Weight loss in 108 obese women on a diet supplying 800 kcal/d for 21 d[1,2]

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ABSTRACT A series of 108 obese women were studied for 21 d in a metabolic ward on a diet supplying 800 kcal/d (3.4 MJ/d), with 4.5 g protein nitrogen, 40% energy from fat, and 46% from carbohydrate. The average total weight loss was 5.0 kg. During the second and third week on the diet the rate of weight loss was 211 ± 77 g/d ($\bar{x} \pm$ SD) and individual values were well predicted by admission resting metabolic rate (RMR) ($r = 0.66$, $p < 0.0001$). The calculated energy density of the weight lost in this phase was 7000 kcal/kg (29.3 MJ/kg). However, the weight loss in the first week had a labile component of 815 ± 1202 g, which was not well predicted by RMR ($r = 0.20$, $p < 0.05$). The effect of this labile component was to obscure the overall rate of weight loss so some of the patients did not show net weight loss until day 13 of the diet, although they were in negative energy balance. *Am J Clin Nutr* 1989;50:41–5.

KEY WORDS Obesity, body composition, resting metabolic rate, weight loss

Introduction

The excess weight in severely obese people is ~75% fat and 25% fat-free tissue (1); therefore, it has an energy density of ~7000 kcal/kg (29.3 MJ/kg) (2). Therefore, in the long term an obese person who maintains an energy deficit of 1000 kcal/d (4.2 MJ/d) will lose weight at the rate of 1 kg/wk. However it is a common observation that during the first few days on a reducing diet weight loss is more rapid than this calculation suggests and the rate then slows to the theoretical rate. This initial rapid weight loss causes confusion in the dieter: if a given diet produces 2 kg weight loss in the first week but only 1 kg in the second, the patient may believe that the body is adapting to the diet by decreasing energy requirements, so soon weight loss will be impossible. Such reasoning is used as an argument to persuade obese people to try other methods to cause weight loss (3). We report here the effect of a diet supplying 800 kcal/d (3.4 MJ/d) for 21 d on the rate of weight loss in 108 obese women.

Subjects and methods

Since 1976 we have admitted 390 patients to a metabolic facility for investigation of energy balance and body composition (4). These investigations have been approved by the Northwick Park Hospital Ethical Committee.

Patients were admitted on Tuesdays or Wednesdays. Records were selected for patients who were female; who were on a diet supplying 800 kcal/d (3.4 MJ/d) for 21 d; who were not involved in an exercise program; who were not taking diuretic drugs immediately before or during admission; who did not experience vomiting or diarrhea in the ward; and in whom we had a measurement of body weight daily on Mondays through Fridays, of resting metabolic rate (RMR) on day 1 and 21, and at least one estimate of fat-free mass (FFM). There were 108 women who met these criteria.

The metabolic ward is a closed environment: no patient is allowed to go off the ward at any time unless accompanied by a member of staff and precautions are taken to ensure that visitors do not bring food onto the ward. All diets are prepared in a metabolic kitchen and plate waste is weighed back (4). The diets supplied 4.5 ± 1.5 g protein nitrogen, with 40 ± 7% of energy from fat and 46 ± 7% of energy from carbohydrate.

Estimates of FFM were made by determination of body density, or total-body water by tritium or deuterium dilution, or by total-body potassium by ^{40}K counting in a whole-body counter. These techniques have been described elsewhere (2). Where more than one method was used to measure FFM in a given patient the mean of the estimates was used as the value for FFM. RMR was measured by open-circuit indirect calorimetry (5, 6).

Data on daily weight loss were summed to give cumulative weight loss for each patient. From day 7 onward the data fit a straight line ($r = 0.999$) but data before day 7 departed from the linear trend (**Fig 1**). A linear regression was therefore performed on the weight loss from day 7 to 21; the slope of this line (gradient) gave the average rate of weight loss after the early fast component of weight loss had gone. The SD of this regres-

