Medical Report on the Members of the JARE South Pole Traverse 1968-69

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1. Introduction

The physiological findings obtained during expeditions by dog sledges or snow vehicles on Antarctica have been reported by WILSON (1960), ANTONIS (1965), ORR (1965), HICKS (1966), and HIROSE (1969). JARE 1968-69 made an inland survey expedition up to the South Pole—South Pole Traverse—from the end of September 1968 to the middle of February 1969 and the traverse is outstanding in scale which covered the distance of 5,182 km during 141 days. Furthermore, because the members of the expedition were composed of the Japanese, it is worthy to analyze the physiological acclimatization to cold observed in these members. This traverse party made a preliminary expedition for 3 weeks from April to May 1968 to train the members of this party and also to establish the fuel depots. In this paper, the results of observation made on the members of the party during these two expeditions are reported in comparisons with their physiological findings obtained at Syowa Station and also with the findings reported by HIROSE (1969) on the members of JARE 1967-68 expedition.

The snow vehicle (KD60) was designed and constructed in Japan to meet the mode of living and also for the body size of the Japanese, and it was fairly comfortable for the party despite their long trip. Soon after their departure for the traverse, one of the party members had his left arm caught in a drilling machine (diesel engine) and suffered from fractures of humerus, radius, ulna, and the 1st metacarpus of the arm, and sent back to Syowa Station. Except for this accident, none of the members suffered from serious disorders (Table 1).

For about a month from their departure till their arrival at the Plateau Station (79°14′ S, 40°30′ E) they were travelling in high altitude; rather sharp ascent to 2,500 m just after their departure from Syowa Station, and the highest altitude they arrived was about 4,000 m. Owing to this high altitude, the party members suffered from dyspnea especially during muscular work. For example, continuous shovelling was limited to about 10 times because of dyspnea. Also

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Table 1. Incidences of disorders during the South Pole Traverse (Oct. 1968-Feb. 1969).

Item	Number
Frostbite (I—II degree)	12
Headache (unknown origin)	6
Contusion	6
Symptom of upper respiratory inflammation	5
Diarrhea (unknown origin)	4
Cough (dry and paroxysmal)	2
Toothache	2
Carbon monoxide poisoning	2
Contused wound	2
Fracture	1
Sprain	1
Total	43

slight intakes of alcohol at night caused palpitations and insomnia. Except for a few cases of psychological perturbation, the members were in good health.

Because the expedition was on Antarctica, the time which the members spent for activities outside the vehicle reached only 13.3% of 24 h. Analyses were made on their activity pattern, energy expenditure, and food intake, body weight, skinfold thickness, blood pressure, hematological findings, and vital capacity to detect changes which might occur in the members under a variety of stresses such as extreme cold, high altitude, labor, lack of sleep, and isolation from the society.

2. Methods

Observations were made on the 11 traverse party members including the leader, and they ranged in age from 27 to 50, an average of 37 years. The medical checkups were conducted as often as possible from the time when they were still in Tokyo, and throughout the voyage to the Syowa Station, during their stay at the station, and during their trip.

2.1. Activity patterns

As shown in Table 2, observations were made at Syowa Station for 5 days in summer (Oct.-Apr.), 8 days in winter (May-Sept.), 7 days on their way to the Pole, and 11 days on their way back, 31 days in total. During their stay at the station, the activities of each of the subjects were observed for 24 hours and the time spent for sleeping, lying, standing, walking, desk work, eating, shovelling, and other activities were recorded in minutes. During the traverse, each subject recorded their own activities into the record form. In order to compare the present results with that reported by Hirose (1969, JARE 1967-68), the classification of activities used by Hirose was also used which consists of 11

Table 2. Subjects and periods of time and motion study.

Subjects	Age	Occupation	At Syowa Station		During South Pole Traverse	
			Summer Oct.-Apr.	Winter May-Sep.	On the way to South Pole	On the way back from South Pole
M. M.	50	Leader		2	1	1
K. T.	42	Mechanic				1
A. K.	41	Surgeon				1
M. H.	40	Mechanic				1
S. K.	39	Cartographer	2	1	1	1
K. F.	37	Geographer	1	2	1	1
T. E.	34	Seismologist		2		1
I. K.	33	Logistics supporter			1	1
R. Y.	33	Mechanic			1	1
N. N.	33	Radio operator			1	1
K. Y.	27	Geologist	2	1	1	1
Total		31 days	5	8	7	11

categories: 1. Lying; 2. Sitting; 3. Standing; 4. Walking indoors; 5. Light work indoors; 6. Moderate work indoors; 7. Hard work indoors; 8. Walking outdoors; 9. Light work outdoors; 10. Moderate work outdoors, and 11. Hard work outdoors.

