PHYSIOLOGICAL CHANGES IN WINTERING MEMBERS OF THE JAPANESE ANTARCTIC RESEARCH EXPEDITION 1968-1969*

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Abstract: Physiological changes of 29 wintering members were observed at Syowa Station and also during the South Pole traverse. The mean atmospheric temperature at the station was −10°C (+9.5°C to −32.4°C), mean wind velocity was 6.4 m/s and mean relative humidity was 62%. About 30% and 13% of the day were spent in various outdoor activities by the traverse members and the base members, respectively. Positive energy balance was observed at the station but negative during the traverse. This means that the body weight increased at the station. The correlation between the changes of the skinfold thickness of the abdomen and the body weight in the both groups was positive significantly.

Basal metabolism of the base members showed a seasonal variation. The value increased when the outside temperature lowered and decreased as the outside temperature rose. This variation may be the result of acclimatization to the cold. Blood pressure tended to fall in the winter. Vital capacity showed a decrease due to physical fatigue. The hemoconcentration was observed after the autumn traverse. Erythrocytosis caused by the high altitude, unexplained leukopenia and relative lymphocytosis were recognized during the South Pole traverse.

1. Introduction

The climate at Syowa Station (69°00′S, 39°35′E), located on East Ongul Island in Lützow-Holm Bay, was not so severe as at the stations on the continent. Monthly mean outside temperatures are shown at the top of Fig. 4. The maximum atmospheric temperature was +9.5°C, the minimum was −32.4°C and the annual mean temperature was −10°C. Annual mean wind velocity was 6.4 m/s with the maximum 52.0 m/s. The direction of wind was almost constantly NE or ENE. Annual mean relative humidity was 62% (MURAYAMA *et al.*, 1969).

Almost the whole ground around the station was covered with snow in the winter. The members at the station had to make water from the snow near the water tank (10 kl in capacity, melting the snow and ice with heat of the radiator of the diesel engine generator), and/or from ice blocks carried by the sledges

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from the icebergs to the station over a distance of several kilometers. About two tons of water were consumed in a day (about 60 liters per person). Cracking icebergs and loading ice blocks onto the sledges were heavy labor, 4.96 in relative metabolic rate, and this hard task was performed three times a week during the winter. In the summer, however, all the snow around the station melt and the artificial reservoir near the station was filled with water which contained small amounts of salts.

Room temperature was automatically controlled at 15–20°C by a light oil heater. After supper, the nights were spent in drinking, playing cards, mah-jong, chess, go and billiard. Therefore, the wintering life indoors was not so severe for the men mentally and physically as compared with the earlier ones.

Nevertheless, the climate in Antarctica is very cold for the members who are used to the warm climate of Japan. Some changes in the body fluid and metabolism may be observed during the year at Syowa Station.

The members were divided into two groups, the traverse group consisting of eleven members, and the base group of eighteen members. The traverse group made a three-week travel in the autumn, from April to May in 1968, covering a distance of 350 km up to the line of 71°S, for the purpose of setting up fuel depots, testing for various observations, and training the men in many ways, especially for acclimatization to cold. The minimum outside temperature was −45°C and all men had frostbites of the second degree at the tip of the nose, forehead, cheeks and fingers (MURAYAMA *et al.*, 1969).

The traverse group made a round trip between Syowa Station and the South Pole. They started at the end of September 1968, and traveled with three or four snow vehicles covering a distance of 5,182 km in 141 days. They took charge of meteorology, glaciology, seismology, geology, geography, geomagnetism, radio operation, logistics and medical research (MURAYAMA *et al.*, 1967, 1969; MURAYAMA, 1971). On October 1st (the third day since the departure from Syowa Station), one of them, a glaciologist, suffered fractures of the left humerus, radius, ulna and first metacarpus by a powered ice drill. He was sent back to the station about 100 km away from the scene of this accident. Since then, he stayed at the station and continued his study of glaciology, with a cast around the upper half of his body. During the South Pole traverse, coldness index reached up to 2,500 and the lowest outside temperature was under −50°C. The traverse group also traveled on the Polar Plateau higher than 3,000 m above sea level for 3.5 months.

As for the base group, the activity pattern of the members differed from that of the traverse group members, and the data on them were obtained at different dates. Therefore, the data were dealt with separately for each group.

In the present study, the activity patterns, energy expenditure and intake, body weight, skinfold thickness, basal metabolism, blood pressure, vital capacity and blood were observed for the period of one year.

2. Materials and Methods

Twenty-nine wintering members of the 9th JARE were the subjects of this study. Eleven traverse members were 27 to 50 years old (average 37 years old) and 18 base members were 25 to 43 years old (average 33 years old). The period from October to April was taken as the summer and May to September as the winter, because the four seasons are not distinct in a high latitude region.

Activity pattern: For this study the author observed the activities of the base members for 16 days in the summer and 5 days in the winter, and those of the traverse members for 5 days in the summer and 8 days in the winter at the station, and 18 days during the South Pole traverse, with a total of 52 days. For 34 days at the station, activities of each of the subjects for 24 hours were observed by the author, and the time spent in sleeping, lying, standing, walking, deskwork, eating, driving, running and other activities was recorded in minutes. During the South Pole traverse, each subject recorded his own activities on the record form because the author remained at Syowa Station.

The classification of the activities used by HIROSE (1969) (the 8th JARE) was adopted here, *i. e.* lying, sitting, standing, walking indoors, light work indoors, moderate work indoors, hard work indoors, walking outdoors, light work outdoors, moderate work outdoors, and hard work outdoors.

