

Seasonal Variations in the Basal Metabolic Rate of the Korean*

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(Received for Publication : 22, Dec., 1969)

ABSTRACT

Basal metabolic rate (BMR) was determined monthly for a period of 2 years in 17 Korean (8 male and 9 female) subjects who live in Seoul, Korea. In addition, several parameters of thyroid function were studied in January, May and November by administering I-131. The average BMR was lowest in May and highest in December in both sexes, the magnitude of annual variation amounting to approximately 7 to 10 Kcal/hr/m². These characteristic seasonal variations were evident even when BMR values were computed per kilogram lean body mass. Although these changes in BMR over a period of a year seem to be inversely related to overall changes in the average monthly ambient temperature, the average BMR is not in phase with ambient temperature. Thus the lowest BMR was seen in May while the highest ambient temperature was noted in August, and the highest BMR occurred in October through December while the lowest temperature was in January. Neither thyroidal uptake of I-131 nor the protein-bound I-131 conversion ratio showed any apparent seasonal variations. These findings indicate that the seasonal changes in BMR of the Korean are not determined primarily by the level of ambient temperature but by other factors, possibly seasonal variation of physical activity.

KEY WORDS: Basal metabolism, Korean, seasonal changes, thyroid function.

INTRODUCTION

The occurrence of metabolic acclimatization of humans to cold has been debated for years. While most investigators in the United States as well as in Europe have failed to demonstrate any increase in the basal metabolic rate (BMR) of cold-acclimatized subjects (2, 4, 6, 11, 15-17, 21-24) many Japanese investigators have reported a consistent increase in the BMR of Japanese in winter (7, 18-20, 25). We have also demonstrated an elevation of the BMR of the diving women (ama) in winter, which was interpreted to be metabolic acclimatization to cold (8-10, 12). However, in contrast to reports by Japanese investigators, we failed to note any seasonal variations in the BMR of non-diving (control) subjects.

Since the above studies (8-10, 12) were conducted in Pusan at the southern tip of Korean peninsula, where the average ambient temperature is relatively warm, the present investigation was undertaken to reevaluate seasonal BMR of Koreans in Seoul, where the average ambient temperature in mid-winter is approximately 7 to 8°C lower than that in Pusan.

METHODS

A. Subjects.

A total of seventeen (8 males and 9 females) Korean subjects were employed and their physical characteristics at the onset of this investigation are

* The present investigation was supported by grants from the National Science Foundation (G-24044), by the U.S. Army (DA-MD-49-193-64-G111), and Public Health Service (GM-11818-01).

Table 1. Physical characteristics of subjects

Sex	Age(yrs)	Ht(cm)	Wt(kg)	BSA(m ²)
Male (8)	30.2±2.2	167.0±1.4	60.0±1.5	1.68±0.02
Female(9)	21.9±1.4	157.0±1.2	49.8±1.9	1.47±0.02

() Number of subjects (Mean±S.E.)

summarized in Table 1. The male subjects were mostly members of the Department of Physiology while the female subjects were medical students of Yonsei University, Seoul, Korea. These subjects were free of any detectable cardio-pulmonary or endocrine diseases. BMR of female subjects were not made during the menstrual period. Mean subcutaneous fat thickness was determined monthly by measuring skinfold thickness at ten representative body areas with a Best caliper (3). Lean body mass was computed by using a formula developed by Allen et al (1).

B. Measurements of basal metabolic rate.

Basal O₂ consumption was measured monthly for a period of two years, starting November, 1964. Measurements were made around the middle of each month in a laboratory room temperature of around 20C. Each subject was instructed to eat a light supper and come to the laboratory the next morning between 6:30 and 7:30 a. m. without breakfast. After a 30 to 60 minute bed rest during which both the pulse rate and the blood pressure were determined every 5 minutes until they reached a steady value, O₂ consumption was measured with a 9-liter Collins spirometer. The values of O₂ consumption were subsequently converted to kilocalories per hour per square meter by a standard nomogram (5) that has been found to be applicable to Koreans. The metabolism was expressed also as percent deviation from the DuBois standard (5).

