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Predictability of Weight Loss

Walter M. Bortz, MD

Weight loss is a process that is susceptible to logical and reasonably precise explanation. Consideration of caloric need and caloric supply indicates the weight balance. Any caloric deficit implies weight loss which will occur at the rate decreed by the caloric value (3,500 calories) of a pound of body fat. Whenever this caloric deficit is reached, the body will be one pound lighter, with respect to body fat. When these concepts are used, weight loss becomes predictable. Such predictability offers multiple advantages to the clinician who is preparing a weight reduction program for his obese patient.

The obese patient constitutes one of the most common yet frequently frustrating and disconcerting problems that confronts the practicing physician. The desire of the overweight patient to reduce is not often more than a protestation of little conviction. The realization of this often shrouds the beginning of a dietary program in the physician's cynicism. This cynicism, no matter how justified, is frequently compounded by the physician's personal lack of knowledge of the factors involved in weight reduction. Present information about weight reduction is often anecdotal or otherwise imprecise. The deluge of proposed dietary regimens and the pseudoscientific rationale with which each is invested only serve to confuse and deny the approach to a scientific basis for weight reduction.

Recent experience with a number of obese patients in the Division of Research metabolic ward of the Lankenau Hospital has indicated that weight change is a process mediated and determined in a precise and predictable fashion. The deviations and fluctuations noted during weight reduction can often be anticipated and logically explained.

The concept of prediction of the rate of weight loss was first proposed by Wilder in 1933.[1] The ideas advanced by him and later by Jolliffe and Alpert[2] furnished the basis for this concept. This communication seeks to confirm and extend their precepts.

The body is a fuel-consuming machine which obeys all the classical laws of thermodynamics and requires a specific number of calories for its steady state maintenance. Weight gain occurs when excess fuel, ie, calories, is consumed; weight loss occurs when there is a deficit of calories. These are the two essentials for the physician to keep in mind when preparing a program of weight reduction: caloric need and caloric supply.

Methods

Caloric need can be determined in a number of ways. First, a trained dietician can estimate quite accurately the calorie consumption. (Patient reliability and a modicum of intelligence and insight are assumed.) Second, the basal metabolic rate (BMR) can be used to provide an idea of caloric need. The BMR test provides the oxygen consumption value per minute which is then translated to oxygen consumption per day and finally to caloric need per day. Ordinarily, 5 calories are roughly equivalent to 1 liter of oxygen. Some extra calories are added as an allowance for suprabasal physical activities. Third, the nomogram of Boothby and Berkson,[2] cited by Jolliffe and Alpert which takes into consideration the factors of sex, age, height, and weight, predicts with adequate accuracy the caloric requirement. In these studies, which were performed in the metabolic ward, all three of these methods were to establish the stabilization requirement, ie, demand. Results of the three modes of determination usually agree within 10%.

The final method of estimation of daily caloric requirement involves simple observance of body weight during extended time periods while the patient is consuming a formula-type diet having an accurately prescribed caloric content.

The second determinant used in calculating the rate of weight loss is the caloric level of the diet, ie, supply. In our research setting this has been either 600 or 800 calories daily, usually fed in three portions. The timing and the relative composition of the diet in terms of protein, fat, and

