SEASONAL CHANGES IN BODY WEIGHT AND SKINFOLD THICKNESS

By A. G. Davies

Abstract. Measurements of body weight and skinfold thickness were made on four men stationed at Horseshoe and Stonington Islands, Marguerite Bay. It was found that weight and skinfold were not increased by exposure to low temperatures. Weight and skinfold were less during spring than during other seasons and this was associated with the greater amount of time spent on sledge journeys during spring. The men appeared to be in negative energy balance during sledge journeys. Urinary studies did not give evidence of cold diuresis or dehydration during sledging.

Before systematic observations were made, it was thought that the cold to which men on polar expeditions were exposed increased the amount of subcutaneous fat. Lewis and others (1960) reported that the body weight and skinfold thickness of the members of the British North Greenland Expedition were greatest during winter and suggested that this was due to a reduction in physical activity during winter. On the other hand, the weight and skinfold of the advance party of the Trans-Antarctic Expedition did not show seasonal changes (Goldsmith, 1959). These men experienced much exposure to cold during the winter but their level of physical activity remained more or less constant throughout the year.

This paper presents the results of an investigation into the pattern of changes in body weight and skinfold thickness of the 1960–61 party stationed at Horseshoe Island (lat. 67°51′S., long. 67°12′W.) and Stonington Island (lat. 68°11′S., long. 67°00′W.), Marguerite Bay.

Methods

Subjects

The four members of the party were aged 24, 26, 26 and 32 years. Before their year at Marguerite Bay three had been in the United Kingdom and one had been at Signy Island, South Orkney Islands.

Body weight

Measurements were made at as near to monthly intervals as the sledging programme allowed. Underpants were worn and the men were weighed, with empty bladders, before retiring to bed. An Avery 150 kg. beam balance was used and the weight of a standard was found to vary by no more than 50 g. throughout the year.

Skinfold thickness

A pair of Harpenden callipers (Edwards and others, 1955) was used, and measurements were made at five of the six sites recommended by Lewis and others (1960): namely, abdominal, pectoral, scapular, outer arm and outer thigh. Each set of measurements was repeated and the mean of the ten readings was used in subsequent calculations. The log transformation suggested by Edwards and others (1955) was not used because the standard error of differences between duplicate measurements was not found to vary with the thickness of the skinfold. The tension in the calliper spring remained constant at 960 g. and there was no monthly variation when the callipers were tested against standard thickness of steel.

Exposure temperature

Dry-bulb shade temperature was measured at 09.00 and 21.00 hr. local time. One subject's outdoor exposure temperature was estimated by relating the number of hours spent out-of-doors each day to the mean of the two temperature measurements for that day.

Dietary and urinary studies

All the food eaten by one subject during 12 consecutive days spent at the station during winter was recorded together with the amount of each type of food. The amounts, for example, "heaped tablespoon", "level teaspoon", were converted into weights after weighing sample quantities of the foods. The amounts of proximate principles, sodium and ascorbic acid were calculated from tables (Diem, 1962; McCance and Widdowson, 1960). The compositions of the meat bar and biscuits in the sledging ration were ascertained from the makers.

The total fluid intake was obtained by adding estimates of the water contents of the diets to measurements of fluid drunk. All the urine passed by two subjects during a continuous period of 32 days in winter was collected. The sixth to fourteenth and nineteenth to twenty-eighth days were spent on dog-sledge journeys, high winds causing the men to lie up for five of these days, and the remainder of the time was spent at the station. An aliquot of urine collected each day (09.00 to 21.00 hr.) and each night (21.00 to 09.00 hr.) from each subject was sealed into a polythene container. The samples were then kept frozen. On return to the United Kingdom the sodium and potassium levels were measured by flame photometry, and the chloride levels were measured by potentiometric titration with silver nitrate.

Results

Body weight and skinfold thickness at different seasons

Fig. 1 shows the monthly mean body weight and skinfold thickness of the party. Analyses of variance showed that the differences between months were significant ($P<0\cdot001$). When the data were grouped according to season, t-tests showed that the difference in weight between spring and each of the other seasons was significant ($P<0\cdot01$ to $P<0\cdot001$). The difference in skinfold thickness between autumn and each of the other seasons was significant ($P<0\cdot001$) and so were the differences between spring and winter ($P<0\cdot01$) and spring and summer ($P<0\cdot02$).

