Activity Patterns and Energy Metabolism of Men in Antarctic Expedition

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南極観測隊員の行動様式とエネルギー代謝

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要　旨

極地という特殊な環境条件が，人間の生活様式に及ぼす効果を検討する目的で，第8次日本南極地域観測越冬隊員を対象として，生活時間調査およびこれに関連するエネルギー代謝につき調査を行なった．昭和基地において，隊員は平均66%の時間を臥位または坐居て過し，また88%の時間は屋内て過した．エネルギー消費量は1人1日平均2850kcal，食事摂取量は2830kcalと計算された．これらは日本て中等度の筋肉労働に従事するものの値に相当している．エネルギー消費量，屋外て過した時間等は，冬期に少なく，夏期には多くなった．これは行動様式が気候条件に影響されることを示している．越冬中昭和基地において隊員が過した場所の気温は平均11 2°Cてあり，0°C以下の温度に暴露されていた時間は全体の 11% てあった．自然条件の厳しい南極てあっても，観測基地で生活する限りは環境条件は極端に厳しいものてはなく，生体に重大な生理的変化を引き起すものてはないと考えられる．

1. Introduction

A considerable number of papers have been written on the physiological changes in men following prolonged exposure to a cold environment (Adams and Smith, 1962; Burton and Edholm, 1955; Hart and others, 1962; Nelms and Soper, 1962; Yoshimura and Iida, 1950). However, controversy has continued as to whether any conclusive evidence of cold acclimatization could exist in men who were living in a polar scientific station (Butson, 1949; Kageyama, 1963; Lewis and others, 1960; Milan and Rodhal, 1961; Norman, 1965; Orr, 1965; Wilson, 1966). Norman (1965) suggested that the climatic stress was not sufficiently severe to produce any significant physiological change to men who were living in a normal polar station, because of the protective effect of housing, clothing and heating. Therefore, it seemed essential to assess the severity of the climatic stress to which man was exposed, before exploring any physiological changes induced by cold in

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such a polar station. Also, it is important to clarify the activity patterns of the subject in order to evaluate the energy expenditure and required level of food intake. In addition it is useful to know if the patterns of activity are related to the environmental conditions including light and darkness as well as climate.

In this study, the measurements of the temperature to which men were exposed, of the activity patterns, and of the energy expenditure and food intake were made during the one year stay at Syowa Station in 1967. Syowa Station (lat. 69°00′S, long. 39°35′E) is situated on a small island on the Prince Olav Coast, and it is 5 km apart from the coast of the Antarctic Continent. The annual mean climatic temperature at the station in 1967 was minus 10.2°C and the mean wind velocity was 6.0m/s. At the time of this study 24 members were wintering over. Although observations were mainly performed at the station, one observation was done during a traverse expedition to inland, in order to compare activity and exposure conditions with those at the station This traversing trip by 9 members took 75 days from the beginning of November, 1967. The study was performed in the area about lat. 75°S, long. 43°E, and elevation 3,500m.

2. Material and Method

2.1 Subjects and days of observation

Nine members were chosen as the subjects of this study. Age and speciality of individual subject and times of observations are given in Table 1. Their average body weight was 63.8 kg and surface area 1.72 m². On the day of observation the subjects were studied for a 24 hour period. Each subject, in addition to his special assignment, took his turn in the daily domestic routine at the station, such as clean-

Table 1 Subjects and days of observation

Subject	Age	Occupation	Days of observation				
			May	August	October	December	Traverse
T H	36	Biologist	1	3	2	1	–
I O	41	Meteorologist	1	3	2	1	–
K S	23	Cook	1	3	2	–	–
Y O	40	Mechanic	1	3	–	–	–
T M	36	Field assistant	1	3	–	–	2
S I	39	Mechanic	–	–	–	–	3
Y Y	36	Geologist	–	–	–	–	2
T I	46	Glaciologist	–	–	–	–	2

ing rooms, serving at table, shovelling snow into a water tank, carrying fuel drums, and other daily chores. During the traverse, driving snow cars, working on vehicle maintenance, and digging a deep hole in the snow for the observation of an artificial earthquake, were imposed as common duties upon all members besides their special works.

