Caloric Equivalents of Gained or Lost Weight

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WHAT is the caloric equivalent of one pound of body weight, gained or lost? To put the question in other words: How many calories in excess of the amount necessary to maintain caloric equilibrium will produce a gain of one pound of body weight; conversely, what caloric deficit will determine a loss of one pound of body weight? It is strange that a marked diversity of opinion exists among authorities on this subject. In this article an attempt will be made to clarify the matter.

PHYSIOLOGIC PRINCIPLES

It was shown by Bozenraad[1] that the average fat content of human adipose tissue taken from various parts of the bodies of well-nourished subjects is 87 per cent. One pound (454 g) of human adipose tissue, therefore, contains 395 g of fat. The caloric value of one g of animal fat is 9.5; consequently, the caloric equivalent of one pound of human adipose tissue may be considered to be about 3,750 cal.

Leathes[2] pointed out that carbohydrate and protein cannot be stored dry, but retain with them three or more parts of water, while fat can be stored in an almost pure state. Retention of a gram of fat gives the body 9 cal of reserve energy, while retention of a gram of water-soaked glycogen or protein provides only about one calorie. Failure to recognize this fundamental point has resulted in the greatest bedevilment.

What is the metabolism of carbohydrate, protein and fat in individuals in negative or positive caloric balances? The caloric value of the glycogen stores in the human body, as compared to protein and fat, is insignificant and undergoes but trivial changes when the individual is in clinical negative or positive caloric balance.

With regard to protein metabolism, the following may be noted. Strang *et al.*[3] studied 13 obese patients under the especially rigid conditions of the metabolic service for an average period of 59 days. The average diet provided 58 g of protein, 14 g of carbohydrate, and 8 g of fat, with a total value of 360 cal. They state: "During the first three weeks of dieting, patients may lose nitrogen to the extent of 40–50 per cent above the nitrogen intake. The addition of 10 to 15 g of carbohydrate to the diet causes an abrupt drop in the nitrogen output and the attainment of a permanent nitrogen balance without the alteration of the nitrogen intake." Another group of patients studied by Strang and Evans[4] was kept approximately in nitrogen equilibrium on diets of 600 to 650 cal.

There is a paucity of work on indirect methods for the study of body composition and the findings are conflicting. Behnke, Osserman, and Welham,[6] in a study of "lean body mass," found: (1) On a restricted diet accompanied by body weight loss constancy in the weight of the lean body mass indicates that nitrogen balance is maintained and that the "lost" tissue is fat. (2) In individuals who gained weight, the changes in the lean body mass were slight and the calculated densities of the tissues gained were all within the range of body fat. Keys, Anderson, and Brožek,[5] in a study of weight gain from simple overeating made observations which are at variance with those of Behnke *et al.*[5] They found the tissue mass gained to be 13 to 15 per cent extracellular fluid, 61 to 64 per cent fat, 0 to 1 per cent glycogen, and the remainder protein.

More recently Young *et al.*[7] studied the nitrogen balance in eight obese young men during an eight-week reducing period during which the protein intake was 115 g daily and the mean weight loss 22.6 pounds. The minimum protein requirement when an individual is in caloric balance is between 0.5 and 0.7 g/kg/body weight/day, so that these subjects re-

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ceived about twice the minimum requirement. During this eight-week reducing period, four of the subjects were in nitrogen equilibrium, and four in slight negative nitrogen balance.

The conclusions that may be drawn are as follows: (1) Glycogen changes are insignificant when a patient is in negative or positive caloric balance. (2) On a customary low-calorie reducing diet, where the protein intake is high, the patient is either in nitrogen equilibrium or in slightly negative caloric balance. (3) Under the circumstances, the caloric deficit in weight reduction is primarily made up by the catabolism of fat.

