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Supplemental Feeding and Thermal Comfort During Sleep in the Cold

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ABSTRACT

KREIDER, M. B. AND E. R. BUSKIRK. *Supplemental feeding and thermal comfort during sleep in the cold.* J. Appl. Physiol. 11(3): 339–343. 1957.—Six men were studied while sleeping in arctic sleeping bags at −34.5°C (−30°F). The men ate the usual three meals per day at conventional times plus a supplement of 0, 600 or 1200 Cal. 10 minutes before retiring. The composition of the supplement was 40% fat, 20% protein and 40% carbohydrate. The following measurements were made during the night: rectal temperature (T_r), mean skin temperature (T_s), toe temperature, and oxygen consumption ($\dot{V}O_2$). When a 600 or 1200 Cal. supplement was given T_r, T_{toe} and $\dot{V}O_2$ were significantly higher than with no supplement. T_s was not changed as a result of supplementation. There appeared to be no difference between the effect of a 600 or 1200 Cal. supplement. The supplement also reduced the number of periods of wakefulness and the subjective discomfort associated with cold.

WHEN men work and sleep in field situations in an arctic environment for long periods of time, it is common practice to eat more or less continuously during the inactive hours spent in camp. The daily meal frequently ends only when the desire for sleep or some interfering circumstance intervenes. People in the Arctic for only brief periods may not follow this practice. These persons usually become 'chilled' in their sleeping bags 3–5 hours after retiring.

Mitchell *et al.* (1) have shown that the rectal temperature of men exposed to cold was slightly higher after eating high fat meals than when eating carbohydrate meals at 2-hour intervals throughout the day. Others (2, 3) have observed a rise in rectal temperature associated with eating one or more meals. The specific dynamic action (SDA) following food ingestion is well known. Increases in metabolic rate of from 2 to 12% of the calorific value of the food eaten have been observed over periods of several hours (4). Thus, some basis in fact exists for the premise that a man may comfortably spend perhaps an hour more in his sleeping bag in an arctic environment if he has eaten just prior to retiring than if he has not eaten. Investigation of this premise from the standpoint of heat exchange is reported in this study.

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GENERAL PROCEDURE AND METHODS

The experiment consisted in exposing men, who were reclining in sleeping bags, to a simulated arctic environment during the night hours for 12 nights. A familiarization period of 4 nights in the cold preceded the 12 days of the experiment. Caloric supplements were given to half the group each night just prior to retiring. Each man received his supplement on alternate nights.

Supplements were given at two caloric levels 30 minutes before the first measurements were made in the cold. During the first 3 weeks when three meals per day were eaten, the supplement was 600 Cal., and during the last week when two meals per day were eaten, the supplement was 1200 Cal. Each supplement was a flavored milk drink with added carbohydrate. The composition was 40% fat, 20% protein and 40% carbohydrate, at both levels of supplementation. Meals were routinely served at the usual time, e.g. 7:30 A.M., 12:00 M, 5:30 P.M., with the exception that the 5:30 P.M. meal was withheld when a 1200-Cal. supplement was

TABLE 1. DESCRIPTION OF TEST SUBJECTS

Subj.	Age, yr.	Ht., cm	Wt., kg	Surface Area, m^2	Body Fat*
1	19	181.4	79.3	1.99	6.3
2	19	173.4	74.3	1.88	9.2
3	20	173.3	68.9	1.82	2.7
4	25	167.0	73.4	1.82	8.8
5	25	165.0	67.0	1.73	9.8
6	22	182.3	77.5	1.98	15.0
$\bar{x}$	22	173.7	73.4	1.87	8.6

* Body fat was measured with skin-fold calipers and converted to percentage of body fat as described by Baker and Daniels (5).

given. Food and water were taken ad libitum during the day.

A portion of each day was spent in organized physical activity to insure a certain degree of 'tiredness' by bedtime. The remainder of the day was spent performing routine and light recreational activities. At night, the men were kept for 1½ hours in a chamber maintained at 27°C (81°F) and 50% R.H. prior to entering their sleeping bags in the cold chamber. The food supplement was given to half the men during this period. The men carried their sleeping bags with them into the cold chamber, and immediately (within 2 min.) were comfortably situated inside the bag for the night. The sleeping chamber was maintained at −34.5°C (−30°F). Air movement was less than 1 mile per hour at sleeping bag level. Each man remained in his sleeping bag from approximately 10:30 P.M. to 6:30 A.M.

