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BASAL METABOLISM AND OTHER PHYSIOLOGICAL CHANGES IN WINTERING MEMBERS OF JAPANESE ANTARCTIC RESEARCH EXPEDITION 1968–1969

BY

Yoshiaki OHKUBO*1

ABSTRACT

Physiological reactions of 29 wintering members in the frigid climate were observed at the Syowa Station and during the South Pole Traverse. 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. Energy balance was positive at the station but negative during the traverse. Therefore, the body weight tended to increase at the station. A significant positive correlation was found in both groups between the changes of the skinfold thickness of the abdominal wall and the body weight.

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 is considered to 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. Hemoconcentration was observed after the Autumn Traverse. During the South Pole Traverse, erythrocytosis caused by high altitude, unexplained leukopenia and relative lymphocytosis were recognized.

INTRODUCTION

Syowa Station (69°00′S, 39°35′E) is situated on the East Ongul Island in the Lützow Holm Bay separated by the Ongul Strait about 5 km away from the Antarctic continent (Fig. 1). The climate at the Syowa Station is not so severe as at the intracontinental stations such as the Amundsen-Scott Station (South Pole), Plateau Station (79°14′S, 40°30′E) and Vostok Station (78°27′S, 106°52′E). At the top of Fig. 6 are shown the monthly mean temperatures at the Syowa Station. The maximum 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 and the annual mean relative humidity was 62% (Murayama et al.[1]).

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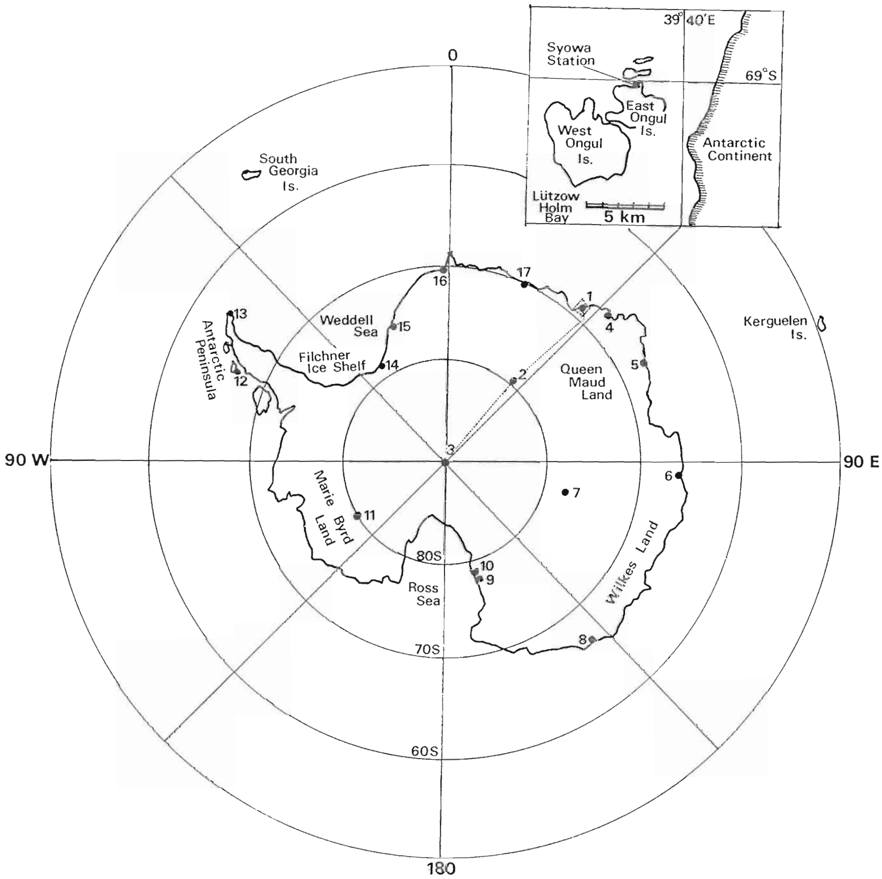

Fig. 1. Main stations in the Antarctic.
1: Syowa (Japan); 2: Plateau (USA); 3: Amundsen-Scott (USA); 4: Molodyozhnaya (USSR); 5: Mawson (Australia); 6: Mirnyy (USSR); 7: Vostok (USSR); 8: Dumont d'Urville (France); 9: Scott (New Zealand); 10: McMurdo (USA); 11: Byrd (USA); 12: Palmer (USA); 13: Bernardo O'Higgins (Chile); 14: General Belgrano (Argentina); 15: Halley Bay (UK); 16: SANAE (South Africa); 17: Roi Baudouin (Belgium).

In the summer, all of the snow melted and the reservoir near the station was filled with water which was used for cooking, drinking, bathing, washing and so on, whereas in the winter, almost all of the ground was covered by the snow and water was made from the snow near the water tank (10 kl capacity, melting the snow and ice by the radiator of the diesel engine generator) at the station, and/or from the ice blocks carried by sledges from the icebergs near the station. About two tons of water were used in a day (about 60 l per person). Cracking icebergs and loading ice blocks onto the sledges were hard work (4.96 in relative metabolic rate), the hard work being required three times a week during the most severe season.

It was comfortable in the room at the Syowa Station. Room temperature was automatically controlled at 15–20°C by a light oil heater. The night were spent drinking and playing cards, mah-jong, chess, go and billiard after supper. Therefore, the wintering this time was not so severe for them on the living condition mentally and physically compared with the earlier winterings.

However, it is very cold in the Antarctic for the members who have lived in the warm climate in Japan. Some changes in the body fluid and metabolism may be observed during the year at the Syowa Station.

The members were separated into two groups, the traverse group and the base group. The members of the traverse group joined the Autumn Traverse for about three weeks from April to May in 1968 up to the line of 71°S. The purposes of this traverse were making depots of fuel, tests for various observations and many kinds of trainings, especially acclimatization to cold. The minimum temperature became −45°C and all members had a frostbite of the second degree at the tip of the nose, forehead, cheeks and fingers (Murayama et al.[1)]).