In total fasting the metabolism is entirely different. In contradistinction to the obese individual on a low-calorie diet who is practically in protein and carbohydrate (glycogen) equilibrium, here decided protein and carbohydrate deficits occur. The loss of one pound (454 g) of protein will yield about 1,850 cal. There will be a concomitant loss of over 3 pounds of water. The loss of 4 pounds of body weight when 1 pound of protein is catabolized, will result from an expenditure of only 1,850 cal; whereas an individual on a low-calorie diet (negative calorie balance) but in protein equilibrium will lose only one-half pound from the same caloric expenditure. When carbohydrate (glycogen) is catabolized the same obtains as with protein. However, since the amount is comparatively small, for practical purposes it need not be considered.

CRITICAL ANALYSIS AND EVALUATION OF THE PERTINENT LITERATURE

Slonim[8] states: "If a person eats more than 35 cal/kg of his ideal weight per day, he will gain weight at the rate of 1 g of fat plus 1 g of water for each 9 cal in excess. If he eats less than the ideal amount, he will lose correspondingly."

According to this concept 1 g of body weight gained or lost, has a value of $4^1/_2$ cal; 454 g (1 lb) will therefore have a value of 2,042 cal. The error of this concept is the idea that a gram of water is stored with each gram of fat. As was pointed out by Leathes,[2] fat is stored "dry" with a negligible amount of water. Further proof of this will be strikingly demonstrated when the work of Benedict is considered below. It may be noted that from the teleologic standpoint it is vital for the very survival of the organism to have a very concentrated source of energy to act as a reserve during a scarcity of food. Thus, adipose tissue, with a caloric value of 8.3 per g, furnishes in an ideal manner.

Strang, McCluggage and Evans[3] made a careful study of the influence of low calorie diets on weight reduction in obese persons. Thirteen persons were placed on a daily diet of 360 cal for a period of 59 days during which time the average weight loss was 0.6 pound per day. They estimated the number of calories necessary to maintain caloric equilibrium in these patients to be 2,500 per day, so that the 0.6 pounds of body weight lost had an equivalent of 2,100 cal. One pound would therefore have a caloric value of 3,500. This is in striking agreement with the value of 3,700 cal obtained by the determination of the caloric value of one pound of human adipose tissue (Bozenraad).

The estimated figure of 2,500 cal to maintain caloric equilibrium decreases slowly with loss of weight and would result in a slight reduction in the caloric equivalent of one pound of body weight lost. This is compensated for by the fact that during the first two to three weeks, as a result of a negative nitrogen balance, there were losses of water. If these losses of water had not occurred, the caloric equivalent of one pound of body weight lost would be higher than 3,500. The two factors apparently neutralize each other.

Joslin,[9] states: "The caloric value of 1 kg of body weight is problematical but most important. Benedict's[10] normal subject for the last 27 days of his fast of 31 days lost an average of 0.7 per cent of his body weight daily, the equivalent of 3,258 cal/kg or approximately 1,500 cal/lb/body weight. For comparison Joslin[11] had an experiment with a healthy nurse who in 1916 volunteered to go through the exact procedure to which diabetics were subjected that time. Her loss of weight in 20 days represented the equivalent of 3,170 cal for each kilogram of her body lost, and this agrees quite closely with Benedict's fasting subject. There-

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fore, one must assume that a patient will not lose, or conversely, gain a pound of actual body tissue unless he receives at least 1,500 cal less or more food than he requires for his standard metabolic need, computed for rest and exercise."

In his conclusions Joslin makes the error of failing to differentiate between the metabolism of the individual who is on a low-calorie diet but who is in protein and carbohydrate (glycogen) equilibrium, and one who is fasting and has marked protein and glycogen deficits. The significance of this point is strikingly demonstrated in Benedict's observation.