One pair of 50% wool, long-sleeved undershirt and ankle-length woolen drawers, and two pairs of socks were worn when in the sleeping bag. Sleeping gear consisted of two down-filled bags, one inside the other, and a full length rubber air mattress. The ensemble (clothing plus bag) furnished insulation of approximately 4–5 clo.

Rectal (T_r) and skin (11 locations) temperatures (T_s) were measured at ½-hour intervals with copper-constantan thermocouples. This procedure has been described elsewhere (5). A hole was cut in the sleeping bag to permit connection of the thermocouples with recorders. This hole was subsequently sealed to maintain bag insulation.

Oxygen consumption ($\dot{V}O_2$) was routinely measured with a continuous flow system in two of the six men. The subjects' head, shoulders and thorax were enclosed in a large plastic hood. The lower portion of this hood was secured around the subjects' waist. Ambient chamber air was pumped at a rate of 18 liters per minute through the hood, and through a dry gas meter. A fraction of air coming from the gas meter was diverted through a Beckman Oxygen Analyzer to obtain $F_{E_{O_2}}$ (fraction of oxygen in expired air). Values for $F_{E_{CO_2}}$ (fraction of carbon dioxide in expired air) were calculated on the basis of numerous determinations in preliminary experiments when the hood was used under cold conditions.

A single device involving a switch in the bag and buzzer-light system at the recorder site, were installed so that the subject could indicate when he was awake or needed assistance. Questionnaires regarding sleep and thermal comfort during the night were given each morning immediately after leaving the cold room.

The characteristics of the six men used in the study are given in table 1. Each man was screened from a larger group of men on the basis of expressed freedom from claustrophobia when inside the sleeping bag and plastic hood.

RESULTS

Early withdrawal from the sleeping bag was permitted on four occasions when the toe temperature of the subject dropped below

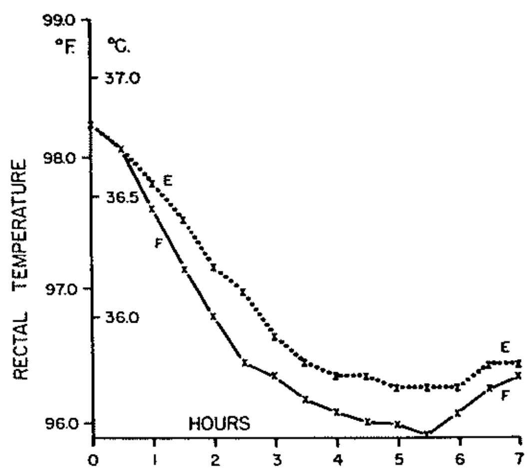

FIG. 1. Mean rectal temperature in 6 men sleeping in arctic bags in −30°F air. *F* (fast), no supplement given before retiring. *E* (eat), supplement given before retiring. (*F* and *E* have same meaning in all figures.) Each curve represents 34 man-nights.

40°F. In each case, total time in the sleeping bag was reduced by only ½ hour, therefore the results were included in analysis of the data presented in subsequent sections. The 600- and 1200-Cal. supplements produced quantitatively similar changes in T_r, T_s, and $\dot{V}O_2$, therefore all supplement data were pooled when comparing supplement to no supplement.