2. 2. Recording of daily activities

On the day of observation, every minute of the activity of the subject was recorded on cards, in a similar way to that designed by EDHOLM and others (1955). In order to make the recording simple, activity was classified into the following 11 categories:

1. Lying
2. Sitting
3. Standing
4. Walking indoors
5. Light work indoors
6. Medium work indoors
7. Heavy work indoors
8. Walking outdoors
9. Light work outdoors
10. Medium work outdoors
11. Heavy work outdoors

The classification of various activities was based on subjective impression. For example, time spent in bed, whether the subject was asleep or awake, was taken as lying. Sitting included resting, talking, writing, eating, and doing instrument maintenance. Light work included dressing, washing, and driving light snow cars. Raising weather balloons, climbing slopes, driving heavy snow cars, and works of mechanical repairing were listed as medium work. Digging snow, carrying heavy boxes, and moving fuel drums were listed as heavy work.

2. 3. Calculation of energy expenditure

It was not possible to measure directly the individual energy expenditure of each subject for all activities. However, LEWIS and MASTERTON (1960) had reported that it was reasonably permissible to use mean values obtained from literature. Therefore, daily energy expenditure of individual subject was calculated from the following formula:

$$A = BMR \times t_1 + BMR \times \sum (1.2 \times RMR)\, t$$

where,

A : Energy expenditure of the day (kcal),
BMR : Basal metabolic rate of the subject (kcal/min),
RMR : Relative metabolic rate for each category of activity,
t_1 : Time spent lying (min),
t : Time spent for each category of activity (min).

According to the results of measurement of relative metabolic rate for various activities of a Japanese (NUMAJIRI, 1955), the following figures have been taken as the value of *RMR* of each category of activity.

Lying: 0.0, Sitting: 0.3, Standing: 0.5, Walking: 2.0, Light work: 1.0, Medium work: 3.0, Heavy work: 5.0.

The basal metabolic rate for individual subject was determined from the published standard value of basal metabolic rate for a Japanese (Kagaku Gijutsu-Cho, 1959)

2. 4. Measurement of food intake

Kind and weight of the food consumed by each subject were recorded. The calorie intake was computed from the published standard component of various kinds of food (Nippon Eiyoshi Kai, 1958)

2. 5. Measurement of exposure temperature

During the period of observation, the measurement of dry bulb temperature was made in the immediate vicinity of the subject both indoors and outdoors

3. Results

3. 1. Activity pattern

The average time spent for each category of activity is shown in Figs. 1 a and

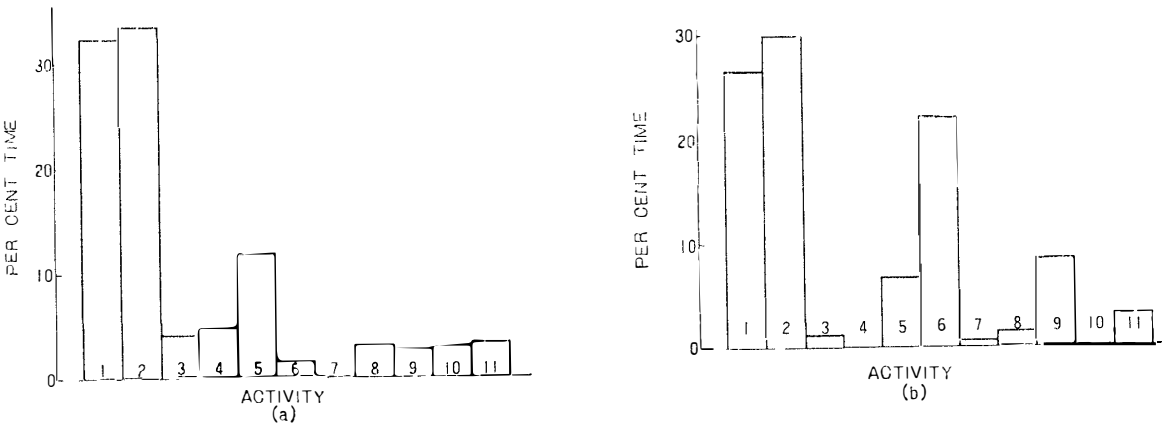

Fig.1 The average percentage of time spent for each category of activity 1 lying, 2 sitting, 3 standing, 4 walking indoors; 5 light work indoors, 6 medium work indoors, 7 heavy work indoors, 8 walking outdoors, 9. light work outdoors; 10 medium work outdoors, 11 heavy work outdoors.

a At the station through the year.

b During the traverse

b, where the mean values for all observations at the station and during the traverse are presented in the form of histogram. The most striking feature of these results was the large proportion of time spent in sitting and lying. Although the time varied considerably with individual subject, the mean value of time spent in sitting and lying was calculated to be 66 per cent at the station, while the value during the traverse was a little smaller than that. The next noticeable feature was the small proportion of time spent outdoors. The mean value of it was about 13 per cent both at the station and during the traverse. Table 2 shows the seasonal changes of average time distribution for each category of activity. The proportion of time spent outdoors was minimum in August (5.6 per cent) and maximum in December (20.1 per cent).