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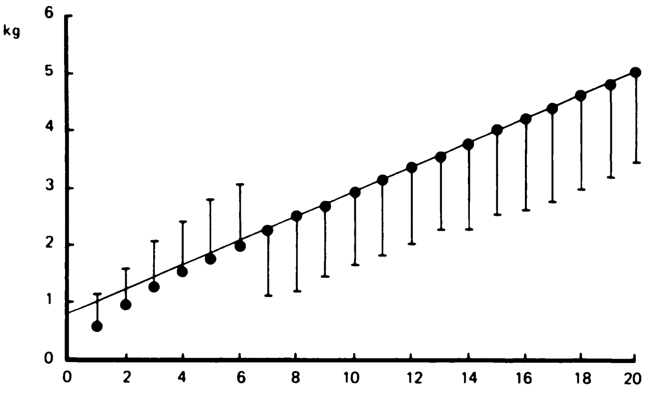

FIG 1. Average cumulative weight loss in 108 obese women on a reducing diet. Vertical bars indicate 1 SD. Continuous line is the best-fit line for data from days 7 to 21.

sion line provided a measure of the fluctuations of daily data points about the regression line and the intercept at 0 time (intercept) was a measure of the rapid component of weight lost in the first week in addition to the average rate of weight loss in the second and third weeks, represented by the gradient.

Statistical analysis was performed by using the SPP package for IBM microcomputer (7). Data are reported as mean ± SD.

Results

The average weight loss in the 108 women was 5.02 ± 1.66 kg over the 21-d period. For the first week the average weight loss was 0.33 kg/d, decreasing day-by-day; in the second and third week it was fairly constant at 0.21 kg/d. The data are plotted as cumulative weight loss in Figure 1; over days 7–21 the regression line has the formula

$$y = 0.815 + 0.211x \qquad (1)$$

indicating a rate of weight loss of 0.211 kg/d (gradient) and an initial rapid component of weight loss of 0.815 kg (intercept).

The characteristics of the 108 women, their body composition, RMR, gradient, and intercept are shown in **Table 1.** In the subsequent statistical analysis the same correlations were obtained whether FFM estimated by potassium, water, or density was used; therefore, a single figure derived from the average of available determinations was used. A correlation matrix for the variables in Table 1 is shown in **Table 2.**

It is evident that the two components of weight loss, gradient and intercept, are differently related to the other variables. Gradient is strongly related to RMR-1 ($r = 0.66, p < 0.0001$) and to other variables that are themselves related to RMR-1. A multiple regression analysis including RMR-1, RMR-21, FFM, body mass index (BMI), and initial weight and age yielded a multiple correlation coefficient of 0.691 and analysis of variance showed that only RMR-1 contributed significantly to the correlation. **Figure 2** shows a plot of gradient against RMR-1: the regression line is

$$y = 1.02x - 66.8 \quad (r = 0.664, p < 0.0001) \qquad (2)$$

where y is gradient (g/d) and x is RMR-1 (mL O_2/min). The slope of this line shows that an increase of 1.0 mL O_2/min in RMR is associated with an increase of 1.02 g/d in the rate of weight loss. We showed (8) that in our metabolic ward an increase of 100 mL/min in RMR is associated with an increase of ~700 kcal/d (2.9 MJ/d) in energy expenditure. Therefore, the extra weight loss of 102 g/d on a fixed energy intake is associated with an extra 700 kcal/d (2.9 MJ/d) energy deficit: in other words the weight being lost between days 7 and 21 has an energy value of ~7000 kcal/kg (29.3 MJ/kg). This is the figure to be expected if the weight lost is 75% fat and 25% FFM, which is the composition of excess weight determined by independent methods (1).

The value of the intercept unlike the gradient is not well predicted by any of the variables shown in the correlation matrix. The best multiple correlation coefficient was 0.248 ($p < 0.001$) when RMR-1, RMR-21, initial weight, BMI, and FFM were included, and of these the most significant contributor was initial weight (or BMI). **Figure 3** shows a plot of intercept against RMR-1; the correlation coefficient is only 0.204 ($p < 0.05$). The slope of the line indicates that the intercept increases by 1 g for each increase of 4.93 mL/min in RMR but it is not possible to calculate the energy density of the material lost in the early phase from these data because the intercept is a weight not a rate of weight loss and 21 of the 108 subjects showed a negative intercept.