C. Determination of thyroid functions.

In order to obtain a measure of the thyroid function, I-131 uptake was studied in November, 1965, January and May, 1966. Fifty microcuries of NaI-131 were administered orally and the I-131 uptake by the thyroid gland was then determined at 2, 6 and 24 hours by means of a scintillation counter with a 2 inch NaI crystal, equipped with

a pulse height analyzer. The protein bound I-131 conversion ratio was also determined at 24 hours after the administration of I-131 by using a well-type scintillation counter (Model DS-202 Nuclear-Chicago Co.). Twenty-four hour urine samples were collected for the determination of I-131 excretion.

RESULTS

A. Basal metabolic rate.

Although the BMR was determined over a period of two years, the overall monthly trend was similar in both years and hence the values for the corresponding months were averaged.

Resting heart rate showed some fluctuations over a period of a year, but there was a clear seasonal variation. As shown in Fig. 1, resting heart rate was lower during the warm seasons (from April to September) than during the cold seasons (from October to March of the following year). Thus, in males, the lowest heart rate of 60 per min was

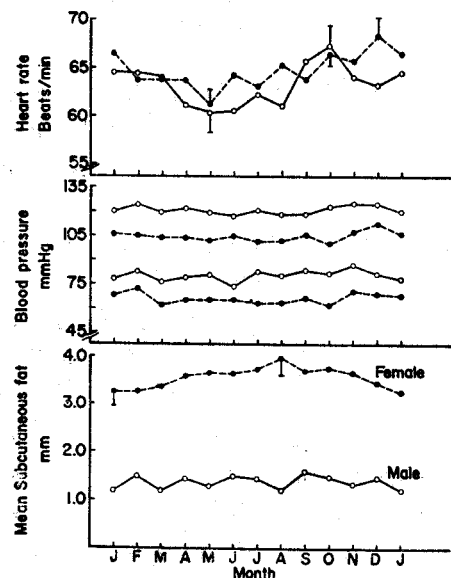


Fig. 1. Monthly variations of the average resting heart rate and blood pressure and the mean subcutaneous fat thickness. In the middle graph, the top two lines indicate the systolic blood pressure while the bottom two lines indicate the diastolic. Vertical bars indicate one standard error.