Table 2 The monthly mean values of the per cent time spent in the varions activities.

Activities	May	August	October	December	Mean	Traverse
Lying	31 3	35 4	31 4	30 6	32 2	26.4
Sitting	35 9	31 7	33 5	32 3	33 3	29 8
Standing	4 1	2 7	5 5	4 6	4 2	1 2
Walking indoors	4 9	5 6	4 2	4 1	4.7	0 0
Light work indoors	10 0	17 8	11 3	8.5	11 9	6 7
Medium work indoors	3 7	1 0	0 9	0 0	1.4	22 1
Heavy work indoors	0 0	0 2	0 0	0 0	0.0	0.6
Walking outdoors	3 1	1 0	4 3	4 0	3 1	1 5
Light work outdoors	1 9	3 1	4 5	1.7	2 8	8 5
Medium work outdoors	3 1	0 4	0 9	7 6	3 0	0 0
Heavy work outdoors	2 1	1 1	3 5	6 8	3 4	3 2
Time spent indoors	89 8	94 4	86 8	79.9	87 7	86 6
Time spent outdoors	10 2	5 6	13 2	20 1	12 3	13.2

3. 2. Energy expenditure and food intake

The calculated energy expenditure and food intake are shown in Table 3. The relation of caloric balance to change in body weight of two subjects are illustrated in Fig. 2. In the life at the station, energy expenditure was minimum and calorie intake was maximum in August. Reflecting this relation, many subjects recorded their maximum body weight in August. During the traverse, energy expenditure exceeded food intake by about 200 kcal per day, and the body weight of the four subjects decreased 2.6 kg on the average.

Table 3 The monthly mean values of energy expenditure and calorie intake

Month	Expenditure (kcal/day)	Intake (kcal/day)
May	2 820	2 300
August	2,580	3,060
October	2,800	2,990
December	3 190	2,970
Mean	2,850	2,830
During traverse	3,270	3,050

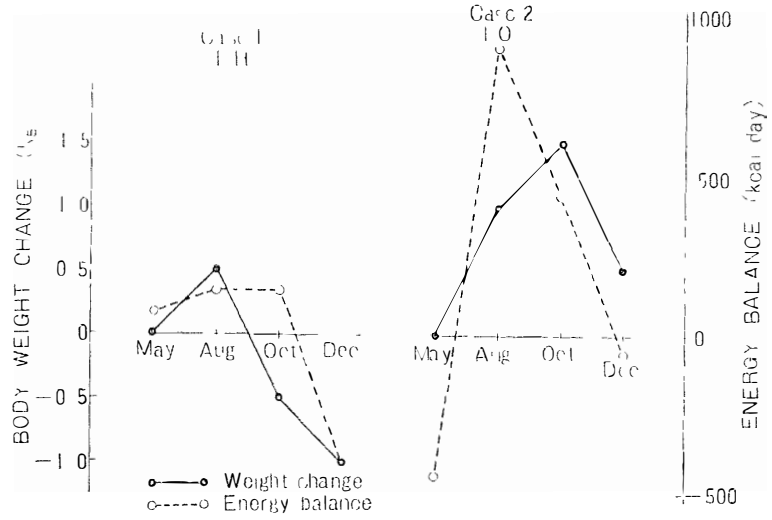

Fig. 2. The changes in body weight and energy balance of two subjects at the station
Dotted line: Changes in body weight.
Solid line: Energy balance

3. 3. Exposure temperature

The distribution of exposure temperature is shown in Figs. 3a and b, where the mean value for one year at the station and during the traverse are presented again in the form of histogram. In the life at the station, almost fifty per cent of time was spent when the temperature was between 15°C to 20°C, and the mean value of exposure temperature at the station was calculated as 11.2°C. For only 11 per cent of time spent, subjects were exposed to the temperature below 0°C. Naturally, values of exposure temperature of each month showed little change

