# ARCTIC AEROMEDICAL Laboratory

ARCTIC SURVIVAL RATIONS

VI. THE PHYSIOLOGICAL EFFECTS OF RESTRICTED DIETS DURING SUCCESSIVE WINTER FIELD TRIALS

TECHNICAL REPORT 58-8

LADD AIR FORCE BASE

A L A S K A

# PUBLICATION REVIEW

This report has been reviewed and is approved.

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Submitted by authors 5 May 1958

Issued by the Arctic Aeromedical Laboratory

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# ARCTIC SURVIVAL RATIONS

## VI. The Physiological Effects of Restricted Diets During Successive Winter Field Trials

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Technical Report 58-8



ALASKAN AIR COMMAND

ARCTIC AEROMEDICAL LABORATORY
LADD AIR FORCE BASE



August 1959

# ABSTRACT

Two out of three different 1000 calorie combinations of pemmican and sugar were fed to each of 12 subjects during a two-phase, winter field study. All of the diets tested consisted primarily of pemmican, with the sugar contribution ranging from 0 to not more than 32% of the calories. The 5-day experimental phases were separated by a 7-day "recovery period."

In both periods, on all diets, performance was considered adequate for survival situations involving moderate activity, thus confirming a previous report (4). The isocaloric substitution of pemmican with 40 gm. of sugar raised the fasting blood sugar levels, decreased the nitrogen balance, and, in some cases, reduced ketonuria. However, a further increase in the proportion of sugar in the ration to 80 gm. had no additional effect.

In the second period, the magnitude of all the above responses was strikingly reduced. In most cases, the degree of reduction did not appear to be related to differences in the composition of the Period I diets. The fasting blood sugars during the second period, however, did bear an inverse and highly significant relationship to the levels of carbohydrate intake during the first period. Thus, the data suggest that the adaptation to caloric restriction which developed during the first period, as evidenced by sequential changes in blood sugar levels, nitrogen balance and ketone body excretion, persisted throughout the recovery period, permitting the subjects to respond more favorably to the second dietary stress.

## ARCTIC SURVIVAL RATIONS

## VI. The Physiological Effects of Restricted Diets During Successive Winter Field Trials

### INTRODUCTION

A previous report in this series (4) dealt with the effects of a supplement of 40 gm. of sugar on physiological reactions to a high-fat, high-protein diet fed at the 1000 calorie level. This study was originally designed to confirm the results of the first study (4) and to extend the observations to the effects of somewhat larger sugar supplements. In an effort to minimize the effects of individual variation, as well as to obtain the maximum amount of data from the available subjects, each subject was exposed to two different diets with an intervening "recovery" period of 1 week. This, of course, is a common procedure in ration studies and was employed only as a means of expediency. The results, however, were so unexpected and, in our opinion, were of such theoretical interest that they overshadowed the original aim of the study. The primary purpose of this paper, then, is to present evidence for the persistence of adaptation to a low-carbohydrate, low-calorie diet over a period of 1 week of ad libitum feeding.

### EXPERIMENTAL

Twelve adult men, including 10 military personnel and 2 civilians, were used as subjects for the experimental field studies. Following a control period to establish levels of fasting blood sugar and urinary nitrogen and acetone production, and to accustom the men to the experimental procedures, all subjects were taken to an isolated site to begin the field study. Period I of the dietary regimen began at this time and continued for 5 days. Unlimited water intake was permitted. The subjects were divided into three groups consisting of four men each, each group receiving rations of the following composition:

| Group | Pemmican[1] gm. | Sugar gm. | Calories |
|---|---|---|---|
| "0" | 168 | 0 | 1000 |
| "40" | 140 | 40 | 993 |
| "80" | 112 | 80 | 990 |

Environmental temperatures during this period ranged from -10° to -48° F.

At the end of Period I, the subjects were returned to the laboratory and allowed to eat a mixed diet ad libitum, either at an Air Force dining hall or at home. This interim "recovery" period lasted 1 week.

At the end of this week, the subjects were again taken to the isolated site to begin Period II. For this study, every man received either more or less sugar than he had received in Period I, in the following manner:

1. Two of the 4 men who had received Diet "0" now received Diet "40"; the remaining 2 received Diet "80."

2. Two of the 4 men who had received Diet "40" now received Diet "0"; the remaining 2 received Diet "80."

[1] Quartermaster Meat Food Bar.

3. Two of the 4 men who had received Diet "80" now received Diet "40"; the remaining 2 received Diet "0."

During the second 5-day period, the environmental temperatures ranged from +10° to -10° F.

The environmental conditions, living arrangements, scope of physical activities, and the experimental procedures employed were exactly the same as reported previously, with the addition of physical fitness measurements administered by the procedure of Johnson et al. (7) before and after each experimental period.

## RESULTS

The results of the field trials reported here can be divided logically into two parts: 1) changes occurring during a given experimental period and related to the current diet, without regard to previous diet or to restricted caloric intake per se, and 2) differences during the second period which appeared to be related to the nature of the diet during the first period.

### Effects of Current Dietary Treatment

As indices of the metabolic effects of varying amounts of sugar substituted isocalorically for a portion of the pemmican, we have used fasting blood sugar levels, nitrogen balances, and ketone body excretion (measured as acetone).

Fasting blood sugar. Table I presents the fasting blood sugar values before and during the experimental periods. An analysis of the adjusted variance in Period I values (table II), using the pre-

## Table I. FASTING BLOOD SUGAR VALUES
mg. %

**Period I**

| Day | Diet "0" | | | | Diet "40" | | | | Diet "80" | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Subject | | | | Subject | | | | Subject | | | |
| | 2 | 3 | 4 | 8 | 1 | 5 | 10 | 12 | 6 | 7 | 9 | 11 |
| Control | 102 | 101 | 100 | 101 | 88 | 89 | 87 | 96 | 96 | 90 | 96 | 105 |
| " | 98 | 91 | 84 | 91 | 95 | 97 | 83 | 85 | 87 | 93 | 88 | 86 |
| 1 | 81 | 83 | 67 | 59 | 82 | 75 | 62 | 67 | 71 | 69 | 71 | 66 |
| 2 | 70 | 74 | 49 | 55 | 86 | 74 | 60 | 67 | 62 | 57 | 77 | 71 |
| 3 | 66 | 76 | - | 62 | 73 | 78 | 58 | 72 | 58 | 67 | 78 | 77 |
| 4 | 71 | 78 | 67 | 70 | 83 | 92 | 67 | 69 | 76 | 84 | 85 | 83 |
| 5 | 74 | 78 | 64 | 66 | 86 | 70 | 76 | 74 | 78 | 71 | 74 | 84 |
| Means[1] | 72 | 78 | 61 | 62 | 82 | 78 | 65 | 70 | 69 | 70 | 77 | 76 |
| | Group Mean: 68 | | | | Group Mean: 74 | | | | Group Mean: 73 | | | |