Energy expenditure and calorie intake: The energy expenditure was calculated from the relative metabolic rate (*RMR*) of each activity, the time expended for the activity and the basal metabolic rate (*BMR*). For the *BMR*, the mean values at the station were used, *i. e.* 1.0 kcal/min for the base members (average height and average body surface area were 167.3 cm and 1.72 m^2, respectively) and 1.1 kcal/min for the traverse members (the same average data were 170.0 cm and 1.85 m^2). The *RMR* values are based on the report by NUMAJIRI (1954), and the calculation is as follows:

$$A = BMR \times t_1 + BMR \times \Sigma\,(1.25 + RMR)t_2$$

where

A = total energy expenditure in a day (kcal)
BMR = basal metabolic rate of the subject (kcal/min)
RMR = relative metabolic rate for each activity
t_1 = time spent lying (min)
t_2 = time spent for each activity (min)

Some examples of *RMR* were ; lying 0.0, sitting 0.3, standing 0.5, walking 2.0, light work 1.0, moderate work 3.0, and hard work 5.0.

As for the calorie intake, the kinds and quantity of food taken were recorded on the same days as the time study of activity, and intake was calculated from the standard calorie values of the food (THE JAPAN DIETETIC ASSOCIATION CORP., 1958).

Basal metabolic rate : Five base members and five traverse ones were observed for *BMR* twice a month. Before rising, the gas expired by the volunteer was gathered in a Douglas bag for about five minutes in bed. Three bags were prepared for each man. They were carried into the medical laboratory through a roofed passage. Douglas bags were made of neoprene or vinyl. Neoprene bags were soft and strong even in a frigid climate, but vinyl bags became hard and fragile at a low temperature. Precautions against tearing the vinyl bag were needed when one passed through a narrow gate with the filled bags. One each pair of volunteers lived in the ionosphere

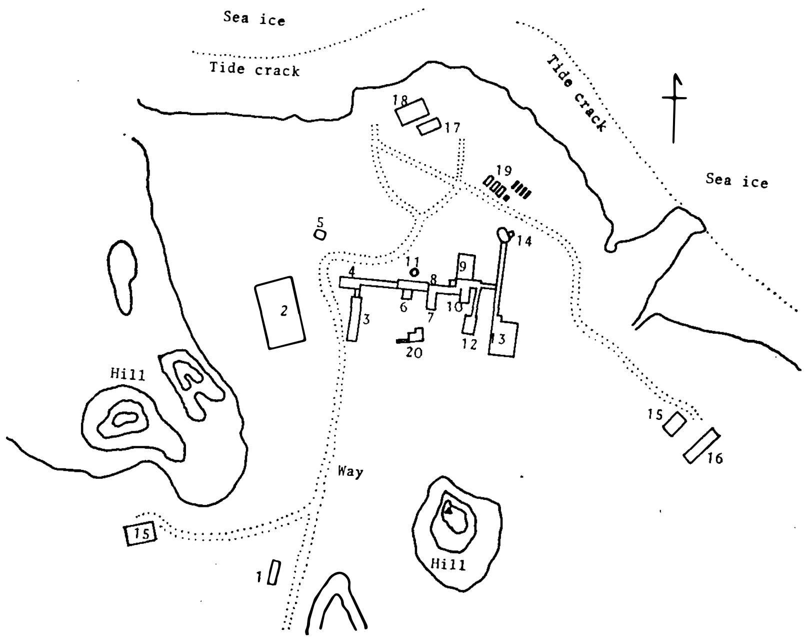

Fig. 1. Syowa Station.

1: Ionosphere laboratory; 2: Heliport; 3: No. 9 living quarters; 4: Radio hut; 5: Air traffic control hut; 6: No. 4 living quarters; 7: Meteorology laboratory; 8: Passage and storage; 9: Mess room; 10: Recreation room; 11: Radar dome for radio-balloon; 12: Geology laboratory; 13: No. 9 generator hut; 14: No. 7 generator hut; 15: Storage; 16: Aeronomy laboratory; 17: Summer dwelling hut or storage; 18: Garage; 19: Fuel oil tanks; 20: Hut for radio-balloon inflation.

laboratory, in No. 9 living quarters, in No. 4 living quarters, in the geology laboratory and in the aeronomy laboratory (Fig. 1). The medical laboratory was in the southwest corner of No. 9 generator hut which had five rooms and a generator room. The gas analyzer, however, was not affected with shake and noise from the generator engine. All rooms were heated by warm water, the temperature being at 9–23°C on the desk which was about 75 cm above the floor. After the gas temperature had become the same as the room temperature, the content of the bag was mixed thoroughly for making homogeneously and the gas volume was measured by the wet gas meter (Shinagawa Seisakusho Co.). Gas sample was analyzed into oxygen and carbon dioxide by the gas analyzer (Labor Institute type) and the basal metabolism was calculated.

Body surface area was calculated by Takahira's formula, which was more suitable for the Japanese than that of Du Bois (Yoshimura *et al.*, 1968), as follows :

$$S = W^{0.425} \times H^{0.725} \times 72.46$$

where

S=body surface area (cm^2)

W=body weight (kg)

H=body height (cm)

Body weight : Body weight of all members was measured once a month at the station naked or with only a thin underwear, when they took a bath. The traverse members were weighed three times during the South Pole traverse at Plateau Station in November, at Amundsen-Scott Station in December 1968, and at Plateau Station in January 1969, on their way back.

As the spring scale was used, it was calibrated against a balance scale every time before weighing at the station, but not during the South Pole traverse. On the Polar Plateau which is about 3,000 m high, however, the body weight may be lighter about only 1/1,000 than that at the sea level (Yanai and Kakinuma, 1971). This value was neglected because it was within an observational error.

Skinfold thickness : Skinfold thickness of all members was measured by skinfold calipers once a month at the station and one time at Plateau Station in November during the traverse. The skinfold calipers (Nutritional Institute type) had a pressure of 10 g/mm^2 based on the international standard applied to the area of 20 mm^2, the error of the estimation being within 0.05%.

Points for measurement were as follows : a : about one centimeter below the inferior margin of the right scapula, b : lateral side of the right upper arm, and c : about five centimeters on the right of the navel. These points were marked with an intradermal injection of cobalt greenpole (0.1 ml), and were measured three times consecutively. The mean value of three readings was used as the skinfold thickness for that particular month.

Blood pressure : Resting blood pressure of the arm was measured by the Riva-Rocci sphygmomanometer once a month at the station and two times during the traverse at Plateau Station in November and January. Systolic and diastolic blood pressures were taken as the first point and fourth point by Swan, respectively.

