Some Relations Between Body Weight, Body Fat, and Calorie Intake

By Morton I. Grossman, M.D., Ph.D., and Harry S. Sloane

The relation between the weight, composition, and configuration of the body and basal metabolic rate has been studied extensively. Likewise, considerable attention has been given to the relation between body size and the energy cost of specific tasks. However, aside from certain theoretical considerations, little information is available on the relation between total energy requirement and body size and body composition.

In the course of studies conducted by the Medical Nutrition Laboratory at Pole Mountain, Wyo., during January-March 1953, information bearing on this problem became available and certain aspects of it are presented in this report.

Observations and Results

The detailed description of the procedures used is given in the report of the experiment.[1] In essence, observations are available on total food intake, body weight, body fat as determined by skinfold measurements, and urine total nitrogen output on a group of 87 test subjects living under controlled conditions. The weight of each food item eaten by each man at each meal was recorded. The caloric content of the food eaten was calculated by the use of standard tabular values.

The Relation of Calorie Intake to Body Weight

During a one-week period (the sixth week of the experiment) when the men were on an *ad libitum* food intake (with a maximum of 4100 calories available), there were 35 men who showed less than 0.5 per cent change in body weight. The activity program during this week was not regulated. In the 35 men with constant body weight, the relation between body weight and calorie intake was analyzed statistically. The correlation coefficient between these variables was +0.303, which is just below that required for significance at the 5 per cent level.

These same data were also analyzed after transformation of body weight and calorie intake values to logarithms. The correlation coefficient was +0.314, which again is just below the value required for significance at the 5 per cent level.

A similar analysis was performed on the data from the third week of the experiment, at which time the men were on an assigned program of activity designed to produce an average expenditure of 3700 calories per day. Food intake was *ad libitum* with a maximum of 4100 calories per day available. There were 52 men whose body weight changed less than 1 per cent during this week. The correlation coefficient was +0.299 (significant at the 5 per cent level).

The data from the third week were also calculated in the logarithmic form. The correlation coefficient was +0.327 (significant at the 5 per cent level of probability).

Comment

The attempt to correlate body weight with caloric requirements is complicated by variations in caloric expenditure for physical activity. Obviously, physical activity will vary even during a period when a prescribed program is being followed. However, in the practical situation, the aim is to adjust for body weight within a group of subjects who are all at the same general level of activity.

From the U. S. Army Medical Nutrition Laboratory, Denver.

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We have been unable to find other data in the literature relating calorie intake to body weight, and our own observations are admittedly limited. The correlation between body weight and calorie intake, although significant, was low. Further observations are obviously required to clarify the relation of body size to total energy requirement.

The Relation of Calorie Intake to Body Weight and Fatness

The same data from the sixth week referred to above were used, but, in addition, the per cent body fat as calculated from skinfold measurements was also incorporated and multiple regression analysis performed. For the regression of calorie intake on body weight and per cent body fat, the multiple regression coefficient, R, was 0.496, which is significant at the 5 per cent level of probability. The partial correlation coefficient of calorie intake and body weight independent of fatness, was +0.466, which is significant at the 1 per cent level. The partial correlation coefficient of calorie intake and per cent body fat, independent of body weight, was —0.412, which is significant at the 5 per cent level.

The data from the third week referred to above were also subjected to multiple regression analysis. The multiple correlation coefficient, R, was 0.494 (significant at the 5 per cent level). The partial correlation coefficients were +0.494 (significant at the 1 per cent level) for calorie intake and body weight independent of fatness, and —0.412 (significant at the 1 per cent level) for caloric intake and per cent body fat independent of body weight.

Comment

It is only within recent years that methods for the accurate estimation of leanness-fatness in man have become available.[2] To our knowledge, no previous studies have been performed utilizing these methods to correlate body fatness and caloric intake. The only studies available on the relation of fatness to food intake are comparisons of normal individuals with the grossly obese (see reference No. 3 for citations to literature). The most recent study of this type was that of Beaudoin and Mayer,[3] who found that obese women consumed more calories than nonobese controls, but since they give no height-weight data on their subjects, it is difficult to evaluate their findings.

For the estimation of body fatness from skinfold thickness in the present study the regression equations derived by Brožek and Keys were used.[4] More recent studies in our laboratory[5] have shown that, while the correlation between fatness, as estimated by skinfold thickness using the Brožek-Keys equation, and by underwater weighing using the Pace-Rathburn equation, is excellent ($r = +0.92$), the skinfold method consistently underestimates the body fatness by approximately 5 per cent. Therefore, the values for per cent body fat reported here are probably lower than the true values, but the relative values for comparisons among different men are probably valid.

The results obtained indicate that for a given body weight the calorie intake decreases with increasing body fatness. The most obvious explanation for this relation is that as the body fatness increases, the fraction of metabolically active tissue decreases. Whether this is the entire explanation for this phenomenon remains to be established. The possibility that a correlation exists between fatness and the amount of activity in which the individual engages should also be considered.

Peckos[6] reported that children with endomorphic physique consumed less calories than mesomorphs or ectomorphs, a finding in keeping with the present results.

