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Seasonal Variation of Energy Metabolism

Shigeki FUJIMOTO and Tsutomu WATANABE

Department of Hygiene,
Nagasaki University
School of Medicine, Nagasaki, Japan

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Seasonal variation of the energy metabolism of Japanese was measured on the following items. 1) Seasonal variation of the basal metabolism by sex and age-group, and by intensity of work on some age-groups. 2) Seasonal variation of the rest metabolism by age-group on male. 3) Seasonal variation of work metabolism and relative metabolic rate (R. M. R.). 4) As supplement, influence of menarche on variation of basal metabolism.

In general, it is shown that the energy metabolism of Japanese variates under the influence of seasonal variation of Japanese climate, as basal metabolism of adult is low in summer and high in winter. But basal metabolism of infant shows two peaks in a year. And rest metabolism of infant and school age children have different seasonal variation from those of adult and aged. On work metabolism, aged subjects showed more variance than other age-groups.

It has been discussed in many papers about the changes of the basal metabolism of some residents along with the seasonal variation of the climate. Even though there were two concepts: 1) There is no relationship between the basal metabolism and the seasons. 2) It is rather high in summer but low in winter, but now the theory that it is low in summer and high in winter is approved. It seems to be admitted now that the seasonal variation of the basal metabolism is mainly caused by the environment, especially the atmospheric temperature. There have also been many opinions about the relationship between the energy metabolism except the basic one, that is, the rest metabolism and the work metabolism, and the seasons, and it has not been cleared yet. So that it is required to study the effects of sex, age and the intensity of work on the relationship between energy metabolism and the seasons.

We have studied on the following problems with Japanese as the sample for our experiment in due consideration of their sex, body build

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and body type of each age, having the typical seasonal changes of the climate here in Japan.

Examination of each subject was carried out once a month for thirteen months period by using the basal metabolism at the post-absorptive state early in the morning.

For the determination of the basal metabolism the Douglas-bag method was employed and expired gas analysis was carried out by Haldane Type gas analyzer modified by Roken.

Experimental value was corrected by yearly difference (growth

Table. 1. Number of subjects by sex and age group

Age-group	♂		♀		Remarks
	Age	N	Age	N	
Aged	68–78	9	64–77	10	
Thirties	30–38	25	30–39	17	♂ Intensity of work { Light 7, Moder. 6, Heavy 12
Twenties	20–29	18	22–30	21	♂ 〃 { Light 6, Moder. 6, Heavy 6 ♀ { Houswife 7, Secretary 6, Nurse 8
High school	15–16	22	16–17	18	♀ concerning menarche
Middle school	12–13	18	13–14	18	
Primary school	6– 7	17	6– 7	18	
Infant	2– 4	13	2– 4	14	

Table. 2. Monthly means of basal metabolism by sex and age-group

Cal/m²/h

Sex	Age-group	N	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
♂	Aged	9	32.06	30.85	31.51	30.80	30.41	29.03	28.63	28.55	29.42	29.67	30.23	31.95	29.99
	Thirties	25	37.22	36.10	36.62	36.07	35.37	34.80	34.31	34.32	34.90	35.63	36.34	36.85	35.71
	Twenties	18	36.31	36.64	36.73	36.10	34.65	34.29	34.11	33.98	34.24	34.49	36.18	35.87	35.30
	High school	22	39.99	40.72	39.72	39.99	39.17	38.54	38.37	39.01	37.97	38.50	39.14	39.50	39.22
	Middle school	18	47.89	47.99	47.32	44.71	43.72	41.24	40.40	40.59	40.39	44.94	45.61	45.89	44.22
	Primary school	17	53.18	52.26	50.88	51.58	48.84	50.78	49.57	50.44	50.54	50.41	51.57	53.10	51.10
	Infant	13	60.58	63.36	62.07	61.45	62.30	57.06	53.87	56.33	64.52	63.16	59.97	58.93	60.30
♀	Aged	10	32.17	31.85	31.09	30.38	30.63	30.10	30.41	29.81	30.27	31.48	31.52	31.97	30.97
	Thirties	17	34.54	34.89	34.47	33.55	32.81	32.12	31.55	30.56	30.99	32.64	32.82	33.82	32.90
	Twenties	21	33.85	33.88	32.67	32.52	32.40	31.56	31.67	31.16	31.31	32.43	32.57	31.99	32.30
	High school	18	36.72	36.88	35.49	35.63	34.45	34.15	33.98	34.83	35.61	36.56	37.37	37.86	35.79
	Middle school	18	39.84	40.09	38.33	37.95	36.90	36.25	35.81	37.32	38.24	37.97	39.00	39.25	38.08
	Primary school	18	48.90	48.49	48.46	46.64	47.95	48.46	48.35	47.89	47.50	47.62	49.53	48.85	48.22
	Infant	14	56.46	56.79	58.26	57.85	57.68	53.91	53.46	52.90	61.63	60.52	59.24	55.68	57.03