Vital capacity : Vital capacities of all members were measured before meal by a wet and rotating type spirometer once a month at the station. The maximum value obtained from the three trials on each person was adopted as his vital capacity.

Blood component : Red blood cell counts, hemoglobin concentration, hematocrit value, white blood cell counts and differential leukocyte counts were observed on the traverse members at the station before and after the autumn traverse and the South Pole traverse. Measurements were made between 10 : 00 and 16 : 00 of the day. Red blood cells and white blood cells were counted with manual method by one person, using a mélangeur and calculation plate under the microscope. Hemoglobin concentration was measured by the Sahli method and hematocrit value was determined by an electronic microhematocrit (YSI Model 30, Yellow Spring Instrument Co., USA) (HINO and FURUSAWA, 1964). During the South Pole traverse, only peripheral blood smear preparations were made and stained by the May-Grünwald solution at Plateau Station on their way to the South Pole in November and at Amundsen-Scott Station in December 1968. These preparations were further stained by the Giemsa solution at Syowa Station and differential leukocyte counts were made.

3. Results

Activity pattern : Activities were classified into 11 patterns in Table 1, following the classification by HIROSE (1969). Time expended in lying and sitting amounted to about 60% of the day, the maximum 65.2% being expended by the base members in the winter. More than 10% of the day were expended in indoor light work by the base members, outdoor light work by the traverse members at the station, and indoor light work and moderate work during the South Pole traverse. When the activities were divided into indoor and outdoor, only 12–13% of the day were spent outdoors by the base members and by the traverse members during the traverse. The traverse members at the station, however, spent about 30% outdoors.

Fig. 2 shows their sleeping time. Almost all members went to bed at about 00 : 00 and got up at about 07 : 00 by the local time (six hours later

Table 1. Seasonal values of times spent in various activities (in %).

Activities	Base group		Traverse group		Maen at the station	South Pole traverse
	Summer	Winter	Summer	Winter		
Lying	31.5	32.6	32.8	33.3	32.6	26.2
Sitting	29.1	32.6	26.4	25.4	28.4	35.7
Standing	4.7	6.6	5.2	3.6	5.0	0.1
Walking indoors	2.3	3.2	1.9	1.3	2.1	0.0
Light work indoors	19.5	12.4	3.2	6.9	10.5	13.2
Moderate work indoors	0.5	0.3	0.0	0.8	0.4	11.5
Hard work indoors	0.0	0.0	0.0	0.0	0.0	0.0
Walking outdoors	2.6	2.0	8.6	5.7	4.7	1.8
Light work outdoors	5.1	9.0	16.0	14.7	11.3	8.3
Moderate work outdoors	4.7	1.3	5.8	8.3	5.0	2.2
Hard work outdoors	0.0	0.0	0.1	0.0	0.0	1.0
Time spent indoors	87.6	87.7	69.5	71.3	79.0	86.7
Time spent outdoors	12.4	12.3	30.5	28.7	21.0	13.3

Note: Summer: October-April, Winter: May-September.

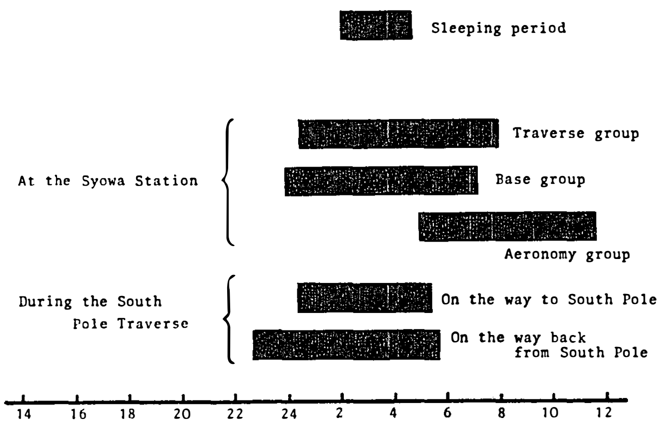

Fig. 2. Sleeping time of the respective groups.

than the Japanese Standard Time). But the sleeping cycle of some members, who made observations of the upper atmosphere physics, such as aurora, geomagnetism and cosmic ray, was from 05 : 00 to 11 : 30, five hours behind that of other members.

Two members for meteorology observation and one radio operator had the same sleeping cycle as the aeronomy observers, because they had to make the routine observation of the upper air meteorology with a radio-balloon at 03 : 00 local time (00 : 00 Greenwich Mean Time) and to send these meteorological data to Mawson Station which was the mother station of Syowa Station for the meteorological network.

The traverse members had only about five hours for sleep on their way to the South Pole, but this became seven hours on their way back.

Energy expenditure and calorie intake: Figs. 3a-3d show the energy expenditure and the time used in each activity in a day. Main activities of the base members were, observation (469 kcal), sleeping (438 kcal) and light work (414 kcal) in the summer (Fig. 3a), and observation (593 kcal), sleeping (426 kcal) and sitting (360 kcal) in the winter (Fig. 3b).

Those of the traverse members were, sleeping (488 kcal) and light work (465 kcal) at the station (Fig. 3c), nearly the same as the base members, but their activities were more varied in kind than those of the base members. During the traverse (Fig. 3d), the main energy output sources were sitting (857 kcal) and driving (733 kcal) the snow vehicles.

