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Food intake in Antarctica

By D. L. EASTY

Division of Human Physiology, National Institute for Medical Research,
London, NW3

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1. Body-weight, skinfold thickness and food intake were measured at regular intervals in twenty-five young men while on an Antarctic expedition.

2. The mean calorie intake over the year was 3600 kcal/man per day; 12·1 % of these calories were supplied by protein, 39·8 % by fat, and 48·1 % by carbohydrate.

3. The calorie intake was equivalent to that which would be expected in a moderately active worker living in a temperate climate. The chemical composition of the diets did not differ from average values for young men in the United Kingdom.

4. There was a significant fall in food intake during the winter months, when the outside temperatures were greatly reduced and there was polar night. During this period the men were largely confined to the limits of the base hut and the levels of physical activity showed a marked fall.

5. During the year there was a gain in body-weight of 2·7 kg. Of this gain 2·5 kg occurred in the first 2 months.

6. Skinfold thickness followed the trend of the body-weights except for the April–May increment which was unaccompanied by a weight change. This dissociation could not be explained.

Observations concerning the influence of cold climates on food intake or body-weight have frequently been at variance. Suggestions that the calorie requirements lie well above 5000 kcal/man per day (Johnson, Crowley, Toth, Koehn & Monahan, 1949) are countered by those who maintain that the difference between consumption in cold and temperate environments is negligible (Gray, Consolazio & Kark, 1951). Furthermore, the evidence concerning the influence of the seasons on food intake appears contradictory; an increased intake during the winter has been reported (Milan & Rodahl, 1961), while other observations have demonstrated a marked fall (Rodahl, 1949). A longitudinal survey was therefore performed to define the effect of a cold environment on food consumption, body-weight and skinfold thickness in a group of men living in the Antarctic.

METHODS

Environment

The observations were made at Halley Bay (75·36° S, 26·39° W), the British Antarctic Survey base on the coast of the Weddell Sea, during the 1961–2 expedition. Table 1 shows the environmental conditions throughout the year. The mean monthly wind speed showed little variation and remained close to the mean level of 10 knots. During the winter months, the men were largely confined to the living quarters, when the ambient temperature ranged from 10–20°.

Table 1. *Meteorological data for Halley Bay: the year has been divided into three seasons*

	Monthly mean temperature (°C)	Mean monthly maximum temperature of daily extremes (°C)	Mean monthly minimum temperature of daily extremes (°C)	Wind speed monthly mean (knots)	Mean no. of hours of daylight
Summer 1					
Feb. 1961	−11·3	− 7·1	−15·7	10	24
Mar.	−17·6	−12·1	−22·0	14	14
Apr.	−22·9	−18·0	−28·0	12	7
Winter					
May	−19·7	−14·2	−24·6	18	0
June	−33·1	−27·1	−38·7	11	0
July	−32·7	−27·2	−38·4	8	0
Aug.	−32·3	−25·5	−38·4	10	0
Sept.	−28·8	−22·2	−34·8	9	12
Summer 2					
Oct.	−14·2	−10·3	−18·6	21	17
Nov.	−12·4	− 7·3	−16·2	10	24
Dec.	− 5·8	− 3·3	− 8·5	12	24
Jan. 1962	− 4·9	− 2·9	− 8·5	8	24

Table 2. *Physical characteristics of the expedition members, with the mean daily food consumption*