Benedict's subject fasted for 31 days, partaking only of distilled water. The pertinent findings are best expressed in Benedict's own words.[12] "During the 31-day fast this subject actually excreted 277.32 g of nitrogen in the urine, thus averaging 8.95 g of nitrogen per day. This would correspond to 1,664 g (3.7 lb) of protein or 8,319 g (18.3 lb) of flesh. Since the entire loss of body weight of this subject was 13.25 kg (30 lb), it can be seen that 63 per cent of the total loss may be accounted in flesh catabolized." Study of Table 63, page 412,[12] shows that whereas during the 31-day fast, the amount of water lost concomitantly from the catabolism of flesh, was enormous (6,383 ml or 14 lb); the amount lost concomitantly from the catabolism of fat was negligible (367 ml or 0.8 lb). The catabolism of 1,664 g of protein which resulted in a loss of 18.3 pound of body weight, yielded only 6,828 cal. If the fasting subject had been in protein and carbohydrate equilibrium the 6,828 calories would have been derived from adipose tissue with a loss of only 1.82 pound (0.83 kg). The categoric conclusion can be drawn that the caloric equivalent of one pound of body weight lost when an individual is fasting, is markedly less than when he is on a low-calorie diet, but in protein and carbohydrate equilibrium.

Clinical observations confirm the error in Joslin's thesis. If a person who requires 2,500 cal/day to maintain caloric equilibrium is on a daily diet containing 1,000 cal, he will give a daily deficit of 1,500 cal or a weekly deficit of 10,500 cal. According to Joslin, such a person should lose 7 pounds of body weight per week. From practical experience we know that this does not occur. In Strang's[3] patients the loss of 0.6 pound of body weight/day resulted from a deficit of 2,100 cal. If Joslin's figure of 1,500 cal for the caloric equivalent of one pound of body weight lost were accepted, they should have lost 1.4 pounds instead of 0.6 pound actually lost.

Utilizing indirect methods for the estimation of body composition Keys *et al.*[6] in a study of individuals who had not previously fasted, found that on a high calorie diet the caloric equivalent of 1 kg of the tissue mass gained was 6,180 cal. They also found that the character of the tissue mass gained in rehabilitation by previously starved men was quite different from that gained by well-fed men who simply ate to excess. Whereas, about two-thirds of the weight gain of the latter was pure fat, in the starved men the gain in early rehabilitation was made up of only 10 to 20 per cent fat.

DISCUSSION

Certain definite conclusions may be made from the observations and studies described above. The average obese individual who is placed on a low-calorie diet for the purpose of weight reduction, is practically in protein and carbohydrate (glycogen) equilibrium. The caloric deficit in these patients is made up almost entirely by the catabolism of fat. The theoretical value of one pound (454 g) of adipose tissue is 3,750 cal.[1] In clinical studies by Strang *et al.*[5] on weight reduction on obese individuals who were on a low-calorie diet a value of 3,500 cal was obtained for each pound of body weight lost. The conclusion can be drawn that 3,500 is the caloric value of one pound of body weight lost.

It must be stressed that it is fundamental that the protein content of the low-calorie diets employed in weight reduction be kept high. If they are so low as to permit appreciable negative nitrogen balances, there will be considerable loss of water. This will result in a decrease in the caloric equivalent of 1 lb of body weight lost and consequently a more rapid rate of loss in weight. This, is, however, a spurious loss because it has no permanency. After the desired weight loss has occurred and

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the patient has been placed on a diet adequate to maintain caloric equilibrium, the protein stores which have been depleted during the period of negative nitrogen balance will be replenished. For every pound of protein replenished there will be an increase of four pounds in body weight. Thus, even though the patient is in caloric equilibrium, he will continue to gain weight until the protein stores have been completely restored.

The value of one pound of body weight gained is also 3,500 cal if there is no deposition of protein or carbohydrate (glycogen). After a prolonged fast, replenishment of the depleted protein and carbohydrate stores will be associated with a concomitant marked deposition of water which will decidedly reduce the caloric equivalent of one pound of body weight gained. When the individual is again in protein and carbohydrate equilibrium, all foods in excess of the amount necessary to maintain caloric equilibrium will be converted into fat and the caloric equivalent of one pound of body weight gained will be about 3,500.