Table 2 shows the energy balance per day. Energy expenditure of the base members was 2,555 kcal and calorie intake was 2,778 kcal in the summer,

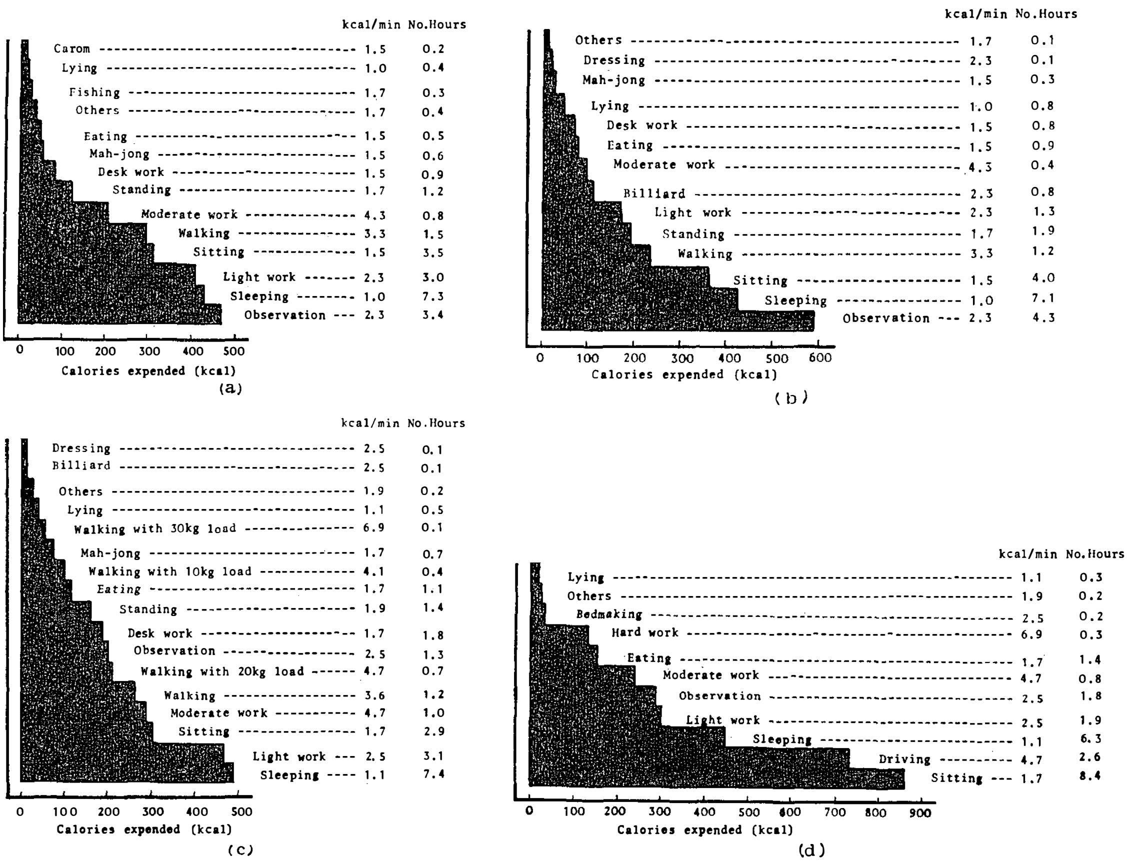

Fig. 3. Calories expended in various activities per day. Base group in summer (a) and winter (b), and traverse group at the station (c) and during the South Pole traverse (d).

Table 2. Mean daily energy expenditutre and calorie intake in Antarctica.

Group and season		Body weight (kg)	Expenditure kcal/day (kcal/kg/day)	Food intake kcal/day (kca/kg/day)	Protein kcal % (g/kg/day)	Fat kcal % (g/kg/day)	Carbohydrate kcal % (g/kg/day)
Base group	Summer	62.1	2,555(41)	2,778(45)	13.9(1.5)	29.2(1.5)	56.9(6.2)
	Winter	66.0	2,455(37)	2,738(41)	17.9(1.8)	20.1(0.9)	62.0(6.1)
Traverse group	Summer	71.3	3,068(43)	3,027(42)	15.2(1.6)	18.9(0.9)	65.9(7.0)
	Winter	68.0	3,181(47)	3,407(50)	13.7(1.7)	33.0(1.8)	53.3(6.7)
Mean at Syowa Station		66.9	2,815(42)	2,988(45)	15.2(1.7)	25.3(1.3)	59.5(6.5)
During South Pole traverse		65.3	3,282(50)	2,992(46)	13.1(1.5)	28.1(1.4)	58.8(6.7)

and in the winter the expenditure was 2,455 kcal and intake was 2,738 kcal, resulting in a positive balance of about 200 kcal and 300 kcal, respectively. For the traverse members, the energy was well balanced at about 3,000 kcal in the summer during the stay at the station. But in the winter it was positive balance of about 200 kcal with expenditure of 3,181 kcal and intake of 3,407 kcal. Mean energy balance of all members at the station was positive, about 170 kcal, resulting in increase of body weight and skinfold thickness. During the traverse, a negative balance of about 300 kcal was recognized, *i.e.* the energy expenditure was 3,282 kcal and the calorie intake was 2,992 kcal.

As for the dietary composition, 33% of calorie intake was from fat in the winter for the traverse members, which is well above the standard value for the Japanese. Protein of 90 to 110 g was taken in a day.

Basal metabolism: Fig. 4 shows the monthly mean values of outside temperature and the basal metabolism in the members of each group. From May to December, the basal metabolism in the five base members increased in the winter and decreased when it became warmer. However, the value in the traverse members increased extremely after the autumn traverse and the South Pole traverse.

Body weight and skinfold thickness: The mean values of the body temperature and the skinfold thickness are shown in Fig. 5a (base members) and Fig. 5b (traverse members). Mean body weight of the base members was less than 61 kg at Tokyo in November 1967, when they were very busy preparing for the departure. And it increased gradually for a year at Syowa Station to the level of 64 kg. The values of skinfold thickness of the back and arm did not change significantly, while that of the abdomen increased gradually in a significant positive correlation ($r=0.741$, $p<0.01$) with the increase of body