2.2 *Energy expenditure and calorie intake*

The energy expenditure was calculated from relative metabolic rate (*RMR*) of each activity and the time expended for the activity and basal metabolic rate (*BMR*). For the *BMR*, the mean value of 35.7 kcal/m^2/h which was obtained at Syowa Station from a member, was used (average height and average body surface area of the member were 170 cm and 1.85 m^2, respectively). *RMR*'s were based on the reports by NUMAJIRI (1964) and the calculation is as follows:

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

where

A = Total energy expenditure of a 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_2 = Time spent for each category of activity (min)

RMR : Lying, 0.0; Sitting, 0.3; Standing, 0.5; Walking, 2.0; Light work, 1.0; Moderate work, 3.0; Hard work, 5.0.

As for the energy intake, the kind and quantity of food taken were recorded on the same days with the time study of activities, and calculated from the standard caloric values of the food (Table of Standard Components of Various Foods, Nippon Eiyoshi Kai, 1958).

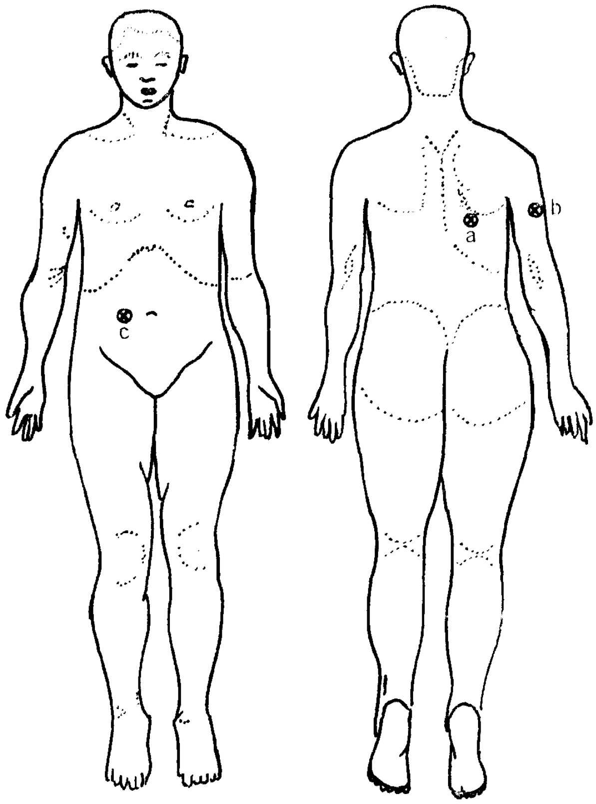

Fig. 1. Sites of measurement of skinfold thickness. Cobalt Greenpole (0.1 ml) was injected intradermally as a marker. a: A region about 1 cm below the inferior margin of right scapula. b: Lateral side of right arm. c: A region about 5 cm right of navel.

2.3. Body weight

During their stay at the station, body weight of the members was measured once a month, naked or with only a thin underwear. A spring scale was used and every time before weighing, the scale was calibrated against a balance scale. During the traverse, they were weighed 3 times, 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.

2.4. Skinfold thickness

Skinfold thickness was estimated by skinfold calipers (Eiken type) once a month at the station and in November at the Plateau Station on their way to the Pole Station. For this determination, the pressure of 10 g/mm^2 was applied on the area of 20 mm^2, and the error of the estimations was within 0.05%. Three sites of skin measured were as follows (Fig. 1):

a: About 1 cm below the inferior margin of right scapula.

b: Lateral side of right arm.
c: About 5 cm to the right of navel.

These sites were marked with the intradermal injection of Cobalt Greenpole (0.1 m*l*), and the region was measured 3 times consecutively, and the mean value of the three readings was used as the skinfold thickness for the month.

2.5. Arterial blood pressure

Resting arterial blood pressure was taken by a Riva-Rocci mercury manometer, once every month at the station and in November and January on their way to and from the Pole Station.

2.6. Hematological findings

Measurements of red blood cell counts, white blood cell counts, hematocrit value, hemoglobin content, and blood pictures on the member were made before and after the autumn traverse and the South Pole Traverse. Also peripheral blood smear preparations were made during their stay at the Plateau Station on their way to the Pole and at the Pole Station, and these preparations were examined under a microscope at the Syowa Station. Hematocrit was determined by a microhematocrit apparatus (YSI Model 30, Yellow Spring Instrument Co., U.S.A.) and hemoglobin was measured by the Sahli method.

2.7. Vital capacity

Vital capacity was measured before meal once a month by using a wet and rotating type spirometer (KYS). The maximum value obtained from 3 challenges of each member was taken as his vital capacity for the relevant months.