The traverse from the Syowa Station to the South Pole was the largest project for the Japanese Antarctic Research Expedition (JARE) 1968–69. There were 12 members on this traverse (traverse members) and they had charge of meteorology, glaciology, seismology, geology, geography, geomagnetics, radio operation, logistics and medical research (Murayama et al.[1,2,3)]). But on the first of September, 1968 (the third day from the departure to the South Pole), one of them, a glaciologist, encountered fractures of the left humerus, radius, ulna and first metacarpus by a powered ice drill. He was sent back to the station which was about 100 km away far from the scene of this accident. Since then, he stayed and studied at the station with a cast around the upper half of his body.

Therefore, the base group consisted of 18 men. Their activity pattern differed from that of the traverse group, and therefore, the materials from them were also obtained at different dates. All data were treated within each group.

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

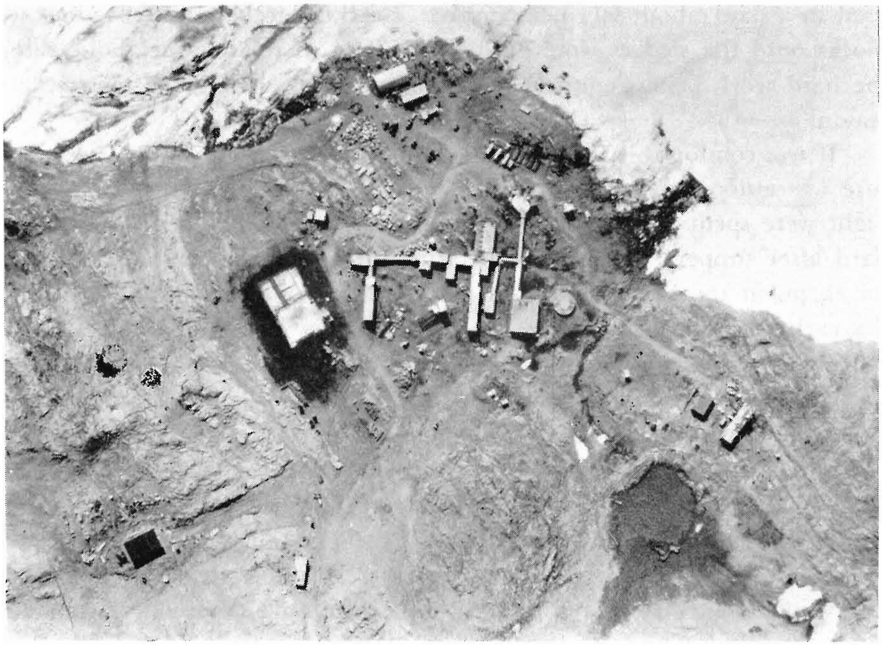


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Fig. 2.

Materials and Methods

Twenty-nine wintering members of the JARE 1968–69 were observed. The party consisted of 11 traverse members of 27 to 50 years old (average 37 years old) and 18 base members from 25 to 43 years old (average 33 years old). As the four seasons in a high latitude are not so distinct, the period from October to April was taken as the summer and May to September as the winter.

Activity pattern: The time consumed for this study was 16 days in the summer and five days in the winter with the base members. With the traverse members five days in the summer and eight days in the winter at the station and 18 days during the South Pole Traverse, totalling 52 days. For 34 days at the station, activities of each of the subjects were observed for 24 hours by the author, and the time spent for sleeping, lying, standing, walking, desk work, eating, driving, running and other activities were recorded in minutes. During the South Pole Traverse, each subject recorded his own activities on the record form because the author stayed at the Syowa Station.

The classification of the activities used by Hirose[4] (JARE 1967–68) was also used 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 basal metabolic rate (BMR). For the BMR, the mean value which was obtained at the Syowa Station was 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). RMR were based on the report by Numajiri[5] and the calculation is as follows:

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

where

Fig. 2. Syowa Station.
1: Ionosphere laboratory; 2: Heliport; 3: No. 9 living quarter; 4: Radio hut; 5: Air traffic control hut; 6: No. 4 living quarter; 7: Meteorology laboratory; 8: Passage and storage; 9: Mess room; 10: Recreation room; 11: No. 10 living quarter; 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: Inflation hut; 21: Water tank.

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 activities, and the intake was calculated from the standard caloric values of the food (The Japan Dietetic Association Corp.[6]).

Basal metabolic rate: Ten subjects, five men of the base group and five men of the traverse group, were observed for BMR twice a month. Before rising, the expired gas of the volunteer was gathered in a Douglas bag for about five minutes while in bed. Three bags were prepared for each man. They were carried outside or in roofed passage from the bed-side to the medical laboratory. Douglas bags were made from neoprene or vinyl. Neoprene bags were soft and strong even in a frigid climate, but vinyl bags became hard and fragile in a low temperature. Precaution not to tear the vinyl bag was needed when one passed through a narrow gate with the filled bags. Each of the groups of two volunteers lived in an ionosphere laboratory, No. 9 living quarter, No. 4 living quarter, geology laboratory and aeronomy laboratory (Fig. 2). The medical laboratory was at the southwest corner in the No. 9 generator hut which had five rooms and a generator room. All rooms were heated by warm water, the temperature being 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 gas volume was measured by the wet gas meter (Shinagawa Seisakusho Co.) with about 50 ml of gas sampling. Gas sample was analysed into oxygen and carbon dioxide by the gas analyser (Labour Institute type) and the basal metabolism 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.[7]), 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 the Plateau Station in November, at the Amundsen-Scott Station in December and at the 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. On the South Polar Plateau which is about 3,000 m high, the body weight may be lighter by about 1/1,000 of the total weight than that at the sea level (Yanai and Kakinuma[8]). However this value was neglected because it was within an observational error.

Skinfold thickness: Skinfold thickness of all members at the station was measured by skinfold calipers once a month and one time at the Plateau Station in November during the traverse. The skinfold calipers (Nutritional Institute type) had a pressure of 10 g/mm² with an international standard applied on the area of 20 mm², the error of the estimation being within 0.05%.

