EFFECTS OF A PROLONGED REDUCTION IN DIET ON 25 MEN

III. INFLUENCE ON EFFICIENCY DURING MUSCULAR WORK

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Of the various forms of muscular activity which might have been chosen for a quantitative study of the efficiency of the human machine under a prolonged period of reduced diet, that of walking was selected since it is the most common and necessary exercise, the element of training is practically negligible, and the results can be expressed in common and well understood terms.

The principle employed in this study consisted of the measurement of the gaseous exchange during the period of walking, and from the oxygen consumed and its known heat value for the determined respiratory quotient the energy requirement was calculated by indirect calorimetry.

The heat requirements thus found may be considered in two ways: (1) as the total cost to the individual to walk a given distance including that fraction of heat which is necessary to maintain the body organs at their normal functions and irrespective of the differences in the amount of body weight transported, or (2) it may be considered on the basis of the cost to the individual to move a unit mass of body weight a unit distance, over and above the cost for the maintenance of the body at some selected basal condition, such as lying or standing quietly. In other words it would be the cost of the superimposed work of walking. In reporting the energy requirement by the latter method it is necessary to know this resting or basal metabolism as well as that of walking.

The problem then was to determine the gaseous exchange of the subjects, at rest and walking, both before and after reduction of diet, and from the differences in the heat developed compute the average energy expended for each man under the different conditions.

Of the various methods of determining the gaseous exchange, the closed chamber principle with gas analyses for carbon dioxide and oxygen at the beginning and end of the experiment was selected for the walking experiments.

Accordingly an air-tight sheet-iron chamber was built large enough to enclose a power-driven treadmill with a man walking on it. The chamber was irregular in shape with a total volume of approximately 2400 liters. Suitable arrangements were installed for controlling the speed of the mill and recording the distance traveled and the number of steps taken.

The temperature of the chamber was determined by six resistance thermometers suitably placed and connected in series with a Wheatstone bridge and galvanometer placed in an adjoining room. Two electric fans stirred the air within the chamber while a blower capable of moving 1000 liters of air a
minute carried the air through a pipe extending from the front of the chamber to a drier and thence back into the rear of the chamber. In this pipe of moving air was placed the psychrometer and from it the gas samples were withdrawn for analysis.

During the period of walking pulse records were continuously made by means of electrocardiograms.

The carbon dioxide was determined in duplicate by means of two Haldane portable gas analysis apparatus, while the oxygen was found by means of the Sondén apparatus.

Two groups of 11 and 12 men respectively were under investigation. One squad, designated as the diet squad, was on a reduced ration from October 4 to February 3, while the other squad, known as the control squad, acted as a control until January 8 when it also went on a reduced diet until January 28.

The first experiment was made on January 6 with the 12 men of the control squad two days before their reduction of diet began. Each man walked in the chamber for twenty-four minutes at a rate close to 69.5 meters per minute. After a preliminary period of four minutes, during which time the necessary adjustments were made, the experiment proper began and continued for twenty minutes. The gas samples were drawn at the start and end of this twenty-minute period and from the increase in the percentage of CO₂ and the decrease in the percentage of O₂ the respiratory quotient was found and the energy expended was computed.

The average total heat, thus measured, figured on a kilometer basis, is given in table 1 and amounts to 62.2 calories.

After this squad had been on a reduced diet for twenty days the experiment was repeated and it was then found to cost each man on an average 53.5 calories per kilometer. No experiment was made with the diet squad in September as the chamber was not in readiness at the beginning of the study, but on February 3 after four months' dieting an experiment made under the same conditions as the two preceding showed an average expenditure of 48.4 calories per kilometer.

As the average normal weights of the members of the two squads before dieting began differed from each other by only 0.5 kilogram, and since the basal metabolism of the two squads as determined in a large respiration cham-

<table>
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<tr>
<th>SQUAD</th>
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<th>TOTAL HEAT REQUIRED PER MAN PER KILOMETER</th>
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<tr>
<td>Control</td>
<td>Normal</td>
<td>62.2</td>
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</tr>
<tr>
<td>Control</td>
<td>20-day diet</td>
<td>53.5</td>
<td>14</td>
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<tr>
<td>Diet</td>
<td>4-month diet</td>
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ber under normal conditions was alike, a comparison of the three sets of experiments may fairly be made. This shows a drop in the energy expended per man per kilometer of 8.7 calories for the twenty-day diet and of 13.8 calories for the four months' diet.

That this drop in the energy requirement is not wholly due to the fact that there was less body weight to be moved may be seen by considering the heat requirements from the second viewpoint, viz., on the basis of a kilogram of body weight transported one horizontal meter.

In considering the energy requirements on this basis, it is usual to deduct from the total heat measured that portion which may be ascribed to the basal requirements of the body in a position of rest. Therefore, in addition to the series of walking experiments just described there was also conducted a series of experiments while the subjects were standing quietly. These were carried out with a portable respiration apparatus in an adjoining room immediately preceding the walking experiment. The difference between the standing and walking metabolisms may then be attributed to the superimposed requirement due to walking, and from the distance walked in unit time and the body weight, the requirement per horizontal kilogrammeter may be obtained.

The three sets of experiments figured upon this basis are given in table 2. Here is shown a decreasing energy requirement from 0.610 gram calorie per horizontal kilogrammeter for the control squad in normal condition to 0.561 gram calorie for the diet squad after subsisting four months on a diet of about two-thirds normal. This reduction in the energy from 0.610 to 0.561 gram calorie per horizontal kilogrammeter amounts to an increase in efficiency of approximately 14%.

The results of these experiments are quite positive and show a marked saving in the energy requirements for walking in favor of the reduced diet whether considered on the basis of the gross energy expended which represents the real cost to the individual and to the national food reservoirs, or on the basis of the energy required per horizontal kilogrammeter. Although the results here submitted are confined to one form of muscular activity nevertheless it is believed that the quantitative results obtained would be duplicated if other forms of muscular work were studied.