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DISCREPANCY BETWEEN SELF-REPORTED AND ACTUAL CALORIC INTAKE AND EXERCISE IN OBESE SUBJECTS

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Abstract *Background and Methods.* Some obese subjects repeatedly fail to lose weight even though they report restricting their caloric intake to less than 1200 kcal per day. We studied two explanations for this apparent resistance to diet — low total energy expenditure and underreporting of caloric intake — in 224 consecutive obese subjects presenting for treatment. Group 1 consisted of nine women and one man with a history of diet resistance in whom we evaluated total energy expenditure and its main thermogenic components and actual energy intake for 14 days by indirect calorimetry and analysis of body composition. Group 2, subgroups of which served as controls in the various evaluations, consisted of 67 women and 13 men with no history of diet resistance.

Results. Total energy expenditure and resting metabolic rate in the subjects with diet resistance (group 1) were within 5 percent of the predicted values for body composition, and there was no significant difference between groups 1 and 2 in the thermic effects of food and exercise. Low energy expenditure was thus excluded as a mechanism of self-reported diet resistance. In contrast, the subjects in group 1 underreported their actual food intake by an average (±SD) of 47±16 percent and overreported their physical activity by 51±75 percent. Although the subjects in group 1 had no distinct psychopathologic characteristics, they perceived a genetic cause for their obesity, used thyroid medication at a high frequency, and described their eating behavior as relatively normal (all $P<0.05$ as compared with group 2).

Conclusions. The failure of some obese subjects to lose weight while eating a diet they report as low in calories is due to an energy intake substantially higher than reported and an overestimation of physical activity, not to an abnormality in thermogenesis. (N Engl J Med 1992; 327:1893-8.)

More than 30 million Americans are obese, and many require medical care for diabetes, high blood pressure, and hyperlipidemia.[1] Some obese subjects seek medical evaluation for failure to lose weight despite a history of severe caloric restriction. These subjects are often assumed to have hypometabolism and are frequently treated with thyroid or other hormonal therapies, but they do not lose weight. The clinical characteristics of this syndrome are poorly described, and the mechanisms of failure to lose weight while following a diet low in calories (usually less than 1200 kcal per day) are unknown.

Two explanations for this failure are a low total energy expenditure and an energy intake substantially higher than reported. Evidence to support the hypothesis that a subgroup of obese subjects has a reduced energy expenditure is based on two indirect observations. The first is the existence of groups of subjects of equivalent age and metabolically active tissue mass who report large differences in daily caloric intake (27 vs. 47 kcal per kilogram of body weight)[2,3] and whose resting metabolic rates differ by 9 to 17 percent.[4] The second observation is that low total and resting energy expenditures are risk factors for long-term weight gain in infants[5] and adults,[6] respectively.

The hypothesis that some obese subjects do not lose weight while following a low-calorie diet because their energy intake is substantially higher than reported is based on the finding that whereas many people underreport their caloric intake, the degree of underreporting is greater in obese subjects.[7-10] Obese subjects may also overestimate the energy they expend in physical activities and may therefore require less energy intake to maintain body weight than their exercise history suggests. Subjects presenting with an inability to lose weight despite a history of caloric restriction may represent a subgroup of obese people who severely misreport their food intake and level of physical activity and who may also have behavioral or psy-

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chological abnormalities that distinguish them from other obese subjects.

We studied whether low total energy expenditure or misreporting of food ingestion and physical activity accounts for the failure to lose weight of obese subjects who reportedly restrict their intake to less than 1200 kcal per day.

Methods

Subjects

We considered consecutive subjects referred for weight control during a two-year period for enrollment in the study if they were more than 20 years of age, had a body-mass index (calculated as the weight in kilograms divided by the square of the height in meters) greater than 27, and had no major illnesses. Subjects taking medications that influence energy expenditure were excluded, except for those with a history of thyroid disease who were euthyroid with or without treatment. The 224 subjects who met these criteria were screened for a history of diet resistance, arbitrarily defined as a current intake of less than 1200 kcal per day as reported on three-day records of food consumption; weight stability (within a range of 3 kg) for the previous six months; and a history of failure to lose weight while following a hypocaloric diet. The 16 subjects who met these criteria were considered for entry into the diet-resistant group (group 1); the remaining 208 subjects were assigned to the control group (group 2).