**Period II**

| Day | Diet "0" | | | | Diet "40" | | | | Diet "80" | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Subject | | | | Subject | | | | Subject | | | |
| | 5 | 9 | 10 | 11 | 2 | 6 | 7 | 8 | 1 | 3 | 4 | 12 |
| Control | 91 | 95 | 87 | 95 | 97 | 87 | 82 | 91 | 90 | 74 | 79 | 91 |
| 1 | 91 | 82 | 87 | 92 | 90 | 91 | 87 | 72 | 97 | 96 | 84 | 81 |
| 2 | 100 | 74 | 61 | 75 | 119 | 72 | 85 | 82 | 94 | 99 | 91 | 83 |
| 3 | 90 | 74 | 64 | 64 | 89 | 74 | 74 | 84 | 89 | 105 | 84 | 79 |
| 4 | 86 | 62 | 62 | 70 | 96 | - | 82 | 73 | 103 | 89 | 82 | 85 |
| 5 | 82 | 75 | 68 | 81 | 98 | 92 | 80 | 83 | 98 | 96 | 93 | 92 |
| Means[1] | 90 | 73 | 68 | 76 | 98 | 82 | 82 | 79 | 96 | 97 | 87 | 84 |
| | Group Mean: 77 | | | | Group Mean: 85 | | | | Group Mean: 91 | | | |
| Period II minus Period I | +12 | -4 | +3 | 0 | +26 | +13 | +12 | +17 | +14 | +19 | +26 | +14 |

[1]Means of post-treatment values

Table II. ANALYSES OF VARIANCE OF CONCURRENT EFFECTS OF DIETARY SUGAR

| | Fasting Blood Sugar[1, 2] (Period I) | | | Nitrogen Balance (5 day totals) (Period I) | | | Nitrogen Balance (5 day totals) (Period II) | | |
|---|---|---|---|---|---|---|---|---|---|
| Source | df | Mean Square | F | df | Mean Square | F | df | Mean Square | F |
| Between diets | 2 | 247.4 | 8.06[3] | 2 | 407 | 3.84 | 2 | 23 | < 1.00 |
| Linearity | (1) | 258.1 | 8.41[3] | | | | | | |
| Residual | (1) | 236.8 | 7.71[3] | | | | | | |
| Within Diets | 8[4] | 30.7 | | 9 | 106 | | 9 | 104 | |
| Total | 10[4] | | | 11 | | | 11 | | |

| | Fasting Blood Sugar (Period II) | | | | 24-Hour Ketone Excretion (Period I) | | 24-Hour Ketone Excretion (Period II) | |
|---|---|---|---|---|---|---|---|---|
| Source | df | | Mean Square | F | Mean Square | F | Mean Square | F |
| Between diets | 2 | | 992 | 2.89[5] | .92 | <1.00[5] | 1.99 | 4.06[5] |
| Between SS treated alike | 9 | | 343 | | 1.77 | | .49 | |
| Total between SS | | 11 | | | | | | |
| Between days | 4 | | 124 | 2.38[5] | 2.78 | 5.45[6] | .63 | 6.3[6] |
| Diets x days | 8 | | 69 | 1.33[5] | .26 | < 1.00[5] | .44 | 4.4[6] |
| SS x days | 36 | | 52 | | .51 | | .10 | |
| Total within SS | | 48 | | | | | | |
| Total | | 59 | | | | | | |

[1]Adjusted for regression upon pre-Period I control levels

[2]Adjusted means: "0" = 63; "40" = 77; "80" = 74

[3] <01 < p <.05

[4]Reduced by 1 df for regression coefficient; b = 1.592; $r_{xy}$ = 0.67

[5]$p > .05$

[6]$p < .05$

Period I control values as the independent variable, shows that the response of fasting blood sugar to stepwise increases in dietary sugar was curvilinear and apparently followed the law of diminishing returns. There is a significant difference between the "0" and "40" diet groups, i.e., an increased level in the "40" group, while there is no significant difference between the "40" and "80" diet groups. A graphic plot of the means of the daily fasting blood sugar values (figure 1) reveals the same pattern of response noted previously (4), i.e., a sharp drop, followed by stabilization at a level appreciably lower than the control values.