When the men slept in the cold, body ('core') cooling began at 0 time (30 min. after eating) and continued for approximately 6 hours. If T_r is considered a measure of internal body temperature ('core') it can be seen from figure 1 that the 'core' cooled at a decreasing rate for 5½ hours, on the average, and thereafter partially rewarmed. This cooling pattern was observed both with and without the evening food supplement. The effect of the supplement was to decrease the rate of drop of the 'core' temperature. This change in rate was manifested approximately 90 minutes after eating. The maximum difference between the two curves (supplement vs. no supplement) occurred 2½ hours after retiring. The differences between the two curves were significant at the 1% level at 1, 3 and 6 hours. Analysis of variance was used to compare mean values at these times. The mean body surface cooled at a fairly constant average rate (0.5°F/hr.), and this rate was not altered when the supplement

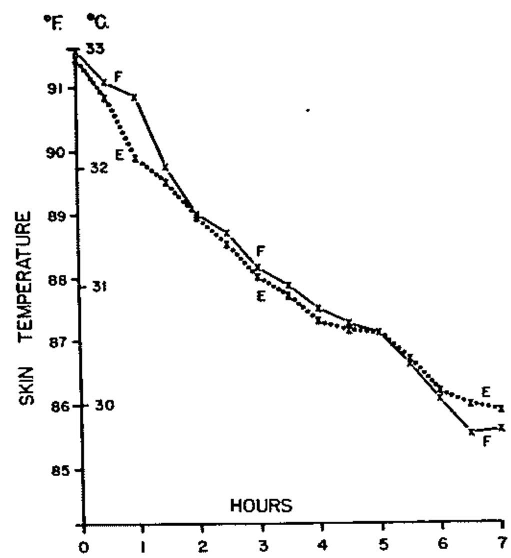

FIG. 2. Mean weighted skin temperature in 6 men sleeping in arctic bags in −30°F air. Each curve represents 36 man-nights.

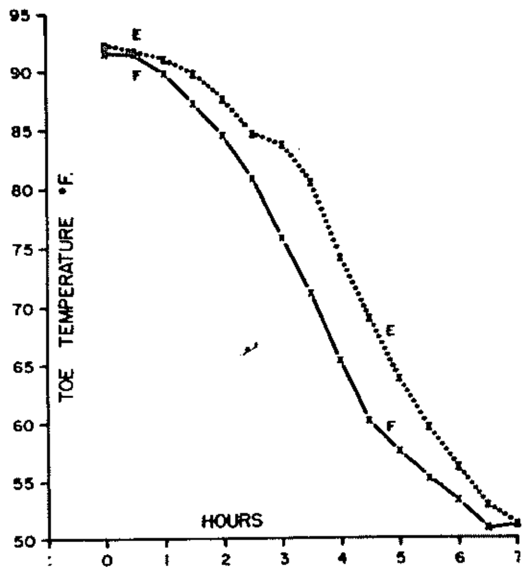

FIG. 3. Toe temperature of 6 men sleeping in arctic bags in −30°F air. Each curve represents 36 man-nights.

was given (fig. 2). Although this was true for mean body surface, at least one specific area cooled at a different rate when the supplement was given. Toe temperature was significantly higher during the 1st to 6th hours of the nights of supplementation, with the maximum difference of 5°C (9°F) appearing at 3½ hours after retiring (fig. 3).

Total body heat content was calculated from mean body temperature ($T_b = 0.67\ T_r + 0.33\ T_s$; where T_b = mean temperature of the tissues) and body weight in kilograms (assumed specific heat 0.83 Cal/kg/°C). During the 7 hours spent in the sleeping bag the heat debt was approximately 100 Cal. (fig. 4). Heat content of the body was only slightly greater with supplementation (4–5 Cal. on the average). This difference was of border-line significance (10% level). By the time the first measurement of oxygen consumption ($\dot{V}O_2$) was made (1 hr. after getting into the sleeping bag in the cold) and peak SDA had evidently occurred. Thus, the $\dot{V}O_2$ curves in figure 5 for *subjects A* and *B* show only the decline after the peak. At 1 hour the SDA became less apparent, particularly in *subject B*, where it became negligible by 3 hours. The effect was more pronounced and sustained in *subject A*. The elevation in $\dot{V}O_2$ observed after 4–6 hours may be associated with increased muscular

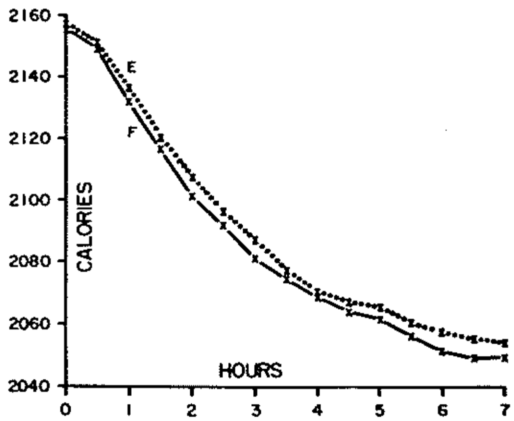

FIG. 4. Mean body heat content of 6 men sleeping in −30°F air. Each curve represents 36 man-nights.

activity or increased body movement during sleep.