Protocol

Each potential subject in group 1 was instructed by a dietitian and was shown a standard educational videotape about keeping daily records of food intake and physical activity.[11,12] The subject was enrolled in group 1 if the average reported daily caloric intake for seven subsequent consecutive days was less than 1200 kcal, with continued weight stability. The 10 subjects who met this criterion completed a medical and nutritional history and underwent physical examination, metabolic testing, body-composition analysis, psychological evaluation, assessment of food-portion size, and testing of ability to recall foods eaten after 24 hours.

Of the 208 subjects assigned to group 2, 80 who agreed to participate in additional evaluations completed a medical and nutritional history and underwent a physical examination. Six overlapping subgroups of these group 2 subjects underwent metabolic testing, body-composition analysis, psychological evaluation, and assessment of food-portion size and 24-hour recall. The study protocol was approved by the institutional review board of St. Luke's–Roosevelt Hospital, and informed consent was obtained from all the study subjects.

Self-Reported Food Intake and Physical Activity

The 10 subjects in group 1 and 6 of the subjects in group 2 were evaluated with regard to self-reported food intake, physical activity, body composition, and total energy expenditure for 14 days. The subjects recorded their daily food intake to the nearest ounce or number of items, and these data were then converted to calories with Nutri-Calc Plus software (version 1.10, Camde, Tempe, Ariz.).[11] Physical activity was recorded at 15-minute intervals; from these records we estimated the number of calories expended in physical activity by multiplying the total time spent engaged in each of 10 categories of activity by the energy cost of the activity.[12]

Metabolic Testing

The resting metabolic rate, the thermic effect of food,[13,14] the thermic response (measured as oxygen consumption) to a standard exercise test, and the total energy expenditure were measured in all the subjects in group 1. A regression line for resting metabolic rate in relation to fat-free body mass was calculated for 75 subjects in group 2.[15] The difference from this regression line was then calculated for subjects in group 1 as the observed resting metabolic rate minus the predicted rate. A resting metabolic rate more than 15 percent below the predicted rate was considered abnormally low.[16]

The resting metabolic rate was evaluated after the subject fasted overnight and remained prone for 30 minutes. Respiratory gas was collected for 20 minutes and its oxygen and carbon dioxide content analyzed during the last 15 minutes of this period with paramagnetic and infrared analyzers (Beckman OM-11 and LB-2, Sensor-Medics, Anaheim, Calif.), respectively. Measures of oxygen consumption and carbon dioxide production were used to calculate the resting metabolic rate.[17]

The thermic effect of food, which is the postprandial rise in energy expenditure, was measured for three hours after the resting subject consumed a 710-kcal liquid meal (Ensure Plus, Ross Laboratories, Columbus, Ohio).[13,14] Gas exchange was measured for 10 of every 30 minutes, and the thermic effect of food was calculated as the integrated energy expenditure 3 hours after a meal minus the resting metabolic rate; the results were expressed as a percentage of the number of calories in the ingested meal.

Oxygen consumption in response to exercise, which is an indication of the energy expended during physical activity, was measured by monitoring gas exchange at rest and during the last two minutes of a five-minute period at three workloads on a treadmill. The thermic response to exercise was measured by calculating the regression equation for oxygen consumption per kilogram of body weight in relation to the workload for each group.[18] The slopes and intercepts of the two groups were then compared. Ten subjects in group 2 completed the studies of the thermic effect of food and the exercise studies.

Total daily energy expenditure was measured for 14 days with doubly labeled water while the subjects maintained their usual food intake. The method, which is accurate to within a range of 5 percent in adults under free-living conditions, is based on the calculation of carbon dioxide production from the differential disappearance rates of two stable isotopes of water.[19-21] Bioimpedance analysis (Valhalla Scientific 1990B, San Diego, Calif.) was used to estimate the total amount of water in each subject's body before the doubly labeled water was administered.[22] The subjects then received 0.25 g of [^{18}O]water (either 7 percent [^{18}O]water from EG&G Mound Laboratories, Miamisburg, Ohio, or 10 percent [^{18}O]water from Icon Laboratories, Summit, N.J.) per kilogram of total body water and 0.2 g of 99.9 percent [^{2}H]water (Icon and Isotec, Miamisburg, Ohio) per kilogram of total body water on day 0. Urine was collected daily from day 0 through day 14, as described elsewhere.[19]