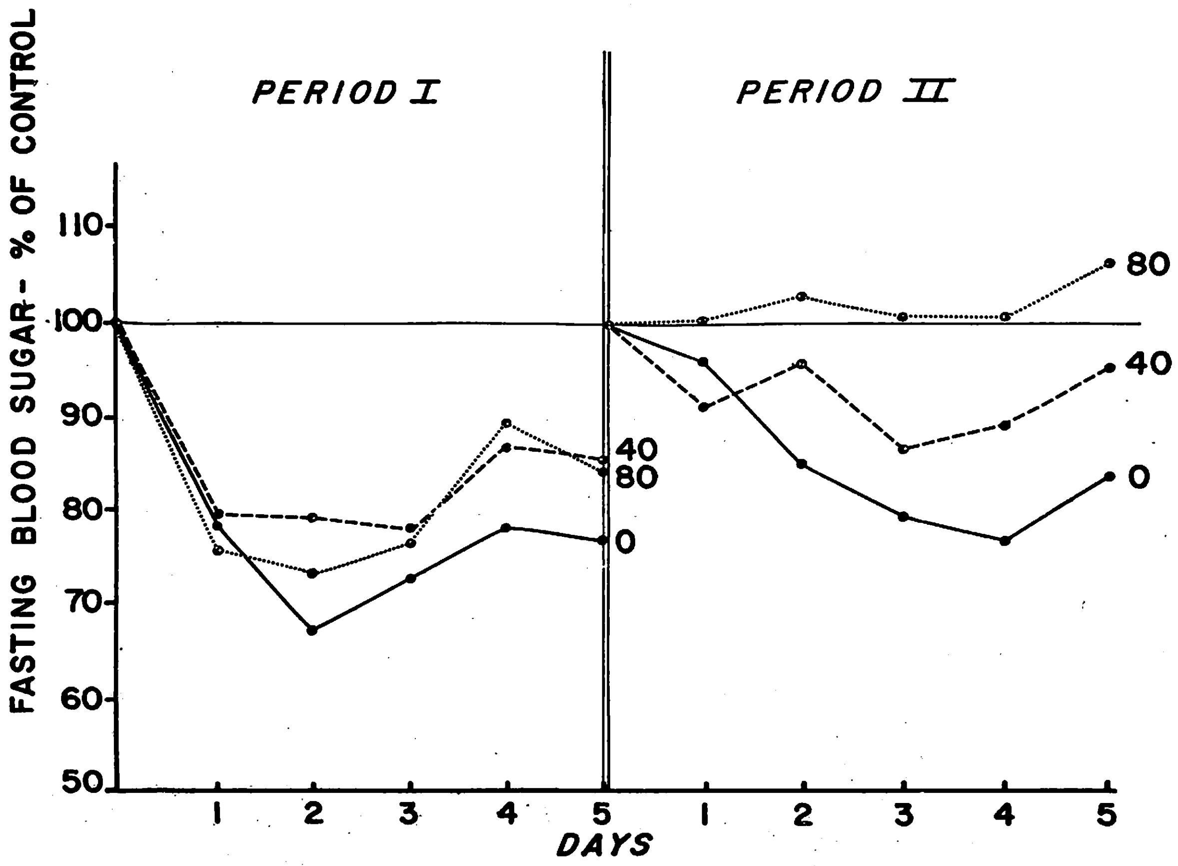


Figure 1. Daily variation in fasting blood sugar

As will be noted shortly, the pre-Period II control fasting blood sugar values were related to dietary composition during Period I. Consequently, an analysis of variance was done on the post-treatment values only. The results are given in table II and show that there is no significant difference in fasting blood sugars which can be related to the level of sugar intake during this period. The time-course of the mean daily fasting blood sugar values is given in figure 1. It can be seen that the sequence of events in Period II differed markedly from Period I. The fasting blood sugar values of the men receiving the "0" and "40" diets did not drop so precipitately, while the subjects receiving 80 gm. of sugar maintained values at or above their control levels.

Nitrogen balance. The nitrogen balances for both periods are presented in table III. The means of the total 5-day nitrogen balances differ according to the diet during Period I. The subjects receiving sugar apparently lost more tissue nitrogen, but these differences could have occurred by chance alone, as determined by an analysis of variance (table II). Graphic plots of the daily group means are shown in figures 2 and 3.

As in the previous study, the tendency for an initially large negative nitrogen balance to occur, followed by an upswing of the curve, is apparent. As with the fasting blood sugar values, the response of the subjects during Period II differed markedly. The means of the total 5-day nitrogen balances are not significantly different, as attested to by the analysis of variance presented in table II. The curves of the daily balances during Period II

## Table III. NITROGEN BALANCES (GRAMS/24 HOURS)

**Period I**

| Day | Diet "0" Subject 2 | 3 | 4 | 8 | Diet "40" Subject 1 | 5 | 10 | 12 | Diet "80" Subject 6 | 7 | 9 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1.1 | -5.6 | -4.5 | +1.3 | -4.7 | -3.8 | -2.1 | -1.0 | -9.7 | -2.8 | -7.8 | -8.0 |
| 2 | -1.3 | -6.9 | -3.4 | -9.8 | -6.2 | -12.5 | -1.6 | -6.8 | -8.0 | -6.6 | -7.7 | -25.6 |
| 3 | -4.3 | -3.6 | -8.5 | -2.2 | -4.9 | -6.6 | -4.4 | -6.0 | -5.4 | -2.2 | -2.4 | -6.8 |
| 4 | +0.1 | -3.4 | -2.5 | +1.2 | -4.5 | -6.2 | +1.6 | -4.0[1] | -5.6 | -18.6 | -0.6 | -5.9[1] |
| 5 | - | +1.0 | -1.6 | +1.0 | -2.4 | -4.9 | -4.4 | -2.0 | -4.8 | -0.5 | -0.4 | -5.0 |
| Totals | -6.6 | -18.5 | -20.5 | -8.5 | -22.7 | -34.0 | -10.9 | -19.8 | -33.5 | -30.7 | -18.9 | -51.3 |
| Group Means | | -13.5 | | | | -21.8 | | | | -33.6 | | |

**Period II**

| Day | Diet "0" Subject 5 | 9 | 10 | 11 | Diet "40" Subject 2 | 6 | 7 | 8 | Diet "80" Subject 1 | 3 | 4 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | -1.2 | -2.3 | +4.6 | -0.2 | +3.9 | -5.0 | -5.6 | +1.3 | -3.1 | -3.8 | -3.5 | -2.2 |
| 2 | -3.4 | -4.7 | +0.7 | -2.5 | -2.0 | -4.4 | -10.5 | +1.8 | -5.8 | -3.6 | +0.9 | -3.9 |
| 3 | -3.6 | -4.5 | -2.6 | -2.1 | -1.3 | -2.0 | -3.2 | +1.1 | -4.7 | -2.2 | +2.7 | -2.8 |
| 4 | +3.1 | -2.4 | +2.0 | -8.9 | -2.2 | -4.0 | -0.9 | -1.2 | -4.6 | -2.6 | -1.2 | -2.8 |
| 5 | -1.6 | -0.9 | +0.5 | -2.6 | -2.2 | -2.8 | -1.1 | +1.2 | -3.0 | -3.3 | +0.1 | -2.0 |
| Totals | -6.7 | -14.8 | +5.2 | -16.3 | -3.8 | -18.2 | -21.3 | +4.2 | -21.2 | -15.5 | -1.0 | -13.7 |
| Group Means | | -11.2 | | | | -11.8 | | | | -12.9 | | |
| II - I | +27.3 | +4.1 | +16.1 | +35.0 | +2.8 | +15.3 | +9.4 | +12.7 | +1.5 | +3.0 | +19.5 | +6.1 |