correction). During the experiment the monthly mean temperature in Nagasaki was high in July and August about 27.1 to 28.6°C and low in January about 4.6 to 7.1°C. The monthly mean value of the relative humidity was 60 to 68% in winter and 80 to 87% in summer.

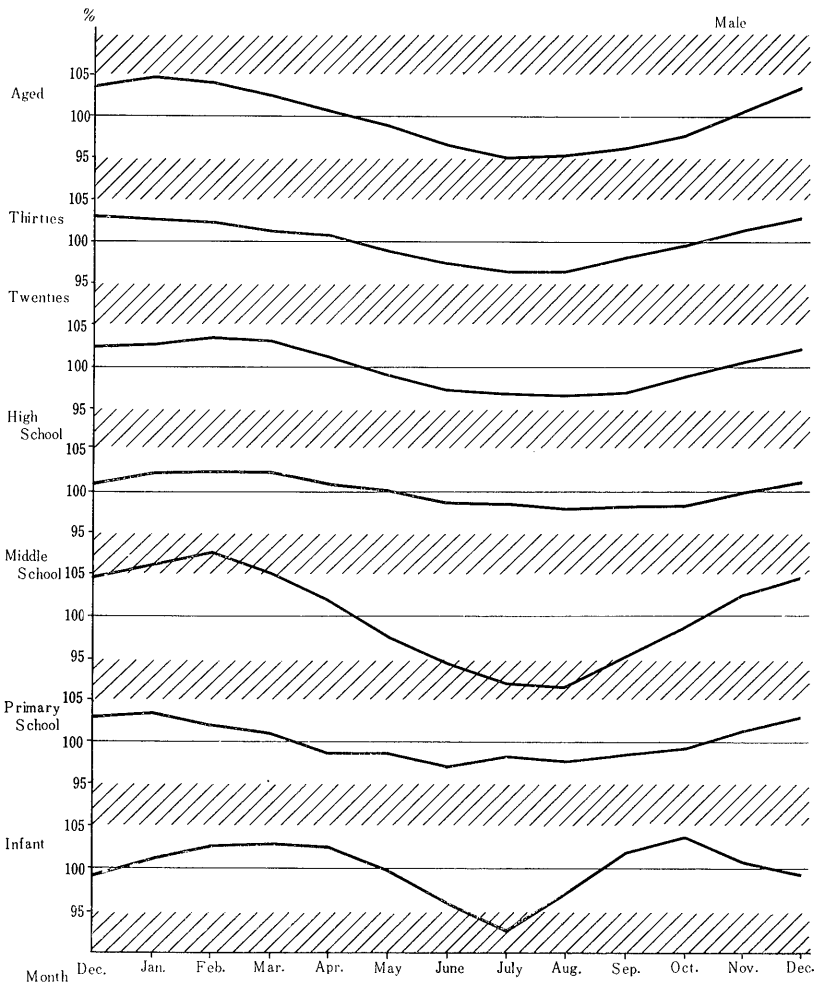
1. SEASONAL VARIATION OF THE BASAL METABOLISM

The subjects examined by the seasonal change of the basal metabolism is shown in Table 1. The new-born baby was removed from our experiment because M. TOMITA recorded that they grow rapidly and they do not expose themselves to the environment changes, so that they do not exhibit typical seasonal change of it.