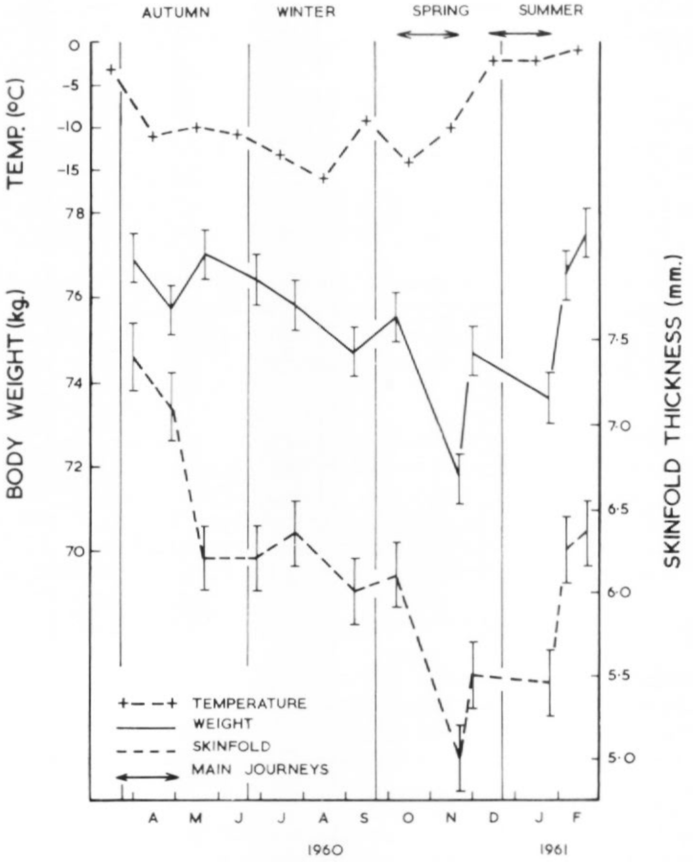

Fig. 1. Mean monthly outdoor temperatures and mean body weight and skinfold thickness of four men at Marguerite Bay during 1960–61. Ranges indicate twice the standard errors of the means.

There was good correlation between weight and skinfold measurements in each subject ($r = 0{\cdot}635$–$0{\cdot}818$, $P<0{\cdot}05$ to $<0{\cdot}01$).

Weight and skinfold changes during sledge journeys

On four dog-sledge journeys lasting between 10 and 49 days the mean weight loss was 3·1 kg. per man (range 1·0–6·3 kg. for 10 man-journeys) and the mean skinfold loss was 0·8 mm. (range: 0–1·8 mm. for 11 man-journeys).

Amount of sledging at different seasons

One subject spent the following number of days on sledge journeys: autumn 34, winter 10, spring 54, summer 34. Times were not recorded for the other subjects but the seasonal activities of the men were very similar and each man spent considerably more time on journeys during spring than during autumn, winter or summer.

Exposure to low temperatures during sledging

Records of the amount of time one subject spent outside at different environmental temperatures indicate that sledging increased both the proportion of time spent outside and the total time of exposure to low temperature (Table I). The large amount of time spent sledging during spring caused the proportion of time spent outside and the total time of exposure to low temperature to be greatest during this season (Table II).

TABLE I. ACTIVITY AND SELECTED EXPOSURE TEMPERATURE OF ONE MAN

Activity	*Proportion of time spent outside* (per cent)	*Mean outside exposure temperature* (° C)	*Proportion of time spent outside when temperature below* −10° C (per cent)
Journey (sledging days)	33·0	−10·5	15·3
Journey (non-sledging days)	5·7	−9·8	2·1
Station (sledging days)	26·5	−7·4	9·6
Station (non-sledging days)	6·4	−7·0	1·4
All activities	16·8	−9·3	6·8
Mean annual outdoor temperature		−9·2	

TABLE II. SEASON AND SELECTED EXPOSURE TEMPERATURE OF ONE MAN

Season	*Proportion of time spent outside* (per cent)	*Mean outside exposure temperature* (° C)	*Proportion of time spent outside when temperature below* −10° C (per cent)
Autumn	13·5	−12·0	6·9
Winter	7·8	−12·6	4·3
Spring	23·1	−10·6	13·0
Summer	22·3	−4·4	1·1
All seasons	16·8	−9·3	6·8