The enrichment of urine with hydrogen-2 and oxygen-18 was measured on days 0, 1, 2, 13, and 14 by isotope-ratio mass spectrometry.[19] The rates of disappearance of the hydrogen-2 and oxygen-18 tracers from body water over the 14-day period were determined by an analysis of the regression of the logarithm of tracer enrichment against time. Rates of daily water turnover and carbon dioxide production were calculated from the product of total body water and the disappearance rates of hydrogen-2 and oxygen-18, with correction for isotope fractionation.[23] Daily oxygen consumption was determined by dividing carbon dioxide production by an assumed respiratory quotient[20] of 0.85; total energy expenditure was then calculated from oxygen consumption and carbon dioxide production.[24] A regression equation relating total energy expenditure to body composition was calculated for 16 subjects in group 2.[15,25] Using this equation, we calculated the difference between the observed and the predicted total energy expenditures for the subjects in group 1.

Analysis of Body Composition

The subjects in groups 1 and 2 who had resting studies of the metabolic rate also had measurements of total body fat and metabolically active fat-free body mass by hydrodensitometry.[26-28] Body composition was also determined by hydrodensitometry before and after the period when doubly labeled water was used, and the results were used to estimate changes in energy stores.[19]

Behavioral and Psychological Testing

All the subjects in group 1 were evaluated with the following tests: the Beck Depression Inventory, a self-administered test designed to screen for the presence and severity of depression[29]; the Minnesota Multiphasic Personality Inventory (MMPI), a self-administered questionnaire that examines a wide range of behavioral characteristics and psychological functions[30]; the Structured Clinical Interview for Diagnosis (SCID), based on the *Diagnostic and Statistical Manual of Mental Disorders* (third edition, revised)[31] and designed to diag-

nose Axis I (major psychiatric illness) and Axis II (disorders of character or personality) psychiatric disorders[32]; and the Eating Inventory, a self-administered questionnaire that evaluates cognitive restraint (conscious attempts to limit food intake), disinhibition (tendency to lose control of a diet), and hunger.[33] The Beck Depression Inventory, the MMPI, the SCID, and the Eating Inventory were also completed by 57, 30, 56, and 47 subjects in group 2, respectively.

Accuracy of Estimates of Portion Size and Meal Recall

Errors in estimating the size of meal portions may cause food intake to be misreported. We therefore tested the accuracy of estimates of portion size by the subjects in group 1 and by 10 of the subjects in group 2.[34] The subjects were asked to estimate the overall size (the linear dimensions and the volume or weight) of various standard foods. The results were expressed as a percentage of the actual weight or volume.

We used a test meal to evaluate the accuracy of the subjects' reports of their food intake 24 hours after they ingested food under standardized conditions.[35] While fasting, the subjects in group 1 and 10 of the subjects in group 2 were given a lunch composed of a variety of foods and instructed to eat until they felt 80 percent full, with a time limit of 45 minutes. The next day, an investigator contacted each subject by telephone and inquired about the foods he or she had eaten during the previous day, and about the amounts eaten. The results of the subject's attempt to recall the test meal were then compared with the weight of the actual foods eaten.[35]

Evaluation of Hypotheses

The hypothesis that low energy expenditure is the mechanism of failure to lose weight was examined by evaluating the resting metabolic rate, the thermic effect of food, the thermic response to exercise, and the total energy expenditure in the two groups. The second hypothesis, underreporting of caloric intake and overreporting of physical activity, was tested by combining the results of records of food and activity kept simultaneously during the 14-day study with doubly labeled water. An average daily self-reported energy intake was calculated from the food records, and an average daily total energy expenditure was estimated from the study with doubly labeled water. Changes in energy stores were calculated on the basis of the difference in fat and fat-free body mass from day 0 to day 14.[6,19] Actual caloric intake was calculated as the difference between total energy expenditure and stored energy. Self-reported caloric intake was expressed as a percentage of actual intake, with overreporting and underreporting indicated by positive and negative values, respectively. Actual energy expended in physical activities was calculated as the total energy expenditure minus the sum of the resting metabolic rate and the thermic effect of food.[36] The daily thermic effect of food was calculated as the thermic effect of the test meal (expressed as a percentage) multiplied by the daily energy intake as estimated from the study using doubly labeled water. The actual energy expended in physical activity (kilocalories per day) was then compared with the amount of energy the subject reported expending in physical activities.

Statistical Analysis

Student's t-test for unpaired observations was used for comparisons of continuous variables between groups, the chi-square test was used for comparisons of categorical variables between groups, Pearson's product-moment correlation coefficient was used to measure association, and stepwise multiple linear regression was used to develop the equations relating resting metabolic rate and total energy expenditure to body composition (SAS version 5 software, SAS Institute, Cary, N.C.). Results are expressed as means ±SD, and P values below 0.05 were considered to indicate statistical significance.