Table 2. Annual variation of basal metabolic rate in individual subjects

Subject	Age (yrs)	B.S.A. (m ²)	BMR (Kcal/hr/m ²)			
			Lowest	Highest	Difference	Annual mean
—Male Subjects—						
M-1	30	1.72	29.6(May)	41.3(Sept.)	11.7	35.9
			32.6(May)	40.6(Oct.)	8.0	36.2
M-2	20	1.62	33.1(Apr.)	45.3(July)	12.2	40.4
			32.1(June)	43.7(Dec.)	11.6	38.4
M-3	32	1.68	31.5(Jan.)	40.0(Apr.)	8.5	33.9
			30.7(Feb.)	37.7(July)	7.0	34.8
M-4	30	1.69	28.8(May)	41.6(Sept.)	12.8	34.9
			28.7(May)	39.8(Oct.)	11.1	34.1
M-5	40	1.80	28.3(May)	42.5(Nov.)	14.2	36.0
			31.3(Mar.)	41.4(Sept.)	10.1	36.7
M-6	34	1.66	32.0(Aug.)	41.2(Nov.)	9.2	35.2
			34.0(Nov.)	43.4(Dec.)	9.4	38.7
M-7	26	1.62	33.5(Apr.)	41.4(June)	7.9	36.4
			31.5(June)	40.0(June)	8.5	35.9
M-8	30	1.63	32.0(June)	42.5(Dec.)	10.5	36.5
			35.4(May)	42.1(July)	6.7	37.5
		Mean	31.5	41.5	10.0	36.3
—Female Subjects—						
F-1	20	1.32	30.0(July)	35.6(Mar.)	5.6	33.3
			25.4(Oct.)	36.4(Jan.)	11.0	31.1
F-2	19	1.49	33.0(Sept.)	39.1(Apr.)	6.1	36.1
			31.3(Aug.)	42.0(Dec.)	10.7	35.0
F-3	20	1.56	28.4(Jan.)	36.0(Sept.)	7.6	31.0
			25.2(Feb.)	33.0(July)	7.8	29.2
F-4	20	1.53	28.6(Sept.)	36.6(Dec.)	8.0	32.0
			27.6(May)	36.0(Dec.)	8.4	32.0
F-5	20	1.59	29.7(May)	34.1(Oct.)	4.4	32.2
			27.3(June)	34.4(Nov.)	7.1	30.4
F-6	26	1.51	30.0(Jan.)	38.0(Apr.)	8.0	33.5
			29.2(Jan.)	38.3(Aug.)	9.1	35.1
F-7	20	1.40	28.2(Mar.)	37.6(Oct.)	9.4	33.3
			28.8(Mar.)	34.2(Dec.)	5.4	31.7
F-8	21	1.45	31.2(Feb.)	39.7(Mar.)	8.5	34.3
			29.0(Mar.)	38.0(Nov.)	9.0	33.8
F-9	31	1.42	29.8(Jan.)	37.6(Oct.)	7.8	34.4
			28.4(May)	36.0(Sept.)	7.6	32.6
		Mean	28.9	36.7	7.8	32.7

() : Month in which the corresponding value was obtained.

The top and bottom BMR values for each subject refer to the first and second year, respectively.

seen in May compared to the highest value of 67 in October, a significant difference ($P < 0.04$). Similar differences were also noted in females ($P < 0.002$). Although the blood pressure (both the systolic and the diastolic) also showed a similar trend, seasonal differences were much smaller compared to pulse rates (Fig. 1). As expected, mean subcutaneous fat thickness was approximately three times greater in females but showed no significant seasonal variations (Fig. 1).

BMR showed a characteristic seasonal variation with lowest values in January through May and highest in September through December in both sexes (Fig. 2). The magnitude of annual variation was approximately 7 to 10 Kcal/hr/m² (Table 2) and was highly significant ($P < 0.02$).

Since the age and the physical characteristics of individual subjects were different, the values of BMR were compared with the DuBois standard, and the percent deviation from the latter value was computed. The average deviation for the entire subject group was then computed for each month to illustrate the representative annual fluctuation in these Koreans. As shown in Fig. 2, average BMR was lowest in May (approximately 13 per cent below DuBois standard) after which it increased steadily, reaching a maximal level (approximately 3 per cent below DuBois standard) in December. Curiously enough, BMR decreased rapidly in January after which it declined steadily until May. The values of BMR per kilogram lean body mass showed similar monthly variations over the course of a year, with the minimal level in May and the maximal in October through December ($P < 0.02$).

Although these change in BMR over the period of a year seem to be inversely related to overall changes in the average monthly ambient temperature, inspection of Fig. 2 indicates that the BMR cycle is not in perfect phase with the temperature cycle. For instance, the highest ambient temperature was in August while the lowest BMR was in May, and the lowest temperature was in January while

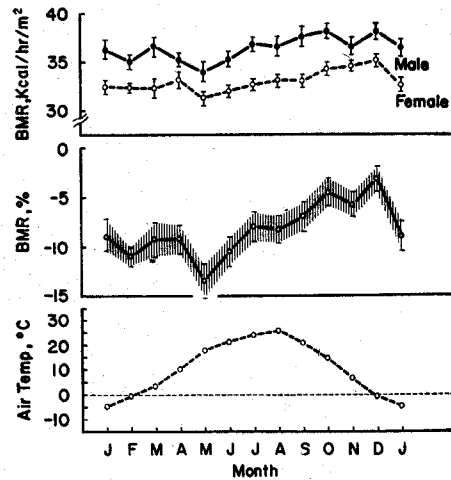


Fig. 2. Monthly variations of the average basal metabolic rate and the air temperature. In the middle graph, the average percent deviation of basal metabolic rate from the DuBois standard for all subjects is shown along with one standard error (shaded area). Vertical bars indicate one standard error.