						% of total calories		
Subject	Age (years)	Body-weight in Feb. 1961 (kg)	Height (cm)	Mean skinfold thickness (mm)	Mean food intake* (kcal)	Protein	Fat	Carbo-hydrate
D.A.	23	81·7	181·5	12·5	3987 ± 536	10·6	43·7	45·6
G.B.	26	100·4	191·5	29·5	4182 ± 1035	11·5	39·3	49·2
M.B.	25	69·9	177·4	9·9	3113 ± 263	12·3	38·2	49·4
C.D.	22	87·2	175·0	12·2	3346 ± 477	13·5	41·9	44·5
E.D.	25	80·3	174·8	8·8	3628 ± 238	13·0	37·5	49·5
D.E.D.	25	93·9	194·0	8·0	5259 ± 546	10·6	34·3	55·0
D.E.	27	73·1	179·3	7·5	3589 ± 586	11·3	42·6	46·1
M.T.H.	23	85·4	190·5	9·5	4625 ± 1483	10·2	47·5	42·2
C.J.	30	72·1	182·0	6·5	3922 ± 1136	11·4	37·9	50·6
E.J.	24	77·8	170·6	9·3	2749 ± 892	11·1	37·6	51·3
D.J.	25	66·1	178·1	7·1	3227 ± 395	11·2	36·8	51·9
M.J.	27	67·0	172·2	7·4	3634 ± 564	12·7	38·1	49·2
R.L.	22	95·4	186·0	12·4	5122 ± 902	10·7	45·6	43·2
A.M.	23	66·3	179·9	6·1	3784 ± 651	11·1	39·4	49·5
G.M.	25	70·9	171·6	11·5	2671 ± 555	13·2	38·2	48·6
S.M.	22	62·0	173·3	6·3	3588 ± 777	15·1	36·6	48·3
P.N.	27	72·4	174·5	13·2	3604 ± 432	13·0	45·3	41·7
A.P.	34	68·2	176·4	6·9	3562 ± 641	10·8	40·0	49·2
B.P.	23	66·9	181·8	7·0	3496 ± 792	12·1	36·0	52·0
M.B.R.	26	70·8	165·9	11·3	3000 ± 572	10·7	38·7	50·6
J.S.	25	66·7	171·6	7·8	3401 ± 631	12·5	40·2	47·3
M.S.	25	61·9	179·8	7·3	3312 ± 536	12·2	40·3	47·5
E.T.	22	66·1	175·8	9·6	2854 ± 820	10·3	39·4	50·3
G.T.	26	60·4	177·2	6·3	3357 ± 334	13·4	42·5	44·1
M.T.	25	77·6	179·8	11·3	2911 ± 589	13·9	39·2	46·9

* Mean values with standard deviations.

Subjects

All twenty-five members of the expedition volunteered as subjects, the average age being 24·5 years (range 22–34), the average height 179·6 cm (range 166–194 cm) and the average body-weight at the initiation of the experiment being 74·2 kg, ranging between 60·4 and 100·4 kg (Table 2). The occupations of the subjects fell roughly into four groups: scientists, technicians, manual workers and cooks. The manual workers did the hardest work, while the work of the scientists was mainly sedentary. The energy expenditure of the other groups was intermediate. The distinction in the type of work done was not rigid, particularly during the first 2 months when all members of the expedition helped in the construction of extensive living accommodation.

The life of the expedition revolved around the seasonal change in the amount of daylight and outside temperatures. During the summer months the men sought outside activity, involving the scheduled programmes such as building, maintenance and repair, the digging out of deeply endrifted food boxes and oil drums, long- and short-distance sledging journeys for reconnoitring and surveying, or more relaxing pastimes such as skiing and long walks. In the winter months the community was forced back into the confines of the base huts; occupations either fell into routine programmes followed throughout the year, for example the recording of meteorological, ionospheric, and auroral observations, or into the performance of extensive interior reconstruction and decoration, the maintenance of intricate scientific instruments, the overhaul of diesel motors, and the repair of the mechanized track vehicles vital in the running of an Antarctic base. Further, hobbies such as carpentry and photography played an important part in relieving the dull winter routine. Towards the end, the psychological tensions resulting from boredom and inactivity became a recognizable hazard in the life of the expedition.

Measurement of body-weight and skinfold thickness

At monthly intervals the nude subjects, after urinating, were weighed on a steelyard bench platform scale (Avery) accurate to ± 50 g. Skinfold thickness was measured at the same time, with the Harpenden spring-loaded caliper at a pressure of 1020 g, to an accuracy of ± 0·1 mm (Edwards, Hammond, Healy, Tanner & Whitehouse, 1955). Measurements were made at the following sites: pectoral, lateral arm, scapula, abdominal and the lateral side of the thigh (Lewis, Masterton & Rosenbaum, 1960). Some difficulty was experienced in measuring the skinfold on the lateral side of the thigh owing to the adherence of the skin to deep fascia and also to the marked variation in the transverse circumferential plane in the amount of subcutaneous fat of the thigh. Each monthly reading at each site was the mean of five individual measurements.

