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Effect of diet on body temperature during sleep in the cold

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KREIDER, MARLIN B. *Effect of diet on body temperature during sleep in the cold.* J. Appl. Physiol. 16(2): 239–242. 1961.—Thirteen young soldiers were divided into two groups and fed liquid diets of similar caloric content but of different composition. One group was fed a normal, high-fat, high-carbohydrate and normal diet in the first, second, third and fourth weeks, respectively; the second group was fed a normal, high-carbohydrate, high-fat and normal diet during the same periods. Three meals were eaten at 8 A.M., 5 P.M., and 10:15 P.M., at which times 30, 30 and 40% of the daily calories were consumed. Measurements of skin (11 points) and rectal temperatures were made at one-half-hour intervals throughout the night when the subjects were in sleeping bags at an ambient temperature of −30°F. Protection against the cold was designed to be inadequate to maintain thermal comfort. Composition of the diet had no effect on rectal, mean weighted skin or toe temperatures throughout the night with a few exceptions. No physiological significance is ascribed to these exceptions since the differences were very small. It is concluded by comparison with a previous study that caloric content rather than composition of the diet is the important factor in decreasing rates of body cooling of men sleeping in the cold.

WE REPORTED THAT when a food supplement of normal composition was eaten before retiring at night in the cold, body temperatures were maintained at a higher level than when no supplement was eaten (1). Mitchell *et al.* (2) found that a high fat diet afforded greater thermal protection in the cold than either high carbohydrate or high protein diets, but only when small meals were eaten at 2-hour intervals. However, rats fasted for 24 hours maintained a higher rectal temperature on a previous diet of 17% fat than when on a previous diet of 3.5% fat (3). There are also reports which indicate that men in the Arctic prefer foods with a high fat content and other reports which indicate no preference.

The foregoing indicates that work should be done to determine whether it is the caloric content, the composition of the diet or both which has beneficial effects on body temperature in the cold.

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The purpose of this study was to determine whether differences in body temperature of men sleeping in the cold would be apparent when they were fed isocaloric diets of high fat, high carbohydrate or normal composition.

PROCEDURE AND METHODS

Thirteen young soldiers consumed liquid diets of normal, high fat, or high carbohydrate (CHO) composition during a 4-week period. At night they slept in sleeping bags in a cold chamber at −34.5°C (−30°F), during which time skin and rectal temperatures were measured.

The schedule of feeding allowed for three meals a day, which were eaten at 8 A.M., 5 P.M., and 10:15 P.M. At these times 30, 30 and 40% of the daily calories were consumed. The 1st period of 5 days consisted of a training period when the 'normal' diet was eaten, and an attempt was made to ascertain the caloric intake necessary to maintain body weight. During this week the subjects were introduced to sleeping in the cold for three nights. At the end of the 5 days, the subjects were divided into two groups. *Group 1* ate the high CHO diet and *group 2* the high fat diet for the next 7 days. For the 3rd period of 7 days, the diets were reversed and finally for the 4th period, the normal diet was eaten again by both groups. Isocaloric content between diets was attempted but was soon modified to allow a greater intake on the high fat diet in order to maintain a constant body weight. During these 4 weeks subjects were restricted to a limited area near the laboratory and were under 24-hour observation to assure that no other food was consumed.

Daily exercise was standardized to provide moderate activity for each man throughout the study. This consisted of 2 hours of hiking and 2 hours of supervised games daily. Ambient temperature range was 65°–85°F.

At night the subjects rested for 2 hours in a room at 78°F before retiring to the cold chamber. During this time skin (11 points) and rectal thermocouples were applied and three control readings made at half-hour intervals. Cotton-wool long underwear and 2 pairs of wool socks were put on ½ hour before entering the chamber (10:30 P.M.). Subjects remained in the cold chamber until 6 A.M. Body weights were measured each morning immediately after arising and voiding.

The diets were made up of three basic items: Dextri-Maltose, milk solids and cottonseed and corn oil. The composition of the three diets was as follows:

	Normal diet	High fat diet	High CHO diet
CHO	50	20	70
Fat	40	70	20
Protein	10	10	10

In addition to the liquid diet, small biscuits and jelly candy were given sparingly when signs of digestive upset were apparent. Black coffee and saccharin were allowed and were often mixed with the liquid food to enhance the flavor and a lemon flavoring was used regularly with the high fat diet to increase palatability. Decavitamins, ferrous sulfate, and sodium chloride were taken daily.

Skin and rectal temperatures were recorded at frequent intervals throughout the night. Mean weighted skin temperature (T_s) was calculated as previously described (4). The subjects slept in the cold only on the last five nights of each diet period.

RESULTS

Figure 1 shows that composition of the diet exerted no influence on mean T_r at any time throughout the night in the cold. T_r decreased on all three diets to a low point of 96.6°F.