[1] Interpolated values

Table IV. KETONE BODY EXCRETION (GRAMS)

| | Period I | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Diet "0" | | | | Diet "40" | | | | Diet "80" | | | |
| Day | Subject | | | | Subject | | | | Subject | | | |
| | 2 | 3 | 4 | 8 | 1 | 5 | 10 | 12 | 6 | 7 | 9 | 11 |
| Control | 0.02 | 0.03 | 0.05 | 0.05 | 0.12 | 0.02 | 0.04 | 0.02 | - | 0.03 | 0.03 | 0.03 |
| " | 0.06 | 0.08 | 0.07 | 0.07 | 0.41 | 0.09 | 0.06 | 0.07 | 0.08 | 0.09 | 0.09 | 0.06 |
| 1 | 0.31 | 0.18 | 0.29 | 0.42 | 0.48 | 0.10 | 0.22 | 0.81 | 0.19 | 0.22 | 0.31 | 1.16 |
| 2 | 1.36 | 0.65 | 1.18 | 5.02 | 0.54 | 0.73 | 3.77 | 1.68 | 0.48 | 0.35 | 0.86 | 3.45 |
| 3 | 1.45 | 0.52 | 0.85 | 1.14 | 0.25 | 0.37 | 0.66 | 0.63 | 0.27 | 0.23 | 0.37 | 1.40 |
| 4 | 0.86 | 0.50 | 0.84 | 1.56 | 0.32 | 0.29 | 0.96 | 0.67[1] | 0.19 | 2.27 | 0.20 | 1.10[1] |
| 5 | 0.86[1] | 0.53 | 1.17 | 2.39 | 0.29 | 0.56 | 1.35 | 0.72 | 0.11 | 0.18 | 0.11 | 0.80 |
| Totals[2] | 4.84 | 2.38 | 4.33 | 10.53 | 1.88 | 2.05 | 6.96 | 4.51 | 1.24 | 3.25 | 1.85 | 7.91 |
| Group Means | 5.52 | | | | 3.85 | | | | 3.56 | | | |
| | **Period II** | | | | | | | | | | | |
| | Diet "0" | | | | Diet "40" | | | | Diet "80" | | | |
| Day | Subject | | | | Subject | | | | Subject | | | |
| | 5 | 9 | 10 | 11 | 2 | 6 | 7 | 8 | 1 | 3 | 4 | 12 |
| 1 | 0.09 | 0.10 | 0.02 | 0.07 | 0.04 | 0.07 | 0.18 | 0.06 | 0.30 | 0.05 | 0.07 | 0.04 |
| 2 | 0.12 | 0.25 | 0.12 | 0.50 | 0.11 | 0.12 | 0.09 | 0.09 | 0.20 | 0.05 | 0.10 | 0.49 |
| 3 | 0.18 | 0.47 | 0.56 | 0.94 | 0.11 | 0.16 | 0.16 | 0.12 | 0.29 | 0.04 | 0.07 | 0.10 |
| 4 | 0.15 | 0.61 | 0.87 | 2.88 | 0.18 | 0.21 | 0.07 | 0.37 | 0.29 | 0.05 | 0.09 | 0.17 |
| 5 | 0.70 | 0.94 | 1.55 | 2.91 | 0.20 | 0.19 | 0.12 | 0.56 | 0.24 | 0.07 | 0.07 | 0.24 |
| Totals[2] | 1.24 | 2.37 | 3.12 | 7.30 | 0.64 | 0.75 | 0.62 | 1.20 | 1.32 | 0.26 | 0.40 | 1.04 |
| Group Means | 3.51 | | | | 0.80 | | | | 0.75 | | | |
| II - I | -0.81 | +0.52 | -3.84 | -0.61 | -4.20 | -0.49 | -2.63 | -9.33 | -0.56 | -2.12 | -3.93 | -3.47 |

[1] Interpolated values

[2] Post-treatment totals

(figure 2) are not appreciably different from each other and the initially large tissue nitrogen losses did not occur as in Period I.

Ketonuria. The excretions of ketone bodies in the urine are presented in table IV. During Period I, there are no significant differences between the dietary groups (table II), although the

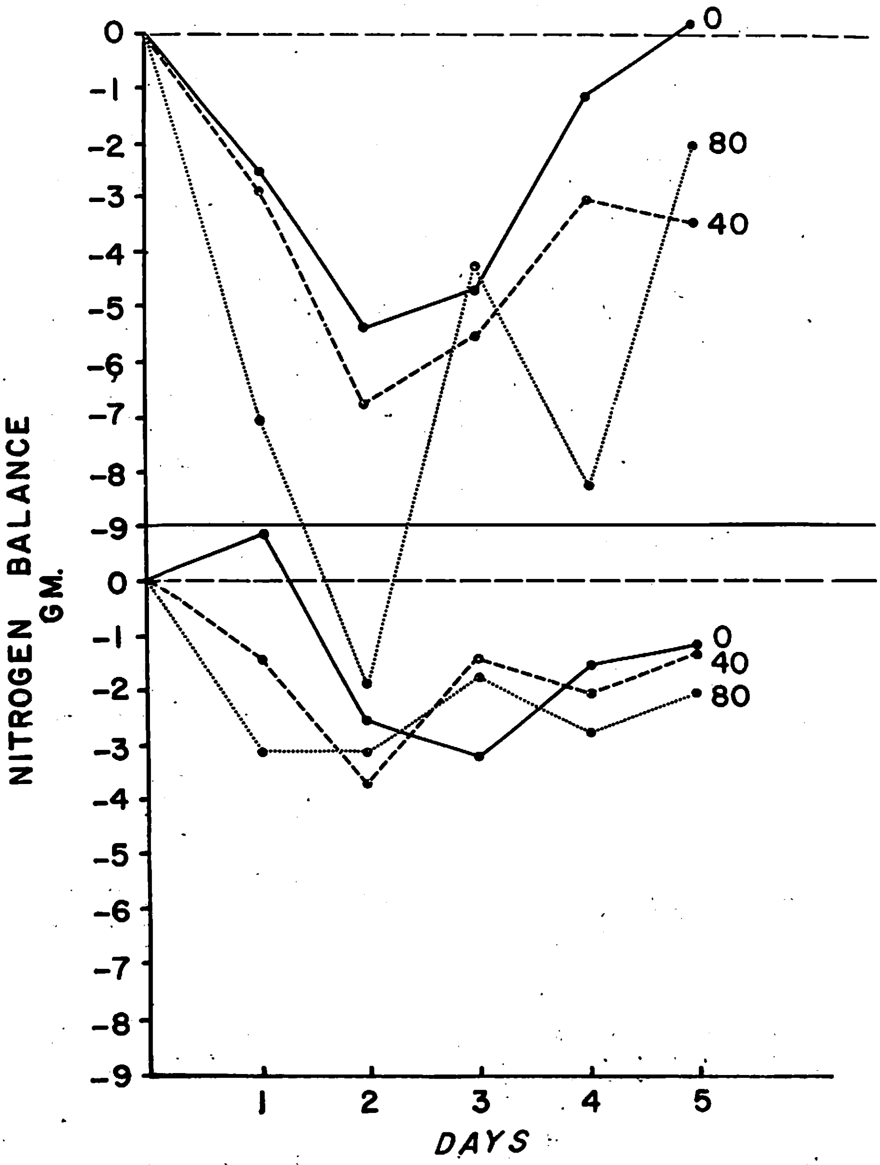


Figure 2. Daily variation in nitrogen balance

means of the 5-day excretions tend to differ according to the amount of sugar ingested (figure 4). The time-course of the ketone body excretions, as shown in figure 5, was similar to that obtained in the previous study: Subjects receiving the "0" and "40" diets tended to increase ketone body excretion on the last day, while the "80" group means fell to quite low levels.