A. Seasonal variation of basal metabolism by sex and age-group

The changes of value of basal metabolism in 12 months by sex and age group are shown in Table 2. The 3-month moving averages of

Fig. 1. 3-month moving averages of variation rate of basal metabolism by age group



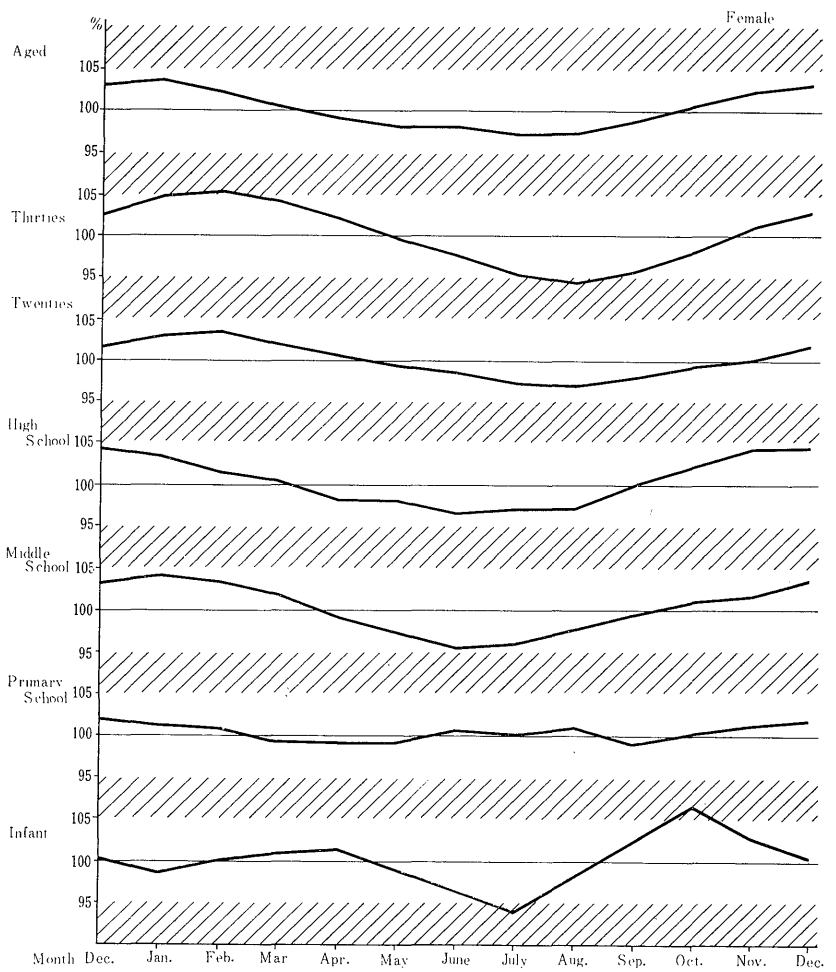
variation rate of them are shown in Fig. 1 and 2. The summary are as follows:

(1) The basal metabolism of both sexes in infant period has two peaks in a year, so that it shows that their basal metabolism rise just before the beginning of both hot and cold season (not in the coldest and hottest seasons). This fact suggests that the infants sensitively respond to the change of atmospheric temperature and they are labile.

(2) During the period of primary school age the basal metabolism of both sexes has less seasonal variation than that of other age period. In junior and senior high school age the variation of it is more sharp, so is led to be like the adult's type which is high in winter and low in summer.

(3) In adult it has stable change being high in winter and low in summer, and has no significant difference in variation between sexes.

Fig. 2. 3-month moving averages of variation rate of basal metabolism by age group



(4) Aged persons have a characteristic that they have relatively sharp rising of basal metabolism towards the cold season from the hot season.

(5) In general, there are monthly variation rate in average of 5% to yearly means, excepting 8% in infant and junior high school age.

B. Seasonal variation of basal metabolism by intensity of work (grade of labor).

In the subjects mentioned above, twenties and thirties males consist of three groups; heavy worker (inside coalminer), moderate (outside coalminer) and light (clerk etc). Twenties females consist also of three groups; heavy worker (nurses), moderate (clerks) and light (housewives).

The seosonal variation of basal metabolism were observed on these subjects based on the grade of labor.

Monthly means of basal metabolism with these subjects are shown in Table 3, and their 3-month moving averages in variation rate are shown in Fig 3.