Sites of measurement were as follows (Fig. 3): a; about 1 cm below the inferior margin of the right scapula, b; lateral side of the right arm, and c; the region about 5 cm right of the navel. These sites were marked with

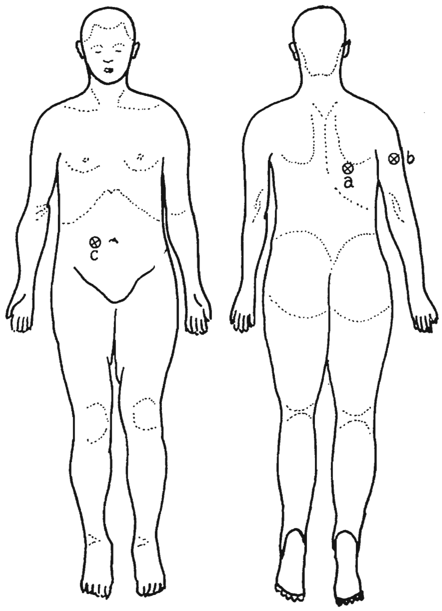

Fig. 3. Skinfold sites. Cobalt greenpole (0.1 ml) was injected intradermally as a marker. a: About 1 cm below the inferior margin of right scapula. b: Lateral side of right arm. c: The region about 5 cm right of navel.

an intradermal injection of cobalt greenpole (0.1 ml). These sites were measured three times consecutively, and the mean value of three readings was used as the skinfold thickness for that particular month.

Blood pressure: Resting blood pressure was measured by the Riva-Rocci sphygmomanometer once a month at the station and two times during the traverse at the 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 components: Red blood cell counts, hemoglobin concentration, hematocrit values, white blood cell counts and differential leukocyte counts were measured 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. 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[9]). During the South Pole Traverse, only peripheral blood smear preparations were made and stained by the May-Grünwald solution at the Plateau Station on their way to the South Pole in November and at the Amundsen-Scott Station in December 1968. These preparations were further stained by the Giemsa solution at the Syowa Station and differential leukocyte counts were made.

Results

Activity pattern: Activities were classified into 11 patterns, following the classification by Hirose[4] (Table 1). Time expended for lying and sitting amounted to about 60% of the day, especially the maximum of 65.2% being expended by the base members in the winter. The time expended for indoor light work by the base members, outdoor light work by the traverse members at the station and indoor and outdoor light work during the South Pole Traverse were more than 10% of the day. 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.

Concerning their sleeping time (Fig. 4), almost all of the members went to bed at about 00:00 and got up at about 07:00 by the local time

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

Activities	Base group		Traverse group		Mean 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: Oct.–Apr. Winter: May–Sept.

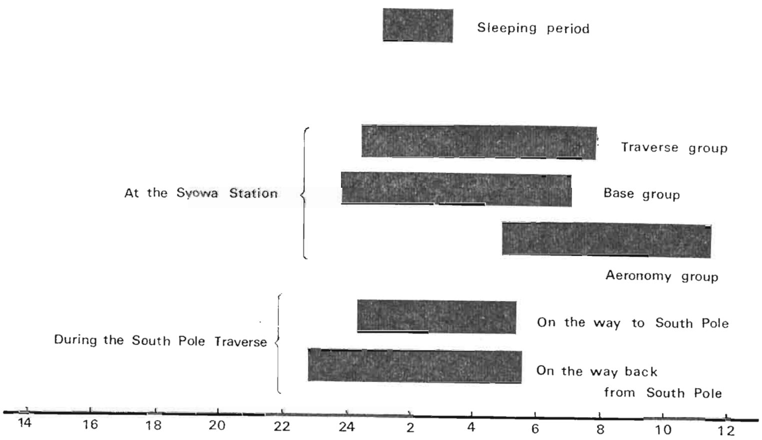

Fig. 4. Sleeping time for the respective groups.

(six hours later than the Japanese Standard Time). But some members, who made observations of the upper atmosphere physics like the aurora, geomagnetism and cosmic ray, slept from 05:00 to 11:30, i.e., their sleeping cycle was delayed five hours compared with that of the other members.

Two members for meteorology and a radio operator had the same sleeping cycle as the aeronomy observers, because they had to make observations 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

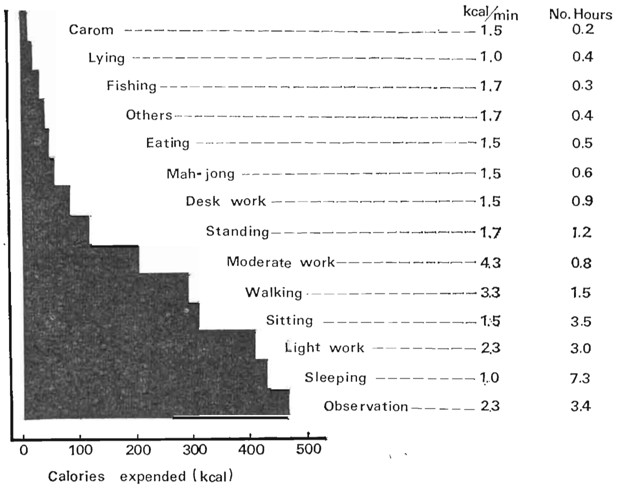

Fig. 5 (a)

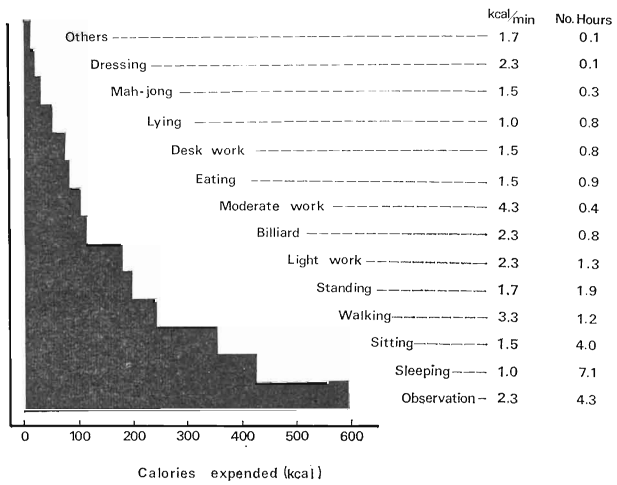

Fig. 5 (b)

to the Mawson Station which was the mother station of the Syowa Station for the meteorological network.

During the traverse, on their way to the South Pole only about five hours were spent for sleep but this became seven hours on their way back.

Energy expenditure and calorie intake: Figs. 5a-d show the energy expenditure and the time used for each activity in a day. The base members expended energy mainly on observation (469 kcal), sleeping (438 kcal) and light work (414 kcal) in the summer (Fig. 5a), and in the winter (Fig. 5b) on observation (593 kcal), sleeping (426 kcal) and sitting (360 kcal).