Relation of Per Cent Body Fat to Per Cent of Calories in the Diet Derived from Fat

Again, using data from the sixth week, but in this instance including 87 subjects, i.e., both those whose weight remained constant and those whose weight changed, a correlation coefficient was computed between per cent body fat and per cent of calories derived from fat. The correlation coefficient was +0.217,

which is significant at the 5 per cent level of probability.

A similar analysis for the third week of the experiment on 85 subjects gave a correlation coefficient between per cent body fat and per cent of calories derived from fat of +0.117, which is not significant at the 5 per cent level.

Comment

Studies in animals have rather clearly established that the per cent of fat in the body increases as the per cent of fat in the diet increases,[7–9] although there would appear to be differences among strains of animals in this regard.[9] Studies of the diets selected by obese human subjects have not revealed a clear difference in the per cent of calories derived from fat when compared to nonobese controls.[3] In the present study, the correlation between per cent of calories derived from fat and body fatness was significant in one period, and just below the 5 per cent level of significance in another period. Since the diet offered was a fixed one, relatively little opportunity was afforded for variation of per cent of calories derived from fat by selection. The suggestive findings in the present study indicate that further studies under more nearly *ad libitum* conditions of selection might give more clear-cut correlations.

Relation of Weight Loss During Calorie Restriction to Body Weight and Per Cent Body Fat

During the seventh to tenth weeks, inclusive, the subjects were placed on restricted calorie intakes (2500 calories during the first 11 days and 2000 calories during the last 12 days). Sixty-two of the subjects consumed all the food offered to them during this period. Multiple regression analysis of weight loss on body weight and per cent body fat at the beginning of the restricted calorie period gave a multiple correlation coefficient, R, of 0.605, which is significant at the 1 per cent level of probability. The partial correlation coefficients were +0.472 (significant at 1 per cent level) for weight loss and initial body weight independent of fatness, and +0.14 (not significant at 5 per cent level) for weight loss and per cent body fat independent of body weight. The mean weight loss was 3.97 ±1.24 (S.D.) kg.

Comment

It was found that weight loss during calorie restriction at a fixed level was strongly correlated with initial body weight, as would be anticipated. Surprisingly, the weight loss was not significantly correlated with body fatness. *A priori,* one would anticipate that weight loss would be less with higher per cent fatness, for two reasons, viz., (1) as demonstrated in the present study, for a given body weight the calorie requirement decreases as fatness increases, and (2) the high calorie value of adipose tissue would require greater calorie deficit per kilogram of loss. However, in regard to this second point, Keys and Brožek[6] have pointed out that the tissue lost during calorie restrictions tends to have a relatively constant composition when subjects in the normal range of body fatness undergo slight weight reduction.

Relation Between Nitrogen Excretion During Calorie Restriction and Body Weight and Per Cent Body Fat

Again using data from the period of restricted calorie intake (seventh through tenth weeks of the experiment), the relation between urine nitrogen output in grams per day on the fifth day of calorie restriction, body weight in kg, and per cent body fat, both of the latter two values being taken at the beginning of calorie restriction, was analyzed by multiple regression techniques. The multiple correlation coefficient was 0.429 (significant at the 1 per cent level). The partial correlation coefficients were +0.425 (significant at the 1 per cent level) for urine nitrogen and body weight independent of fatness, and −0.361 (significant at the 1 per cent level) for urine nitrogen and per cent body fat independent of body weight. The mean urine nitrogen was 12.35 ±2.76 (S.D.) grams per day.

A similar analysis was performed on the data obtained later in the period of calorie

TABLE I

Means and Standard Deviations

Analysis No.	Week		Description	Mean & standard deviation	n
I	6th	Y	Calorie Intake	3645.6 ± 328.5	35
		X	Body Weight (kg)	70.1 ± 7.61	
II	6th	Y	Calorie Intake	3645.6 ± 328.5	35
		X	Body Weight (kg)	70.1 ± 7.61	
III	3rd	Y	Calorie Intake	3583.6 ± 408.6	52
		X	Body Weight (kg)	71.0 ± 10.72	
IV	3rd	Y	Calorie Intake	3583.6 ± 408.6	52
		X	Body Weight (kg)	71.0 ± 10.72	
V	6th	Y	Calorie Intake	3645.6 ± 328.5	35
		X_1	Body Weight (kg)	70.1 ± 7.61	
		X_2	% Body Fat	4.88 ± 2.69	
VI	3rd	Y	Calorie Intake	3583.6 ± 408.6	52
		X_1	Body Weight (kg)	71.0 ± 10.72	
		X_2	% Body Fat	5.95 ± 3.73	
VII	7th–10th	Y	Weight Loss	3.97 ± 1.24	62
		X_1	Body Weight (kg)	69.93 ± 8.34	
		X_2	% Body Fat	4.55 ± 2.72	
VIII	7th	Y	Urine nitrogen output in grams per day	12.35 ± 2.76	62
		X_1	Body Weight (kg)	35.55 ± 4.51	
		X_2	% Body Fat	2.53 ± 1.51	
IX	9th	Y	Urine Nitrogen	11.71 ± 2.21	75
		X_1	Body Weight (kg)	68.67 ± 8.65	
		X_2	% Body Fat	3.36 ± 1.90	

restriction, using urine nitrogen in grams per day on the fifteenth day of calorie restriction, body weight in kg on the fifteenth day of calorie restriction, and per cent body fat on the twentieth day of calorie restriction. The multiple correlation coefficient was 0.242 (not significant at 5 per cent level). The partial correlation coefficients were +0.239 (significant at 5 per cent level) for urine nitrogen and body weight independent of fatness, and −0.194 (not significant at 5 per cent level) for urine nitrogen and per cent body fat independent of body weight.