3. Results

3.1. Activity patterns

Table 3. Changes of activities with season (percentages of a day).

Activities	Summer (Oct.-Apr.)	Winter (May-Sept.)	During South Pole Traverse
1. Lying	32.8	33.3	26.2
2. Sitting	26.4	25.4	35.7
3. Standing	5.2	3.6	0.1
4. Walking indoors	1.9	1.3	0.0
5. Light work indoors	3.2	6.9	13.2
6. Moderate work indoors	0.0	0.8	11.5
7. Hard work indoors	0.0	0.0	0.0
8. Walking outdoors	8.6	5.7	1.8
9. Light work outdoors	16.0	14.7	8.3
10. Moderate work outdoors	5.8	8.3	2.2
11. Hard work outdoors	0.1	0.0	1.0
Time spent indoors	69.5	71.3	86.7
Time spent outdoors	30.5	28.7	13.3

Activities were classified into 11 patterns, following the classification by HIROSE (1969) (Table 3). Calorie output used for lying and sitting amounted to about 60% of a day and that for outdoor light work at the station or the light work in the vehicle during the traverse exceeded 10%. When the activities are devided between outdoor and indoor, 13.3% of their time was spent outside the vehicle during the traverse and about 30% at the station in summer and also in winter. According to HIROSE (1969), 13.2% of a day was spent outside the vehicle during the expedition which agrees with the present observation.

As for their sleeping time (Fig. 2), they slept about 7.5 h at the station, but their sleeping time became as short as 5 h after they started on the traverse, especially on their way to the Pole, but they could sleep nearly 7 h on their way back, which may indicate the heavy load forced on them on their way to the Pole.

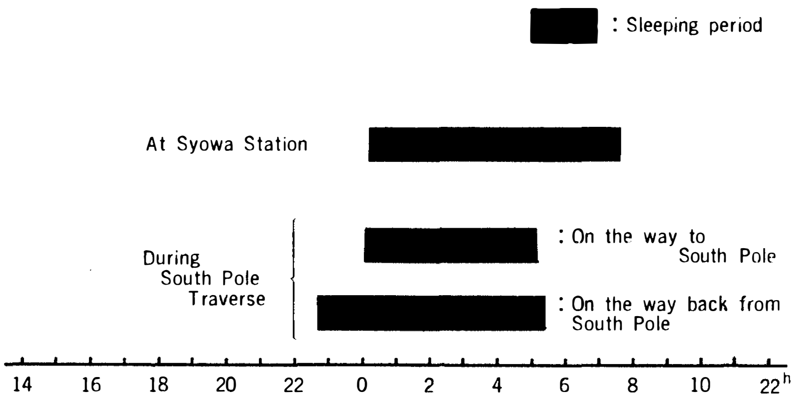

Fig. 2. Sleeping time at Syowa Station and during the South Pole Traverse.

3.2. Energy expenditure and calorie intake

When the energy expenditure is divided into activities, high energy was consumed in total for sleeping (488 kcal/day) and for light work (465 kcal/day)

Table 4. Mean daily energy expenditure and calorie intake at Syowa Station and during the South Pole Traverse.

Seasons	Body weight kg	Energy expenditure kcal/day (kcal/kg/day)	Intake kcal/day (kcal/kg/day)	Percentage of calories derived from		
				Protein (g/kg/day)	Fat (g/kg/day)	Carbohydrate (g/kg/day)
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)
During South Pole Traverse	65.3	3,282 (50)	2,992 (46)	13.1 (1.5)	28.1 (1.4)	58.8 (6.7)

at the station (Fig. 3). During the traverse, sitting (857 kcal/day), driving (733 kcal/day), and sleeping (416 kcal/day) were the major energy output source (Fig. 4).