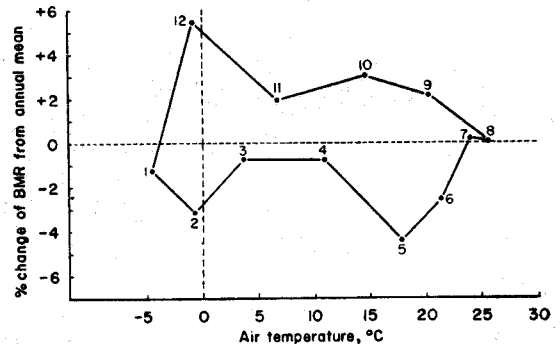


Fig. 3. The monthly basal metabolic rate expressed as percent deviation from the annual mean as a function of the air temperature. The numerical figures indicate the month of year. Each point represents the average on all subjects.

the highest BMR was in October through December. Thus a correlation between BMR and corresponding ambient temperature does not exist. The value of BMR for a given ambient temperature was greater during the second half of the year than during the first half (Fig. 3).

B. Thyroid functions.

The thyroïdal uptakes of I-131 in January, May and November were not significantly different from one another (Table 3). Neither the urinary I-131 excretion nor the protein-bound I-131 con-

Table 3. Various parameters of thyroid functions

	January (14)	May (6)	November (11)
I-131 uptake(%)			
2 hrs	10.8±0.8	13.6±1.2	12.1±0.9
6 hrs	16.4±2.0	18.4±1.7	17.4±0.9
24 hrs	23.1±2.4	30.9±5.0	24.8±1.9
Urinary I-131 excretion (%)	47.4±3.5	—	48.5±2.6
PBI-131 conversion ratio (%)	29.9±2.4	—	31.0±2.9
Basal Metabolic Rate (Kcal/hr/m ²)			
Male	36.3±0.9	34.1±1.0	36.4±0.9
Female	32.5±0.7	31.3±0.8	34.5±0.5

(): Number of subjects (Mean±SE)

version ratio showed any difference between January and November.

DISCUSSION

Many investigators in America and Europe have attempted in vain to find evidence of metabolic acclimatization to cold (2, 4, 6, 11, 15-17, 21-23, 25). Curiously enough, however, many Japanese investigators have observed characteristic seasonal variations in BMR, which increases significantly in winter (7, 18-20, 25). Recently, we also reported a similar seasonal variation in the diving women of Korea, who are exposed daily to severe cold water stress in winter (9, 13). Although these findings seem to indicate the possible development of metabolic acclimatization to cold in both the Japanese and the Korean, we were disturbed to note the absence of any seasonal variation in BMR of non-diving women of Korea living in the Pusan area. Although Pusan is located at the southern tip of the Korean peninsula, the annual range of ambient temperature is similar to that of Kyoto, Japan, where the BMR has been reported to increase significantly in winter (25). This led

us to reinvestigate seasonal BMR in Seoul where the average ambient temperature in winter is 7 to 8°C lower than that in Pusan.