Intake and urinary excretion of water and sodium

It was estimated that the water content of the food eaten at the station was 700 ml./man/day, whereas the dehydrated sledging ration provided only 60 ml./man/day. The mean daily total fluid intake of the two subjects was a little greater at the station than when travelling ($P<0\cdot001$) or lying up ($P<0\cdot02$), and greater on lie-up days than on travel days ($P<0\cdot02$). The 24 hr. differences were due to differences in the day but not in the night volumes. The smallest 24 hr. urine volume was 900 ml.

The food survey at the station showed that one subject's intake of sodium was 203 mEq./day excluding salt added to food after serving. The total intake during the journeys was 120 mEq./man/day. The 24 hr. urine sodium content was greater at the station than when travelling or lying-up ($P<0\cdot001$) and the urinary sodium was greater, but not significantly greater, when lying up than when travelling. As with urine volume, the differences in 24 hr. urinary sodium level were due to changes in the day but not in the night collections.

Food intake

In Table III details of the diet of one subject at the station are compared with the standard sledging ration in use in 1960. The weight of the subject was 74·9 kg. at the beginning and end of the dietary survey.

TABLE III. DAILY FOOD INTAKE OF ONE MAN

Calories (kcal.)	*Protein* (percentage of kcal.)	*Fat* (percentage of kcal.)	*Carbohydrate* (percentage of kcal.)	*Sodium* (mEq.)	*Vitamin C* (mg.)
12 days' survey at station 3,300 (2,900–4,100)	9·8	42·0	48·2	203	19·4
Standard 1960 sledging ration 4,100	11·5	56·9	31·6	120	11·7

DISCUSSION

Correlation between weight and skinfold thickness

In each subject the correlation between body weight and skinfold thickness was statistically significant. Graham (1959) and Lewis and others (1960) found this, but Wyatt (1963) noted a significant correlation in only seven of his 12 subjects. Orr (1965) and Easty (1967) did not calculate correlation coefficients but the monthly means of Orr's measurements appear to correlate poorly, whereas Easty's appear to show moderately good correlation. Correlation is likely to be poor when the experimental error of skinfold measurement is relatively large and when weight changes are not due to changes in calorie balance, for example, when there are changes in hydration and possibly when there are changes in the mass of bowel contents. Without using a permanent mark such as a tattoo, it is very difficult to repeat measurements at exactly the same site on different occasions and even measurements at the same site at one time may vary appreciably.

Effect of sledging on exposure

Standard meteorological data give little idea of the thermal demand an environment makes on a man because clothing and shelter are not taken into account. Knowledge of the exposure climate, viz. the climate in the immediate vicinity of a clothed subject, is more pertinent to climatological studies. An even more precise understanding of the real exposure is obtained from measurements of the sub-clothing temperature, as this is the temperature to which the surface of the body is actually exposed. At Halley Bay, Norman (1960, 1965) measured the sub-clothing temperature of men living at the station. His subjects' mean annual sub-clothing temperature was 32·8° C, and he concluded that because this was so close to normal body temperature the men were unlikely to show evidence of general acclimatization to cold. This may not be true of men who spend much time sledging for, whereas Norman's subjects spent only 9 per cent of time outdoors, the proportion of time spent outside by Wyatt's subjects at sledging stations was 12 per cent and in the present study the figure was 17 per cent. During a 6-day man-haul journey, Norman found that 40 per cent of the time was spent outside; on travelling days on dog-sledge journeys, Wyatt (1963) found that the proportion of time spent outside was 34 per cent, which was practically the same as in the present study. Records have shown that low temperatures do not reduce the time spent outside (Davies, 1962; Wyatt, 1963). It is, of course, common experience that the drifting of snow caused by high winds hinders outdoor activities and therefore tends to reduce the amount of time spent outside.

