

Food requirements and weight changes of men on Antarctic expeditions

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In the comparatively short history of Antarctic exploration the scourges of scurvy and semi-starvation have played as important a part in the success or failure of expeditions as have the hazards of exposure and accident. Studies have recently been made of the mechanisms that might be involved in man's physiological response to polar conditions (Lewis & Masterton, 1963). These have included routine measurements of body-weight, skinfold thickness and energy balance, which have helped in evaluating the nutritional requirements of men working in polar regions.

On the British North Greenland Expedition (BNGE, 1952–4) Lewis, Masterton & Rosenbaum (1960) found an overall increase of 1.5 kg in body-weight during 1 year with marked seasonal fluctuation. Estimates of food intake on the same expedition showed that men were eating 3000–4000 kcal/day at the base camp but also showed that an intake of 4800 kcal/man daily was insufficient to maintain calorie balance in men who were sledging (Masterton, Lewis & Widdowson, 1957). On the Norwegian–British–Swedish Expedition (NBSE, 1949–52), Wilson (1960) noticed a similar weight increase of 3 kg over 2 years, with seasonal variations. Milan & Rodahl (1961) studied the calorie balance of International Geophysical Year scientists and US naval personnel working in the Antarctic. They showed differences in daily calorie intake between 3400 and 4900 kcal/man depending on the time of year and the activity of the men. They also recorded an overall increase in body-weight, and showed that it could be accounted for by a calorie intake in excess of energy expenditure.

It is now generally agreed that seasonal fluctuations in weight and skinfold thickness reflect the activity patterns of men involved in strenuous outdoor activity during the summer but remaining relatively inactive during the winter; this has been confirmed by Goldsmith (1959), who showed no seasonal variation in the men of the advance party of the Commonwealth Transantarctic Expedition who were forced by circumstances to work out-of-doors on restricted rations throughout the polar winter.

It has been noticed on several occasions that men have lost weight during sledging journeys and have rapidly regained it on return to base. Usually it has been assumed that such sudden changes in weight could only be accounted for by changes in fluid balance. Massey (1956) demonstrated a mean weight loss of 5 kg in nine men after sledge journeys lasting from 30 to 85 days on diets yielding 4100 kcal/man daily. During the 1st day after returning to base there was an average increase of 1.4 kg with a further increase of 1.4 kg by the 5th day. Massey found parallel changes in skinfold

thickness. From these findings he postulated that loss of weight during sledging journeys was due to dehydration and loss of fat. Wilson (1960) observed a loss of weight of 3 kg during a 40-day sledge journey when 4200 kcal/man was the daily ration. He considered that a 3 kg weight loss could be expected for men involved in strenuous physical activity and surmized that sweating, increased respiration and a disinclination to replace fluid losses caused dehydration and a consequent loss of 5 % of body-weight. Norman (1960) showed that men expended about 5055 kcal/man daily when sledging and also that they increased their fluid intake. He could demonstrate no dramatic change in fluid balance on return to base.

The experiments now described were designed to clarify some of the problems of weight change and calorie balance in Antarctica.

EXPERIMENTAL AND RESULTS

The experiments were carried out at Hope Bay, a British Antarctic Survey sledging base, situated at the northern tip of Grahamland (lat. 63° 24' S, long. 56° 59' W). They covered 2 years, and thirty men were involved altogether.

Subjects

The mean age of the thirty subjects was 26 years (range 19–38). Nine men were over 183 cm (6 ft) in height and the mean was 178 cm: the shortest man was 165 cm and the tallest was 185 cm. The mean weight of the men was 73.25 kg with a range of 90.75–58.25 kg. Skinfold thickness ranged between 12.3 mm and 4.9 mm with a mean of 8.1 mm.

The relatively low latitude of Hope Bay made it possible to travel throughout the year and all personnel from geologists to diesel-electric mechanics spent an average of 45 % of their time away from base. Men travelled with dog teams in parties of two or three and journeys lasted from 2 weeks to 4 months.