Dietary survey

The food supply throughout the year was plentiful. The men could always consume as much as they pleased, and there was never any restriction or rationing. However, there was a tendency to become bored with the largely tinned or dehydrated diet and the subjects periodically expressed the desire for more fresh food. The survey was carried out by weighing the total food intake for one subject each day. In this way each subject was observed every 6 weeks, and a total of 200 estimations was made during the year.

All the food eaten by the subjects in the dining room was weighed in the kitchen before the meal began on a dietary balance accurate to ± 2 g. At the end of the meal plate waste was removed by scraping and was weighed. The constituents of the prepared dishes were accurately measured. Allowances were made for change in weight as a result of cooking.

A relatively large amount of food was consumed as snacks during tea breaks in the morning, afternoon and evening. The subjects themselves weighed the food eaten during the snacks and recorded the quantity on diary cards.

The dietary intakes were calculated as protein, fat and carbohydrate in grams and as total calories. The percentage composition and calorie equivalent were obtained from the tables of McCance & Widdowson (1946).

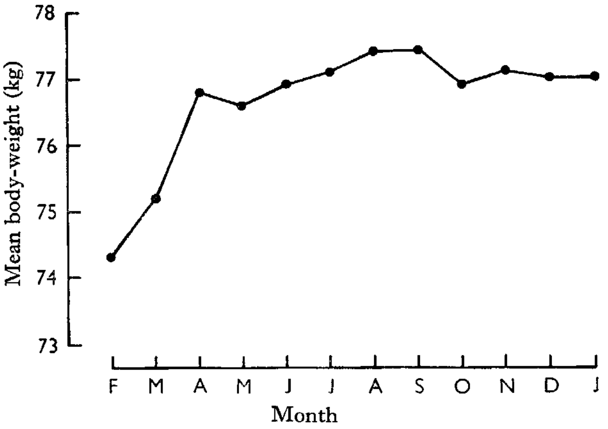

Fig. 1. Mean monthly assessments of body-weight for twenty-five members of the expedition.

RESULTS

Body-weight

During the year, the mean weight of the group rose by 2·7 kg ($P < 0·001$). Of this, the largest gain of 2·5 kg occurred during the first 2 months of the year of observation; there was a further increase of 0·6 kg between May and August (non-significant) and a loss of 0·4 kg in the remaining months (non-significant, see Fig. 1).

Skinfold thickness

Fig. 2 demonstrates the monthly mean values of skinfold thickness at four sites as a log transformation of the original units of measurement (Edwards *et al.* 1955). The rise which occurred between February and May was significant for the sites demonstrated ($P < 0·001$), but was non-significant for measurements taken from the lateral side of the thigh over the same period. The monthly mean skinfold thickness values for all the subjects, for the four sites which showed significant changes during the period February 1961 to January 1962, in the original units of measurement, were: 7·8, 8·3, 8·7, 9·5, 9·1, 9·3, 9·3, 9·3, 9·2, 9·2, 9·3 and 9·3 mm.