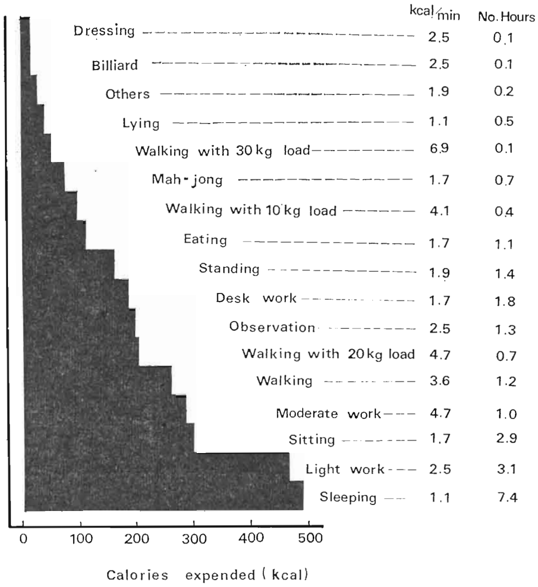

Fig. 5 (c)

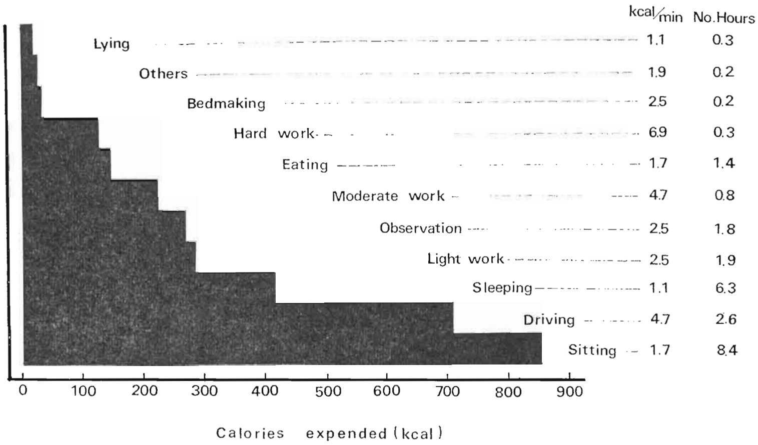

Fig. 5 (d)

Fig. 5. Energy 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).

The traverse members at the station (Fig. 5c) expended 488 kcal on sleeping and 465 kcal on light work the same as the base members, but the kinds of activities were more varied than that of the base members. During the traverse (Fig. 5d), the main activities on the snow vehicle were

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

Group and season		Body weight kg	Expenditure kcal/day (kcal/kg/day)	Food intake kcal/day (kcal/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)

sitting (857 kcal) and driving (733 kcal), these being the major energy output sources.

Table 2 shows the energy balance per day. The base members consumed an energy of 2,555 kcal and calorie intake was 2,778 kcal in the summer, and in the winter expended 2,455 kcal and with an intake of 2,738 kcal, resulting in a positive balance of about 200 kcal and 300 kcal, respectively. In the case of the traverse members, the energy expenditure and food intake were well balanced, each showing a value of approximately 3,000 kcal during the stay at the station in the summer. Energy expenditure in the winter was 3,181 kcal and the intake was 3,407 kcal, indicating a positive balance of about 200 kcal. All members at the station showed a positive balance of about 170 kcal, resulting in changes in body weight and skinfold thickness. During the traverse, the expenditure was 3,282 kcal while the intake was 2,992 kcal, showing a negative balance of about 300 kcal.

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

Basal metabolism (Fig. 6): There was a special relation between the changes in the monthly mean values of basal metabolism in the five base members from May to December and those in the outside mean temperature, i.e., when the outside temperature became lower the basal metabolism increased and when it was warmer the basal metabolism decreased. However, with the traverse members, the value of the basal metabolism increased extremely after the Autumn Traverse and the South Pole Traverse.

Body weight and skinfold thickness: The mean values of the body weight and skinfold thickness are shown in Figs. 7a and 7b. Mean body weight of the base members was less than 61 kg in Tokyo in November

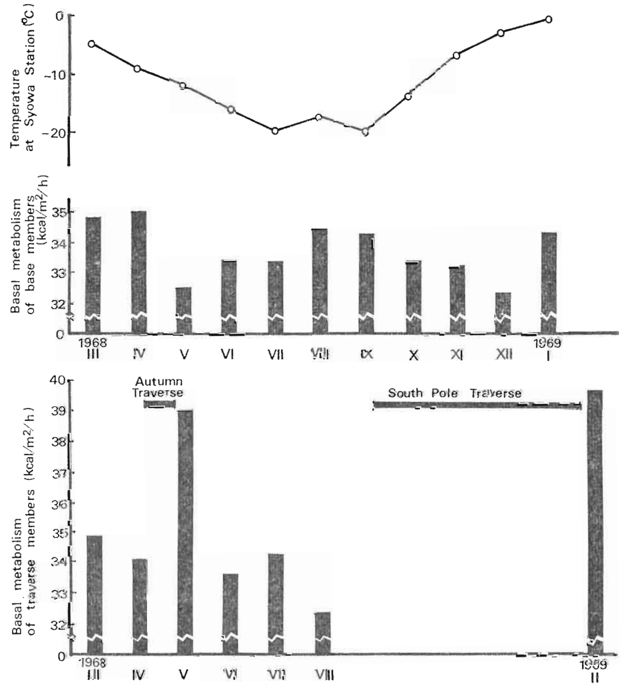

Fig. 6. Monthly mean values of outside temperature at Syowa Station (top) and basal metabolim (middle and bottom). Mean basal metabolism of five base members (middle) increased when outside temperature lowered and decreased as it rose from May to December. Extreme increases of basal metabolism were recognized after the traverses in five traverse members (bottom).

1967, when they were very busy preparing for departure. But it increased slowly for a year at the Syowa Station, reaching the level of 64 kg. Skinfold thickness of the back and arm did not change significantly, while that of the abdominal wall increased gradually and showed a significant positive correlation ($r=0.741$, $p<0.01$) with the increase of body weight (Fig. 7a).