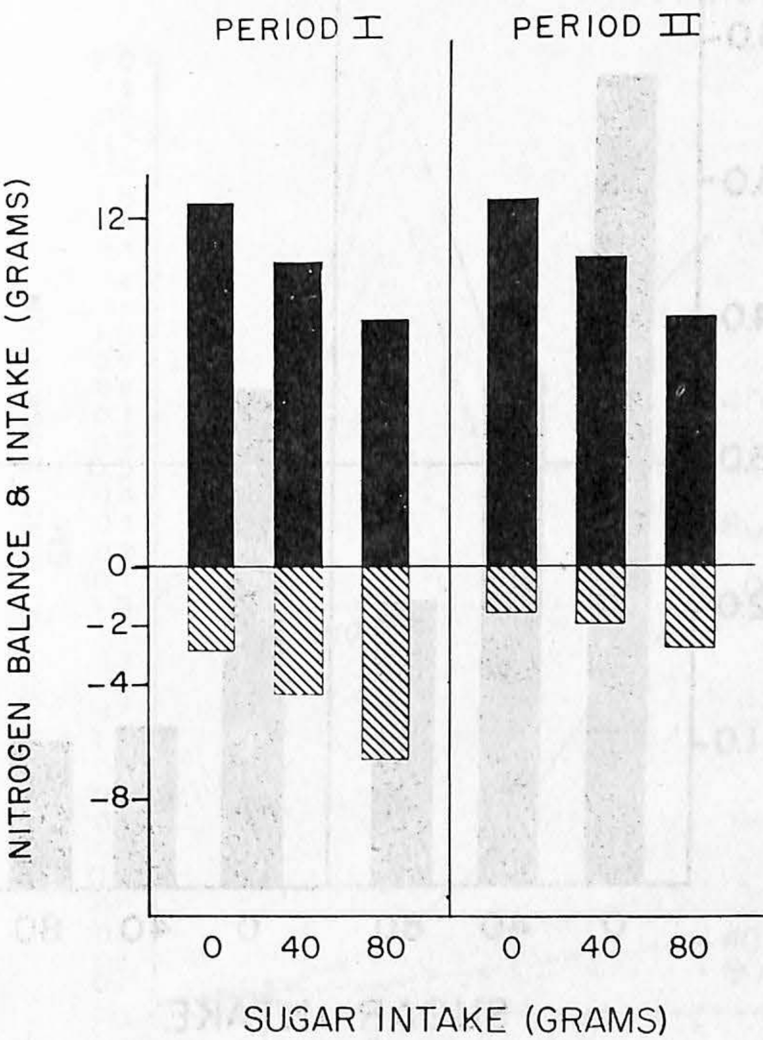


Figure 3. Mean daily nitrogen catabolism. Each bar represents four subjects

During Period II, however, the responses of the subjects to the experimental diets changed drastically. The ketone body excretion of the "O" group is significantly higher (table II) than that of the

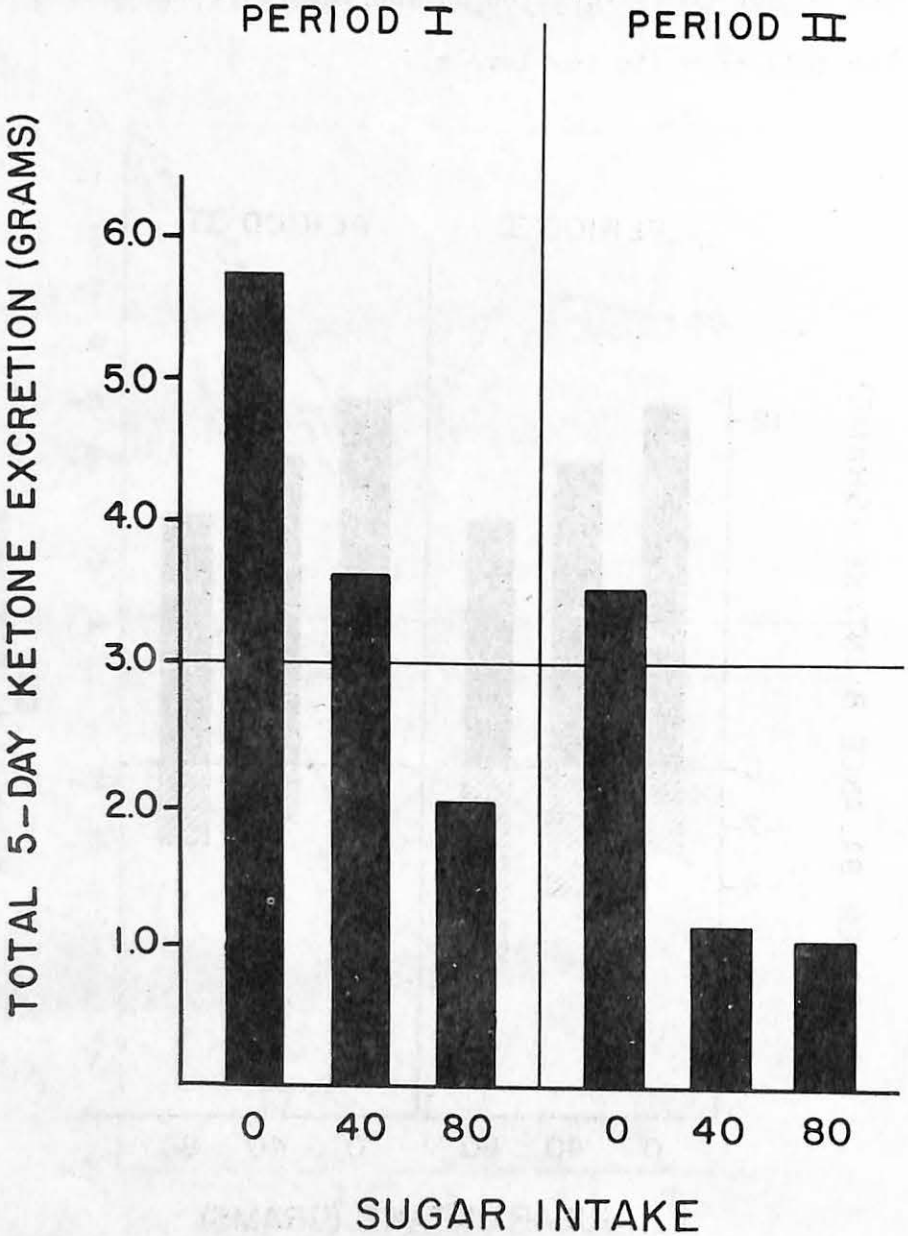


Figure 4. Ketonuria. Each bar represents the mean of four subjects

groups receiving sugar. Furthermore, the time-course of daily ketone excretions was changed. Instead of the sharp initial rise, group "O" excretions rose slowly during the 5 days, reaching a maximum on the 5th day. Neither of the other groups exhibited a rise in ketone excretion during the 5-day period.