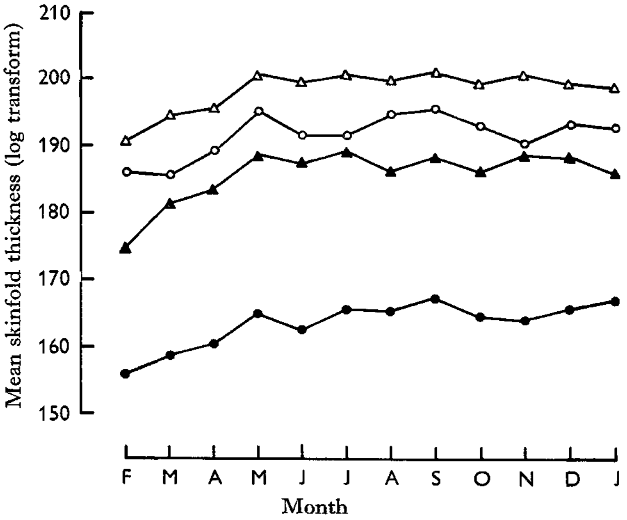

Fig. 2. Mean monthly skinfold thickness readings for twenty-five subjects, expressed as the log transform of the original units of measurement. ●——●, pectoral site; ▲——▲, abdominal site; ○——○, lateral arm site; △——△, scapular site. The non-significant changes in skinfold thickness on the lateral side of the thigh are not shown.

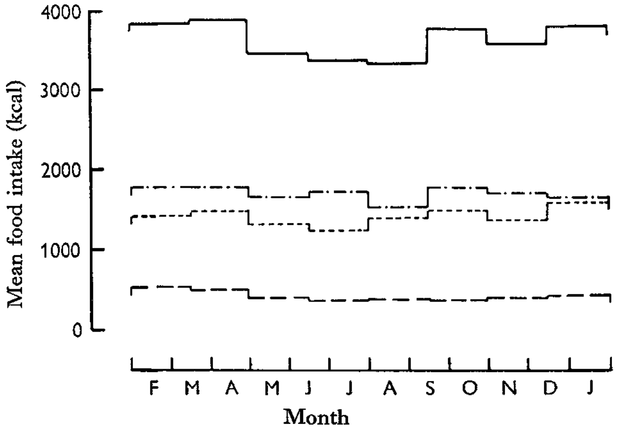

Fig. 3. Mean food intake, with the intake of protein, fat and carbohydrate, expressed as kcal for each dietary period. ——, total calories; —·—·—, carbohydrate calories; -----, fat calories; – – – –, protein calories.

Dietary survey

The mean daily food intake of all subjects for the year provided 3600 kcal/man per day; 12·1 % of these calories came from protein, 39·8 % from fat, and 48·1 % from carbohydrate. The mean individual intake varied between a minimum of 2700 kcal/man per day and a maximum of 5200 kcal/man per day (Table 2).

In Table 3 the calorie consumption of four occupational groups has been shown.

It is seen that the technicians had the lowest intake, and that the manual workers had the highest intake, as would have been expected. The only significant difference occurred between the manual workers and the technicians ($P < 0{\cdot}002$).

Table 3. *Estimated food intakes for four occupational groups in Antarctica*

Occupational group*	Total number of single estimations of food intake	Mean body-weight in Feb. 1961 (kg)	Mean food intake (kcal/day)	% of total calories			Calorie intake calculated for a standard reference man of 70 kg (kcal/day)
				Protein	Fat	Carbohydrate	
Manual workers (6)	48	78·1	4115	11·9	39·7	48·4	3612
Technicians (8)	64	70·1	3152	11·7	39·6	48·7	3143
Scientists (9)	72	77·1	3729	12·2	40·4	47·4	3262
Cooks (2)	16	70·4	3227	12·2	38·8	49·1	3213

* Figures in parentheses are the numbers of subjects.

Table 4. *Seasonal change in calorie intake at Halley Bay*

	Summer 1	Winter	Summer 2
Total calories* (kcal/day)	3850 ± 917	3363 ± 889	3663 ± 926
Protein (% total calories)	13·9	11·4	11·1
Fat (% total calories)	38·9	39·6	41·6
Carbohydrate (% total calories)	47·2	49·1	47·3

* Mean value with standard deviation.

The standard deviation of the grand mean of all assessments of total calorie intake, namely 3600 kcal, was ± 929.