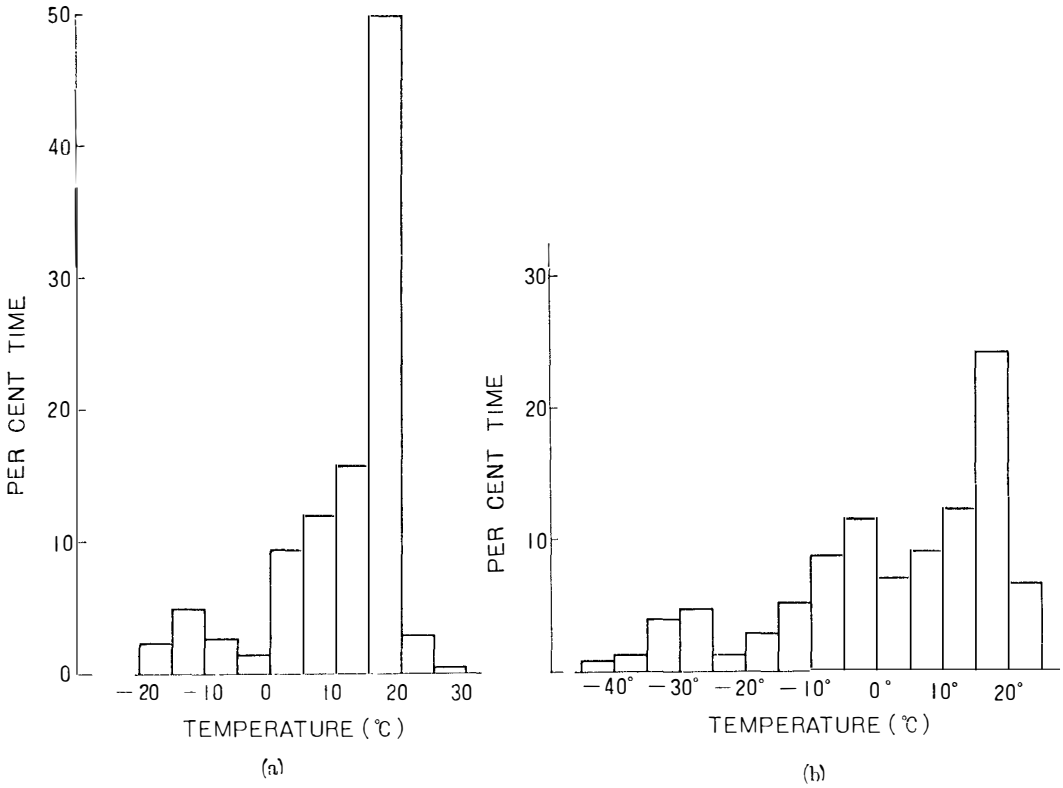

Fig. 3. The mean distribution of the temperature to which subjects were exposed.
a. At the station.
b. During the traverse

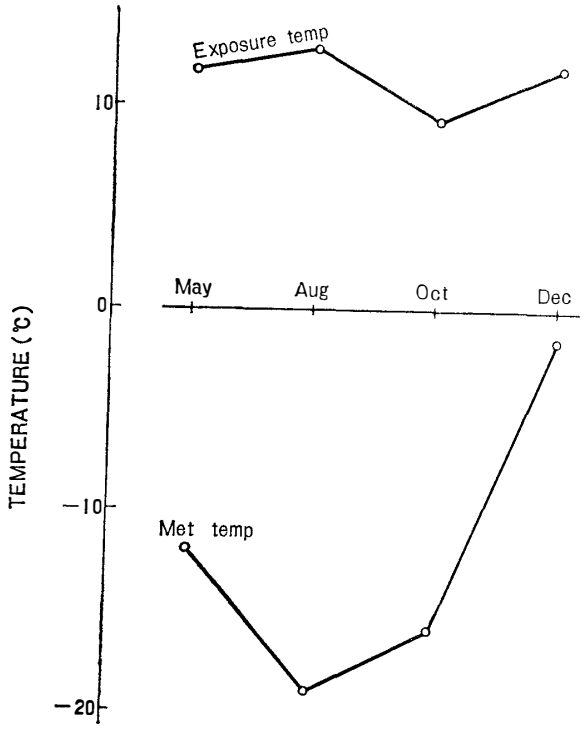

Fig 4 The mean values of the meteorological temperature and exposure temperature at the station in 1967.

comparing with those of meteorological temperature (Fig. 4). During the traverse, subjects were exposed to a rather cold condition. The mean exposure temperature was calculated to be 2.1°C, and for more than 50 per cent of time, subjects were exposed to the temperature below 0°C.