Mean weighted skin temperature (T_s) showed some difference between diets. All T_s were the same at the beginning of the night, but by 2 A.M. T_s for the high fat diet was lower (about 1°F) than for the other diets. Both groups of subjects contributed equally to the lower T_s on the fat diet. Toward the morning this difference disappeared. T_s also followed the typical pattern of change through the night described previously (1).

Toe temperatures (fig. 1) were generally the same for all three diets. Before retiring toe temperatures on the high fat diet were 2°F higher than on the other two diets, but after retiring this difference disappeared. By the end of the night toe temperature on the normal diet was a significant 2°F below the level of the other two diets. There was little variation in body temperatures from one night to another within each dietary period, with one exception: T_r at the end of the last period on the normal diet was 0.4°F higher than at the beginning of that period. This difference was unaccompanied by any skin temperature differences.

Changes in body weight occurred during the study (fig. 2). Both groups lost slightly more than 1 kg body weight during the first week on the liquid diet of normal composition. Most of this decrease occurred during the first day. In the following weeks, body weight varied with the diet. It increased in both groups on the CHO diet and decreased on the fat diet. The decrease was much greater for *group 1* following the week on the high CHO diet and amounted to more than 1 kg. During the final week on the normal diet body weight approached the control level of the 1st week.

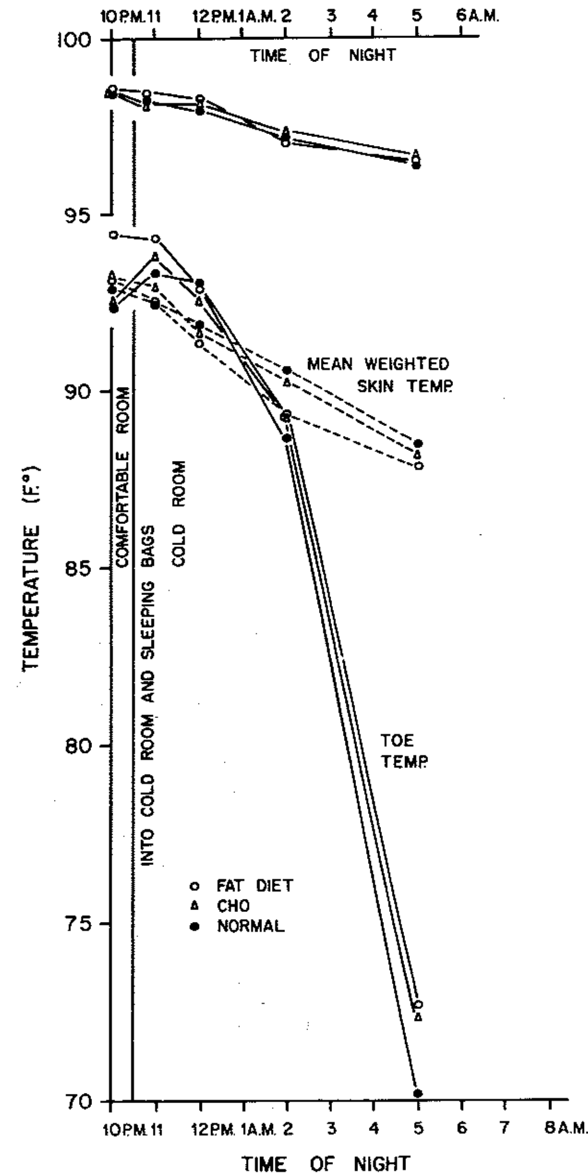

FIG. 1. Rectal temperatures (*upper curves*), mean weighted skin and toe temperatures of 13 young men during five nights on each of three diets.

Most of the decrease in weight during the first few days was probably due to an inadequate caloric intake; caloric intake was then adjusted to a higher level. At the beginning of each new diet period the total intake was reduced to facilitate adjustment to the new diet. It was hoped that the level of caloric intake necessary to maintain body weight would be found empirically during the first week and this level maintained for the remainder of the study. However, adjustments of this level were required during successive weeks (fig. 2). Values in figure 2 include the caloric intake of the liquid