Results

Base-Line Characteristics

The subjects in groups 1 and 2 were similar in age, body weight, body-mass index, percentage of body fat, level of education, marital status, and employment history (Table 1). More subjects in group 1 than in group 2 had received or were currently receiving thyroid hormone therapy (P<0.01). The subjects in group 1 had made twice as many attempts to diet as the subjects in group 2 and attributed their obesity more to genetic and metabolic factors and less to overeating than did the subjects in group 2.

Energy Expenditure

The regression equations for resting metabolic rate and total energy expenditure as a function of fat-free body mass are shown in Figure 1 for the subjects in group 2. Resting metabolic rate and total energy expenditure were highly correlated with fat-free body mass (r = 0.83 and 0.77, respectively; P<0.001 for both).

The mean resting metabolic rate for the subjects in group 2 was 1473±188 kcal per day, which differed by 10±112 kcal per day (1±8 percent) from the value predicted by the regression equation for that group (1463±161 kcal per day) (Fig. 1). No subject in group 1 had a resting metabolic rate that was more than 10.4 percent below the predicted rate (Fig. 2). The thermic effect of food did not differ significantly between group 1 (11±4 percent) and group 2 (9±3 percent). The oxygen consumption in response to exercise was measured in six subjects in group 1; one of the remaining four subjects had limited mobility caused by a hip impairment, and the three others became exhausted early in the protocol. The slope and intercept of the regression line for oxygen consumption in relation to workload were similar in the subjects in groups 1 and 2.

Total energy expenditure is a measure of habitual energy intake under free-living conditions in energy balance and with stable body weight. Total energy expenditure in group 1 averaged 2468±429 kcal per day, or 88±305 kcal per day (4±13 percent) above

Table 1. Base-Line Characteristics of the Two Study Groups.*

Characteristic	Group 1 (N = 10)	Group 2 (N = 80)
Sex (F/M)	9/1	67/13
Age (yr)	48±12	47±12
Weight (kg)	85.8±9.9	94.1±18.0
Body-mass index	33.8±4.1	36.4±7.4
Percent body fat	48.8±3.8	44.8±9.1
No. (%) using thyroid medication†	7 (70)	21 (26)‡
Previous diet attempts per subject (no.)	8±7	4±3
Causes of obesity§ (no. of subjects)		
Decreased physical activity	5 (50)	57 (71)
Overeating	1 (10)	65 (81)¶
Metabolic	3 (30)	4 (5)‡
Genetic	7 (70)	22 (28)‡

*Plus–minus values are means ±SD. Values in parentheses are percentages.

†Includes both past and current use.

‡P<0.01 for the comparison between groups.

§As perceived by the patient.

¶P<0.001 for the comparison between groups.

that predicted by the regression equation for the subjects in group 2 (2333±340 kcal per day) (Fig. 1). No subject in group 1 had a total energy expenditure more than 9.6 percent below the predicted value (Fig. 2). Thus, resting metabolic rate, the thermic effect of food, oxygen consumption in response to exercise, and total energy expenditure did not differ significantly between groups 1 and 2, and no subject in group 1 had a substantially reduced resting metabolic rate or total energy expenditure.

Reporting of Food Intake and Physical Activity

The energy intake reported by the subjects in group 1 during the 14-day study period was 1028±148 kcal per day, whereas their actual energy intake was 2081±522 kcal per day. Thus, these subjects significantly ($P<0.05$) underreported their energy intake by a group mean of 1053 kcal per day, or a mean for individual subjects of 47±16 percent (Fig. 2). These subjects underreported their energy intake even more if their total energy expenditure (2468 kcal per day) represents the long-term energy intake required to maintain a stable weight.

The energy intake reported by the six subjects in group 2 was 1694±364 kcal per day, and their total energy expenditure was 2647±650 kcal per day. Their actual intake was 2386±775 kcal per day. Thus, individual subjects in this group also underreported their energy intake (by 19±38 percent; P not significant).

The subjects in group 1 reported the amount of energy they expended in physical activities as being 1022±185 kcal per day, whereas the actual energy so expended was 771±264 kcal per day, an overestimation by 251±286 kcal per day, or a mean of 51±75 percent for individual subjects ($P<0.05$). The subjects in group 2 also overestimated their physical activity (actual, 877±421 kcal per day; reported, 1006±265 kcal per day; P not significant). Their overestimation, which amounted to 129±228 kcal per day (a mean of 30±43 percent for individual subjects), was smaller than that in group 1.