Comment

Studies on obese subjects[10,11] have revealed that during calorie restriction they exhibit a smaller negativity of nitrogen balance than do nonobese subjects. In the present study, this relation was found to obtain also among men within the normal range of leanness-fatness, that is, nitrogen excretion decreased as body fatness increased. This would appear to cast some doubt upon the concept expressed above, that the composition of tissue lost during calorie restriction does not vary with initial fatness. However, the correlation between body fatness and nitrogen excretion which obtained early in the course of calorie restriction was not present later.

A summary of the means and standard deviations for the various sets of data is given in Table I. The details of the statistical analyses are contained in a report from this laboratory.[12]

Discussion

The caloric requirements of an individual can be divided into the following components: basal metabolism, specific dynamic action, and energy expenditure involved in physical activity. An expression of the form,

$$\text{basal metabolism} = aW^n$$

predicts basal metabolism with reasonable accuracy (where a and n are constants and W is body weight). The n constant is usually taken to be 0.73 (or a value of this general magni-

tude) and the a constant varies with sex and age. Specific dynamic action is in general related to the amount of food eaten and is usually taken as 0.66 to 0.10 times the caloric value of food eaten. The energy expenditure involved in physical activity is usually divided into two components, one related to and directly proportional to body size, and another relatively unrelated to body size. The FAO Committee on Calorie Requirements,[13] from a theoretical analysis of these components, arrived at the conclusion that total energy requirement for people of various sizes and activities could be estimated with reasonable accuracy from an equation of the same form as that relating body weight and basal metabolism, namely $aW^{0.73}$, by selecting a value of a appropriate for the activity level of the group. This is essentially the same as the frequently employed method of estimating energy requirement by multiplying basal metabolism by a factor appropriate for the activity of the individual.[14] As a test of the validity of this equation we have calculated the a and n constants from our own data. For men with an average body weight of 71 kg and an average calorie intake of 3600, the equation in the form suggested by the FAO Committee is $\hat{y} = 163W^{0.73}$, whereas the corresponding equation derived directly from our data for the third week of the experiment is $\hat{y} = 1168.5W^{0.262}$. When the variances of the observed calorie intakes from the regression lines described by these two equations are compared, a variance ratio, or F value, of 1.53 is obtained (not significant at the 5 per cent level of probability). Therefore it cannot be stated with certainty that the equation derived directly from the data has better predictive value than the theoretically derived equation of the FAO Committee. Perhaps the point of greatest interest is that the correlation between calorie intake and body weight, although statistically significant, is of low order, and that accurate prediction of calorie requirement requires the consideration of parameters in addition to body weight. As pointed out elsewhere in this paper, body fatness is one such factor, and taking it into account improves the correlation between body weight and calorie intake.

Summary

During the course of a field experiment in which 87 soldiers served as test subjects, the following observations were made:

1. The correlation between body weight and calorie intake, although statistically significant, was low.
2. When calorie intake was related to per cent body fat independent of body weight, an inverse relationship was revealed, i.e., calorie intake decreased as per cent body fat increased.
3. During two one-week periods the relation between per cent body fat and per cent of calories derived from fat was examined. In one instance a significant positive correlation was found. In the other instance the correlation was not significant.
4. The loss of body weight during a period of calorie restriction at a fixed level was found to be significantly correlated with initial body weight but not with initial body fatness.
5. Nitrogen excretion in the urine early during the period of calorie restriction was significantly positively correlated with body weight and significantly negatively correlated with per cent body fat. At a later time during calorie restriction nitrogen excretion was correlated with body weight but not with body fatness.

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The Patient's Expectations

"The average patient appears to expect one of four things from his doctor: (1) some form of medicine, (2) advice or guidance in connection with a particular action or event going on at the time he is attending, (3) support (usually against some member of the family) in some particular action, or (4) "a letter to see a specialist." In addition all want to be told "what is the matter" and, of course, to be reassured that the condition is not serious.

Yet at the end of the first consultation most are content to go away without any of these things if they have an appointment to come again. Despite the usual cry, "The patient expects a bottle of medicine," I have found that if he is given ample time and the opportunity to talk fully, and is thoroughly examined before being told it is necessary to seek the cause of his symptoms by means of further interviews, he is happy to accept this—and there is seldom any later demand for medicine. Similarly, though it is said that the public has become "hospital-conscious" or "specialist-minded," I find that most patients who ask for "a letter to see a specialist" will agree to attend for further discussion of their troubles once they have been encouraged to talk freely."

—P. Hopkins. *Medical World* 83: 20, 1955.