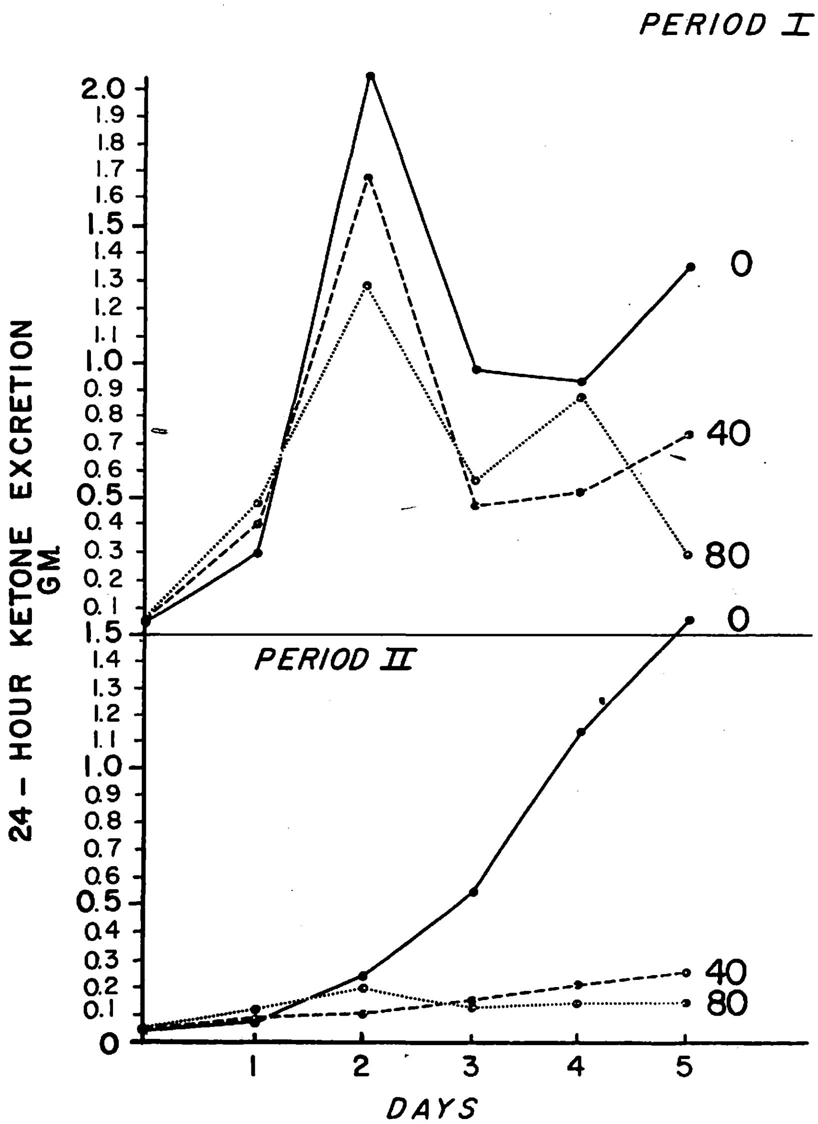


Figure 5. Daily variation in excretion of ketones

Effects of Previous Diet

From the results presented thus far, it is quite evident that the subjects' responses to the dietary treatments during Period II were modified in such a way as to preclude consideration of the latter as a simple replication of Period I. It further appeared necessary to assume that the experiences of Period I were affecting responses to the Period II treatments in at least two ways. The data were analyzed with respect to these points of view: 1) that responses to the second period treatments had been influenced by a non-specific effect such as caloric restriction in general, common to all the dietary treatments of the first period and unrelated to the particular composition of any of the diets of either period; 2) that, in addition, the results obtained during Period II were related specifically to the amount of sugar eaten in Period I.

The means of the fasting blood sugar values are higher in Period II than in Period I (table I). This difference is highly significant (table V). When the differences of the means are analyzed with respect to the amount of sugar eaten during Period I, it will be seen (table V) that the increases in fasting blood sugar from Period I to Period II are greatest for the subjects who had previously received no sugar and least for the men receiving 80 gm. of sugar. A somewhat different breakdown of these differences (table V) shows that the subjects who received more sugar in Period II than in Period I exhibited the greatest increase in fasting blood sugar levels. In the previous discussion of the analysis of the fasting blood sugar values during

Table V. ANALYSES OF VARIANCE OF RESIDUAL EFFECTS

Period I vs Period II

| Source | Fasting blood sugar df | Fasting blood sugar Mean Square | Fasting blood sugar F | Adjusted weight loss df | Adjusted weight loss Mean Square | Adjusted weight loss F | Nitrogen Balance df | Nitrogen Balance Mean Square | Nitrogen Balance F | Ketone excretion df | Ketone excretion Mean Square | Ketone excretion F |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Periods | 1 | 4915 | 23.74[1] | 1 | 6.04 | 3.11 | 1 | 870 | 20.71[1] | 1 | 41.8 | 11.61[1] |
| Subjects | 11 | 479 | | 11 | 1.78 | | 11 | 183 | | 11 | 8.5 | |
| Subjects x Periods | 11 | 207 | | 11 | 1.94 | | 11 | 42 | | 11 | 3.6 | |
| Days | 4 | 133 | 3.02[1] | | | | | | | | | |
| Subjects x Days | 44 | 42 | 1.00 | | | | | | | | | |
| Days x Periods | 4 | 203 | 4.61[1] | | | | | | | | | |
| Subjects x Days x Periods | 44 | 44 | | | | | | | | | | |
| Total | 119 | | | 23 | | | 23 | | | 23 | | |