Body weight of the traverse members was 67.4 kg in Tokyo, and increased to 68.6 kg at the beginning of their stay at the Syowa Station. Just after their return from the Autumn Traverse in May, the value was 65.6 kg, with a decrease of 2.3 kg (3%) as compared with the value in April before their departure. The loss in body weight was regained within three to five days, and, later on, the body weight showed a maximum value of 69.1 kg in August in the midwinter. During the South Pole Traverse, decrease was observed up to a minimum value of 65.1 kg at the Plateau

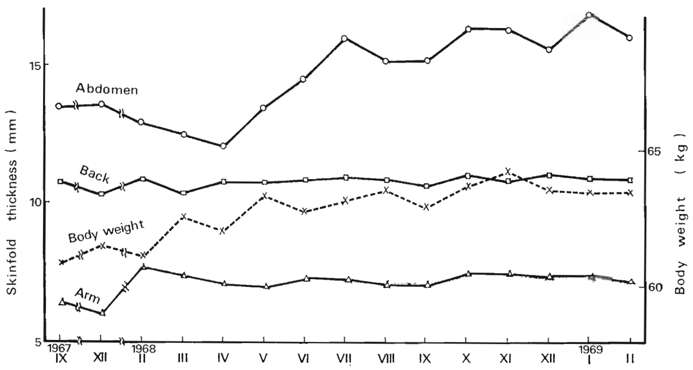

Fig. 7 (a)

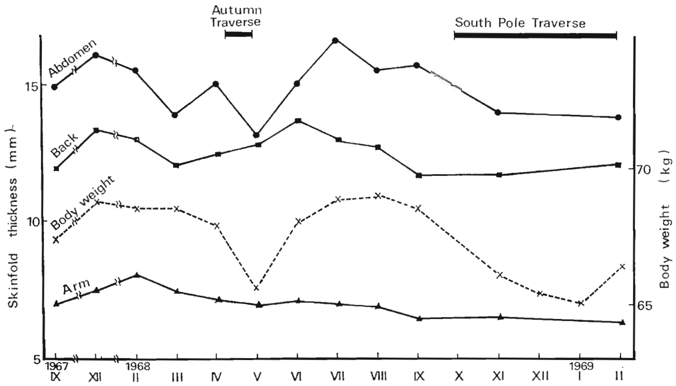

Fig. 7 (b)

Fig. 7. Monthly mean values of body weight and skinfold thickness of base members (a) and traverse members (b). Changes in body weight correlated significantly with those of skinfold thickness of the abdominal wall in both groups.

Station on their way back in January 1969. This decrease in body weight was 3.5 kg (5%) from the value in September before their departure (Fig. 7b). It took about ten days for the value of the body weight to become constant after their return to the station, but even after 40 days in Tokyo the value did not yet reach the level in September.

Skinfold thickness of the arm of the traverse members remained unchanged. While that of the back showed the maximum value in June, no correlation with the changes of body weight was recognized ($r=0.373$). The skinfold thickness of the abdominal wall, however, showed a positive correlation ($r=0.784$, $p<0.01$) with the changes in the body weight, as with the case of the base members.

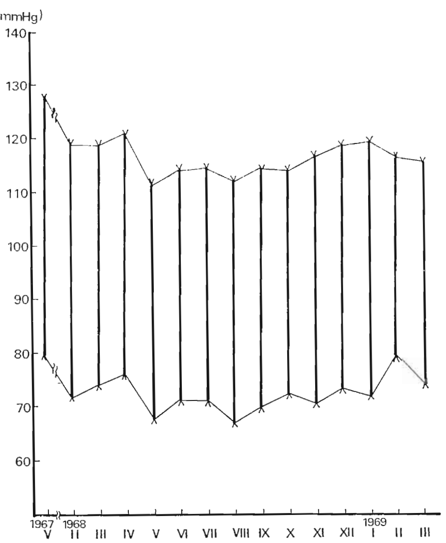

Fig. 8 (a)

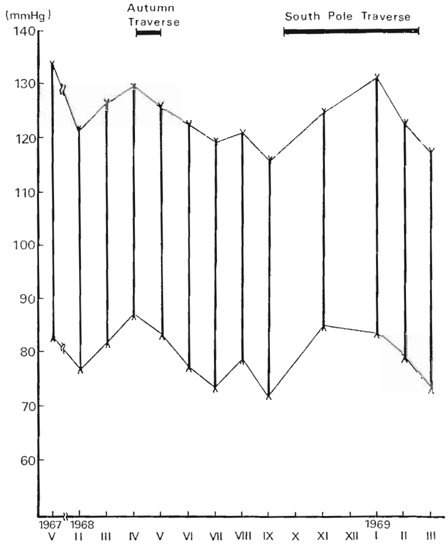

Fig. 8 (b)

Fig. 8. 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.

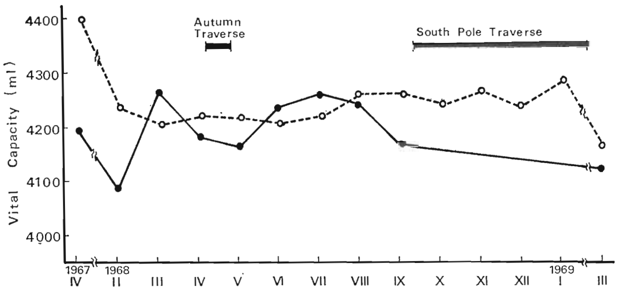

Fig. 9. Monthly mean values of vital capacity in two groups.

Blood pressure: Mean blood pressure of the base members showed the maximum level in Tokyo in May 1967. During the wintering, both the systolic and diastolic blood pressure lowered in the winter and rose a little as it became warmer, but these changes were not so remarkable (Fig. 8a). Blood pressure of the traverse members also showed a little depression in the winter. During the Autumn Traverse and the South Pole Traverse, the blood pressure rose markedly (Fig. 8b).