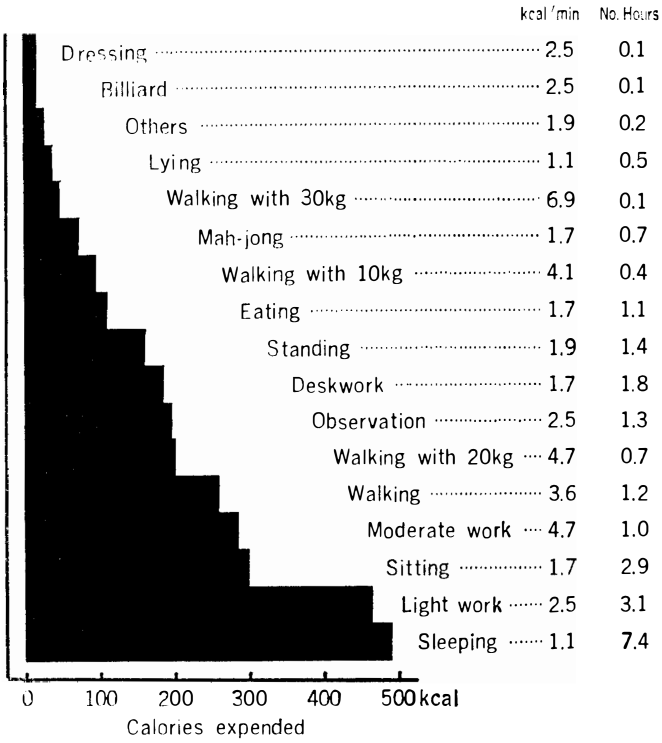

Fig. 3. Energy expenditure per day at Syowa Station.

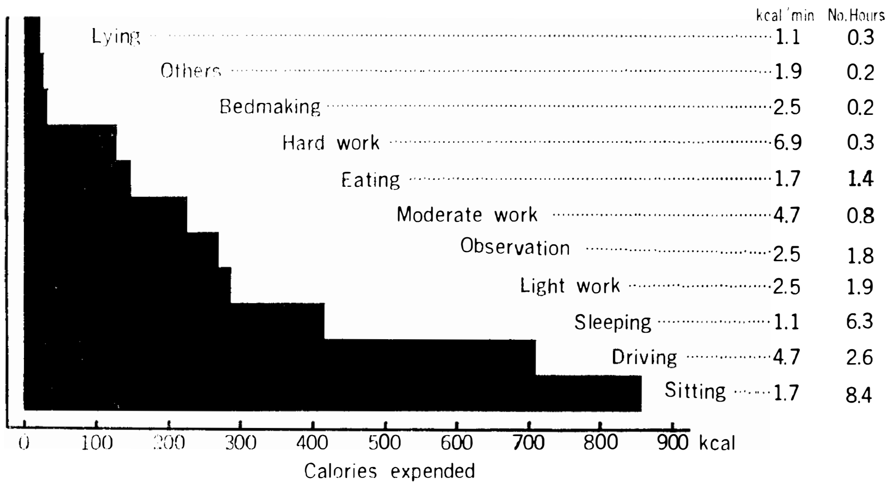

Fig. 4. Energy expenditure per day during the South Pole Traverse.

Concerning the energy balance (Table 4) per day, the energy output and food intake were well balanced, each showing the value of approximately 3,000 kcal/day during the stay at the station in summer. The energy output in winter was about 3,200 kcal/day while the intake was about 3,400 kcal/day, indicating a positive balance of about 200 kcal/day. During the traverse, the expenditure was about 3,300 kcal/day and the intake was about 3,000 kcal/day, showing a negative balance of about 300 kcal/day.

As for the dietary composition of these members, 33% of their calorie intake in winter was from fat, which is well above the standard value for the Japanese, approaching the dietary composition of European.

3.3. Body weight and skinfold thickness

The mean values for body weight and skinfold thickness are shown in Fig. 5. The mean body weight of the members was 67.4 kg in Tokyo, and this increased to 68.6 kg at the beginning of their stay at 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 3–5 days, and later on, the body weight marked a maximum value of 69.1 kg in August in the midwinter. During the South Pole Traverse, a steady decrease was observed up to a minimum value of 65.1 kg at the Plateau Station on their way back (Jan. 1969). This decrease in body weight was 3.5 kg (5%) from the value in September before their departure. The recovery of their body weight after their return to the station took more than a week (Fig. 6), which means that it took longer for the recovery of body weight by several days, as compared with the recovery of body weight after the autumn traverse.