All of the subjects indicated a preference for the supplement over no supplement. The number of times the men awakened during the night was reduced after supplementation. Most men indicated that their feet were 'very cold' or numb by morning. The incidence of the 'numb' rating was reduced by two-thirds when the supplement was given.

DISCUSSION

Food eaten immediately before retiring for the night in the cold was associated with the maintenance of a higher rectal temperature (T_r) throughout the night. Mean weighted skin temperature (T_s) was not altered, therefore heat content of the body was only slightly higher after the evening food supplement. Oxygen consumption ($\dot{V}O_2$), measured in two men, suggested that heat production was higher after the supplement for at least the first few hours spent in the cold. The higher toe and rectal temperatures which obtained for most of the night following the late meal may be largely responsible for the improvement in the subjective tolerance with the supplement during periods of wakefulness. Thus, feeding the supplement appeared to have some practical advantage, although thermal gains calculated from the temperature data seemed to be marginal.

A 'normal' diurnal change in resting $\dot{V}O_2$ and resting T_r has been observed when meals are served at the usual times (6). The changes in resting $\dot{V}O_2$ and resting T_r during daylight hours are more dependent upon eating than upon the physical activity level, provided strenuous work is not performed.

The normal pattern of diurnal events shows a fall in $\dot{V}O_2$ and T_r during the night hours when sleep or rest is obtained under 'comfortable' ambient conditions. This has been interpreted as a change in the 'set' of the thermoregulating mechanism. It is interesting to note that when cooling occurs at a relatively slow rate as in these experiments, an elevation in heat production does not occur until 4–6 hours after retiring. When the body is abruptly exposed to cold, an elevation in heat production occurs immediately. This suggests that the thermal gradient across the 'cold receptors' is not sufficiently large during the slow cooling to initiate a shivering response, and that this mechanism is not involved in the response.

When T_r reached 35.5°–35.7°C, an inflection in both the $\dot{V}O_2$ and T_r curves occurred. Perhaps under conditions of slow cooling and small thermal gradients in the periphery of the body,

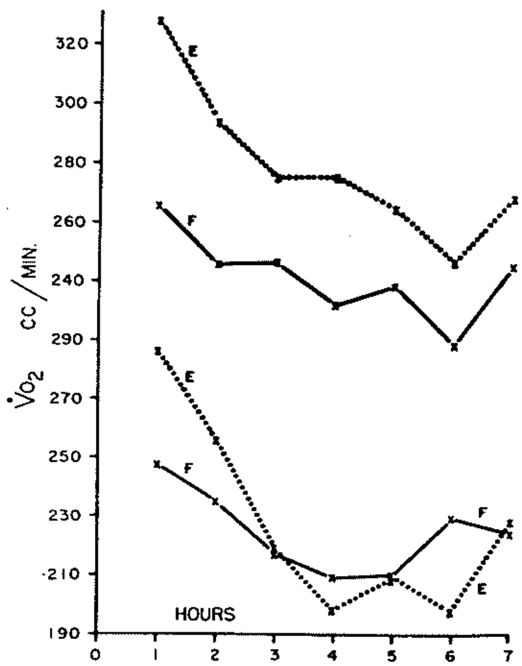

FIG. 5. Oxygen consumption ($\dot{V}O_2$) of 2 men sleeping in arctic bags in −30°F air. Each curve represents 6 man-nights.

the 'core' temperature (perhaps temperature of the blood perfusing the thermoregulating centers) is the important factor in initiating the elevation in heat production. The results of this work offer no explanation for the significant difference in rectal temperature (0.2°C) at the inflection point for the supplemented and nonsupplemented groups.

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