Vital capacity: Fig. 9 shows the mean values of the vital capacity. The mean vital capacity of the base members recorded the maximum vo-

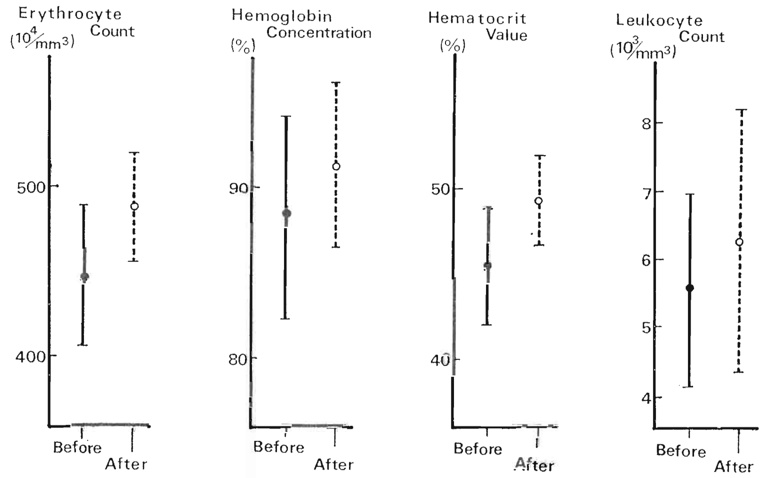

Fig. 10 (a)

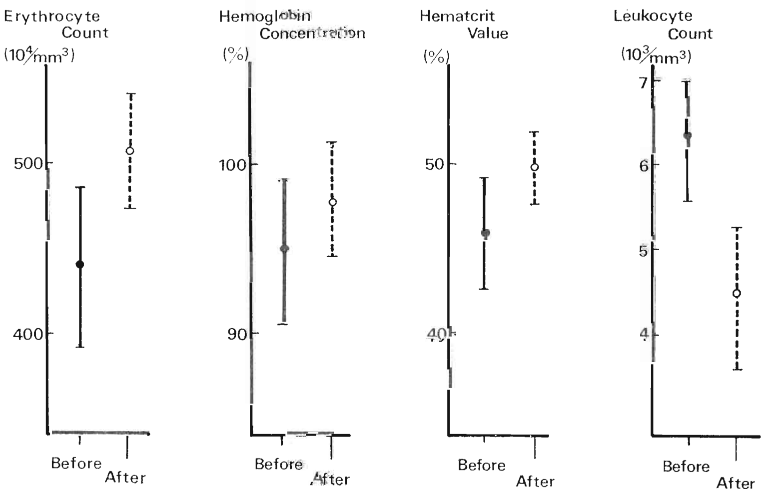

Fig. 10 (b)

lume in Tokyo before departure to the Antarctic and decreased at the beginning of wintering and after returning to Tokyo. Vital capacity of the traverse members showed the minimum value in February, 1968, at the beginning of their life at the Syowa Station, and the maximum value in July. After then it decreased gradually.

Blood: Concerning the changes in the blood components before and after the Autumn Traverse, red blood cell counts and hematocrit value increased significantly ($p<0.05$), and hemoglobin concentration and white

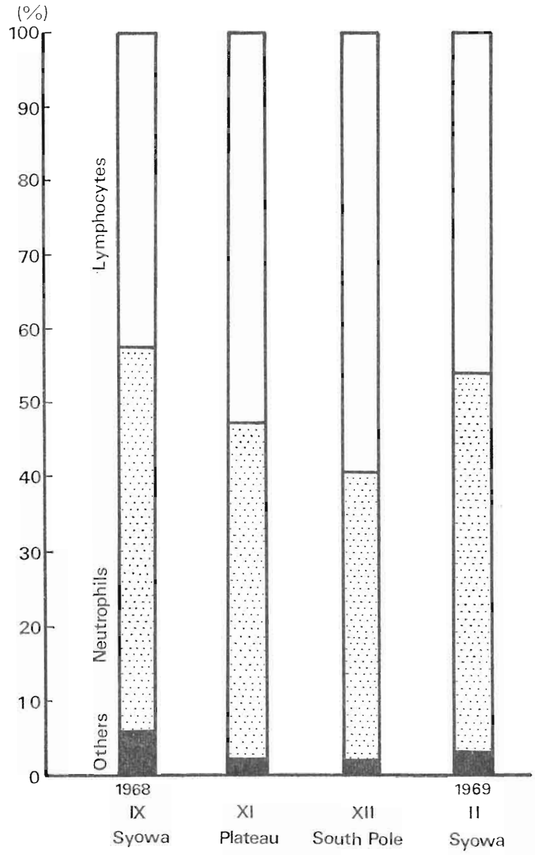

Fig. 10 (c)

Fig. 10. Average values of erythrocyte counts, hemoglobin concentration, hematocrit value and leukocyte counts with standard deviation before and after Autumn Traverse (a) and South Pole Traverse (b). Increases in both erythrocytes and leukocytes were shown after Autumn Traverse (a), but leukocytes decreased significantly after South Pole Traverse (b). Relative lymphocytosis and relative neutropenia were recognized at Plateau Station and South Pole Station (c).

blood cell counts also increased (Fig. 10a). But the differential leukocyte counts did not show a remarkable change. Red blood cell counts and hematocrit value after the South Pole Traverse showed a significant increase ($p<0.01$) compared with those before the traverse, only the white blood cell counts decreasing significantly ($p<0.01$) (Fig. 10b). Furthermore, differential leukocyte counts at the Syowa Station before and after the South Pole Traverse showed little change as the case of the Autumn Traverse. However, at the Plateau Station and the South Pole Station where only the peripheral blood smears were prepared, a relative increase in the lymphocytes and a relative decrease in the neutrophils were observed (Fig. 10c).

Discussion

The seasonal changes in the activity patterns were not so remarkable in both the base group and the traverse group. After all, it may be considered that they had a life with a stationary observation through a year. The members, who observed phenomenons, which became active like the aurora in the winter, had to move about outdoors for a long time.

The traverse members, who must work outside for various observations of geology, geography, gravity, sea-ice and sea-bed geography around the Syowa Station and for the preparation of the traverse such as snow vehicles, sledges, equipments against cold and rations, and furthermore, for the test of observation and radio operation, expended about 30% of the 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 the 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),

$$K_0=(10\sqrt{v}+10.45-v)(33-T_a)$$

where

K_0 = coldness index (kcal/m², h, °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[10]). Fig. 11 shows various effects of the wind on the human body with the temperature being constant. For example, when it is calm and the temperature is −25°C the coldness index becomes 600 and a person feels "very cool", and when the wind velocity is 3 m/s and the temperature is the same −25°C the coldness index becomes 1,400 and the "exposed flesh freezes". Usually there is katabatic with a wind velocity of 5–10 m/s from the inland to the sea at the coast of the Antarctica. As the Syowa Station is based on the Ongul Island about 5 km away from the Antarctic Continent (Fig. 1), it was saved from this katabatic. Syowa Station was sometimes visited by a blizzard with a low pressure, but usually it became warmer because the blizzard carried the warm air from the north.