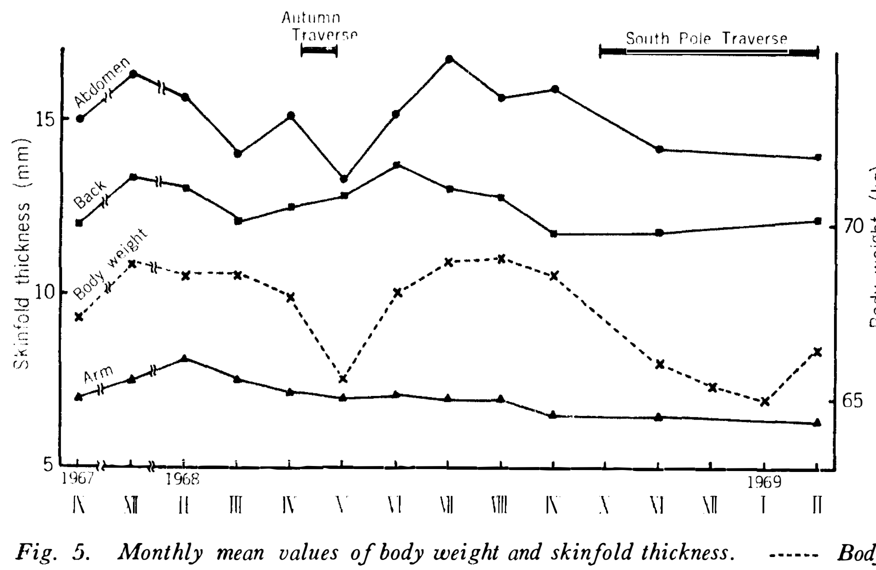

Fig. 5. Monthly mean values of body weight and skinfold thickness. ------ Body weight. —— Skinfold thickness of three sites. Body weight and skinfold thickness of abdominal wall showed significant correlation.

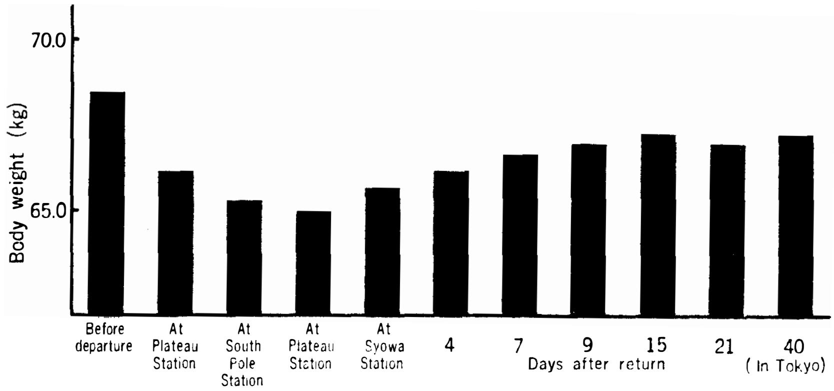

Fig. 6. Mean values of body weight before and during the South Pole Traverse and after return.

Skinfold thickness of inferior margin of scapula (a in Fig. 1) showed a maximum value in June (early in winter) while that of lateral side of right arm (b in Fig. 1) remained unchanged, and that of abdominal region (c in Fig. 1) recorded the largest variation (Fig. 5). The skinfold thickness of the abdominal region showed a positive correlation ($r=0.784$, $P<0.01$) with body weight, but those of the inferior margin of scapula ($r=0.373$) and lateral side of right arm showed no correlation with body weight, which fact agrees with the findings by NAGAMINE and SUZUKI (1964).

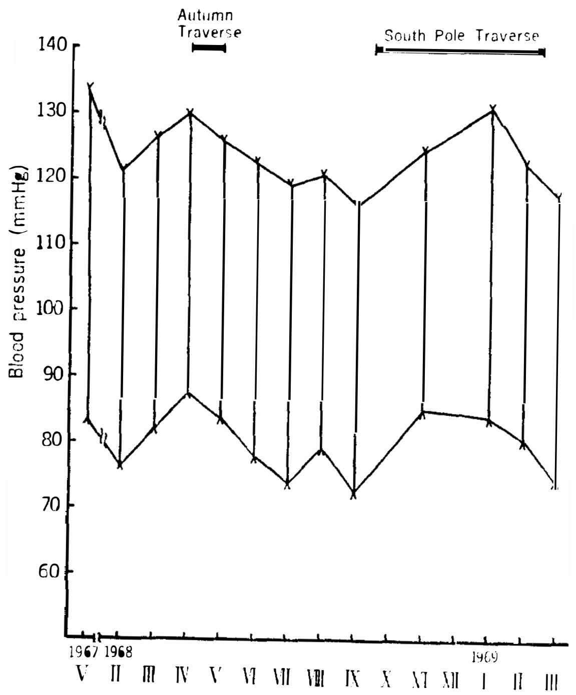

Fig. 7. Monthly mean values of arterial blood pressure.

3.4. Arterial blood pressure (Fig. 7)

In February 1968, just after the start of their life in Syowa Station, arterial blood pressure showed rather low values, both in systolic and diastolic blood pressures. Although both the systolic and diastolic blood pressures increased during the autumn traverse, they clearly decreased as winter proceeds and recorded a minimum value. On the other hand, during the South Pole Traverse, the blood pressure rose markedly with subsequent fall on the return to the station. The low values observed in winter at Syowa Station was regained only after their return to Tokyo.

3.5. Hematological findings

As shown in Fig. 8, significant increases ($P<0.01$) in erythrocyte and in hematocrit were observed just after the South Pole Traverse, while leucocyte decreased significantly ($P<0.01$). Hemoglobin showed an increase after the traverse, but was not significant.