In prolonged fasting there is a marked negative protein balance with a concomitant loss of large amounts of water. There is also a negative carbohydrate (glycogen) balance with a loss of water of the same order. However, since glycogen stores are small, this factor is not important. The enormous losses of water, combined to a small degree with the fact that the caloric values of protein and carbohydrate are less than half the value of a similar amount of fat, resulted in a large reduction of the caloric value of one pound of body weight lost. Thus Joslin[6] calculated that each pound of body weight lost by Benedict's subject, who fasted for 31 days and lost 30 pounds had a value of 1,500 cal, which is less than half of that determined for one pound of body weight lost in clinical weight reduction.

The following two points are relevant to this subject. A person who weighs 300 pounds and is putting out 3,000 cal a day in bodily activities may be placed on a reducing diet. Because of hunger he may reduce his activities to, perhaps, 2,000 cal/day. Thus he would lose weight more slowly than he would on a regimen of activity equal to that before the diet.

As weight loss occurs, caloric expenditure decreases. For example, a male, age 40 years, 300 pounds in weight, 70 in. in height, has a daily basal caloric expenditure of 2,265 cal. If the weight were reduced to 200 pounds, the basal caloric expenditure would drop to 1,995 cal, a difference of 270 cal/day or 8,100 cal/-month. Thus, on the same regimen of activity and diet, he would lose two and one-third pounds more per month when the body weight is 300 pounds than when it has been reduced to 200 pounds.

It is of importance to discuss the weight curve of patients undergoing weight reduction on low-calorie diets. Many observers have emphasized the fact that although a patient may burn many grams of stored fat per day he does not necessarily lose weight every day. The curve of the daily weight change is a series of ups and downs with frequent periods of no apparent weight change. As has been repeatedly demonstrated, these irregularities are intimately associated with the storage and release of relatively large quantities of water. The influence of this phenomenon on the true weight loss is minimized if the period of observation is sufficiently long. It is possible to predict with gratifying precision the weight loss to be expected from the deficiency in exogenous calories.

The fact that 1 g of flesh has a value of approximately 1 cal and 1 g of adipose tissue a value of approximately 8 cal is of considerable practical importance. Thus, in certain conditions where parenteral alimentation has to be resorted to for any considerable length of time, it is important to supply protein derivatives so as to keep the negative nitrogen balance as low as possible, and prevent large weight losses from the loss of flesh. This is of even greater importance in chronic diseases such as anorexia nervosa, carcinoma of the esophagus, carcinoma of the stomach, and other conditions where alimentation is very difficult. Here the primary consideration is to furnish a diet high in protein. If a large negative nitrogen balance is permitted, the loss of weight from the catabolism of flesh will be large with a yield of only a small number of calories.

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SUMMARY AND CONCLUSIONS

The low-calorie diets on which individuals are placed for the purpose of weight reduction should be high in protein so that protein and glycogen will be approximately in equilibrium. The calorie deficit will be made up chiefly by the catabolism of fat. Under the circumstances (high-protein intake) the caloric equivalent of one pound of body weight lost is approxmately 3,500 cal.

The caloric equivalent of one pound of body weight gained is dependent on the state of the protein and carbohydrate (glycogen) stores. If the protein and glycogen stores have been depleted as the result of fasting, their replenishment will be associated with a concomitant deposition of large quantities of water. During this period the caloric equivalent of one pound of body weight gained will be markedly less than 3,500.

When a state of protein and glycogen equilibrium is reached, all food ingested in excess of the amount necessary to maintain caloric equilibrium will be converted into fat (adipose tissue). The caloric equivalent of one pound of body weight gained will then be 3,500.

In fasting there are always decided negative protein and carbohydrate (glycogen) balances. The catabolism of protein and glycogen is associated with losses of large quantities of water. The caloric equivalent of one pound of body weight lost in fasting (negative nitrogen balance) is always markedly less than 3,500.

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