By the way the time spent by lying and sitting occupied 60% of the day, which agreed with the results of Hirose[4] and Norman[11]. It is con-

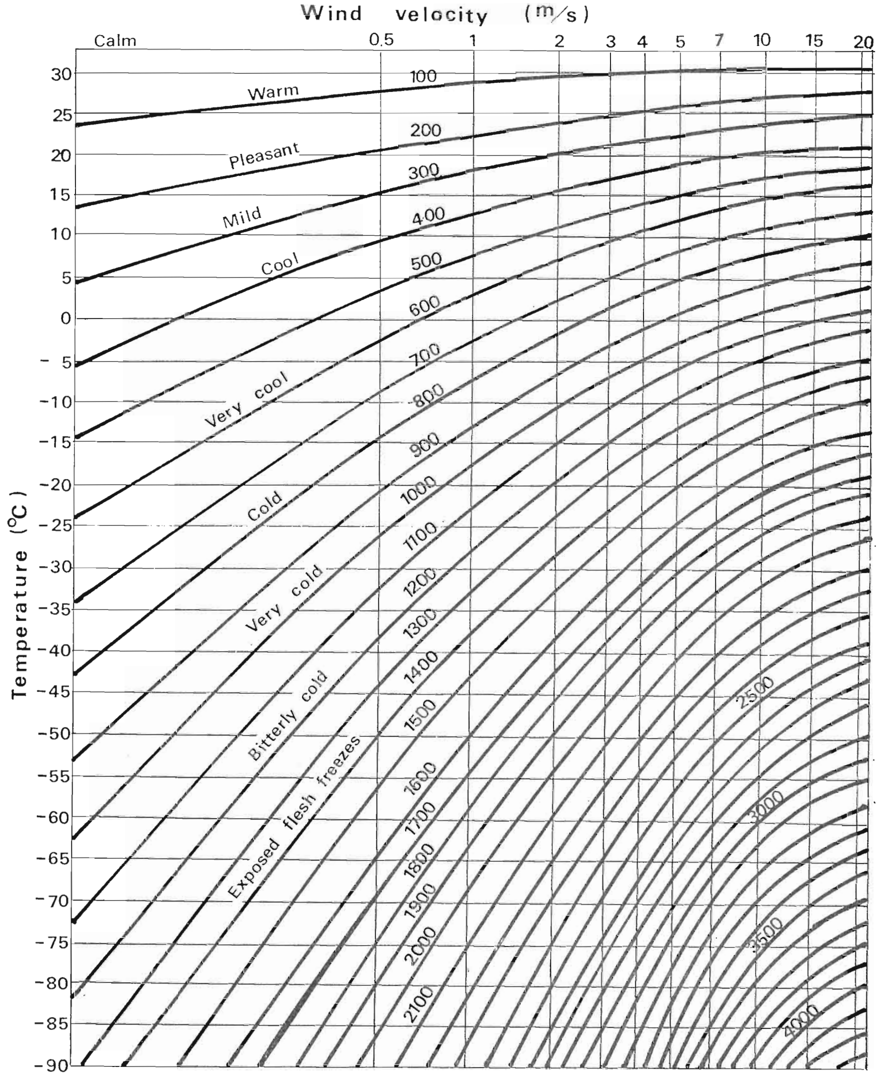

Fig. 11. Chart of coldness index.

sidered that the living conditions in the Antarctic were the same at any station.

The living pattern at the station was very different between the base and the traverse members for their wintering purpose. Judging from this fact, the members who make observations only at the station will be able to winter if they have a common physical strength. However, the members who must make an inland traverse and do outside observations will require a strong physical strength and strong mental power.

Activity pattern during the South Pole Traverse was similar to that of the traverse to the Plateau Station by JARE 1967–68 (Hirose[4]). This may be a natural result because of the same scale of observations and snow vehicles. Activities during the traverse were observations such as direction, position, altitude, meteorology, geography, geology, glaciology, seismology, geomagnetics, gravity and low frequency wave, and arrangements of various logistics.

And next, the energy expended in various activities is shown in Figs. 5a-d. The base members expended most of the energy on observation, 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 had many kinds of activities. On the other hand, during the traverse, they stayed mainly in the snow vehicle which proceeded to the South Pole slowly at a speed of 2–5 km/h with heavy loads. A report by Milan and Rodahl[12] at the Little America V shows that hard work outside, sleeping, sitting, walking inside the tunnel and driving a tractor were the main activities during the day, which is similar to the life of the traverse members at the station.

Energy balance of the day (Table 2) showed positive while they lived at the station, but negative only during the traverse. The ration of about 4,000 kcal/day and about 500 kinds of foods were prepared for wintering (Hara[13]). They had sufficient food which were prepared by a professional cook at the Syowa Station. During the traverse, 100 kinds of foods of about 5,200 kcal/day were prepared, but taking meals prepared by a non-professional in a limited space after observations was not sufficient for them, which was followed by a negative energy balance. Some reports on the foreign traverse parties showed only 20–30 kinds of foods (La Grange[14], Lewis[15]). Muir[16] and Lloyd[17] reported that negative energy balance, hard work and cold exposure had a close relation with ketonuria, but, unfortunately, it was not studied in this study.

The members took a maximum of 3,500 kcal in a day, but foreign parties took amounts of 4,000–5,000 kcal according to the reports of Milan and Rodahl[12] and Orr[18]. Furthermore, they took fat consisting 30–40% of the total calorie intake which is fairly higher than the value observed in the Japanese. Several hundred miligrams of ascorbic acid were taken every day for a year.

Edholm[19] and Wilson[20] reported that the seasonal change in the basal metabolism was not recognized in the Caucasian in the Antarctic. Yoshimura et al.[21] and Yukiyoshi[22] showed in their reports that the basal metabolism in the Japanese decreased in the summer and increased in the winter, but that in the Canadian showed a constant value throughout the year in Japan.