Lack of effect of exposure on weight and skinfold

The winter maxima of weight and skinfold reported by many authors (Table IV) gave rise to the suggestion that exposure to cold might cause an increase in the amount of subcutaneous fat. Because sledging increased exposure, the weights and skinfolds of the Marguerite Bay party might have been expected to be greatest during the spring. In fact, the opposite was found and it is thought that the explanation lies in the suggestion by Lewis and others (1960) that seasonal changes in weight and skinfold are due to changes in the balance between energy intake and expenditure.

TABLE IV. SEASONAL VARIATION IN BODY WEIGHT AND SKINFOLD THICKNESS OF POLAR EXPLORERS

Reference	*Season at which body weight was at a maximum*	*Season at which skinfold thickness was at a maximum*
Cavalli, 1903	Winter	
Ekelöf, 1904	Winter	
McLean, 1919	Winter	
Goldsmith, 1959	No season	No season
Graham, 1959	Late autumn	Late autumn
Jones, 1959	Winter	Winter
Lewis and others, 1960	Winter	Winter
Wilson, 1960	Winter	
Milan and Rodahl, 1961	Progressive increase	
Tikhomirov, 1963	Summer	
Wyatt, 1963	Winter	No season
Orr, 1965	No season	Autumn
Easty, 1967	Autumn increase	Autumn increase

Intake and excretion of water and sodium on sledge journeys

There was no evidence of dehydration during journeys. Though fluid was restricted during actual sledging, intake was not limited in the tent and urine output was always more than twice the minimum essential for normal kidney function.

On travelling days the urine volumes and sodium levels were smaller than on days spent at the station or lying up. Bass (1954) has shown that the excretion of water and sodium is increased by acute exposure to cold. Though the urine collections made during sledging did not give evidence of cold diuresis, the possibility that cold diuresis may have occurred for short periods is not excluded. It is thought that the changes in urine volume and sodium content were due to changes in intake and changes in sweating and loss of water in the breath.

Food intake and energy expenditure during sledge journeys

The reduction in weight and skinfold during journeys is thought to have occurred because energy expenditure was greater than calorie intake. There are a number of reports of weight loss by sledgers using 4,100 kcal. rations. Fuchs (1952) noted that the greatest weight loss on two 90-day journeys was 2·7 kg. Massey (1956) reported an average weight loss of 5·0 kg. during journeys lasting 35–85 days and the average loss observed by Wyatt (1963) during a 6-week journey was 3·8 kg. Orr (1965) observed weight losses during sledging when the standard ration was used but he found there was no loss of weight when the intake was increased to 5,000 kcal./man/day.

Masterton and others (1957) calculated that the average expenditure of energy by men dog-sledging in Greenland was 5,200 kcal./day and it is likely that inland sledging in Graham Land entails a similar energy expenditure. Possibly the reason why Fuchs (1952) recorded a relatively small weight loss was that his party was eating a certain amount of seal meat in addition to the sledging ration. Another cause of difference in the weight changes of different sledge parties is the proportion of days spent lying up. At Marguerite Bay, 18 per cent of the days spent in the field were lie-up days, compared with 31 per cent recorded by Wyatt (1963).

The sledging ration

The men wanted more salt than the small amount provided by the sledging ration and extra salt was carried on the spring and summer journeys. Apart from an account of cramps due to salt deficiency (Andrew, 1946), there are no reports of loss of physical condition in men using the standard ration, and there was no reason to suspect that the calorie deficit impaired performance during sledging at Marguerite Bay. However, it would seem advisable to make a higher calorie allowance on very long journeys and when strict load economy is not essential, for example, during sledge journeys with air support. A higher calorie intake can be provided either by using the standard ration at a greater rate or by using another ration such as that designed and tested for the Medical Research Council (Lewis and Masterton, 1958).

Bartley and others (1953) have recommended a daily allowance of 30 mg. of ascorbic acid for adults in Great Britain. It is likely that the physical exertion and exposure associated with sledging increase the utilization of ascorbic acid so the ration should provide at least this amount. Men using the standard ration are supposed to take ascorbic acid tablets each day, but this is by no means always done. If sledging rations do not provide the required amount of ascorbic acid, tablets could be supplied in each ration box. Ascorbic acid may (like nicotinic acid) produce unpleasant symptoms in some individuals (Fuchs, 1952). It would therefore seem wise to take ascorbic acid after food. Another practical point to be borne in mind is that containers must be absolutely air-tight to prevent hydrolysis.

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