Diet

The food at base was varied and plentiful. Mostly tinned or dehydrated, it was liberally supplemented with fresh seal and penguin flesh and with frozen beef and mutton.

The sledging diet was standard and uniform. A box weighing 24 kg contained rations for two men for 10 days: there were small variations from year to year. In 1958 this ration supplied 3900 kcal and in 1959 4100 kcal/man daily. Supplementary rations of biscuits, coffee, chocolate and luxury items were carried if the sledge loads and length of the journey allowed.

A number of experimental boxes were prepared by the Medical Research Council each year (Lewis, de Jong & Harries, 1963). These boxes were heavier (28 kg) than the routine boxes (24 kg) but they provided more calories (5300 kcal/man daily) and greater variety. Though many of the additions were appreciated, most men, especially if they were travelling hard, found the wide variety and the complexities of modern packaging no improvement on the previous simplicity.

Water was obtained by melting snow and ice and, with few fuel restrictions, was always abundant. The daily intake of water on sledging journeys ranged between 1500 ml and 4000 ml/man.

Body-weight

All the men were weighed when they were on base at approximately monthly intervals. They were weighed in pyjama trousers to the nearest 0.25 kg in the morning after urinating. An average was taken of all the base measurements of each subject: this was called his average base weight and formed a base-line for comparisons. Salter bathroom scales (Windsor pattern) were carried on certain sledge journeys and early morning measurements were made in the tent.

Skinfold thickness

Measurements of a double layer of skin and subcutaneous tissue were taken with Harpenden springloaded calipers (Edwards, Hammond, Healy, Tanner & Whitehouse, 1955). The men were often in either cold or uncomfortable situations and it was important to choose sites that were accessible as well as reasonably representative. The five sites that were finally used were:

- outer arm, between deltoid and elbow;
- chest, anterior axillary line 2.5 cm above the nipple;
- abdomen, 2.5 cm to the side of the umbilicus;
- back, over the inferior tip of the scapula;
- cheek, full thickness over the opening of Stensen's duct.

All measurements were taken on the left side of the body. Each site was remeasured, and from the mean of all five sites a figure for each man's average base skinfold thickness was calculated in the same way as for the body-weights. Only changes greater than 0.4 mm were considered to be outside the range of experimental error.

The calipers were also carried on certain sledging journeys and measurements were made at the same time as men were weighed.

Fluid balance

Fluid intake and urine output were measured during and after certain sledging journeys. Fluid intake was comparatively simple to measure as the sledging rations were all dehydrated. Mugs were calibrated for each member of the party and the amount of melted snow added to food or drinks was recorded to the nearest 10 ml. Urine was passed into 2 l. calibrated Polythene bottles and a record of the 24 h sample was kept. Specific gravity of early morning samples of urine was measured as often as possible. No attempt was made to calculate or assess extrarenal fluid loss.

Base measurements

A comparison of all measurements taken in any one month over 2 years gives an indication of any seasonal variation that might have occurred. The measurements are presented as percentage means for all the men involved (Table 1). It will be seen that there was little fluctuation in body-weight during 2 years (range 98–103 % of base

average) but that very much higher readings (112 and 109%) were recorded for skinfold thickness in April of both years, with low readings between July and January.

It was possible to follow twenty subjects for 1 year from the time they arrived on base (Table 2). Again there was little change in body-weight throughout the year but a sharp fall in skinfold thickness after the 2nd month of residence in Antarctica. Most of the subjects had become involved in cargo hauling and sledging activities by this time and the skinfold measurements remained at the lower level for the remainder of the year.