The present investigation revealed that there are indeed certain seasonal variations in BMR of subjects living in Seoul, which are roughly correlated to the ambient temperature (see Fig. 2). However, the overall dependence of BMR upon the ambient temperature (see Fig. 3) was much less marked compared to the Japanese. Moreover, the lowest BMR in warm seasons precedes the peak of ambient temperature whereas the highest BMR in cold seasons precedes the nadir of ambient temperature. In other words, the BMR increased during the hottest season (July and August) while it decreased during the coldest season (January). In addition, the BMR for a given ambient temperature was greater during the second half of a year as compared to the first half (see Fig. 3). A similar type of seasonal variation in BMR was also obtained recently by Nakamura from the subjects living in the northern part of Japan where the range of annual changes in ambient temperature is very similar to that in Seoul (25). Our findings suggest that the ambient temperature is not the major determinant of the level of BMR. If the magnitude of BMR is determined primarily by the ambient temperature, the lowest peak of BMR should appear during July to August and the highest peak of BMR during January. Moreover, if this is a metabolic acclimatization to cold or heat, the level of BMR at a given ambient temperature should be lower during the second half of a year as compared to the first half, as a result of previous acclimatization to cold or heat.

The present findings are at variance with most of earlier Japanese reports (7, 18-20, 25). As stated earlier, the weather in the Seoul area has a wider annual maximum-minimum compared to Pusan; thus if the ambient temperature is the primary determinant of BMR one should expect to find a difference in the average BMR of our Seoul subjects between mid-summer and mid-winter.

The BMR of Canadian missionaries living in Japan do not manifest any seasonal variation (25), further suggesting that some factors other than the ambient temperature are perhaps involved in initiating the characteristic seasonal variations in BMR. Of these other factors, the nature of diet has been considered to be very important (18, 25). For instance, the magnitude of annual variation in BMR of Japanese has been decreasing progressively during the last 15 years while the fat to carbohydrate ratio of Japanese diet has been increasing progressively (18). If this view is correct, one would expect to find a much greater seasonal variation in our subjects, for Koreans are living on diets with a lower fat to carbohydrate ratio compared to Japanese (14, 18). Yoshimura et al. also showed an inverse relationship between the magnitude of seasonal variation in BMR and the body surface area, to which they partly attributed the lack of seasonal variation in Canadian missionaries living in Japan (25). However, the average physical characteristics of Koreans are comparable to those of Japanese, ruling out this factor. Recently, Wilson (23, 24) has shown that the level of BMR is dependent primarily upon the degree of physical activity. There was a significant increase in the BMR of Swedish subjects when they increased the extent of physical activity either in cold or in warm environment. Moreover, Sasaki reported an increase in BMR of Japanese in summer in school children or marathon runners who are quite active during the summer season (19). Canadian missionaries living in Japan, who seem to have larger physical work in summer than in winter, also maintained a higher BMR level in summer (25).

Of various factors contributing to the seasonal variations in BMR, the degree of physical activity may be quite important. Unfortunately, we have not estimated the degree of daily physical activity of our subjects in the present investigation and hence it is not possible to evaluate our data on this basis. In general, people living in Seoul experi-

ence a feeling of lassitude in spring as the ambient temperature continuously increases and they tend to limit the range of daily activity in January and February on account of severe cold. However, the autumn weather in Seoul is ideal for vigorous activities. In other words, the overall physical activity may prove to be rather light during the first half of the year and more vigorous during the second half. Such an activity pattern would fit in with the overall changes in BMR of our subjects over the period of a year.

In view of these considerations, it is speculated that the seasonal variation of BMR as seen in the present investigation is initiated by the level of physical activity which in turn is determined by ambient temperature. In other words, the degree of cold to which we are exposed daily is not big enough by itself to induce metabolic acclimatization.

Whatever the nature of seasonal changes, BMR was independent of the level of thyroid function (see Table 3). Although some Japanese workers have shown a seasonal variation in thyroid functions the magnitude of these changes were relatively small (25). Wilson also showed that the increase in BMR induced by greater physical activity was not accompanied by any significant changes in thyroid function except for a small reduction in PBI-131 conversion ratio (24, 25).

Acknowledgement: It is our great pleasure to acknowledge all subjects without whose splendid cooperation this investigation could have never been accomplished. We are also greatly indebted to Dr. Hermann Rahn and Dr. D.W. Rennie of the State University of New York at Buffalo for their interest and help in the conduct of this investigation.

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