Only blood smears for differential leucocyte count were obtained at the Plateau Station and the Pole Station, and the results are shown in Fig. 9 together with the results at Syowa Station just before and after the traverse. Almost no change was observed in the differential counts between those taken before their departure from Syowa Station and after their return. On the other hand, relative decrease of neutrophils and relative increase of lymphocytes were observed at the Plateau Station and the Pole Station.

3.6. Vital capacity (Fig. 10).

Minimum vital capacity values were recorded in February 1968 at the beginning of their life at Syowa Station, and the values increased to maximum values in July. Vital capacity was not measured during the traverse but it showed decrease from the value obtained just before the departure for the traverse to the value obtained after their return to Tokyo.

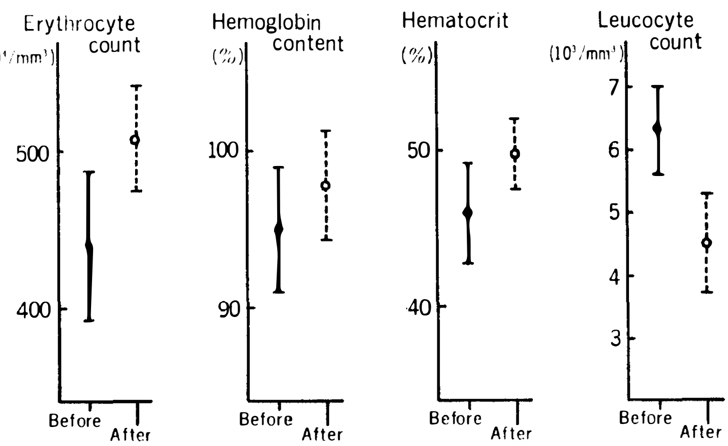

Fig. 8. Mean values of erythrocyte counts, hemoglobin content, hematocrit value and leucocyte counts before and after the South Pole Traverse, with standard variations.

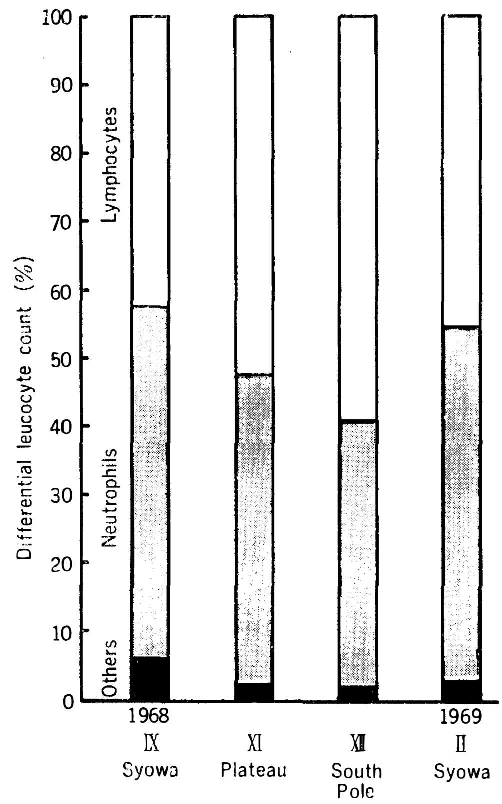

Fig. 9. Mean values of differential leucocyte count at each station.

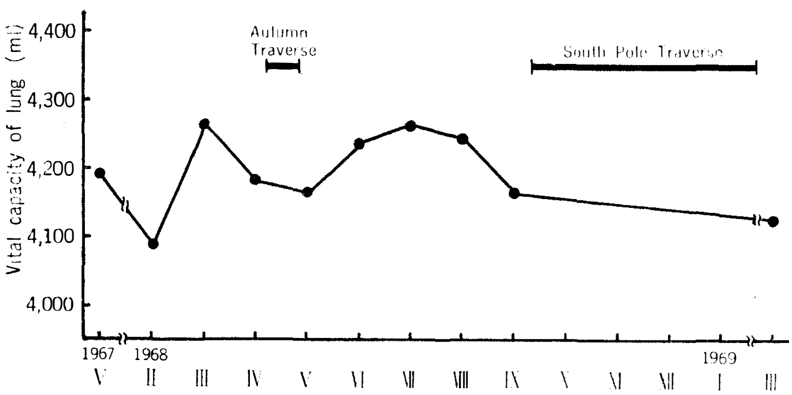

Fig. 10. Monthly mean values of vital capacity.

