight during the study. Besides their caloric intakes as estimated were above their basal expenditures by 138 calories, 52 calories and 292 calories respectively. However these margins for activities are small. Subject I and II were small women and caloric intakes of 1290 and 1425 were probably sufficient for the maintenance of their health. Subject III was a large woman but she had an average caloric intake per day of 1673 calories. As she gained weight it is surmised that she was not under nourished. But subject IV, who was also a large woman, lost weight during the period of study and ate 89 fewer calories than required to meet her measured basal needs. Therefore her average intake of 1160 indicate a degree of undernourishment. Her low basal metabolism and very small fat pads also point to this conclusion.

The above discussion points to the fact that the present methods of evaluation of energy expenditure are unsatisfactory and more basic information is necessary regarding a precise evaluation of energy output by individuals.

The basal metabolic rates of the young women are compared in terms of calories per square meter per hour. The predicted calories for this age group are 35.7. The average heat production of all the other subjects is below prediction. The subjects are ranked below in order of their heat production.

	Calories per square meter per hour
Subject II	35.09
Subject III	33.54
Subject I	32.40
Subject IV	30.34

The above figures are in relation to actual weight. The calories per square meter per hour computed by using the predicted weights present essentially the same picture (Table V, page 57). Subject IV who probably was undernourished tends to have the lowest basal metabolic rate. Such a lowering of basal metabolic rate due to undernutrition has been observed by Talbot (1938).

The percentage deviation from the Aub and DuBois standard is least for Subject II and most for Subject IV. From the Aub and DuBois standard Subject I to IV deviate minus 9.2 per cent, minus 2.7 per cent, minus 5.2 per cent and minus 15 per cent respectively. The deviation from standards for Subject I is close to what has been reported in previous studies namely 14 per cent below the Aub and DuBois standard for a 21 year old Chinese girl studied by Blunt and Dye (1921) or 10.2 per cent below the same standard for six Chinese girls and two Japanese girls reported by MacLeod, Crofts and Benedict (1925). Subject II deviated less than the 17 per cent below the Aub and DuBois standard reported by Mason and Benedict (1931) and Krishnan and Vareed (1932) for Indian women. The data recorded for this subject agreed with Bose and De's (1934) investigation that Indian women on a mixed diet have a metabolism close to United States standards.

The deviation shown by Subject III is the same as that reported for normal Caucasian women, Benedict (1928). The observation of a 15 per cent deviation from the Aub and DuBois standard on Subject IV is very similar to that reported for American negro women by Maxwell and Wakeham (1945).

This study confirms to a surprising degree the results obtained by previous investigators on subjects from the four races. This confirmation makes one wonder whether the different races have a fixed pattern of metabolism independent of environmental influences. However, Caucasian women in Australia and in America also show deviations from the standard which come within the ranges observed in the present study. The present prediction standards probably are high even for the populations for which they were intended to be used. Benedict (1928) stated that the studies on a large number of normal American women has led to the observation that the present standards are too high and should be lowered by about five per cent. When such a five per cent correction is made for the data in the present study the deviations from the standard became practically negligible except for Subject IV.

An analysis of variation of the basal metabolism from day to day compared with one day of testing reveals that Subject I responded with a more uniform degree of relaxation than demonstrated by the other three subjects (Table VI, page 58).

Whether the stability manifested by Subject I is an individual trait due to unusual amount of poise and repose or whether it represented a general characteristic of Chinese women, is hard to tell. It would be of interest to explore the variations in the basal metabolism of other Chinese women as well as women from other racial groups.

The results of this study are inconclusive but the method of approach to the study of racial differences of metabolism justifies further exploration.

The variation of the basal metabolism of the subjects during the menstrual cycle indicated a premenstrual rise and a lowering during menstruation and in the immediately post menstrual period. This observation is in accordance with the reports of Snell, Ford and Rowentree (1920) Wakeham (1923), Benedict and Finn (1928), Conklin and MacClendon (1930), Maxwell and Wakeham (1945).

The highest metabolic rate in Subject II appeared to occur during menstruation followed by a drop in the week following the cessation of menstruation. Such a contradictory case has been reported in the literature by Conklin and MacClendon (1930) and Wible (1931).

Since the menstrual cycle was divided arbitrarily into four periods, the occurrance of the high and low points in the different periods for different subjects as indicated in Table VII, page 59, and Figure I, page 61, probably is not important, as these are thoughts to be related to the rhythms of ovulation, which are not measureable from the data of this study. The important observation in these data is that a rise and lowering of the basal metabolism occurred in all of the four subjects.

SUMMARY AND CONCLUSIONS

The basal metabolism of four young women of Michigan State College belonging to different races between the ages of 30 to 33 years, was observed during the winter months of 1950. Sixteen to 26 tests were made on each subject. The subjects were physically fit and lived in a similar environment.

Anthropometric measurements of the subjects showed that their body proportions were within the averages reported for Caucasian women. The average weights of Subjects I to IV were 49.3 kg., 62.9 kg., 61.1 kg., and 63.8 kg. respectively, and the predicted weights in proportion to the bony size and depth and contour of the fat pads were 49.5 kg., 53 kg., 65 kg., and 65 kg.

The average basal metabolic rate expressed in calories per square meter per hour was for Subject I, 32.40; Subject II, 35.09; Subject III, 33.54 and for Subject IV 30.34, according to actual weight, and according to predicted weight the rates were 32.37, 37.39, 32.66, 29.90 respectively.

The variation of basal metabolism from the Aub and DuBois standard was for Subject I, -9.8 per cent, Subject II, -2.7 per cent, Subject III, -5.8 per cent, and Subject IV, -15. per cent.