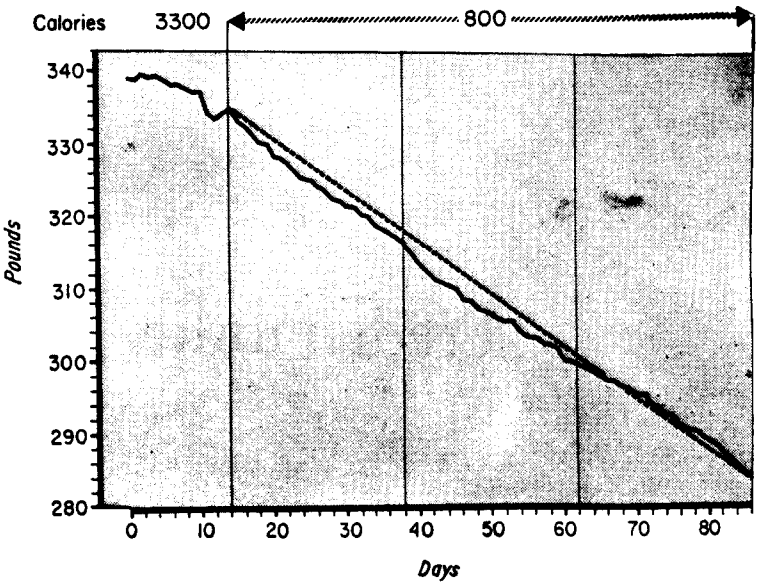
From the Department of Medicine and the Division of Research, Lankenau Hospital, Philadelphia.
Reprint requests to the Division of Research, Lankenau Hospital, Lancaster and City Line Avenues, Philadelphia 19151 (Dr. Bortz).

carbohydrates content are of little long-range consequence.[3]

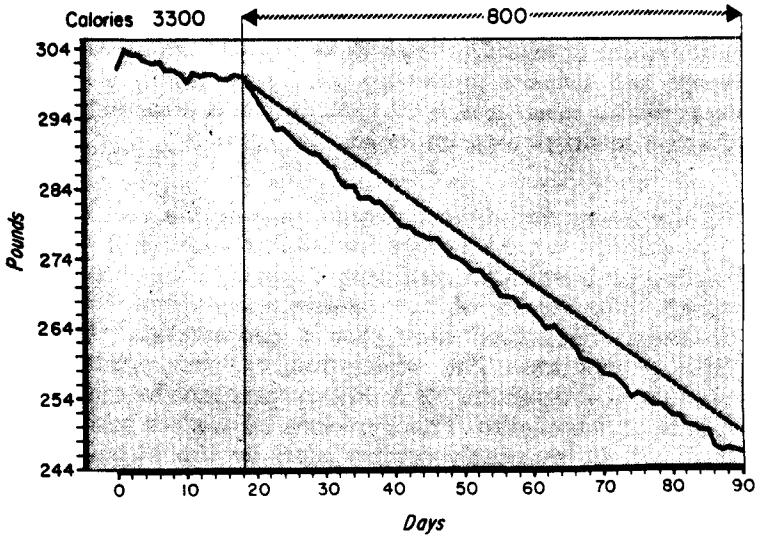
Knowing the daily caloric requirement necessary for weight maintenance and the number of calories contained in the diet for weight reduction, one can accurately determine the daily caloric deficit (demand minus supply). How is this deficit to be met, and what are its consequences in terms of weight loss? The human body at any one time contains 200 to 300 gm of utilizable carbohydrate as glycogen and sugar. In time of debit this amount can obviously supply only a minute fraction of a continuing need. Logically then, one might expect protein to serve as a reserve fuel, since it is present in more adequate supply. Protein supplies 4 calories/gm, or roughly 1,800 calories/lb. However, this 1,800 calories is supplied by a pure, unhydrated mixture of amino acids, unknown as such in nature and available only from a powder in a bottle on the chemist's or nutritionist's shelf. Body protein, 80% water by weight, would yield only about 450 calories/lb. This clearly is an uneconomic energy supply. Apparently the body is too wise to use this matrix as an energy source. Balance studies indicate that the body in a state of starvation undergoes an initial protein wastage, but then effectively manages to conserve protein, and the amount of nitrogen in the urine falls to low levels. This process has often been observed in undernourished populations.

It can be assumed, then, that fat is the overwhelmingly predominant energy source during periods of caloric restriction. Respiratory quotient measurements repeatedly confirm this fact. Fat is admirably suited to being an energy source, since it has an extremely high caloric content per unit weight. Nine calories per gram equates to 4,000 calories/lb, unhydrated. Fat is only slightly hydrated (15% water by weight). The caloric value, therefore, of body fat is 3,500 calories/lb. This is *the* figure on which all weight gain and weight loss depends. It is the figure that dieters of all types must recognize and understand, for with this figure and the daily caloric deficit, one can predict the rate of weight loss.