4. Discussions

The traverse party, unlike the members at the station who devote themselves only to observations at the station, must work outside even in winter and the time spent outside amounts to about 30% of a day, to provide snow vehicles and other provisions for the traverse, to prepare for observations during the traverse, and also for observations in geology, geography, and gravity around the station. In HIROSE's report (1969), no distinction was made between the base party and the traverse party during their stay at the station, and it is impossible to obtain the amount of outdoor work of the traverse party. However, JARE 1967-68 party travelled over a distance of 2,600 km and for 72 days, which was just about one-half the scale compared to that of JARE 1968-69. Consequently, the time spent for outdoor work in preparation for the traverse might be less with JARE 1967-68 party than that of JARE 1968-69 party. JARE 1968-69 party spent about 13% of a day for outdoor work during the journey, which is almost the same value as that observed in JARE 1967-68 party. Outdoor work during the trip included observations on meteorology, altitude, astronomy, glaciology, geomagnetism, gravity, seismic sounding, VLF, and also for maintenances of vehicles and cargos, and also for digging out the sledges, and other work. They spent almost the rest of their time on driving the vehicles or sleeping (Table 3).

The activity patterns (Figs. 3 and 4) show remarkable contrast between the station life and the traverse life. The former contains variety of activities while the latter shows simplified activity pattern.

MILAN and RODAHL's observations (1961) on the members of 1958 Little America V revealed that hard work outside, sleeping, sitting, walk inside tunnels, and driving of a tractor are ranked as high sources of energy expenditures. Their results agree well with the present findings (Fig. 3) except some difference in the grade of activities. This fact might indicate that the daily routine in the Antarctic is similar at any station, from maintenance of the station to observations for the wintering purposes.

As is obvious from daily energy balance (Table 4), the energy intake shows positive balance at the station while it shows negative balance during the traverse. At the station, meals were enjoyed by all the members, after the heavy outdoor work, which might have contributed to the positive balance. On the other hand, during the traverse a small number of members take meals in a confined space in the vehicle between heavy daily schedule of observations and other work. Even though the meals were the greatest enjoyment for them during the traverse, they were likely to take insufficient quantity of food because of their mental and physical stresses, which might be responsible for the negative balance of energy intake. The foodstuff prepared by JARE 1968-69 for the traverse consisted of 100 varieties (5,200 kcal/day) as compared to 20-30 varieties prepared by other parties (LA GRANGE, 1963; LEWIS, 1963), and they were so designed to meet the taste of the Japanese, and cooking facility was furnished in a corner of the vehicle, but there was no cook in the member, and they had to cook by themselves. As a consequence, simple meals, such as hotchpotch, instant meals now in wide use in Japan, and beefsteak were used, which also might have been responsible for insufficient food intake.

As for the foodstuff in Syowa Station, about 500 varieties with 4,000 kcal/day (HARA, 1966) were prepared, but the maximum calorie intake was 3,500 kcal/day.

Also overall vitamin preparations were provided. Especially, the members took 100–500 mg/day of ascorbic acid and ate frozen vegetables at the station, and dried and frozen vegetables during the traverse. According to MILAN and RODAHL (1961), and ORR (1965), the members of other party took 4,000–5,000 kcal/day but this may be attributed to the differences in physical constitution. As for the food composition, the members of other party took fat by 30–40% of the total calorie intake which is fairly higher than the value observed in the Japanese.

As shown in Fig. 5, in December 1967, the body weight and skinfold thickness increased, as compared with September of the same year before departure of the members from Japan. This may be due to the lack of physical exercise on board FUJI, the ice-breaker, which caused positive balance of calorie intake.

During the autumn traverse between April and May, 1968, the party underwent a very severe training spending nights in a tent under the environmental temperature of $-40°C$ (Fig. 11) and kept driving all night. All of the

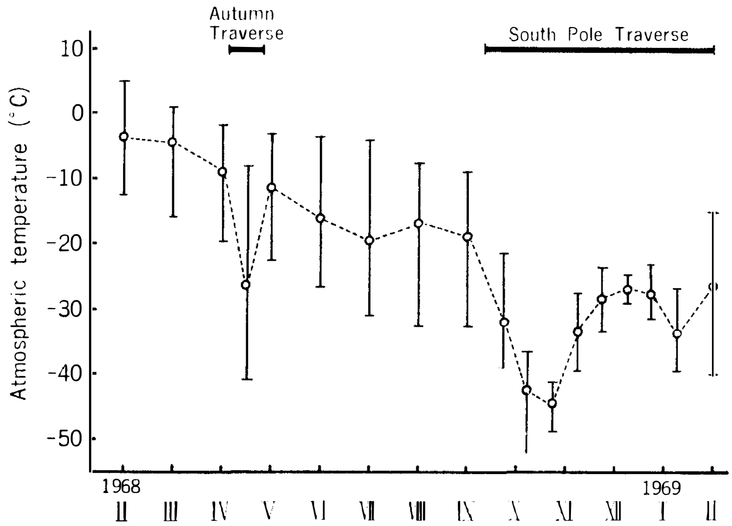

Fig. 11. Atmospheric temperature at the station and during the South Pole Traverse.