Discussion

It is obvious that the rate of weight loss among people on a constant low-energy diet should be proportional to energy expenditure and because energy expenditure is closely related to RMR, RMR should predict weight loss in these circumstances (4). The data presented here show that the expectation described above is fulfilled so far as the gradient is concerned but not with respect to the intercept. Thus there is an early component of weight loss that is not simply related to the difference between energy input and output. This component of weight loss cannot have a high energy density and it must contain a fairly high proportion of water.

We have no direct evidence about the composition of the extra weight represented by the intercept but it is evident from Table 1 that the magnitude of this component varies from −1.24 to +2.80 kg (5th to 95th centile range); it must be largely water because it would not be possible otherwise for it to increase in subjects who are in negative energy balance.

If the water is not free it must be associated with either protein or glycogen; in either case there would be ~3 g water associated with 1 g solid; therefore, the energy density of the mixture would be 1000 kcal/kg (4.2 MJ/kg).

TABLE 1
Characteristics of the 108 women on a diet supplying 800 kcal/d for 21 d

Variable	Number of subjects	Value*	Centiles 5th	25th	50th	75th	95th
Age (y)	108	36.9 ± 12.2	19	27	34	48	56
Height (m)	108	1.62 ± 0.07	1.52	1.57	1.62	1.66	1.76
Initial weight (kg)	108	100.8 ± 23.6	72.2	82.7	96.0	112.3	149.0
BMI (kg/m^2)	108	38.1 ± 8.4	27.8	32.6	37.0	41.6	55.1
FFM-K† (kg)	102	50.9 ± 9.4	38.2	44.2	49.0	56.4	69.0
FFM-W‡ (kg)	35	53.5 ± 9.5	38.6	48.2	51.8	57.7	73.8
FFM-D§ (kg)	72	59.2 ± 8.1	47.5	53.2	58.0	65.1	75.0
FFM (kg)	108	54.6 ± 9.2	40.9	48.2	53.3	60.6	71.5
Fat (kg)	108	46.2 ± 17.0	26.7	34.5	41.5	54.9	80.0
RMR-1‖ (mL O_2/min)	108	272 ± 49.7	201	235	264	305	360
RMR-21¶ (mL O_2/min)	108	247 ± 45.0	188	216	238	276	327
Gradient (kg/d)	108	0.211 ± 0.077	0.109	0.153	0.198	0.269	0.348
Intercept (kg)	108	0.815 ± 1.202	−1.24	0.07	0.76	1.53	2.80
SD** (kg)	108	0.274 ± 0.120	0.119	0.178	0.251	0.347	0.512

* $\bar{x}$ ± SD.
† Fat-free mass (FFM) determined by total body potassium.
‡ FFM determined by total-body water.
§ FFM determined by density.
‖ Resting metabolic rate (RMR) on day 1.
¶ RMR determined on day 21.
** SD of the weights about the regression line for days 7 to 21.

The loss of ~0.8 kg of this fast component of weight loss would then be associated with ~200 g protein or glycogen. It is unlikely that there is a loss of 200 g protein in the first phase of weight loss because this would have been detected in N balance studies; therefore, the likeliest candidate for the fast phase of weight loss is water associated with glycogen. The magnitude of the loss is also compatible with this hypothesis: there might be no labile glycogen store at the start of a period of dieting (and therefore no fast component) or there might be 520 g glycogen, thus explaining the 95th centile value of 2.8 kg of fast-phase loss. The difference would depend on the previous diet. This explanation also explains the relative constancy of the slow-phase loss. After a week on a constant diet supplying 800 kcal/d (3.4 MJ/d) the glycogen stores would be depleted to a constant level.

Among the women in this series the total weight loss (intercept plus gradient for 3 wk) ranged from 0.9 to 12.7

TABLE 2
Correlation matrix between variables measured in 108 obese women who were on a diet supplying 800 kcal/d for 21 d*