Table 1. *Comparison of body-weight and skinfold thickness of a total of thirty men measured over 2 years at an Antarctic sledging base*

Month	1959									1960						1961							
	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
No. of subjects involved	17	12	13	17	3	0	0	16	8	10	14	13	6	10	10	7	11	5	11	11	8	0	13
Body-weight (% base average)	99	100	101	99	99	—	—	100	98	99	100	100	100	100	101	100	99	100	103	102	101	—	100
Skinfold thickness (% base average)	112	107	101	94	99	—	—	99	95	96	101	104	109	99	100	101	99	—	97	99	91	—	95

Table 2. *Comparison of body-weight and skinfold thickness of a total of twenty men measured over 1 year at an Antarctic sledging base*

Months of residence in Antarctica	1	2	3	4	5	6	7	8	9	10	11	12	13
No. of subjects involved	20	12	13	11	7	5	1	12	6	4	8	5	3
Body-weight (% base average)	100	100	100	100	100			100			101		
Skinfold thickness (% base average)	110	109	100	98	100			97			96		

Measurements after sledging

Body-weight and skinfold thickness of two parties returning to base from sledging journeys were measured immediately they had arrived and before they had had anything to eat or drink. During the next 4 days they were measured in the mornings. The members of the first party were 5.25 kg below their base average weights on the evening of their return after 42 days on sledging rations (Table 3). The following morning they had put on 1 kg and by the 3rd morning 3.5 kg.

Their skinfold thickness measurements were 1.0 mm below their base average and rose steadily on return.

The two men who made up the second party were 3.5 kg below their base average

weight after 40 days on sledging rations (Table 4). The following morning they had gained 2.25 kg and by the 2nd morning they had gained 4.25 kg. The skinfold measurements fluctuated within 0.4 mm of their base average. The records of these two parties established the fact that men could put on weight surprisingly quickly when they returned from sledging journeys, and in the subsequent experiments the problem was studied in more detail.

Table 3. *Changes in weight and skinfold thickness of three men after sledging in the Antarctic on sledging rations*

Subject	Base average	Sledging (42nd day)	At base			
			43rd day	44th day	45th day	46th day
Body-weight (kg)						
FK	69.5	63.0	64.0	—	67.5	66.5
RT	80.25	75.5	76.5	78.75	78.5	78.25
JA	69.0	64.5	66.0	68.0	68.0	69.0
Mean	73.0	67.75	68.75	—	71.25	71.25
Skinfold thickness (mm)						
FK	4.9	3.7	3.8	—	3.9	4.0
RT	10.2	9.2	9.7	9.7	10.2	11.5
JA	9.2	8.4	8.6	8.8	8.7	9.4
Mean	8.1	7.1	7.4	—	7.6	8.3

Table 4. *Changes in weight and skinfold thickness of two men after sledging in the Antarctic on sledging rations*

Subject	Base average	Sledging (40th day)	At base			
			41st day	42nd day	43rd day	44th day
Body-weight (kg)						
KA	70.5	66.5	69.25	71.25	70.0	71.25
FK	69.5	66.5	68.25	70.25	69.5	71.0
Mean	70.0	66.5	68.75	70.75	69.75	71.25
Skinfold thickness (mm)						
KA	5.9	6.0	5.8	6.1	5.8	6.2
FK	4.9	4.9	4.9	4.9	4.9	4.3
Mean	5.4	5.5	5.4	5.5	5.4	5.8

Journey I

Two men travelled 650 km in 19 days in the spring (November). They ate the routine ration supplying 3900 kcal/day for the first 16 days and then, while still travelling 32 km/day, they ate as much as they wanted from the ration boxes. During the first 2 days of recuperation their intake rose to over 9000 kcal/day. Fluid intake and urine output were measured daily.

At the end of 16 days on the strict ration the two men were very hungry, and were 2.25 kg below their base average. The 1st day after eating to capacity the men had

gained 1.75 kg; by the 2nd day they had regained their base average and on the 3rd day there was again a drop of 0.5 kg (Table 5).

There were only small fluctuations of skinfold thickness, within 0.4 mm, throughout the journey.

Fluid intake ranged between 1810 and 3375 ml/day while the men were travelling and dieting. The mean daily intake of the two men was 2672 ml/man. During the 1st day of unlimited food the fluid intake was 3125 ml/man.