An idealized example is as follows: The subject is a 30-year-old housewife who is 162.6 cm (5 ft 4 inches) tall and weighs 102 kg (225 lb). Her daily caloric requirement is estimated to be 2,600 calories to maintain present body weight. Electing a common-sense caloric level of 1,200 for the weight reduction diet, there is a daily caloric deficit of 1,400 calories. This deficit is to be supplied largely by the body fat at the rate of 3,500 calories/lb. Weight loss will therefore occur at the rate of 1,400/3,500 lb day or 0.4 lb/day. If the mirror

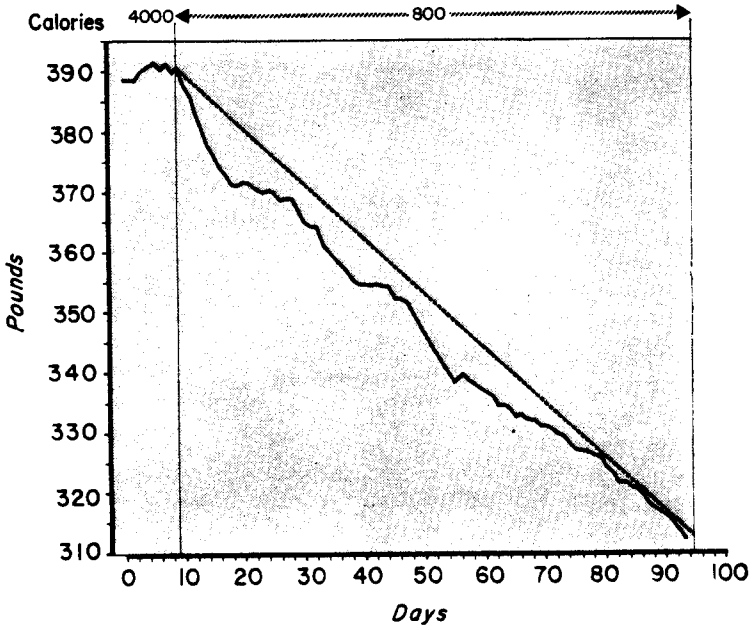


1. Actual (solid line) and predicted (dotted line) weight loss for 19-year-old girl, 175.5 cm (5 ft 9 inches) tall.

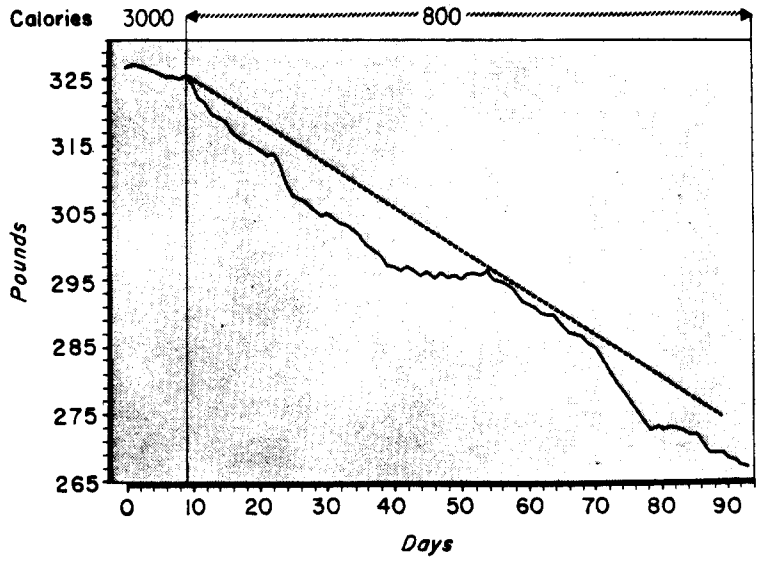


2. Actual (solid line) and predicted (dotted line) weight loss for 29-year-old man, 172.7 cm (5 ft 8 inches) tall.

weight (ideal weight) of this individual is 56.7 kg (125 lb), she has a loss of 45.4 kg (100 lb) planned. At the rate of 0.4 lb/day it should take 250 days to reach this goal and it will, or will closely enough for any practical purpose. Two hundred and fifty days may seem to be a long period, but it is realistic. It can be shortened only in two ways: (1) increasing caloric demand, and (2) decreasing caloric supply. I have found that increasing caloric demand with exercise is of limited practical advantage in most instances of dieting. Other investigators are more enthusiastic about this aspect, however. A decrease in caloric supply is accomplished by reduction in the number of calories which are consumed daily. The maximal reduction is, of course, total starvation, which would then yield a daily caloric deficit of 2,600/3,500 lb, or roughly 0.714 lb of body weight. At this rate, the 100-lb weight loss will take 140 days. This is the



3. Actual (solid line) and predicted (dotted line) weight loss for 22-year-old man, 118 cm (6 ft 2 inches) tall.



4. Actual (solid line) and predicted (dotted line) weight loss for 19-year-old girl, 170.2 cm (5 ft 7 inches) tall.