Result of basal metabolism in the base members at the Syowa Station also showed a similar tendency from May to December, i.e., the basal metabolism increased with the lowering of temperature and decreased with the warmer climate as in Japan. There is a time lag of six months between Antarctic and Japan, and, therefore, this indicated that the changes in the basal metabolism represented the result of acclimatization. Especially during the base construction period, they got up at seven and began to do hard labor such as loading, engineering, construction and so on. Such a work was continued until 20:00 or 21:00. Because there is a white night in the summer, they could work outside without light throughout the night. As almost all of the observation members had not experienced physical hard work in Japan, physical fatigue from suddenly working might affect the basal metabolism.

Basal metabolism of the traverse members increased after the Autumn Traverse and the South Pole Traverse. This increase may be also affected by physical fatigue and also by the excitement of success of the traverses.

Yukiyoshi[22)] reported about the difference in the basal metabolism between the Japanese and the Caucasian stating that this difference is related to the physique, habitude (endocrinic function) and nutritive condition. In the large man less seasonal changes were observed even in the Japanese, the Caucasian having a more steady value in the thyroid function than the Japanese.

Body weight increased when they lived at the station, but that of the traverse members decreased fairly after the traverse. During the Autumn Traverse, it was -30 to $-40°C$ every day and they had to camp out, set up some fuel depots and travel all night running on the cold snow vehicle. Therefore, all of the members had a frostbite of the first to second grade on their faces and fingers, and their body weight and skinfold thickness decreased suddenly. Hematological findings after the Autumn Traverse showed an increase in both the red blood cells and white blood cells, and the body weight returned to the former value within five days after returning to the station. Therefore these changes might be caused by dehydration as during the inland journeys by Hicks[23)], Davies[24)], and Orr[18)].

After the South Pole Traverse, red blood cells increased while the white blood cells 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, weight loss observed during this traverse may be attributed to the negative balance caused secondarily by various stresses.

Lewis[25] reported that a positive correlation was recognized between the changes in body weight and skinfold thickness of the back, but the changes in the body weight correlated with that in the skinfold thickness of the abdominal wall (base group; $r=0.741$, $p<0.01$, traverse group; $r=0.784$, $p<0.01$) in this study being like the results which Nagamine and Suzuki[26] obtained from the studies on the young Japanese in Japan. It is very interesting whether this is a phenomenon peculiar to the Japanese based on the ethnic difference.

Budd[27], Kageyama[28] and Tikhomirov[29] also reported that the blood pressure lowered during their wintering in the Antarctic. The lowering in the blood pressure in the winter might be due to the 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 rising of the blood pressure observed during the traverse might be attributed to the continuous stress such as the life on the snow vehicle, sunshine during the whole day, severe climate which had a coldness index of over 2,000, and a society of only few men per vehicle (Fig. 12). Palmai[30] reported that the changes in the blood pressure correlated with those of the skinfold thickness, but such a correlation was not observed in this study.

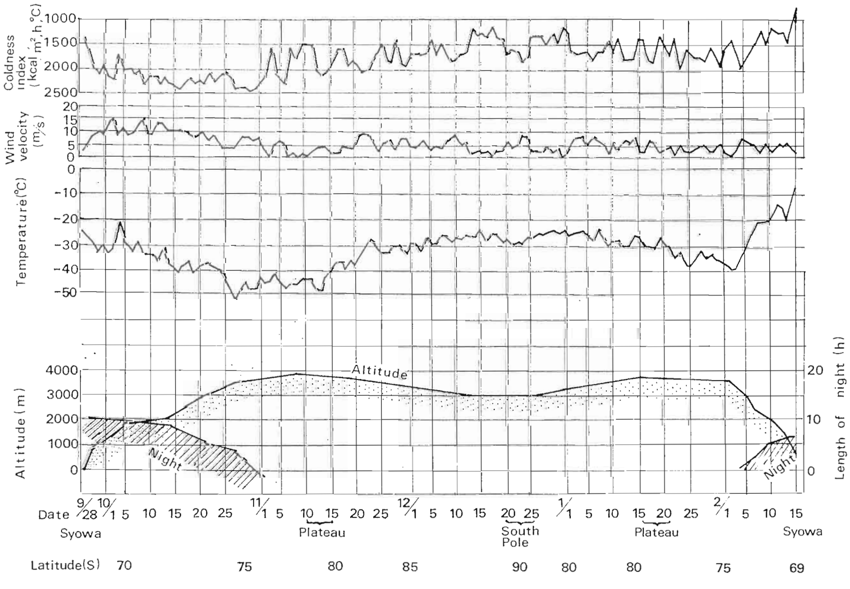

Fig. 12. Coldness index, wind velocity, temperature, altitude and length of night in hours during South Pole Traverse.

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

As all components of the peripheral blood increased after the Autumn Traverse, hemoconcentration might be considered. After the South Pole Traverse, however, the white blood cells decreased significantly ($p<0.01$) as compared to the red blood cells which increased significantly ($p<0.01$). Erythrocytosis might be caused by the adaptation to the altitude, traveling on the South Polar Plateau of 3,000 m high for about five months (Fig. 12). Tikhomirov[31] reported on his observation at the Vostok Station, which is located about 3,500 m high, that the erythrocyte counts also rose (19.8%) during the first two months.

Leukopenia during the wintering was observed by Kageyama[28], Popov[32] and Tikhomirov[31], emphasizing the extreme decrease of bacterial infection and strong ultra-violet rays. Furthermore, Popov[32] indicated the suppression of the reticulo-endothelial function as the cause of leukopenia. The members during the inland traverse on the snow were in a more sterile condition than that 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 the Syowa Station 20–25% more than in Japan, and at the height of 3,000 m they must be ten-fold compared with that at the sea level (Suda[33]).

Relative lymphocytosis and relative neutropenia were obvious at the Plateau Station and Pole Station. Barsoum[34] also observed the same temporary relative lymphocytosis on the Filchner Ice Shelf in the Antarctic. Reason for this phenomenon is not known, but it may be due to the continuous stimulus of coldness or other factors. As the differential leukocyte counts were not made during the Autumn Traverse, it is not known whether relative lymphocytosis occurred or not. This is one of the problems to be studied in the future.

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