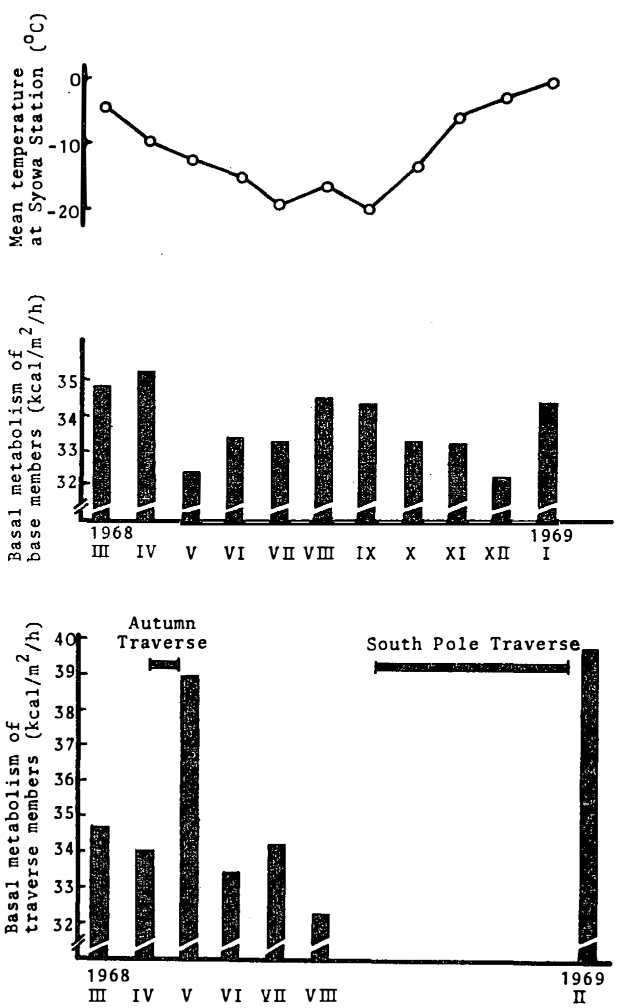

Fig. 4. Monthly mean values of outside temperature at Syowa Station (top) and basal metabolism (middle and bottom). Mean basal metabolism of five base members (middle) increased when outside temperature lowered and decreased as it rose from May to December. Extreme increases of basal metabolism were recognized in five traverse members after the traverses (bottom).

weight.

Body weight of the traverse members recorded two minimums, *i.e.* the first was 65.6 kg just after the autumn traverse in May and the second was 65.1 kg at Plateau Station on their way back from the South Pole in January 1969. These values were 2.3 kg (3%) and 3.5 kg (5%) less than the values just before the respective traverses. After the autumn traverse the body weight regained within three to five days, but after their return from the South Pole

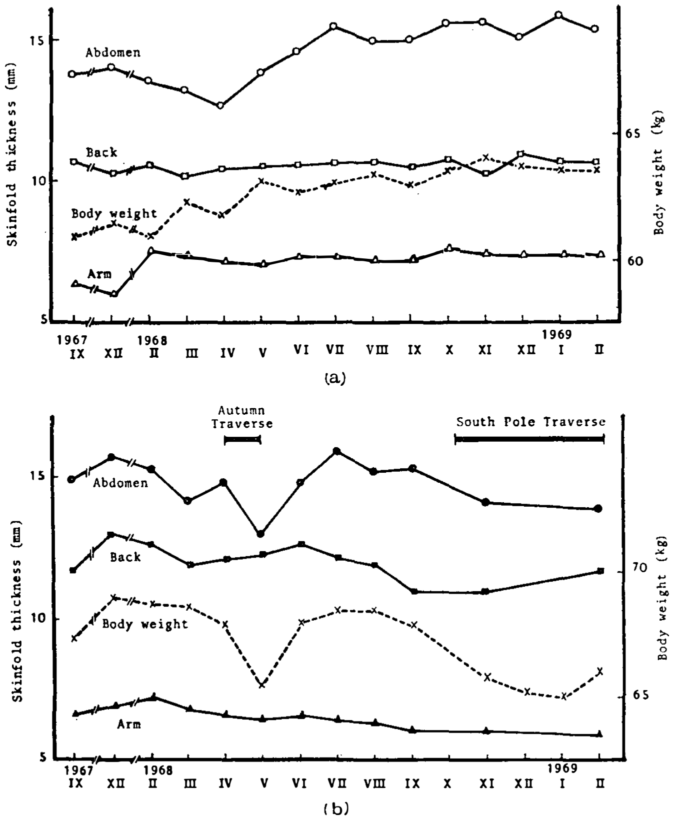

Fig. 5. Monthly mean values of body weight and skinfold thickness of base members (a) and traverse members (b). Changes in body weight were correlated significantly with those of skinfold thickness of the abdomen in both group.

it took about 10 days for the value to become constant.

There is no change in the skinfold thickness of the arm of the traverse members. While that of the back showed the maximum value in June, no significant correlation with the changes of body weight was recognized (r=0.373). The skinfold thickness of the abdomen, however, showed a positive correlation (r=0.784, p<0.01) with the changes in the body weight, as in the case of the base members (Fig. 5a).

Blood pressure (Figs. 6a and 6b): Mean blood pressure of the base members showed the maximum level at Tokyo in May 1967. Both systolic and diastolic blood pressures lowered in the winter and rose a little as it became warmer, but these changes were not so remarkable. Blood pressure of the traverse members also lowered a little in the winter. During the autumn traverse and the South Pole traverse, the blood pressure rose markedly.