The changing levels of food intake over the whole year are shown in Fig. 3. These results suggested a seasonal effect in total food intake. In Table 4 the mean seasonal food intake and its constituents are shown. An analysis of variance was carried out to assess the significance of these effects. The fall of calorie intake from summer 1 to the winter was 486 kcal ($P < 0{\cdot}001$) and this fall resulted from a decrease in protein, fat and carbohydrate ($P < 0{\cdot}001$, $P < 0{\cdot}01$, and $P < 0{\cdot}01$ respectively). However, the rise of 300 kcal ($P < 0{\cdot}05$) in food consumption between the winter and summer 2 was due to an increase in the calories supplied by fat ($P < 0{\cdot}01$), there being no significant changes in the other two constituents. The between-men effects in the statistical analysis of the four parameters was significant for total calories and for fat and carbohydrate calories ($P < 0{\cdot}001$), but was non-significant for protein intake. The effects of the seasons can also be demonstrated in the four occupational groups. Thus, the manual workers showed a first summer intake of 4158 kcal/man per day, a winter intake of 3919 kcal, and a second summer consumption of 4210 kcal. Similarly, the respective intakes, per man per day, for the other groups were: technicians, 3320, 2874 and 3317 kcal; scientists, 4200, 3467, and 3675 kcal; cooks, 3450, 3120 and 3126 kcal.

DISCUSSION

The mean intake of 3600 kcal/man per day at Halley Bay contrasts with the findings of Johnson *et al.* (1949) and those of Swain, Toth, Consolazio, Fitzpatrick, Allen & Koehn (1949), who suggested that the calorie requirements in cold climates would be of the order of 5500 to 6000 kcal/man per day, both for men engaged in field operations and those on routine base duties. A marked increase in intake has also been reported in the papers of Johnson & Kark (1947) and of Kark, Croome, Cawthorpe, Bell, Bryans, MacBeth, Johnson, Consolazio, Poulin, Taylor & Cogswell (1948). However, in a survey of European trappers in Greenland by Rodahl (1949), the subjects maintained constant body-weight on an average gross consumption of 3000 kcal/man daily. Masterton, Lewis & Widdowson (1957) assessed the level for four men in Greenland as being 3911 kcal/man per day while on the base, and an intake of 4770 kcal/man per day for the same group when participating in a sledging expedition. The daily food requirement during sledging in the Antarctic was estimated by Orr (1965) to be approximately 5000 kcal.

The mean intake of the Halley Bay subjects is similar to levels reported for industrial workers (Bransby, 1954), Sandhurst cadets (Edholm, Fletcher, Widdowson & McCance, 1955), and army troops on exercise (Adam, Best, Edholm & Wolff, 1957). It is lower than the evaluation of 4030 kcal/man per day for miners (Garry, Passmore, Warnock & Durnin, 1955) and higher than the level of 2950 kcal/man per day for students (Kitchen, Passmore, Pyke & Warnock, 1949). Norman (1965) recorded detailed time and motion information on four scientists at Halley Bay during 1 year, from which he calculated the mean energy expenditure to be 3390 kcal/man per day, while the average level found by Masterton *et al.* (1957) was 3580 kcal/man per day. The food intake at Halley Bay is close to these latter results and corresponds to the expenditure which would be expected in a moderately active worker such as a carpenter.

Though the dietary intake of the manual worker at Halley Bay was equivalent to that of miners (Garry *et al.* 1955), the intake when recalculated for a standard reference man of 70 kg fell from 4115 to 3612 kcal/man per day (Table 3). The difference between the standardized intakes for manual workers and technicians was then found to be non-significant. It is apparent therefore that the significance of the difference in the unstandardized results was due to the excessive weight of the manual workers. The standardizep figures for the technicians, scientists and cooks are below the intake of clerks as reported by Garry *et al.* (1955), the latter result having been recalculated for a 70 kg man and found to be 3297 kcal/man per day.

The composition of the diet at Halley Bay did not differ from the figures given by the Ministry of Agriculture, Fisheries and Food: National Food Survey Committee (1962), which were 11·5, 39·3 and 49·3 % for protein, fat and carbohydrate respectively. Recently Morris, Marr, Heady, Mills & Pilkington (1963) have reported that the percentage of calories furnished by fat in ninety-nine bank men was 41 %, which is greater than the Halley Bay result. Hence, the percentage composition recorded in the expedition members is in agreement with the observations of Johnson & Kark (1946) that in Arctic environments the percentage of calories furnished by protein, fat and carbohydrate is not significantly different from that reported for troops eating garrison rations in temperate climates.