Daily urine output varied between 875 and 2725 ml with a mean of 1647 ml/man when the men were on a restricted diet. Subsequent urine outputs were, if anything, slightly higher than before.

Urine specific gravity was measured on 6 mornings and averaged 1023 with a range of 1018–1024.

This journey showed that men travelling hard and eating only the routine daily ration of 3900 kcal lost weight. There was no evidence of dehydration during this time. When food became unlimited the men's daily intake of dry food increased to 9000 kcal with associated increases in body-weight and no significant change in fluid intake.

Table 5. *Sledging journey 1: mean values for two men when eating to capacity from sledging rations from the 16th day*

	Base average	Sledging (16th day)	Sledging (17th day)	Sledging (18th day)	Sledging (19th day)
Body-weight (kg)	75.25	73.00	74.75	75.5	75.0
Skinfold thickness (mm)	5.3	4.9	4.9	5.0	5.0
		(Mean of 29)			
Fluid intake (ml)	—	2672	3125	3563	2932
Urine output (ml)	—	1647	1937	1813	2025
Difference (ml)	—	1025	1188	1750	907
Urine sp.gr.	—	1023	—	—	—
		(Mean of 6)			

Journey 2

Two men repeated the conditions of journey 1 as nearly as possible in the early winter (May). They travelled 260 km in 15 days. During the first 13 days they rationed themselves to routine boxes yielding 4100 kcal/man daily. Then, while still travelling, they ate as much as they wanted with a daily intake of between 8000 and 9000 kcal/man.

On the 13th day of restricted diet the men were 3.25 kg below their base average. The following day, with unlimited food intake they had gained 2 kg and on the next day a further 0.5 kg (Table 6).

Skinfold thicknesses were 0.5 mm below the base average on the 13th day and fluctuated within 0.1–0.3 mm after recuperation.

The daily fluid intake while sledging on a restricted diet varied between 2300 and 3500 ml/man with an average of 2915 ml/man. The fluid intake on the 1st day of unlimited food was 2978 ml/man and on the next day was 2812 ml/man.

Daily urine output varied between 950 and 3600 ml/man with an average of 2025 ml/

man. With unlimited food intake the urine output was 1750 ml/man on the 1st day and 1950 ml/man on the 2nd day.

Urine specific gravity varied between 1019 and 1031, with a mean of 1025. Both men collected early morning specimens subsequently on base and found a mean specific gravity over 10 days of 1024.

The findings on this journey confirmed those of the previous journey in showing that men lost weight on sledging journeys when they confined themselves to rations yielding 4100 kcal/day or less. There was no evidence of dehydration during either journey. The rapid gain in weight when food became unlimited, although the men were still travelling, could be associated with an increase in the amount of food eaten rather than with any very dramatic change in water balance. Skinfold changes showed a drop while men were travelling on a restricted diet but no great change when the diet became unlimited.

Table 6. *Sledging journey 2: mean values for two men when eating to capacity from sledging rations from the 13th day*

	Base average	Sledging (13th day)	Sledging (14th day)	Sledging (15th day)
Body-weight (kg)	80.75	77.50	79.50	80.00
Skinfold thickness (mm)	8.0	7.5	7.4	7.5
	(Mean of 18)			
Fluid intake (ml)	—	2915	2978	2812
Urine output (ml)	—	2025	1750	1950
Difference (ml)	—	890	1228	862
Urine sp.gr.	—	1025	1022	1029

Journey 3

Three men travelled 400 km in 70 days during a survey journey in late winter and early spring (August–October). The routine ration of 3900 kcal/day was liberally supplemented with extra biscuits, chocolate and pea flour to yield about 5000 kcal/day. As the party broke up and continued to travel at the end of 70 days no base measurements after sledging were possible.

At the end of 70 days on a supplemented sledging diet the mean weight of the three subjects was 0.25 kg above their base average. Skinfold measurements differed from the base average by between 0.1 and 0.3 mm (Table 7).

Fluid intake varied between 1625 and 3750 ml/day (mean 2532 ml/day) and urine output varied between 875 and 2750 ml/day (mean 1470 ml/day).