Vital capacity (Fig. 7): The mean vital capacity of the base members

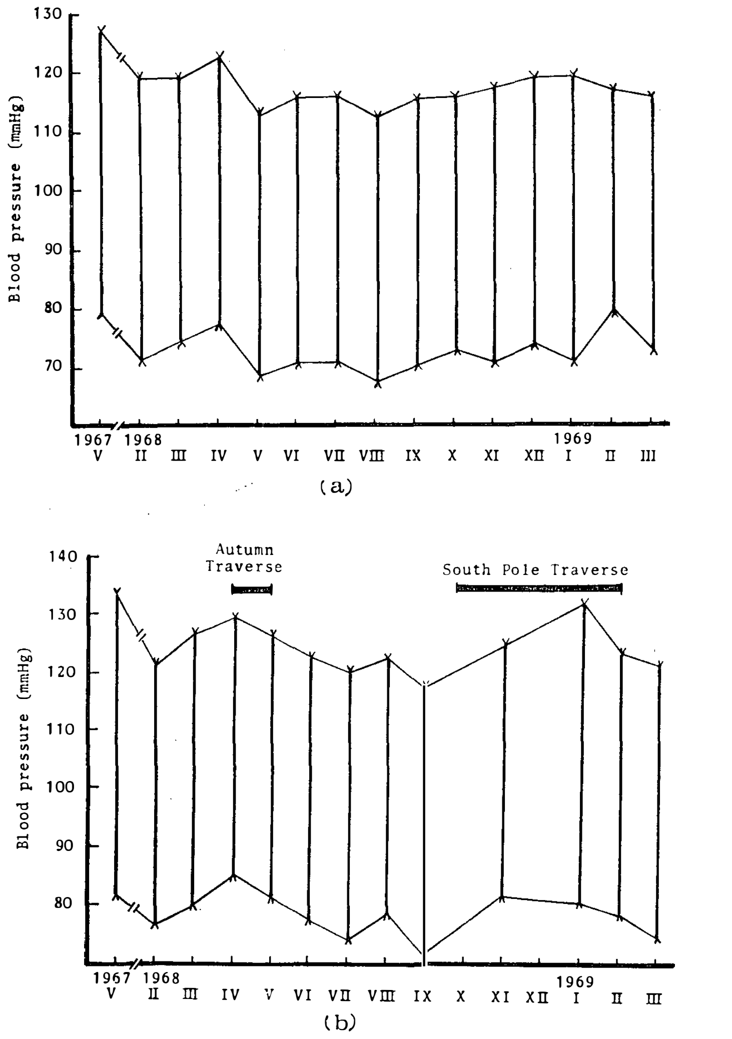

Fig. 6. Monthly mean values of arterial blood pressure in base members (a) and traverse members (b). Blood pressure tended to drop in winter in both groups.

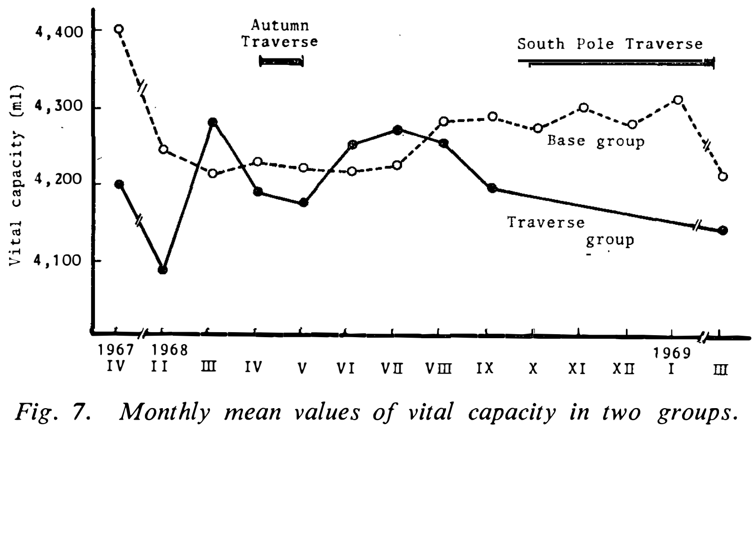

Fig. 7. Monthly mean values of vital capacity in two groups.

recorded the maximum at Tokyo before the departure and decreased at the beginning of their wintering and after returning to Tokyo. That of the traverse members tended to decrease after traverses.

Blood component: Red blood cell counts and hematocrit value increased significantly ($p<0.05$) after the autumn traverse compared with those before it. Hemoglobin concentration and white blood cell counts increased, too (Fig. 8a), but the differential leukocyte counts did not show a remarkable change.

After the South Pole traverse, the red blood cell counts and the hematocrit value showed a significant increase ($p<0.01$) but the white blood cell counts decreased significantly ($p<0.01$) compared with those before the traverse (Fig. 8b). The differential leukocyte counts at the station before and after the