An analysis of variance of basal metabolic rate from day to day compared with variance within one day of testing showed that Subject I had a more stable metabolism than the other three subjects who showed almost the same degree of variability.

The basal metabolism of the subjects underwent cyclic variations. The general trend showed a premenstrual rise, a lowering of metabolism during menstruation, and a post menstrual drop, followed by a gradual rise thereafter.

No definite conclusions were drawn from the data as the number of subjects studied were few. Deviations in the recorded studies were within the ranges found for American college women in different sections of the country.

Further studies in the pattern of this experiment using a greater number of subjects in each racial group are suggested for investigating the racial factor in metabolism.

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APPENDIX

TABLE VIII

BASAL METABOLIC RATES OF SUBJECT I

Date	Calories		
	Per hour	Per square meter per hour	
		Actual weight	Predicted weight
1-19	50.6	33.71	33.71
	47.0	31.31	31.30
1-26	46.2	31.03	30.82
	48.0	32.22	32.01
2-2	47.0	31.35	31.35
	47.9	31.94	31.94
2-9	45.5	30.31	30.31
	43.7	29,15	29.15
2-16	48.6	32.37	32.37
	46.8	31.19	31.19
2-23	52.2	35.02	34.79
	51.3	34.42	34.19
3-2*	46.5	31.01	31.01
	47.4	31.61	31.61
3-9	48.0	32.19	31.97
	48.0	32.19	31.97
3-23	49.5	33.43	32.98
	50.3	34.01	33.56
3-25	53.2	34.87	34.64
3-29*	51.4	34.47	34.24
	48.7	32.63	32.47

* Menstrual days

TABLE IX

BASAL METABOLIC RATES OF SUBJECT II

Date	Calories Per hour	Per square meter per hour Actual weight	Per square meter per hour Predicted weight
1-21	55.9	34.09	36.54
	52.0	31.75	34.03
1-23	51.3	31.26	33.51
	57.5	35.04	37.56
2-4	57.3	34.93	37.44
	56.4	34.40	36.87
2-11*	54.0	33.13	35.30
	68.0	41.72	44.45
2-18	52.2	32.02	34.11
	55.7	34.19	36.42
2-25	57.8	35.21	37.75
	56.0	34.11	36.57
3-9*	60.4	36.58	39.44
	64.7	39.19	42.26
3-11*	57.9	35.29	37.92
	57.0	34.76	37.25
3-18	53.3	32.72	34.86
	53.3	32.72	34.86
3-28	59.7	36.20	39.04
	61.4	37.24	40.16
3-30	57.7	34.99	37.73
	58.6	35.53	38.32
4-3*	65.8	40.41	43.05
	58.9	36.16	38.58
4-8	49.0	29.90	32.05
	55.3	33.74	36.17

* Menstrual days

TABLE X

BASAL METABOLIC RATES OF SUBJECT III

Date	Calories Per hour	Calories Per square meter per hour Actual weight	Calories Per square meter per hour Predicted weight
1-26	60.5	35.56	34.35
1-31	61.9	36.22	35.19
2-12*	57.4	33.57	32.62
	55.6	32.54	31.61
2-14*	54.1	31.61	30.72
	57.6	33.65	32.70
2-21	53.6	31.32	30.43
	54.5	31.84	30.94
2-28	60.6	35.24	34.44
	58.9	34.22	33.44
3-7	60.6	35.24	34.44
	52.2	36.69	31.95
3-13*	56.2	32.67	31.94
	58.9	34.42	33.44
3-20	58.1	34.17	33.01
	59.0	34.69	33.51
3-31	58.2	33.63	33.06
	60.9	35.10	34.58
4-6*	58.3	33.87	33.10
	54.6	31.74	31.02
4-11	52.9	30.76	30.06
	56.4	32.77	32.03

* Menstrual days

TABLE XV

BASAL METABOLIC RATES OF SUBJECT IV

Date	Calories Per hour	Per square meter per hour Actual weight	Per square meter per hour Predicted weight
1-26	57.0	32.93	32.74
	50.0	28.82	28.65
2-2*	51.2	29.61	29.44
	53.0	30.63	30.45
2-9	46.4	26.95	26.64
	51.6	29.99	29.65
2-16	51.0	29.69	29.34
	51.9	30.20	29.85
2-23	57.8	33.61	33.03
	52.2	30.51	29.99
3-2*	50.1	29.47	28.79
	49.2	28.95	28.28
3-9	54.2	31.68	31.14
	53.3	31.16	30.63
3-16	52.5	30.86	30.15
	51.6	30.35	29.65

* Menstrual days

Res.

Name________________________ Date________________________

Record of Day's Activity

Time	Activity
A.M. 6:00 - 7:30	
7:30 - 8:00	
8:00 - 9:00	
9:00 - 10:00	
10:00 - 11:00	
11:00 - 12:00	
P.M. 12:00 - 1:00	
1:00 - 2:00	
2:00 - 3:00	
4:00 - 5:00	
5:00 - 6:00	
6:00 - 7:00	
7:00 - 8:00	
8:00 - 9:00	
9:00 - 10:00	
10:00 -	

Res.

Name ______________________ Date ______________________

Summary of Day's Activities

Activity	No. hours per day	Factor	Total Calories
Sleeping			
Sitting			
Standing			
Laboratory - Class			
Laundry - Ironing			
Walking slowly			
Active exercise			
Physical Education (course:)			
Dancing			
Walking fast			
Other activity:			
Total			

ROOM USE ONLY

ROOM USE ONLY