Table. 3. Monthly means of basal metabolism by intensity of work

Cal/m²/h

Age & Sex	Intensity of work	N	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
	Light	7	36.64	35.36	36.13	35.68	34.21	33.61	33.96	33.41	34.16	35.27	36.40	35.54	35.03
30 yrs	Moderate	6	37.34	36.10	36.66	35.73	36.02	35.42	34.16	33.96	34.10	35.72	36.33	36.85	35.70
male	Heavy	12	37.42	36.38	36.83	36.42	35.69	35.12	34.59	34.90	35.62	35.69	36.25	37.54	36.04
	Light	6	34.71	36.15	34.57	34.56	32.41	33.92	32.74	32.92	32.82	32.91	35.78	34.54	34.00
20 yrs	Moderate	6	38.19	36.47	38.16	37.34	36.46	34.92	34.29	34.15	34.19	35.28	35.77	36.65	35.99
male	Heavy	6	35.74	36.93	37.07	36.07	34.59	33.98	35.71	34.88	35.64	34.18	36.83	36.20	35.65
	Houswives	7	33.37	34.85	32.94	32.71	32.26	31.70	31.80	31.12	31.63	32.16	31.44	31.26	32.42
20 yrs	Clerks	6	35.02	33.06	33.35	33.82	32.86	32.39	32.75	31.38	30.77	33.23	32.74	32.09	32.79
fema-	Nurses	8	33.44	33.73	32.04	31.52	32.32	30.95	30.90	31.00	31.43	32.08	32.85	32.64	32.09
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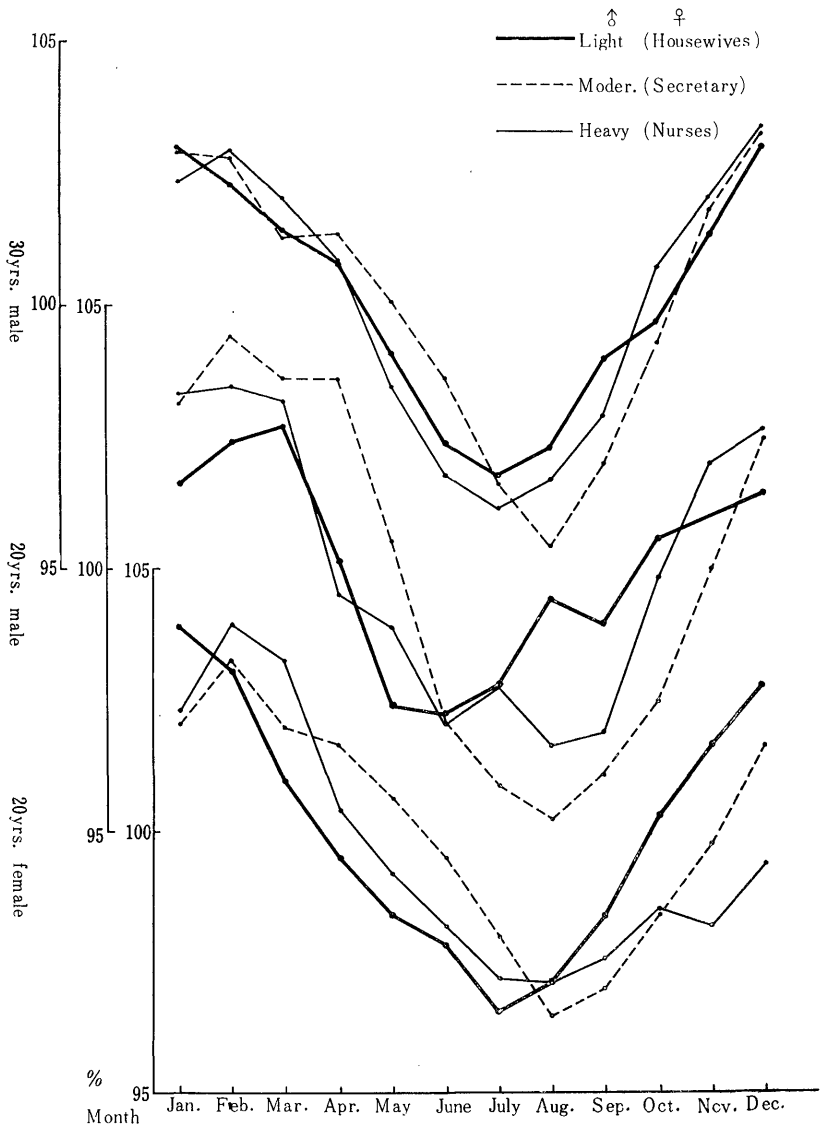
(1) As shown in some references, the basal metabolism per unit body surface area is rather high on the subject with heavy labor than with light labor. The results obtained with our subjects showed similar tendency with the others.