members suffered from I to II grade of chilblains on their face and some of them on their fingers, and their body weight and skinfold thickness showed a sharp decrease. The energy balance was not recorded during this period, but body weight recovered in 3–5 days after they returned to the station. Results of examinations on erythrocyte, hemoglobin, hematocrit value, and leucocyte just after their return to the station showed high values simultaneously. These facts may indicate that the decrease of their body weight is mainly due to their dehydration.

On the other hand, during the South Pole Traverse, the body weight showed a decrease of 3.5 kg (5%) on an average and food intake was markedly insufficient

(Table 4), but symptoms of dehydration were not so pronounced. In other words, the number of erythrocyte, hemoglobin content, and hematocrit value increased, but on the other hand, the number of leucocyte decreased markedly (Fig. 8) and the recovery of body weight took more than a week (Fig. 6). Besides, drinking water was sufficiently supplied by the water-making apparatus equipped in the snow vehicles used for this traverse. Accordingly, the weight loss observed during this traverse may be attributed to the negative balance of calorie intake caused secondarily by various stresses. On the other hand, the weight loss observed during the autumn traverse might be due to dehydration and negative balance of calorie intake as reported by ORR (1965), HICKS (1966), and DAVIES (1969).

LEWIS (1960) reported that the skinfold thickness, especially at the inferior margin of scapula, shows positive correlation with body weight, but the findings obtained by us proved that the body weight shows a positive correlation ($r=0.784$, $P<0.01$) with the skinfold thickness of abdominal region (Fig. 5), as reported by NAGAMINE and SUZUKI (1964). It is not known whether this is a phenomenon peculiar to the Japanese based on ethnic difference, but it is worthy of note.

As pointed out by KAGEYAMA (1963) and BUDD (1965), blood pressure tends to drop slightly during wintering in Antarctica. Our findings show that systolic and diastolic blood pressure tend to fall in winter, while they showed increase during the traverse. TIKHOMIROV (1963) also observed fall in blood pressure during winter at Vostok Station (78°28′S, 106°48′E). Hence, the fall in blood pressure in winter might be due to a depressive effect of the central nervous system or vagotonia caused by the outdoor darkness and limited outdoor activities during the polar night. On the other hand, the increase in blood pressure observed in party members during the traverse may be attributed to continuous stress in the snow vehicle under the polar day. PALMAI (1962) reported that blood pressure showed close correlation with skinfold thickness, but our results did not confirm this correlation.

Fig. 8 shows that erythrocyte count and hematocrit value increased significantly ($P<0.01$) and leucocytes decreased significantly ($P<0.01$) before and after the traverse. This finding is not due to hemoconcentration, instead it could be interpreted as being due to erythrocytosis caused by the adaptation of human body to the altitude since the inland of the continent is more than 3,000 m high. At Vostok Station, erythrocytes recorded a maximum in the first 2–2.5 months (TIKHOMIROV, 1961). TIKHOMIROV (1961), KAGEYAMA (1963), and POPOV (1965) noted a decrease in leucocyte, and a marked decrease in infectious sources and strong ultraviolet rays are pointed out as the factors for the leucopenia (KAGEYAMA, 1963; TIKHOMIROV, 1961). POPOV (1965) considered that leucopenia, eosinopenia, and monocytopenia are related to functional suppression of the reticulo-endotherial system. Because sterilities of stations in Antarctica have been pointed out, it may as well be considered that the traverse in Antarctica was made in almost sterile condition, but it remains for discussions whether this sterile condition is the cause of the fall in leucocyte count or not. The effect of ultraviolet rays or some other radiations might be more potent factors.

Concerning the differential count of leucocytes (Fig. 9), relative increase in lymphocytes and relative fall in neutrophils became pronounced as the party proceeded from Syowa Station to the Plateau Station and further to the Pole Station. The report by BARSOUM (1962), who examined 10 members at United States Navy International Geophysical Year Station on the Filchner Ice Shelf in the Antarctic, showed exactly the same relative and temporary increase of lymphocytes. BARSOUM (1962) attributes the cause of this change to the effect of continuous exposure to cold, but this phenomena still remain for further investigations.

Vital capacity showed low values at the beginning of wintering when the labor for constructions was heavy (February 1968), and after the autumn traverse (May 1968). These decreases may be due to physical fatigue. It registered a highest value in July, reflecting relatively sedentary life in the mid-winter.

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