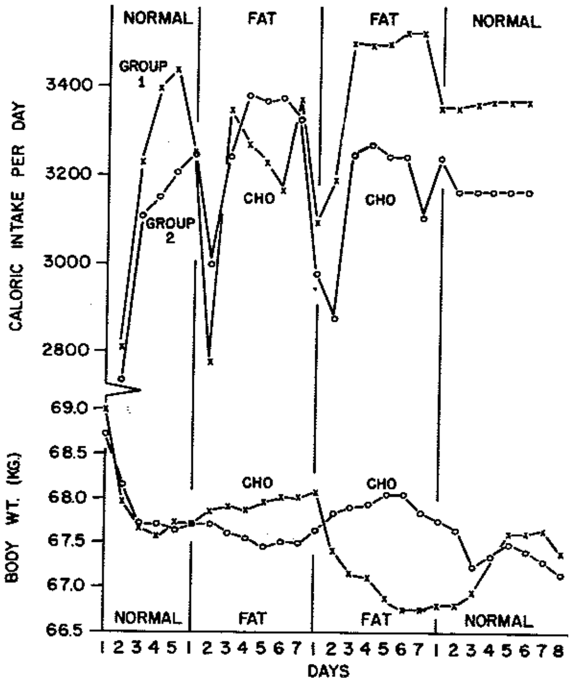

FIG. 2. Mean daily caloric intake and body weight of 13 young men during successive weeks on three diets.

diet plus the caloric value of the cracker wafers and jelly bars and a subtraction of the approximate amount of food lost through vomiting.

The caloric requirement to maintain body weight was 200 kcal/man/day higher for *group 1* than for *group 2* in both the initial and final control periods despite the fact that the initial weights were similar. It is also interesting to note that caloric intake was highest during the period of high fat intake when body weight decreased most.

The response of subjects to the liquid diet was varied. Although the taste and consistency were similar to a thick milk shake for the normal composition meal, some subjects did not like it, and in one case the meal was lost by vomiting. Two subjects in *group 1* had difficulty in the first few days on the high CHO diet, but none in the following week on the high fat. Three subjects in *group 2* had difficulty in the first few days on the high fat diet, but only one had difficulty in adjusting to the high CHO diet the following week. The same subject also lost a meal at the beginning of the final week on the normal diet.

DISCUSSION

The results of the present study cast some doubt on the concept that high fat diets maintain higher body temperatures during cold exposure than high CHO diets. It is possible that other feeding schedules would produce different results. In this regard, it was reported (2) that a supplement had to be fed at intervals no greater than 2 hours in order to give a greater temperature effect on a high fat diet. This was contradicted, however, by work on rats (3) in which a beneficial effect of a previous fat diet was found even after a 24-hour fast. If the body requires a high level of fat in the process of digestion and absorption in order to show a temperature differential, the conditions of the present study should provide this (40 % of the daily caloric intake was consumed within 15 minutes and 70 % within 5 hours of the experimental period) at least for the first part of the night.

It should be pointed out that more definite conclusions could be made here regarding the effect of diets in the cold in general if the cold exposure was continuous during day and night. However, in the experiment mentioned above in which a high fat diet was found to produce an increased body temperature, the cold exposure was discontinuous. The present experiment also does not attempt to determine whether cold exposure produces a preference for fats in the diet.

The results of this study combined with a previous one on supplemental feeding (1) suggest that the level of caloric intake before retiring in the cold may affect the body temperature, i.e. the higher the caloric intake, the greater the effect on body temperature. However, this conclusion would be more secure if the same test subjects were used in both studies, if the schedule of feeding were similar, and if the degree of prior acclimatization were identical; the first study was carried out in June and the other in August. The studies were alike in most aspects, i.e. clothing, ambient temperature during exposure and during daytime activities, level of exercise, and type of food as supplement.

The schedules of feeding varied in the following way. In the earlier study in which two levels (600 and 1200 kcal.) of supplements were used just before retiring, the regular meals were eaten at 7:30 A.M., 12:00 N., and 5:30 P.M., except that with the 1200 kcal. supplement the 5:30 P.M. meal was omitted. This level of intake represents about 1500 and 1200 kcal., respectively, within 5 hours of retiring. In the present study, in which the meals were eaten at 8 A.M. and 5 P.M., the supplement consumed immediately before retiring was actually slightly less (1020 kcal.) than the highest level (1200 kcal.) used in the previous study, but the level of caloric intake within the 5 hours previous to retiring was doubled (2380 kcal.) In the present study. This may account for the smaller body temperature drop found in the second study. The body temperatures after 6.5 hours in the cold were 96.4°, 86.0° and 52.5°F for rectal, mean weighted skin and toe temperatures, respectively, in the earlier study, whereas the comparable temperatures in the latter study were 96.6°, 88.5° and 70°F. It would appear, then, that the level of caloric intake affects the body temperature during cold exposure.

The reason for the decrease of body weight on the high fat diet is uncertain. It may be due to an increased water loss; unfortunately this measurement could not be made. If the weight decrease was due to the utilization of tissue for fuel in addition to the dietary fuel, a higher temperature would be expected on the high fat diet, which was not observed. It is also possible that much of this weight loss occurred during the day when the thermal environment was not controlled. Another possibility should be stated in passing, which is that at this high fat—CHO ratio, fats may not be burned as efficiently. Whatever the reason may be, Mitchell likewise found that a higher level of caloric intake was required on the fat diet than on other diets to maintain body weight.

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