The specific gravity of the early morning urine sample varied between 1011 and 1032 (an average of 1023), and fluid balance measurements during this and the previous journeys gave no indication of dehydration during sledging journeys: the men lost virtually no weight after 70 days on a generously supplemented sledging ration.

The experiment showed that it was not necessary for sledgers to lose weight if their ration was adequately supplemented.

Table 7. *Sledging journey 3: mean values for three men on the 70th day when eating to capacity from sledging rations*

	Base average	Sledging (70th day)
Body-weight (kg)	71.25	71.5
Skinfold thickness (mm)	5.7	5.8
(Mean of 18)		
Fluid intake (ml)	—	2532
Urine output (ml)	—	1470
Difference (ml)	—	1062
Urine sp.gr.	—	1023

Journey 4

Three men, with three dog teams, travelled 650 km in 19 days in early summer (November). They based their rations on three MRC Mark IV ration boxes (Lewis *et al.* 1963). The addition of a few luxury items, which were carried separately, brought the daily intake over 18 days to about 5600 kcal/man.

After 18 days of hard travelling the mean weight of the three men was 84.0 kg, identical with their base average.

Skinfold thickness measurements showed a distinct drop in all three subjects, from a mean value of 9 to one of 7.6 mm. The party broke up at the end of the journey so that recuperative base measurements were not taken.

This experiment confirmed the findings of previous workers who have postulated that an adequate sledging diet should supply between 5000 and 5500 kcal/man daily if it is to maintain body-weight. The fall in skinfold thickness reflected loss of fat associated with strenuous physical exercise.

DISCUSSION

Body-weight

Little overall increase was recorded over 2 years. But, unlike most polar explorers, the subjects were involved in comparatively strenuous outdoor activity all the year round and this was reflected in the absence of the seasonal fluctuations which have been reported previously.

Individual variations in body-weight were, however, recorded when men were involved in sledging journeys. Previously these weight changes have been largely attributed to changes in the body's hydration. Measurements of fluid intake and urine output gave no indication that the men were either dehydrated while they were travelling or that they retained more fluid on return to base. Though no doubt there were changes in water balance when there were changes in the composition or the quantity of the rations, these were not large enough to be detected and were certainly not responsible for measurable changes in weight.

Men lost weight when travelling on a diet yielding 3900 kcal/day and lost little or no weight when travelling under similar conditions on a diet yielding 5000–5600 kcal/day. One can only deduce that the main cause of weight loss was a calorie deficit.

Some other mechanism than calorie imbalance must have been responsible for the sudden increases in weight that were demonstrated when men who had been rationing themselves to the routine sledging diet took unlimited food. On the sledging diet most men were hungry and when they found supplies of unlimited and varied food they ate voraciously. The same voracity has been noticed in released prisoners of war, and in students subjected to experimental semi-starvation. Widdowson (1951) during her experiments in Wuppertal at the end of the Second World War, reported that prisoners released from Russia were eating daily up to 9 lb of solid food and 3 pints of soup. Murray (1947) reported that men liberated from German prison camps were eating daily up to 8000 kcal, and the subjects of the Minnesota experiment (Keys, Brožek, Henschel, Nickelsen & Taylor, 1950), when they were allowed unlimited food after 6 months of experimental semi-starvation, were eating daily up to 11 000 kcal.

During the experiments described here, though conditions were by no means so rigorous, the subjects ate daily up to 8000 or 9000 kcal during the first 2 days that food became unlimited. This represented an increase of about 1.25 kg in the amount of dry food eaten, which, together with the extra fluid needed for its hydration, closely corresponded to the immediate gain in weight.

Skinfold thickness

It was originally assumed that when men in polar regions increased their body-weight and became fat it was due to a physiological response of the body to cold. However, detailed measurements of nutritional balance have shown that seasonal fluctuations in body-weight and skinfold thickness are more closely associated with changes in activity than directly with changes in temperature. Furthermore, Norman's (1960) work on man's 'microclimate' in Antarctica has shown that the polar explorer, when properly clothed, is exposed to remarkably little cold stress.