Period II Fasting Blood Sugar Levels

| Source | Δ(II - I) when sorted by Period I diet df | Mean Square | F | Δ(II - I) when sorted by direction of diet shift[3] df | Mean Square | F | Pre-Period II control values sorted by Period I diet[4] df | Mean Square | F |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | 2 | 291.6 | 7.15[1] | 1 | 533.3 | 12.78[1] | 2 | 192.6 | 4.90[1] |
| (Linearity) | | | | | | | (1) | 204.8 | 5.21[5] |
| (Residual) | | | | | | | (1) | 180.5 | 4.59[5] |
| Error | 9 | 40.8 | | 10 | 41.7 | | 8[6] | 39.3 | |
| Total | 11 | | | 11 | | | 10[6] | | |

[1] $p < .05$
[2] Mean differences (II - I): $I_0 = 22$; $I_{40} = 11$; $I_{80} = 5$
[3] Mean level for Ss shifting up = 19; mean level for Ss shifting down = 6
[4] Adjusted means: "0" group = 80.4; "40" group = 93.7; "80" group = 90.6
[5] $0.05 < p < 0.10$
[6] Reduced by 1 df for regression coefficient; b = 1.406, $r_{xy} = 0.57$

Period II relative to the Period II diets, it was stated that the pre-Period II control values could not be used as independent variables because of their dependence upon the amount of sugar ingested during Period I. Proof of this is offered in table V. A striking similarity exists between the pre-Period II control values and the post-treatment fasting blood sugars in Period I. The group previously receiving the "40" diet had higher control fasting blood sugars than the group receiving no sugar, while there were no differences between the "40" and "80" group. Moreover, there is a curvilinear relation between the pre-Period II control values and the amount of dietary sugar in Period I, as the analysis in table V shows.

An analysis of variance of the 5-day nitrogen balances (table V) demonstrates that the differences in the means between Period I and Period II are significant. Furthermore, when the individual nitrogen balances for each subject are considered, it will be noted that each subject, regardless of the diet in Period II, catabolized less tissue protein during Period II (table III). Turning to the effect of the previous diet upon these nitrogen balances, no effect of this diet could be detected in these differences; i.e., the improvements in nitrogen balances were quite randomly distributed among the subjects. Subjects receiving the same diet in Period II, however, could be compared with respect to their diet in Period I. The bar graphs in figure 6 demonstrate such a comparison. It will be noted that subjects receiving the greater amounts of sugar in Period I exhibited a larger negative nitrogen balance in Period II, when the

Period II diet was the same.

The 5-day excretions of ketone bodies also exhibited a significant improvement (table V). Table IV reveals that all subjects except one excreted less ketone bodies during Period II than during Period I.

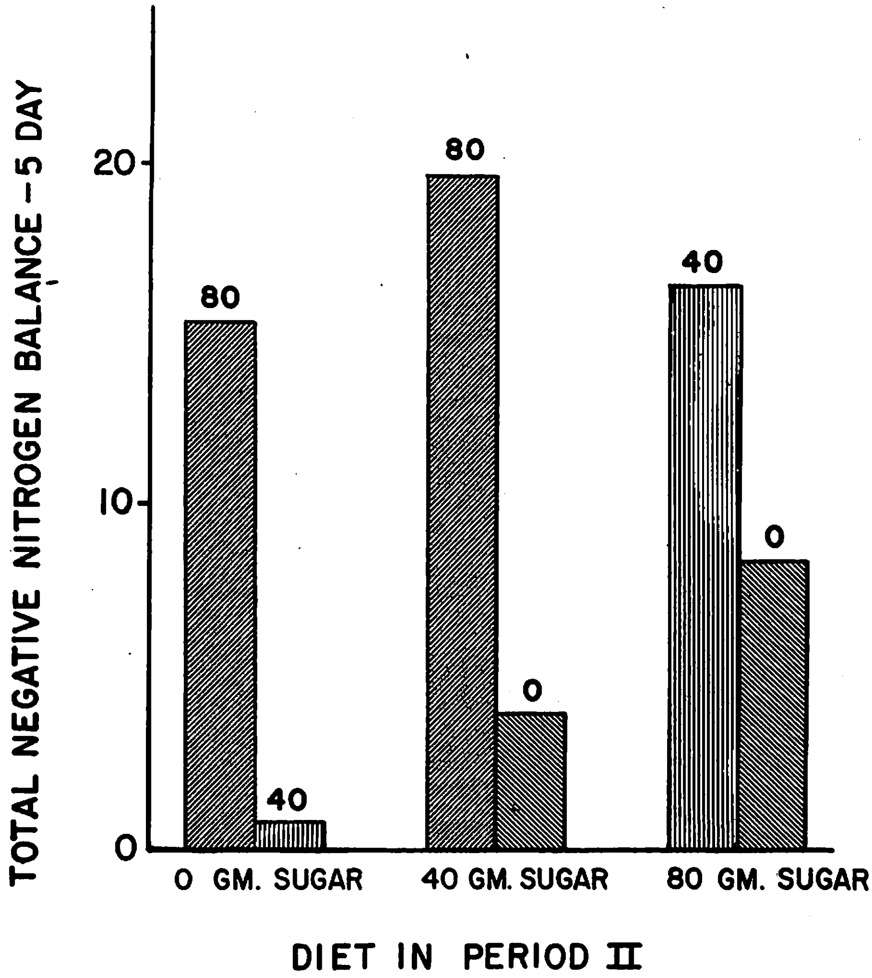


Figure 6. Negative nitrogen balance during Period II. Numbers above bars refer to diet in Period I. Each bar represents the mean of two subjects

A breakdown of these results with regard to the diet ingested previously in Period I failed to demonstrate any relation between previous diet and either 1) Period I minus Period II differences or 2) the Period II values when compared within groups receiving the same diet during Period II.

Since the subjects' metabolic responses to the stress of simulated survival improved, according to the indices used in this study, the question naturally arose as to whether or not the imposed stress during Period II was as severe as in Period I. Due to the unexpected nature of these results, the only measures of total stress that could be used were weight loss and physical fitness. These results are given in table VI.

On a severely restricted diet, body weight decreases rapidly during the first day or two, then stabilizes to a fairly constant rate of loss. To correct for this initial loss (which we believe is largely water loss). the line connecting the points which represent constant weight loss was extrapolated to zero days and the difference between this point and the measured initial weight was subtracted from total weight loss. Despite the trend for the adjusted weight losses to be greater in Period II, the differences are not significant (table V). By this criterion, then, stress during Period II was of the same magnitude as in Period I.