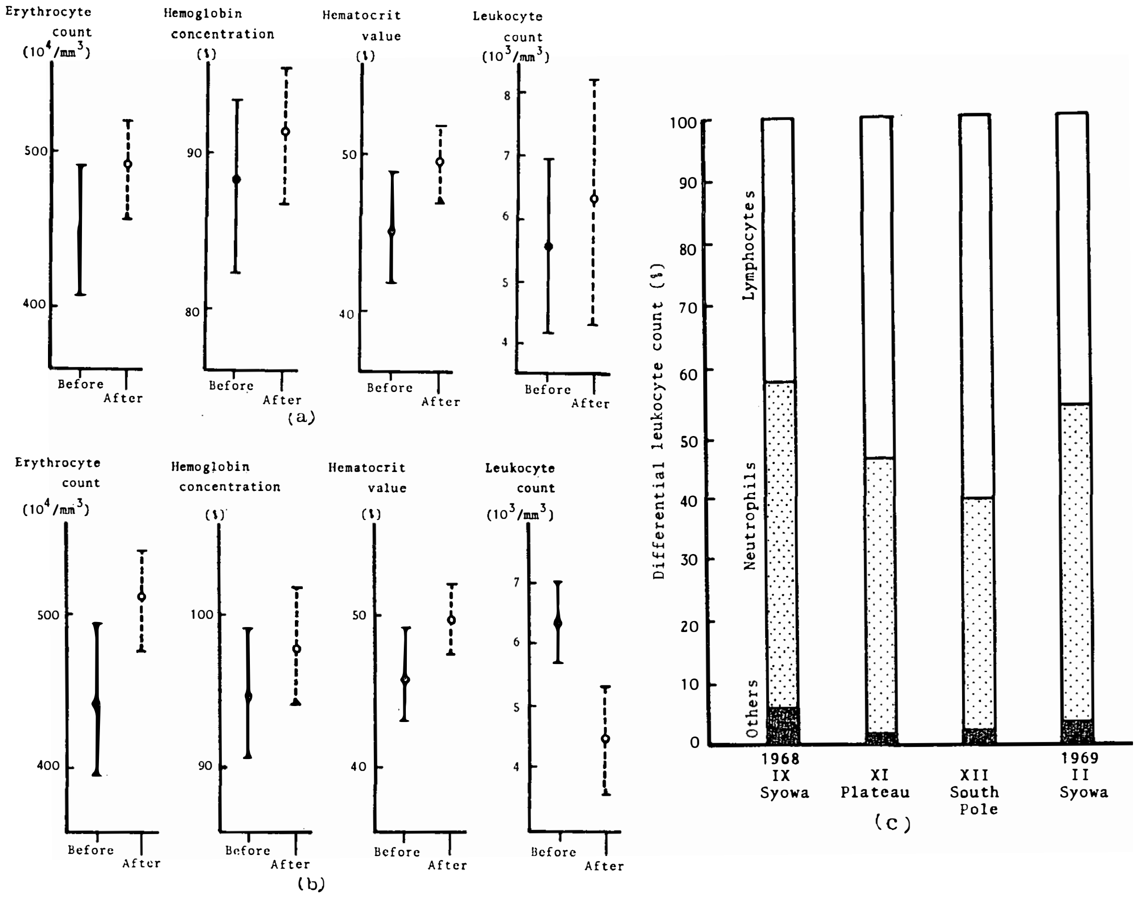

Fig. 8. Average values of erythrocyte counts, hemoglobin concentration, hematocrit value and leukocyte counts with standard deviation before and after the autumn traverse (a) and the South Pole traverse (b). Both erythrocytes and leukocytes increased after the autumn traverse (a), but leukocytes decreased significantly after the South Pole traverse (b). Relative lymphocytosis and relative neutropenia were recognized at Plateau Station and South Pole Station (c).

South Pole traverse did not show any change. However, at both Plateau and South Pole Stations where only the peripheral blood smears were prepared, a relative increase in lymphocyte and a relative decrease in neutrophils were observed (Fig. 8c).

4. Discussion

Activity patterns at the station did not much vary for both the base group and the traverse group. This may be ascribed to that they had a stationary observation life throughout the year. The traverse members had to work outside for various observations of geology, geography, gravity, sea-ice and sea-bed geography around Syowa Station, and for the preparation of the traverses, checking snow vehicles, sledges, equipments against cold, rations, as well as for tests of observations and radio operation. Therefore, they spent about 30% of a day outdoors in both summer and winter. It must be very hard to work outside under the temperature of $-20°$ to $-30°C$ for about eight hours (30% of a day). Coldness index, which represents the coldness related to temperature and wind, is obtained from the following formula by the High Jump Operation of USA,

$$K_o=(10\sqrt{V}+10.45-V)(33-T_a)$$

where

K_o=coldness index (kcal/m^2, hr, °C)

V =wind velocity (m/s)

T_a=atmospheric temperature (°C)

They say that it is dangerous to continue traveling and living in a temporary house like a tent when the coldness index reaches up to 2,000 (MURAKOSHI, 1958). They feel warm at 100 of the coldness index, pleasant at 200, mild at 300, cool at 400, very cool at 600, cold at 800, very cold at 1,000, bitterly cold at 1,200 and exposed flesh freezes at 1,400. For example, when it is calm and the temperature is $-25°C$, the coldness index is calculated as 600, and a person feels "very cool", but when the wind velocity is three meters per second and the temperature is the same $-25°C$, the coldness index becomes 1,400 and "exposed flesh freezes". On the coast of Antarctica there is usually a katabatic wind blowing from the inland to the sea at a velocity of five to ten meters per second. Syowa Station is fortunately saved from this katabatic, because it is situated on Ongul Island about five kilometers away from the Antarctic Continent. Although Syowa Station was sometimes visited by blizzard with low atmospheric pressure, the climate usually became warmer after that, because the blizzard carried the warm air from the north. Therefore, the coldness index at Syowa Station did not show very high values.

The living pattern at the station was very different between the base and the traverse members because the purpose of wintering differed between the two groups. The base members were engaged in routine observations at the station for the most part of a day. If they have ordinary physical strength, it may be easy for them to winter at the station. However, the traverse members had to make inland traverses and, even at the station, they carried out outside observarions. They must have strong physical strength and strong spiritual strength.

The time spent in lying and sitting occupied 60% of a day, which agreed with the result of HIROSE (1969) and NORMAN (1965). It is considered that the living condition may be similar at any Antarctic stations.

The activity pattern during the South Pole traverse was similar to that of the traverse to the Plateau Station by the 8th JARE (HIROSE, 1969). This may also be a natural result since the scope of the observations and the snow vehicles were identical in the two cases.

The energy expended in various activities is shown in Figs. 3a-3d. The base members expended most of the energy in observations, which might indicate the steady and permanent work at the station. The traverse members were busy outdoors with various observations and preparation for the traverse and conducted many kinds of activities. On the other hand, during the traverse, they stayed mainly within the snow vehicles which proceeded to the South Pole at a low speed of 2–5 km/h on account of a heavy load. MILAN and RODAHL (1961) reported that hard work outside, sleeping, sitting, walking inside the tunnel and driving a tractor were the main activities at the Little America V, which is similar to the life of the traverse members at Syowa Station.

Energy balance per day (Table 2) was positive while they lived at the station, and negative only during the traverse. Since the first wintering, the ration was prepared so as to afford 4,000 kcal/day and 500 kinds of foods (HARA, 1966). Therefore, at Syowa Station, they took sufficient meals which were prepared by a professional cook. During the traverse, however, 100 kinds of foods and about 5,200 kcal/day were provided, and it was not a comfortable situation for the members to take meals prepared by one of the members in a limited space of the snow vehicle after observations. This accounts for the negative energy balance. Some reports on the foreign traverse parties recorded only 20 to 30 kinds of foods (LA GRANGE, 1963; LEWIS, 1963).

MUIR (1969) and LLOYD (1969) reported that negative energy balance, hard work and cold exposure had a close relation with ketonuria, but it was not observed in the present study.