In the experiments described here, though there was little change in body-weight throughout the year, there was a distinct decrease in skinfold thickness during the first 2 or 3 months of residence in Antarctica. The decrease in skinfold thickness could well have been the result of increased activity, and the maintenance of body-weight could have been the result of muscular development also associated with increased activity.

During sledging journeys there was usually a decrease in skinfold thickness, which again reflected increased activity. At the end of sledge journeys, when the body-weight increased sharply there was no sharp change in the skinfold thickness, which tended to increase slowly and gradually if the subject remained on base. The steady increase in skinfold thickness suggests that fat was being stored when unlimited food made it possible.

Fluid balance

It has been shown experimentally that under conditions of moderate work man's fluid intake may vary between 2000 and 4500 ml/day (Bard, 1941). McCance, Young & Black (1943-4), in experiments on dehydration and controlled rehydration, showed that dehydrated subjects passed between 335 and 864 ml urine/day, with a specific

gravity of 1.030 and over. With controlled rehydration they showed a very large increase in water consumption and a temporary fall in urine output until rehydration was complete.

During sledging journeys the daily fluid intake varied between 1500 and 4000 ml and the daily urine output between about 850 and 3000 ml and showed none of the signs, in either quantity or concentration, of dehydration. There was certainly no great increase in fluid intake on return to base or when food became unlimited.

Diet

There is still considerable difference of opinion as to what constitutes the ideal polar diet. Frazier (1945) reporting on physiological work undertaken during the establishment of Little America III stated that appetites were increased by the cold. Johnson & Kark (1947) compared the diets suitable for troops operating in the tropics and in polar regions and suggested that as much as an additional 2000 kcal/man daily or more was required by men working in the cold. Webster (1952) has calculated that men exposed to temperatures of -30° F would expend as much as 1000 kcal in warming and humidifying the expired air alone. And yet, more recently Iampietro, Bass & Buskirk (1957) after conducting cold-chamber experiments in America have stated that there was no evidence that cold stress imposed additional calorie requirements apart from those resulting from increased muscle activity.

Whether their large appetites are the result of climatic changes or of increased activity or of both, it is certain that men on polar expeditions need a large calorie intake if they are to maintain their body-weight. The exact calorie requirement depends on the size of the man and the work in which he is involved, and there has possibly been a tendency in the past to overstandardize diets so that all men, large and small, active and static, have been given the same ration. Though 3000–4000 kcal/day have supplied the needs of men on base, it was found during the trials under discussion that 5500 kcal/day were just sufficient to maintain the body-weights of large men who were travelling hard.

The composition of the ideal diet is also subject to individual variations. With the great emphasis on pemmican during the early days of Antarctic exploration, the diets probably consisted of between 22 and 33 % protein. And though the rations yielded about 5000 kcal/man daily much of it may have been wasted. McLean (1919) said that fat was necessary in an Antarctic diet, and both Butson (1950) and Masterton *et al.* (1957) have shown that a high-fat diet was well tolerated and absorbed under polar conditions. Mitchell, Glickman, Lambert, Keeton & Fahnestock (1946) studied the effects of various diets on man's tolerance to cold and showed that foods high in carbohydrate or fat were preferable to high-protein foods. They also showed that small meals at short intervals were more successful than large meals separated by the usual 4–6 h intervals. A number of men, either through force of circumstances or for preference, have existed in the Arctic and in the Antarctic on a diet consisting almost entirely of fat and protein and appear to have thrived (Nansen, 1898; Stefansson, 1921).