irreducible minimum time required to lose this weight without a marked change in the exercise pattern. One hundred and forty days of starvation is a long, long time. A practicable number of calories, 1,200, is the lowest that seems reasonable, inasmuch as this number is compatible with our social pressures.

There is an additional feature to be considered. Experience indicates that to maintain weight, for each 11.3 kg (25 lb) of excess weight, the body requires 100 calories more than the number required at ideal weight. Conversely, for each 25 lb lost, the caloric deficit will be 100 calories or 0.03 lb less. Therefore, if a great amount of weight is lost, the rate of loss on the same caloric intake will be 0.03 lb/day less for each 25 lb that are lost. For most dieting patients, this consideration may be omitted.

Results

That this exercise in weight-loss mathematics is more than theoretical can be seen in Fig 1 to 6, which represent experience with some obese subjects.

All the information necessary for the prediction of weight loss, (1) the number of calories necessary for weight stabilization and (2) the caloric content of the diet, is presented in Fig 1 to 4. The difference between the two is the daily caloric deficit which, when divided by 3,500, yields the daily weight loss in pounds. The dotted lines show this calculation as plotted in anticipation of the low-calorie program. The solid lines show the actual daily weights. These charts are typical of all patients of whom observations were made. In approximately 40 obese subjects observed under strict metabolic ward conditions, the prediction so far has not varied more than 10% from the actual weight loss in any of the subjects.

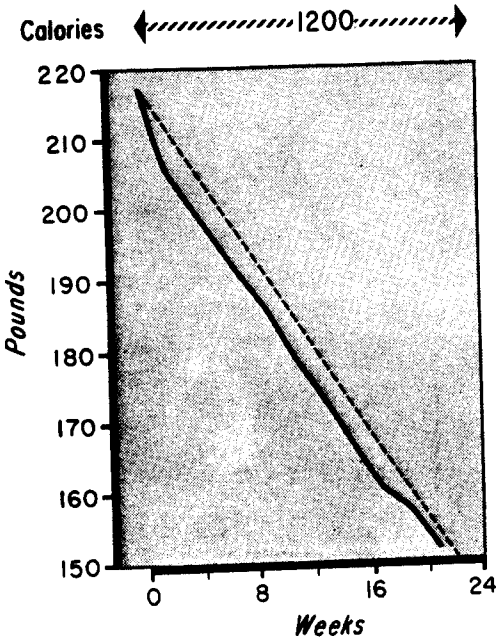
One cannot expect and should not demand the degree of agreement shown in Fig 1 to 4 when dealing with an outpatient. That this capacity to predict weight loss is not confined, however, to the artificial environment of a metabolic ward is seen in Fig 5. The patient was a 19-year-old girl whose predicted and actual weight losses were as charted. She was an outpatient.