(2) In the heavy labor groups of twenties and thirties male, the lowering of the seasonal variation rate in summer appears in early period and those grade are somewhat a little.

This fact may suggest that these changes are caused by the rather specificity of environmental and thermal condition (25 – 30°C through year) at coal-mining spot at which they were working about one third of every day (8 hours) for many years, than the heavy labor.

Fig. 3. 3-month moving averages of basal metabolism by intensity of work



SUPPLEMENT

Relationship between basal metabolism and menarche

T. KAWAGOE measured the basal metabolism of 18 females every month for period from before menarche to 12 months after. These seasonal variation rate corrected due to growth is the highest in February and the lowest in July, and the range between them is about 10 %. Then their basal metabolic values corrected due to growth and season shows sharp fluctuation at menarche. It has a tendency of rising

from several months before menarche and reaches maximum peak during two months after it. It gradually falls down after then. These rising and lowering are statistically significant.

2. SEASONAL VARIATION OF REST METABOLISM BY AGE-GROUP.

In order to clarify the influence of seasons on energy metabolism at work, the male subjects of aged, adult, adolescence and school-child period are used.

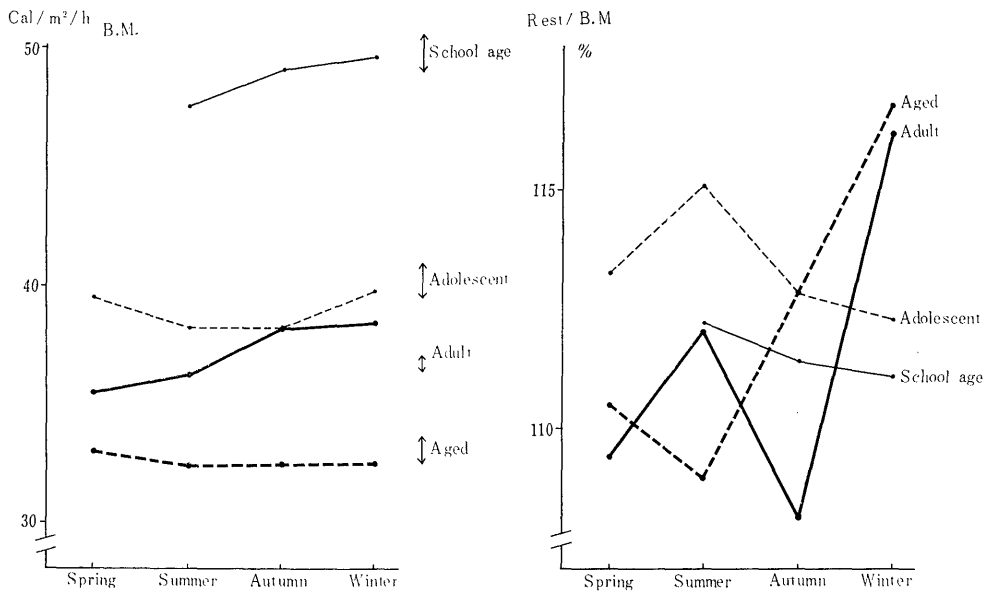
Their basal, rest and work metabolism in case of loading hand-ergometer, bicycle-ergometer and step were measured five times of each work in every season.

The school-child in spring and aged subject in autumn tests were

Table. 4. Seasonal variation of basal metabolism and ratio of rest metabolism to basal metabolism in % by season and age group

	Age	N	Basal metabolism (Cal/m²/h)					Rest metabolism/Basal metabolism (%)				
			Spring	Summer	Autumn	Winter	Mean	Spring	Summer	Autumn	Winter	Mean
Aged	65 – 74	6	32.88	32.28	–	32.36	32.51	110.5	108.9	–	116.6	112.0
Adult	28 – 34	5	35.52	36.13	38.03	38.30	36.80	109.3	112.0	108.0	115.7	111.4
Adolescent	15 – 17	5	39.41	38.16	38.08	39.74	38.85	113.2	115.1	112.8	112.3	113.4
School age	8 – 9	5	–	47.42	48.92	49.60	48.50	–	112.1	111.3	111.1	111.5

Fig. 4. Seasonal veriation of basal metabolism and rest metabolism/basal metabolism by age group



omitted, the test with hand-ergometer in aged was omitted too.