A critical assessment of some of the more successful sledging diets which have been

Table 8. *A comparison of sledging rations (oz/man day) used on various expeditions*

	Winter journey, 1911 (Scott, 1913)	Scott's Summit ration, 1911-12 (Scott, 1913)	Mawson, 1911 (McLean, 1919)	Arctic Air Route, 1930-1 (Lindsay, 1932)	British Grahamland Expedition, 1934-7 (Rymill, 1938)	Falkland Island Dependencies Survey, 1948-50 (Fuchs, 1952)	Falkland Island Dependencies Survey, 1958 (Orr, 1963)	MRC Experimental Box, 1959 (Lewis <i>et al.</i> 1963)
Pemmican	12	12	8	8	5.6	5.6	—	—
Biscuit	16	16	12	4	2.7	3.75	4.8	4.0
Butter or margarine	4	2	2	8	5.6	4.8	4.8	5.0
Sugar	—	3	4	4	3.2	3.2	3.1	3.2
Cocoa	—	0.57	1	1	0.8	0.8	0.6	1.5
Tea	—	0.86	0.25	—	—	0.4	0.2	0.25
Chocolate	—	—	2	3	2.4	2.4	0.4	4.0
Milk	—	—	5	2	1.6	1.6	1.6	2.0
Pea flour	—	—	—	2	1.6	0.8	—	—
Oats	—	—	—	3	2.0	2.5	2.4	2.0
Potato powder	—	—	—	—	—	0.8	0.4	1.0
Onion flakes	—	—	—	—	—	0.4	0.4	0.1
Nescafe	—	—	—	—	—	0.2	—	0.25
Marmite	—	—	—	—	—	0.2	0.1	0.1
Bacon	—	—	—	—	—	—	0.8	—
Meat bar	—	—	—	—	—	—	5.0	6.0
Soup powder	—	—	—	—	—	—	1.0	1.0
Fruit bar	—	—	—	—	—	—	1.5	0.75
Curry powder	—	—	—	—	—	—	—	0.25
Cheese	—	—	—	—	—	—	—	2.0
Glucose lemon	—	—	—	—	—	—	—	1.0
Sweets	—	—	—	—	—	—	—	1.0
Pumpernickel	—	—	—	—	—	—	—	0.45
oz/man day	32	34.43	34.43	35	25.5	27.45	27.1	35.85
kcal/man day	5100	5100	5100	5500	4000	4100	3900	5400
Protein (%)	22	28	33	27	19	17	17	14
Fat (%)	42	31	25	34	38	38	37	25
Carbohydrates (%)	36	41	42	39	43	45	46	61

used over the years (Table 8) shows that they have yielded about 5000 kcal/man daily, of which about 20% was protein, 40% was fat and 40% was carbohydrate. These figures are remarkably similar to those given for the energy requirements during strenuous muscular exercises of Harvard football players, who required 5500 kcal to maintain their body-weight; about 12% of this requirement was provided by protein, 44% by carbohydrate and 44% by fat (Edwards, Thorndike & Dill, 1935).

If intelligent use is made of the food available on the base and of all the natural resources, vitamin supplements should be unnecessary in Antarctica. Sledging rations have provided little vitamin C except that in powdered milk. The addition of potato powder and dried onion brings the intake of vitamin C from the ration used in the experiments described here to just within acceptable limits, and the intake could be augmented by the addition of more milk, or jam or concentrated orange juice.

SUMMARY

1. Changes in body-weight and skinfold thickness were recorded in thirty men during a period of 2 years at an Antarctic sledging base. There was little overall change in body-weight but marked fluctuations in skinfold thickness. These fluctuations reflected different levels of activity rather than changes in temperature or season.

2. During four sledging journeys changes in body-weight and skinfold thickness were compared with those in calorie intake and fluid balance. The results of these experiments suggested that long-term changes in body-weight reflected a calorie imbalance, whereas sudden changes in body-weight reflected sudden changes in the bulk of the food eaten. There was no evidence of dehydration during sledging journeys and no marked increase in fluid intake on return to base.

3. The calorie intake needed to maintain body-weight varied very widely from man to man and depended on the size of the man and his activity. For most, 5000 kcal/man daily formed an excellent basis for a sledging ration, the composition of which varied again with individuals and with the environment in which they were working.

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