Figures 1 to 5 are notable for the accuracy of the prediction. Such accuracy must of necessity involve long-term observation under reliable conditions. Shorter-term observations are often misleading. Figures 3 and 4 represent studies in which isocaloric substitution of carbohydrate for fat, in the presence of salt, led to temporary weight plateaus.[4] Apparent deviation from the prediction, therefore, need not implicate cheating on the part of the dieter.

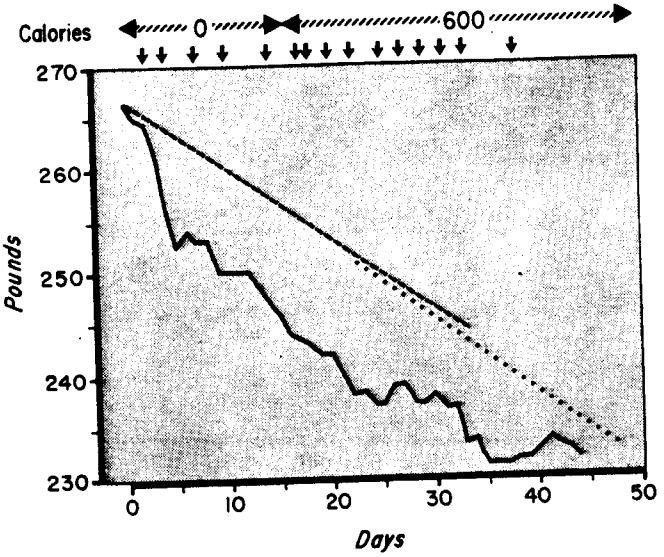
In another obese individual there was a period of 21 days in which no weight was lost whatsoever, despite an anticipated weight loss of 1.2 lb/day, calculated from a 4,200 calorie daily deficit. This period tested the patient's determination and the doctor's faith. The weight-loss prediction was of considerable assistance in reassuring both patient and physician that nothing was amiss. The explanation for this protracted weight plateau in such an extremely obese individual was, of course, fluid retention. This was confirmed by observations of fluid and sodium balance.

A further example of the value of a weight prediction chart follows: Another physician was puzzled by the erratic response of a woman patient's body weight to the vigorous measures he prescribed. Initial testing of thyroid function revealed a somewhat low protein-bound iodine level of 3.6μg/100 ml

and a red blood cell triiodothyronine (T_3) uptake value of 24.8% (normal, 28%-35%). The basal metabolic rate was +2%; however, her serum cholesterol level was only 184 mg/100 ml. After testing, 200 mg of thyroid to be taken daily was prescribed; the dosage was gradually increased to 650 mg daily after the second week. The patient was given dextroamphetamine sulfate capsules (Spansule), in a dose of 10 mg twice a day, which was later increased to 15 mg in the morning and 10 mg at night. Five hundred milligrams of chlorothiazide was given daily. Mercurial diuretics were administered as shown by the arrows at the top of Fig 6. Initially, a diet which contained virtually no calories was prescribed and was liberalized to 600 calories on the 12th day. Weight loss proceeded as seen on the graph. The patient was extremely gratified by her early response. In the first nine days, she lost nearly 17 lb. In the succeeding nine-day periods, she lost 7, 4, 8, and 0 lb. On the 29th day of her program, her physician requested consultation with me because the patient felt that the medicines were no longer working, and her physician felt that she was cheating. A weight-loss prediction chart was drawn retrospectively (Fig 6, heavy dotted line). Her initial basal oxygen requirement, 251 ml/min (361.4 liters of oxygen per day or 1,807 calories/day), plus a 40% activity allowance were used to determine the chart. This yielded a daily caloric deficit of 2,530 calories, since there was no caloric intake. During the first nine-day period, therefore, she should have lost 6.5 lb (2,530/3,500 × 9). Instead she had lost 16.75 lb. On the 12th day, another BMR test showed that the basal oxygen consumption had risen to 309 ml/min or 2,225 calories/day. When a 40% activity addition is allowed, the total of 3,115 is derived as the daily caloric need. The new daily deficit (Fig 2, light dotted line) can be calculated by subtracting the 600 calories contained in the diet. The observed weight loss is seen to be beneath the predicted lines for the early portion of the program only to approach and nearly meet it later on. This was believed to be due to water loss which led to a false notion concerning the amount of weight lost. Later on, the contracted state of the body fluids had become resistant to persistent diuretic attempts, and weight stabilization occurred.