In Table 4 and Fig. 4, case number, age, basal metabolic rate and ratio in % of sitting rest heat production to basal heat production are shown.

The seasonal variation of basal metabolism of these subjects showed typical Japanese characteristics like above mentioned. Its range in aged was rather small.

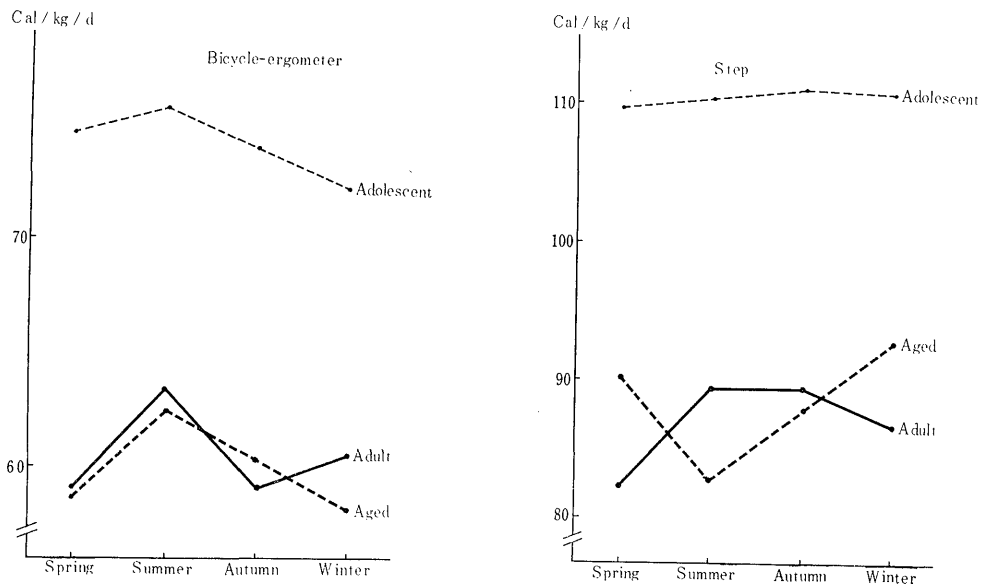
The range of the ratio of rest heat production vs basal metabolism

Table. 5. Seasonal variation of extra-calories Cal/kg′/day

Work	Age-group	Spring	Summer	Autumn	Winter	x̄	
Hand-ergometer	Aged	—	—	—	—	—	
	Adult	25.92	14.40	17.20	15.84	18.36	
	Adolescent	31.32	28.54	24.97	31.37	29.14	
	School age	—	16.25	15.89	19.57	17.23	
Bicycle-ergometer	Aged	58.73	62.45	—	58.10	59.76	
	Adult	59.04	63.36	59.04	60.48	60.48	
	Adolescent	74.63	75.63	—	72.17	74.14	
	School age	—	21.02	25.53	19.57	22.08	
Step							Step height
	Aged	90.04	82.55	—	92.40	88.33	20cm
	Adult	82.08	89.28	89.28	86.40	86.76	30cm
	Adolescent	109.41	119.02	110.97	110.60	110.25	30cm
	School age	—	20.27	20.32	18.49	19.65	20cm

kg′ : whole body weight

Fig. 5. Seasonal variation of extra calories by age group



was 108 to 115%. This values were high in summer and winter. This seasonal variation of the ratio mentioned above was statistically significant, however that of basal metabolism was different from it.

3. SEASONAL VARIATION OF WORK METABOLISM AND RELATIVE METABOLIC RATE (R. M. R.).

A. Extra-calorie

Calories (Heat production) used only for work, that is total heat production minus that of the rest (including basal metabolism), is called "Extra-calorie".

Each Extra-calories per kilogram ot whole body weight per day of three kinds of work, age-group and season are shown in Table 5 and Fig. 5. The whole body weight in the case of the handergometer-test means naked weight including clothes and respiration-mask and including two bags that of bicycle-ergometer and step-work.

To obtain the steady state condition of the metabolism at aged and school age subjects, the step work test was carried out with 10 cm lower step-stand. As the results, seasonal variation of "Extra-calorie" is not uniform, it is low in autumn by hand-ergometer-work and there is some lowering tendency of it in spring and winter by bicycle-ergometer-test and step test. The typical tendency is not observed in age-group.