It has been shown in the laboratory that both fat and carbohydrate are of benefit to the living organism in its ability to tolerate or resist cold stress (Leblond, Dugal & Therien, 1944; Templeton & Ershoff, 1949). Recently, Beaton (1963) has shown that in the rat dietary protein may play an important role during exposure to cold. The fact that the intake of the Halley Bay group did not differ from the intake in the United Kingdom suggests that either no particular constituent is of benefit in the cold, or that cold stress was not great enough to influence the food choice of the expedition personnel. It has been shown that Halley Bay scientists spend 9% of their elapsed day out of doors (Norman, 1965), a finding which would substantiate the hypothesis of Edholm (1960) that there is little or no process of acclimatization to cold in man owing to his thermal isolation from the environment.

The winter fall in food intake was the expected result. During the period of darkness and low temperatures, activity was reduced. It shows agreement with the winter fall of 1300 kcal in the European trappers investigated by Rodahl (1949), this being to some extent due to self-imposed rationing. Furthermore, Norman (1965) reported a summer energy expenditure of 3770 kcal/man per day, with a winter expenditure of 3120 kcal, while the outside exposures for these periods were respectively 15% and 5% of the elapsed day. However, the opposite occurred in a dietary survey of personnel at Little America V who gained weight markedly on an increased calorie intake in the winter months (Milan & Rodahl, 1961). Though the scientists apparently led a more sedentary life, they nevertheless show a definite seasonal change in their food intake. The sharp fall between the first summer and the winter indicates the greater role played by the scientists in the preliminary building programme as compared with the technicians, the time of the latter group being filled with the performance of routine observations.

The tendency to consume a greater proportion of the food as protein calories in the first season may largely have resulted from psychogenic causes. The evidence that protein is consumed excessively or is necessary in men performing heavy work is unconvincing (Mayer & Bullen, 1959). Though the tinned meats were acceptable in the first months of the year, later the subjects became bored with the food, and the protein appears to have shown the winter fall more dramatically than the other two constituents. That the protein intake may be influenced by the presentation and cooking is possibly shown by the non-significant 'between-men' effect in the analysis of variance.

It is generally accepted that an increase in body-weight occurs on Antarctic expeditions. The manner in which such changes become manifest, however, is not always the same. Thus, Lewis *et al.* (1960) and Wilson (1960) noticed a seasonal effect upon body-weights, with a rise in the winter and a fall in the summer; B. Sparke (personal communication) reported a progressive weight increase throughout the year, and Orr (1965) observed virtually no increase at all. In more adverse circumstances, Goldsmith (1959) and Tikhomirov (1963) have reported a winter fall in body-weight. The Halley Bay gain occurred maximally in the first 2 months, after which the body-weight remained constant. The lack of agreement in the weight changes occurring during different expeditions therefore makes it unlikely that body-weight can be accepted as an index of cold acclimatization. On each expedition, it is apparent that the weight changes indicate either positive or negative calorie balance *per se* and are not physiologically related to adaptation to low temperatures.

During the period April to May, the skinfold thickness showed an increase which was unaccompanied by change in body-weight. Lewis, Masterton & Ferres (1958) reported positive correlation between changes in body-weight and skinfold thickness. Close perusal of their findings reveals that the respective maxima and minima do not coincide. Furthermore, a marked dissociation of these parameters was noticed by Orr (1965). In the present experiment the April–May increase in skinfold may have been due to the transfer of fat from one depot to another, e.g. the deep body fat to the subcutaneous fat. It is a possibility that cannot be excluded; however, whether the small increase can alter the body insulation to cold is arguable (LeBlanc, 1954). The dissociation of the changes in skinfold thickness and body-weight cannot be explained without further experimentation.

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