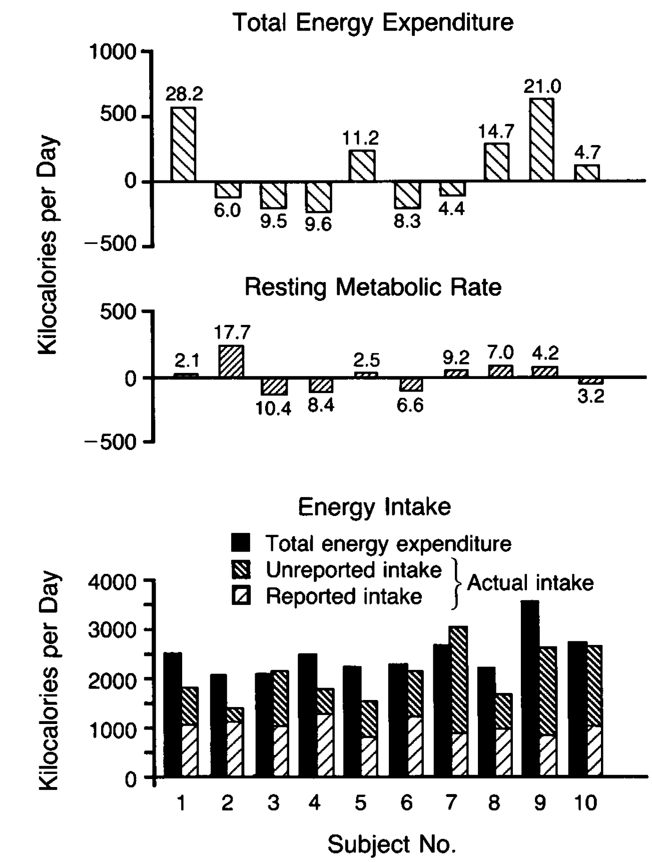

Figure 2. Two Explanations of Self-Reported Diet Resistance in the Subjects in Group 1.

The top panel shows the absolute difference between measured and predicted total energy expenditure, with the numbers above or below each bar representing the percent difference for each subject. The middle panel shows a similar plot for resting metabolic rate. The bottom panel shows total energy expenditure, actual intake, and reported intake during the 14-day period of the study with doubly labeled water. Low energy expenditure was excluded as a mechanism of self-reported diet resistance, because no subject had a total energy expenditure or resting metabolic rate more than 10 percent below the predicted values. The substantial difference between actual intake and reported intake (mean, >1000 kcal per day) implicates severe underreporting as the basis for the failure to lose weight.

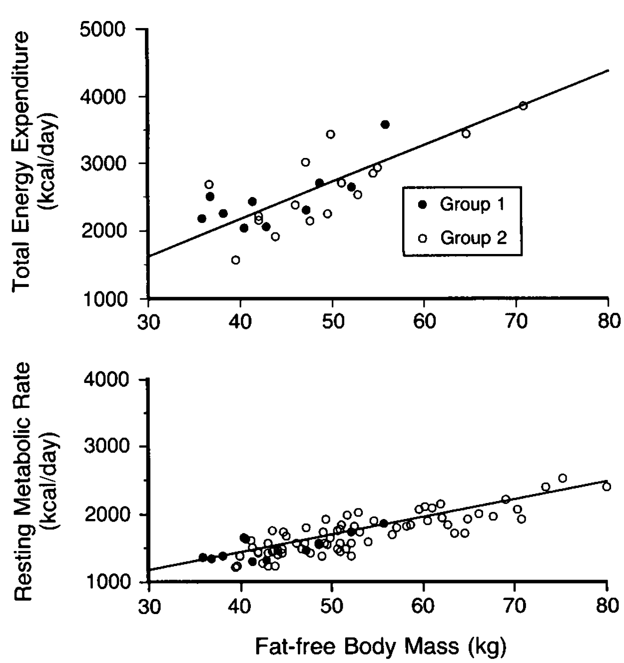

Figure 1. Comparison of Resting Metabolic Rate and Total Energy Expenditure with Fat-free Body Mass in the Two Study Groups.