5. Actual (solid line) and predicted (dotted line) weight loss for 19-year-old girl, 167.6 cm (5 ft 6 inches) tall.



6. Actual (solid line) and predicted (dotted line) weight loss for 52-year-old woman, 162.6 cm (5 ft 4 inches) tall.

Comment

The early days of any hypocaloric program are characterized by a considerable diuresis in the patient, even in the absence of added diuretics. The actual weight loss then exceeds that predicted. Often a secondary weight plateau is reached, despite continued dieting. This is the result of the body's reconstitution of the early large fluid loss. It must be emphasized, however, that loss of weight due to fat utilization, which is really the essence of the problem, goes on regardless of fluid shifts. Unfortunately, the bathroom scale cannot discriminate between weight due to fat and weight due to fluid. The weight prediction charts are of especial benefit to those individuals who demonstrate an exaggerated fluid-retaining capacity.

Other studies from our metabolic ward have shown that the timing of consumption of the day's calories is not central to the rate of weight loss.[5] Furthermore, any advantage of the low-carbohydrate reducing diets is confined to their dehydrating potential.[4] A number of recent studies have demonstrated the ability of dietary carbohydrate to retain sodium and fluid.[6-8] Conversely, lack of carbohydrate leads to marked fluid loss. The disadvantage, then, to restriction of dietary carbohydrate in prescribing a diet is that the initial weight and water debt that is incurred will have to be repaid when carbohydrate is refed, as it eventually will be.

Recognition of the caloric value of a pound of body fat puts into perspective the reports of individuals who gain or lose 5 lb or more in a day. This must be a loss of fluid. Such changes are particularly evident when body fluid-retaining mechanisms

are highly activated due to hormonal, emotional, medicinal, or dietary factors. Realization of this will help the dieter who has steadfastly maintained a 2- or 3-lb weekly weight loss when he finds, after a Thanksgiving indulgence, that he has gained back, in one meal, the weight lost during two weeks of dieting. He should be made to understand that resumption of the diet will result in nearly complete elimination of this excess fluid and leave him with only a minor shift in his weight-loss chart and a pleasant memory of a delicious meal.

Comprehension of these few basic facts makes rational the physician's relationship with his obese patient. Realistic goals can be set, and a practicable schedule prescribed. There is no single best weight-reduction formula. I feel that a balanced diet of 1,200 to 1,600 calories is one that is consistent with a long-range program on which any genuine effort to reduce weight must rest. Crash programs, while of temporary novelty interest, are insufficient. The addition of drugs to the program only serves to introduce artifactual and confusing features. In addition, drugs can be habituating and harmful. But most important of all, they serve to transfer the responsibility of dieting from the patient, where it must remain, to the pill bottle. If success in weight reduction is to be attained, the credit will belong to the individual and not the pill; conversely, if failure results, it is certainly not the fault of the pill.

Certainly, all the factors operative in human obesity are not fully understood; important work remains to be done in this field. However, knowledge of the scientific principles involved in weight reduction can offer greater opportunity for success in this widespread problem. It is the physician's responsibility to assume an enlightened educative role in the therapy of human obesity.

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Generic and Trade Names of Drugs

Dextroamphetamine sulfate—*Dexedrine.*
Chlorothiazide—*Diuril.*

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