4 Discussion

The proportion of time spent in sitting and lying by the subjects in this study was very large, being 66 per cent. However, similar data have been obtained by many other investigators. Edholm and others (1955) reported 75 per cent for British military cadets, Garrey and others (1955) reported 69 per cent for coal miners, and Ito (1966) reported that 56 per cent of time was spent in these activities by refiners of a sulfur mine in Japan. In Antarctica, Norman (1965) reported 75 per cent. Therefore, it can be said that these patterns of activity are not peculiar to the Antarctic region, but are rather common patterns of human life. During the traverse, time spent in sitting and sleeping was calculated as 55 per cent, and the difference of this value from that at the station seems to indicate relatively heavy physical strains in the traverse. Unexpectedly, the proportion of time spent outdoors during the traverse was not different from that at the station. Norman (1965) reported that 39 per cent of time was spent outdoors during their sledge expedition, while 9 per cent at their station. The difference comes from the snow cars used in our traverse. As these snow cars had a cabin of closed type, the subjects were completely protected from the severe outdoor condition, so far as they remained inside the vehicles. The subjects were exposed to cold outdoor temperature during the traverse only when they were doing scientific observations or daily works of car maintenance.

The large proportion of time spent in sitting and sleeping does not necessarily mean that the level of physical work was particularly low. According to Numajiri (1955), the energy expenditure of 2,800 kcal/day, which was the mean value for the subjects at the station, corresponded to that for workers engaged in medium class physical work in Japan. Kawahata and others (1966) reported that the energy expenditure of a Japanese university student was 2,560 kcal/day, and Ito (1966) reported that a Japanese sulfur mine refiner expended 3,035 kcal/day. The energy expenditure of 3,270 kcal/day during the traverse corresponded to that for heavy physical workers in Japan. Other investigators reported that more than 5,000 kcal/day was expended by the subjects in their sledge expeditions in the polar region (Norman, 1956; Orr, 1965; Masterton and others, 1957).

Therefore, even if the difference of body construction between Japanese and

Europians was considered, the physical strain in our traverse expedition did not seem to be extremely severe. The mean value of food intake during this traverse (3,050 kcal/day) was less than that of the energy expenditure by 200 kcal per day. The reason was not the shortage of provisions but the loss of appetite, which presumably came from the relatively monotonous composition of the rations.

The seasonal fluctuations of energy expenditure and changes of activity pattern seem to reflect the influence of environmental conditions. In the coldest August when the daytime is shortest of all the months of observation, time spent outdoors recorded the minimum and correspondingly energy expenditure was in the minimum. On the contrary, in December, time spent outdoors and energy expenditure showed their maximum values. Changes in body weight, increasing in dark months and diminishing towards the end of winter, were attributed to this energy balance and activity patterns.

Similar tendency has been reported also by other observers (WILSON, 1966; MUTO, 1967). In order to express the climatic stress, the use of only the conventional meteorological data, such as maximum and minimum values of temperature and wind velocity, is not sufficient. The necessary data is the values of temperature and wind velocity to which man is really exposed (NORMAN, 1965). In this study the observation of wind velocity in this sense was not performed. However, the exposure temperature alone will be enough to express the difference between climatic data and real environmental condition. The meteorological data at Syowa Station shows that a very cold temperature is reached when the wind velocity is very low, and high wind velocity is usually accompanied by a relatively warm temperature. Thus, when a subject was exposed to a very cold temperature the wind velocity was very low, so that the stress to the subject was not so severe. The average value of exposure temperature (11.2°C) at the station is considered not very cold comparing with that in the life of Japanese farmers or fishermen.

On the other hand, the exposure tempeature during the traverse was considerably low, but the protective effect of the snow cars was obvious as compared with the earlier sledge expeditions. The degree of cold exposure required to stimulate physiological adaptation in man is not known. From the subjective impression it seems that man can tolerate severe cold with thinner clothing in the late stage of wintering, comparing with the beginning. However, it appears probable that in the daily life at Syowa Station, the exposure is not sufficiently severe to produce any significant physiological changes.

5. Conclusion

The following facts have been confirmed on the men who passed one year at Syowa Station:

(1) The proportion of time spent out of doors was very small

(2) The energy expenditure and caloric intake per day were similar to those of the workers engaged in medium class physical work in Japan.

(3) The time during which men were exposed to extremely cold temperature was very short.

The influence of the environmental stress at the station to the patterns of activity and physiological changes has been discussed.

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