As in the previous study (4), increasing weakness and aversion to heavy work were noted as the study progressed. As a further indication of the extent of stress during the experimental periods, physical fitness tests were run. Since the change in the physical

Table VI. COMPARISON OF WEIGHT LOSSES AND PHYSICAL FITNESS INDICES BETWEEN PERIOD I AND PERIOD II

| Subject | Weight Losses | | | | Physical Fitness Indices | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Period I | | Period II | | Period I | | | Period II | | |
| | Measured lb | Adjusted[1] lb | Measured lb | Adjusted[1] lb | Before | After | Difference | Before | After | Difference |
| 1 | 7.50 | 5.00 | 9.00 | 5.50 | - | - | - | - | - | - |
| 2 | 7.50 | 7.50 | 9.00 | 5.50 | 33 | 26 | -7 | 45 | 39 | -5 |
| 3 | 9.50 | 4.00 | 8.00 | 6.50 | 30 | 18 | -12 | 29 | 28 | -1 |
| 4 | 8.75 | 6.25 | 12.50 | 7.50 | 29 | 24 | -5 | 33 | 26 | -7 |
| 5 | 11.00 | 6.00 | 12.25 | 7.25 | 36 | 32 | -4 | 46 | 34 | -12 |
| 6 | 10.75 | 5.25 | 10.00 | 6.50 | 41 | 33 | -8 | 67 | 72 | +5 |
| 7 | 5.25 | 5.25 | 6.50 | 3.25 | 46 | 37[2] | -9[2] | 47 | 34 | -13 |
| 8 | 2.00 | 2.00 | 9.50 | 7.00 | 37 | 23 | -14 | 44 | 32 | -12 |
| 9 | 5.25 | 3.25 | 8.50 | 5.75 | 24 | 28 | +4 | 34 | 31 | -3 |
| 10 | 6.50 | 6.50 | 6.75 | 6.75 | 61 | 32 | -29 | 64 | 32 | -32 |
| 11 | 8.00 | 4.50 | 8.75 | 6.50 | - | - | - | - | - | - |
| 12 | 8.00 | 5.00 | 7.50 | 4.50 | 63 | 57 | -6 | 78 | 88 | +10 |
| Means | 7.50 | 5.00 | 9.00 | 6.00 | | | -9 | | | -7 |

[1]See text
[2]Interpolated values

fitness index should give some indication of the magnitude of the stress involved, a comparison was made of the changes induced by Period I versus Period II. The decrements in the physical fitness indices induced by the Period II treatment are essentially the same as those induced by Period I (table VI).

## DISCUSSION

Although the use of pemmican as an emergency ration has received unfavorable comment in the past (3, 8, 10), observations during this and the previous study (4) indicate that pemmican can be used effectively during short periods of enforced caloric restriction. Many of the untoward reactions (nausea, giddiness, etc.) occur during the first 3 days and can be tentatively traced to the sharp drop in fasting blood sugar level and dehydration, both of which are attendant features of caloric restriction in general. Isocaloric supplementation with 40 gm. of sugar alleviates these symptoms somewhat, possibly due to its beneficial effect on the blood sugar levels. However, an 80-gm. supplement of sugar does not appreciably increase the fasting blood sugar level beyond the point reached at 40 gm. nor does it further lower the level of ketone excretion. Furthermore, this added sugar replaces a certain amount of the dietary protein, causing the body to catabolize larger amounts of stored nitrogenous material (figure 3).

The Period I curves presented in figures 1, 2, and 5 suggest that adaptive changes have taken place. The rise in the fasting blood sugars indicates the establishment of a new level compatible with increased fat catabolism. When exogenous sugar is superimposed upon this level, the fasting blood sugar rises, possibly as a result of depressed carbohydrate metabolism (2, 6, 9). Exogenous sugar, however, does not spare protein in these studies. As a matter of fact, the rise in fasting blood sugar levels coincides with the decrease in protein catabolism, suggesting that gluconeogenesis is occurring from fat (1, 12) rather than from protein. Suggestions concerning tentative pathways of adaptation to the combined effects of pemmican and restricted caloric intake are discussed in the previous report (4).

As indicated in the introduction, the dissimilarity between the results of Period I and Period II was unexpected, and our experimental design proved inadequate to secure the data necessary to arrive at a final decision between several statistically tenable hypotheses. Fortunately, some of these hypotheses can be rejected on logical grounds. For example, the first possibility that comes to mind is that the environmental stress was not as severe during the second period. However, since the caloric intake was identical, and since there was no significant difference in the weight losses, it follows that the energy expenditure must have been substantially the same. This, plus other considerations not amenable to statistical treatment, such as physical fitness decrements and subjective impressions, have led us to conclude that the differences in results stemmed from a true difference in initial physiological state.

We consider it probable, although admittedly not finally proven, that a metabolic adjustment or adaptation to restricted caloric intake, and possibly even to the slight differences in composition of the various diets, persisted throughout the intervening period. It is common knowledge that dietary adaptations do occur. The question here is how long they can last after cessation of the exciting stimulus. We have no quantitative information on this point, but other observations in the literature indicate that the influence of fasting, at least, may persist for an appreciable period. Folin and Denis (5) observed that a trend toward lower ketone and nitrogen excretion in fasting obese individuals began in the second fasting period. Taylor et al. (11) have noted that men undergoing successive fasts separated by 5-6 week intervals maintained their blood sugar at higher levels, lost less nitrogen, and excreted less ketone bodies during the 5th fast than during the initial fast. The similarity between the pre-Period II control and Period I fasting blood sugar levels, as well as the reflection of the Period I dietary treatments in the Period II increases in fasting blood sugar, also suggest a persistence of Period I effects.

It is, of course, possible that the effects noted during the second period were due to dietary habits indulged during the interim, ad libitum, feeding period which, in turn, were conditioned by the Period I treatments. This seems rather unlikely in view of the very small differences between the carbohydrate contents of the experimental diets, particularly in the face of the overriding, general caloric deprivation.

Even though a simple explanation of the dissimilarities between the two experimental periods is not possible, occurrence of such dissimilarities indicates the need for caution in the interpretation of the results of field studies which are separated by short recovery periods. It is not unreasonable to suppose that individuals who have apparently recovered from a stress retain a latent capacity for the effective management of a subsequent stress of the same type.

## SUMMARY

The adequacy of pemmican as an emergency ration for short-term survival has been confirmed.

The isocaloric substitution of pemmican with sugar in amounts over 40 gm. was found to have little, if any, effect on fasting blood sugar, nitrogen balance, and ketonuria.

Evidence is presented that caloric restriction per se, as well as the composition of the diet during caloric restriction, has effects which persist throughout an intervening period of ad libitum dietary intake.

## ACKNOWLEDGMENT

The authors are indebted to Lt. Colonel R. B. Payne for his valuable assistance with the statistical analyses.

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