B. Relative metabolic rate (R. M. R.)

Furusawa advocated "Relative metabolic rate" as the index of intensity (the grade) of work (R. M. R.).

$$\text{R. M. R.} = \frac{\text{Total heat production of work} - \text{Rest heat production in sitting}}{\text{Basal heat production}}$$

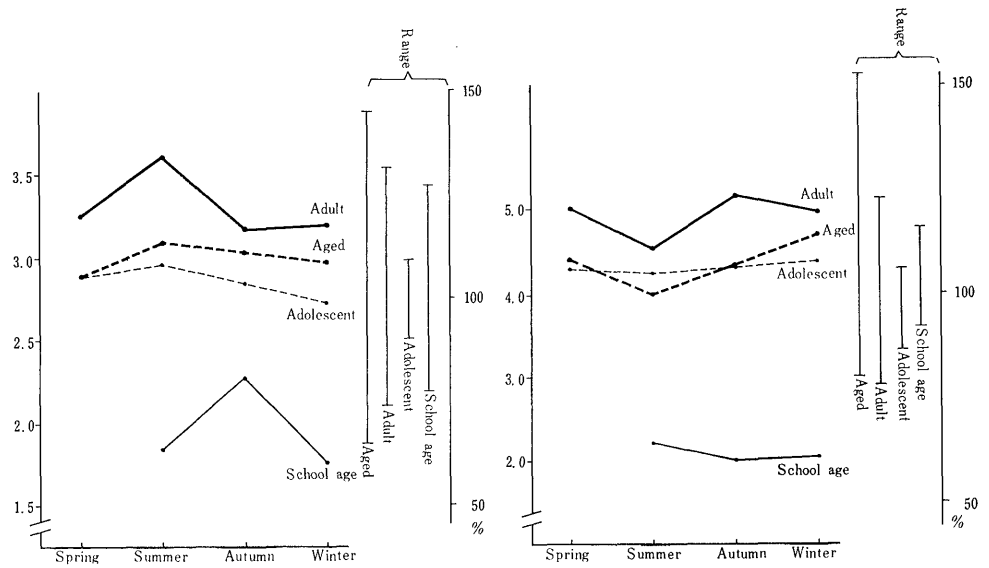
The difference between is so-called "Extra-calorie" mentioned above including the excess heat production over the rest at recovery stadium.

Table. 6. Seasonal variation of R. M. R. (Cal.) by age-group

Work	Age-group	Spring	Summer	Autumn	Winter	$\bar{x}$
Handergometer	Aged	—	—	—	—	
	Adult	1.09	0.85	0.90	0.92	0.94
	Adolescent	1.11	1.03	—	1.13	1.09
	School age	—	1.11	1.04	1.26	1.13
Bicycleergometer	Aged	2.89	3.07	—	2.96	2.79
	Adult	3.25	3.60	3.17	3.18	3.30
	Adolescent	2.89	2.96	—	2.74	2.86
	School age	—	1.83	2.28	1.75	1.95
Step	Aged	4.39	4.01	—	4.71	4.37*
	Adult	5.04	4.54	5.14	4.96	4.92
	Adolescent	4.32	4.25	—	4.38	4.32
	School age	—	2.20	1.99	2.02	2.07*

* Step height = 20cm

Fig. 6. Seasonal variation of R. M. R. (Cal.) by age group



FURUSAWA and others have shown that this index has no individual difference and maintains steady status (constancy) within a certain range of the age or intensity of work. But many investigators have recognized that heat production (above mentioned) is rather constant than R. M. R. in work loaded intensely by body weight as step work etc.

R. M. R.s in work, age-group and season are shown in Table 6, and these on bicycle-ergometer and step work are shown in Fig. 6. "Range" in the figure means per cent range of means in every season and every subject to total mean.

In almost of all cases, R. M. R. tends to be high in summer on bicycle-ergometer test, and low in summer on step test. When tested by statistical method of analysis of variance, the variances of almost factors of work, season and individual and their interactions were significant against the error variance from interation, that is variance of factor of work, season and individual removed from the whole.

However, when tested against the variance of individual, the variance of seasonal factor is not significant. The breadth of variance shown by range is particularly larger in aged group compared with others, and shows no tendency in variation by season.

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