The Japanese wintering members, as a matter of fact, took a maximum of about 3,500 kcal in a day, but foreign party members took 4,000–5,000 kcal in a day according to the reports of MILAN and RODAHL (1961) and ORR (1965). Furthermore, they took fat constituting 30–40% of the total calorie intake which is fairly higher than the value observed in the Japanese. Several hundred milligrams of ascorbic acid were taken every day for a year to compensate the lack of fresh vegetables.

EDHOLM (1960) and WILSON (1962) reported that the seasonal change in the basal metabolism was not recognized in the Caucasians in Antarctica. YOSHIMURA *et al.* (1966) and YUKIYOSHI (1968) showed in their reports that the basal metabolism in the Japanese decreased in the summer and increased in the winter, but that in the Canadians showed a constant value throughout the year in Japan.

At Syowa Station, five base members showed a similar tendency from May to December, *i.e.* the basal metabolism increased with lowering of outside temperature and decreased as the climate became warmer (Fig. 4). It is known that there is a time lag of six months between Antarctica and Japan. For instance, January is winter in Japan but is summer in Antarctica. This fact, therefore, indicates that the changes in the basal metabolism represent the result of acclimatization.

Ice breaker FUJI reached the station at the beginning of January. Then, all of the JARE members had to work in the base construction and the preparation for wintering. During this period, they got up at seven and began their hard labor such as loading, engineering, construction and so on, which was continued until 20:00 or 21:00. Because there is no dark night in the Antarctic summer, they could work outside without light throughout the night. As almost all of the observation members had not experienced heavy labor in Japan, physical fatigue from this hard schedule might have affected their basal metabolism.

Basal metabolism of the traverse members increased after the autumn traverse and the South Pole traverse. This increase may be ascribed to physical fatigue and also to the excitement at the success of the traverses.

YUKIYOSHI (1968) reported that the difference in the basal metabolism between the Japanese and the Caucasians is related to the physique, habitude (endocrinic function) and nutritive conditions. In a big man less seasonal changes were observed even in Japanese. And the Caucasians have a more steady value in the thyroid function than the Japanese.

Body weight increased when they had lived at the station, but that of the traverse members considerably decreased after the traverses. During the autumn traverse, the temperature was $-30°$ to $-40°C$ every day and they had to camp out, set up some fuel depots and travel over night in the cold snow vehicle. Therefore, all of the members had a frostbite of the first to second degree on their faces and fingers, and their body weight and skinfold thickness decreased markedly. Hematological examination after the autumn traverse revealed an increase in both the red blood cell counts and the white blood cell counts, and the body weight regained the former value within five days after returning to the station. Therefore, these changes might have been caused by dehydration, as observed during the inland journey by DAVIES (1969), HICKS (1966) and ORR (1965).

After the South Pole traverse, the red blood cell counts increased while blood cell counts decreased significantly ($p<0.01$), and it took more than a week to regain the body weight. They could have sufficient water for drinking, thanks to an apparatus for melting snow in the vehicle. Concluding from the changes mentioned above, the weight loss observed during this traverse may be attributed to the negative calorie balance caused secondarily by various kinds of stress.

LEWIS (1960) reported that a positive correlation was recognized between the changes in body weight and skinfold thickness of the back, but in the present study the change in the body weight was correlated with that in the skinfold thickness of the abdomen (base group: $r=0.741$, $p<0.01$, traverse group: $r=0.784$, $p<0.01$), like the results obtained by NAGAMINE and SUZUKI (1964) from the studies on the young Japanese in Japan. It would be interesting to find out whether this is a phenomenon peculiar to the Japanese due to some ethnic difference.

BUDD (1965), KAGEYAMA (1963) and TIKHOMIROV (1963) also reported that the blood pressure lowered during their wintering in Antarctica. The lowering in the blood pressure in the winter may be explained by a suppressive effect on the sympathetic nervous system caused by the outdoor darkness and limited outdoor activities during the polar night. On the other hand, the rise of the blood pressure observed during the traverse might be attributed to a continuous stress caused by the life in the snow vehicle, the long days without sunset, the severe climate with coldness index exceeding 2,000, and a society of only a few men per vehicle. PALMAI (1962) reported that the changes in the blood pressure were correlated with those of the skinfold thickness, but such a correlation was not observed in the present study.

Vital capacity decreased temporarily during the construction period and after the traverses. This phenomenon might be due to the physical fatigue.

After the autumn traverse, hemoconcentration was expected because all components of the peripheral blood increased. But after the South Pole traverse, the white blood cell counts decreased significantly ($p<0.01$) as compared with the significant increase ($p<0.01$) of the red blood cell counts.

Erythrocytosis might be caused by the adaptation to the altitude, travelling on the 3,000 meters high Polar Plateau for about 3.5 months. TIKHOMIROV (1964) reported on his observation at Vostok Station, which was located at an elevation of about 3,500 meters, that the erythrocyte counts rose (19.8%) during the first two months. Erythrocytosis in the present study was about 16 percent.

Leukopenia during the wintering was observed by KAGEYAMA (1963), POPOV (1965) and TIKHOMIROV (1964). They emphasized the almost aseptic surroundings and strong ultra-violet rays as the cause of leukopenia. Furthermore, POPOV (1965) indicated the suppression of the reticulo-endotherial function. The members during the inland traverse on the snow were in a more sterile condition than the men at the station. It is also considered that leukopenia may be a sign of radiation disorders. For, it is said that low energy cosmic rays were observed at Syowa Station 20–25% more than in Japan, and at the height of 3,000 meters, those must be tenfold compared with those at the sea level (SUDA, Meteorological Research Institute, personal communication).

Relative lymphocytosis and relative neutropenia were obvious at Plateau Station and Pole Station. BARSOUM (1962) also observed the same temporarily relative lymphocytosis on the Filchner Ice Shelf in Antarctica. The cause of this phenomenon is not known, but it may be due to the continuous stimulus from coldness or other factors. Decrease of immunological stimulus also may be part of the cause. As the differential leukocyte counts were not made during the autumn traverse, it is not known whether relative lymphocytosis occurred or not.

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