The regression lines shown are for group 2 (resting metabolic rate = 25.0 (fat-free body mass) + 363; n = 75, r = 0.83, and $P<0.001$; total energy expenditure = 53.0 (fat-free body mass) + 1.8; n = 16, r = 0.77, and $P<0.001$).

Behavioral and Psychological Evaluations

There were no significant differences between the two groups in the mean scores on the Beck Depression Inventory (Table 2), the scores on the 10 major clinical scales of the MMPI, and the Axis I and Axis II psychiatric diagnoses. Scores on the Eating Inventory

Table 2. Results of Psychological and Behavioral Evaluations in the Two Study Groups.*

Variable	Group 1	Group 2
Beck Depression Inventory†	11.8±10.3	9.6±7.8
Eating Inventory‡		
Cognitive restraint	16.9±2.6	11.2±4.5§
Disinhibition	6.7±3.6	11.1±3.6§
Hunger	3.4±2.9	7.1±3.3§
Percent of actual portion size	98±17	96±11
Test meal (kcal)		
Amount ingested	676±327	807±569
Amount recalled	546±419¶	913±635

*Plus–minus values are means ±SD.

†Scored on a scale of 0 to 63 on which a score of 0 to 9 denotes no depression, 10 to 15 mild depression, 16 to 29 moderate depression, and 30 to 63 severe depression.

‡Scores on this inventory ranged from 0 (absent) to 21 (present) for cognitive restraint, from 0 (absent) to 16 (present) for disinhibition, and from 0 (absent) to 14 (present) for hunger.

§P<0.02 for the comparison between groups.

¶P<0.05 for the comparison between the amount recalled and the amount ingested.

differed significantly for all three scales (P<0.02) (Table 2), indicating more self-reported cognitive restraint, less disinhibition, and less hunger in the subjects in group 1.

Accuracy of Portion-Size Estimates and Meal Recall

The estimates of portion size were accurate and similar for the two groups (Table 2). One day after the test meal, the subjects in group 1 recalled having eaten approximately 20 percent less than they actually ate (P<0.05) (Table 2). The subjects in group 2 overestimated the amount eaten at the test meal by approximately 12 percent (P not significant).

Discussion

The main finding of this study is that failure to lose weight despite a self-reported low caloric intake can be explained by substantial misreporting of food intake and physical activity. The underreporting of food intake by the subjects in group 1 even occurred 24 hours after a test meal eaten under standardized conditions. In contrast, values for total energy expenditure, resting metabolic rate, thermic effect of food, and thermic response to exercise were comparable with those of obese subjects in group 2 who did not report a history of diet resistance.

In addition to their greater degree of misreporting, the subjects in group 1 used thyroid medication more often, had a stronger belief that their obesity was caused by genetic and metabolic factors and not by overeating, and reported less hunger and disinhibition and more cognitive restraint than did the subjects in group 2. Subjects presenting for weight-control therapy who had these findings in association with a history of self-reported diet resistance would clearly convey the impression that a low metabolic rate caused their obesity.

The results of the evaluation of all major aspects of energy metabolism in the subjects in group 1 confirmed that substantial misreporting of food intake and physical activity accounted for the diet resistance they reported. There are, however, physiologic explanations for short-term diet resistance that should be considered in subjects with unexpectedly slow weight loss. Under certain conditions, fluid retention can mask weight loss for up to 16 days in subjects who are actually losing fat through dieting.[36] After several weeks of weight loss, energy expenditure decreases and adaptive changes in protein metabolism occur, reducing the degree of negative energy and nitrogen balance and slowing the weight loss until it is almost imperceptible. Also, subjects with undiagnosed or untreated thyroid disease and those taking medications that lower energy expenditure may lose weight slowly.

Misreporting by the subjects in group 1 does not appear to be a facile deception, for several reasons. First, underreporting of food intake has been noted in obese and nonobese subjects with no history of diet resistance.[6-9,37,38] The mechanisms responsible for this phenomenon are not well understood. Second, the subjects in group 1 participated voluntarily in a complex, time-consuming protocol designed to evaluate the cause of their perceived diet resistance. Several had a history of up to 20 serious diet attempts, and most had had extensive medical evaluations for obesity. Third, the subjects in group 1 were distressed when they were given their study results. Thus, important basic psychological issues require elucidation before this form of diet resistance can be properly understood.

In conclusion, all the obese subjects we studied who had a history of self-reported diet resistance had appropriate energy expenditure, but they misreported their actual food intake and physical activity.

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