	1	2	3	4	5	6	7	8	9	10
1 Age (y)										
2 Height (m)	−0.28†									
3 Initial weight (kg)	0.03	0.36‡								
4 BMI (kg/m^2)	0.14	−0.00	0.93‡							
5 FFM (kg)	−0.04	0.50‡	0.81‡	0.68‡						
6 Fat (kg)	0.07	0.24§	0.95‡	0.93‡	0.59‡					
7 RMR-1	−0.14	0.41‡	0.84‡	0.74‡	0.80‡	0.73‡				
8 RMR-21	−0.04	0.38‡	0.81‡	0.73‡	0.76‡	0.71‡	0.88‡			
9 Gradient	−0.23§	0.41‡	0.58‡	0.46‡	0.54‡	0.51‡	0.66‡	0.57‡		
10 Intercept	0.03	0.09	0.23§	0.21§	0.24†	0.20§	0.20§	0.19	−0.21§	
11 SD	−0.17	0.21§	0.31‡	0.25†	0.40‡	0.21§	0.30†	0.27†	0.21§	0.08
	1	2	3	4	5	6	7	8	9	10

* *See* Table 1 for definitions of terms.
† $p < 0.01$.
‡ $p < 0.001$.
§ $p < 0.05$.

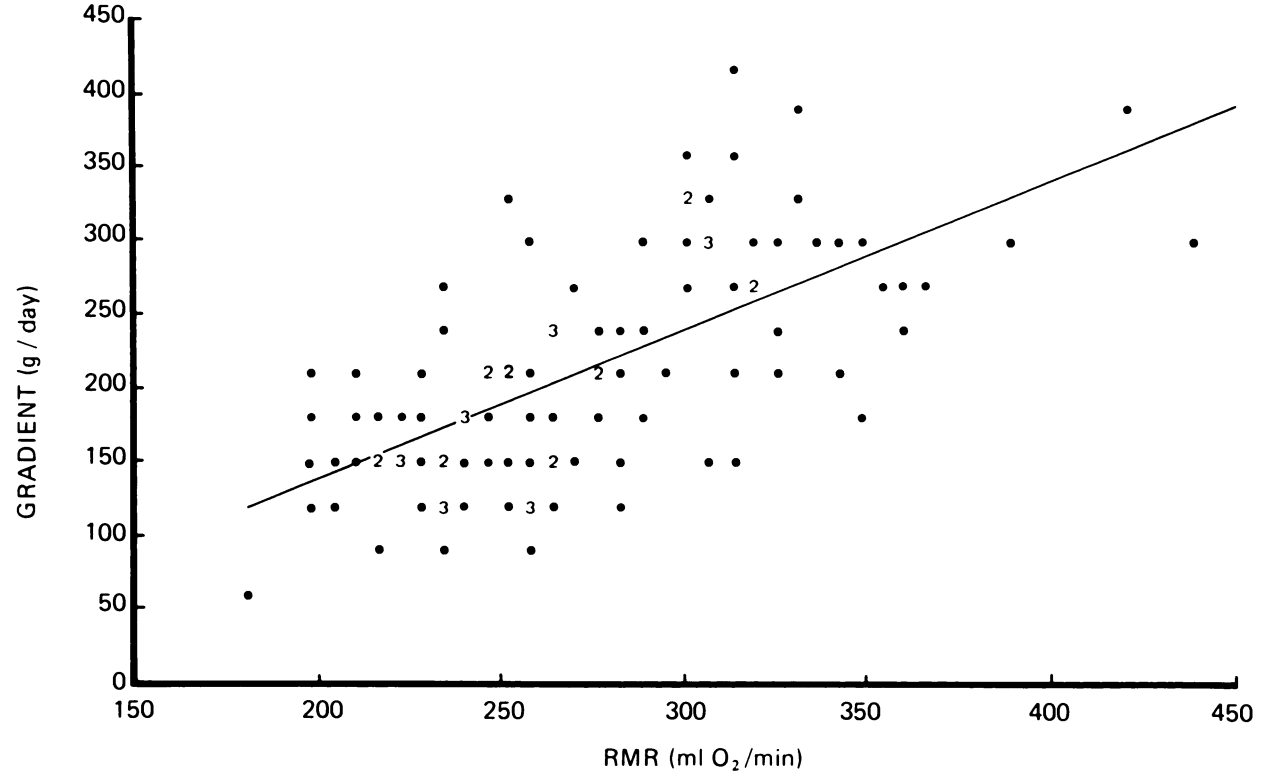

FIG 2. Scatter plot of the average rate of weight loss (g/d) from days 7 to 21 against resting metabolic rate (RMR) on admission in the women shown in Figure 1. Regression line is $y = 1.021x - 66.8$; $r = 0.664$, $p < 0.0001$.

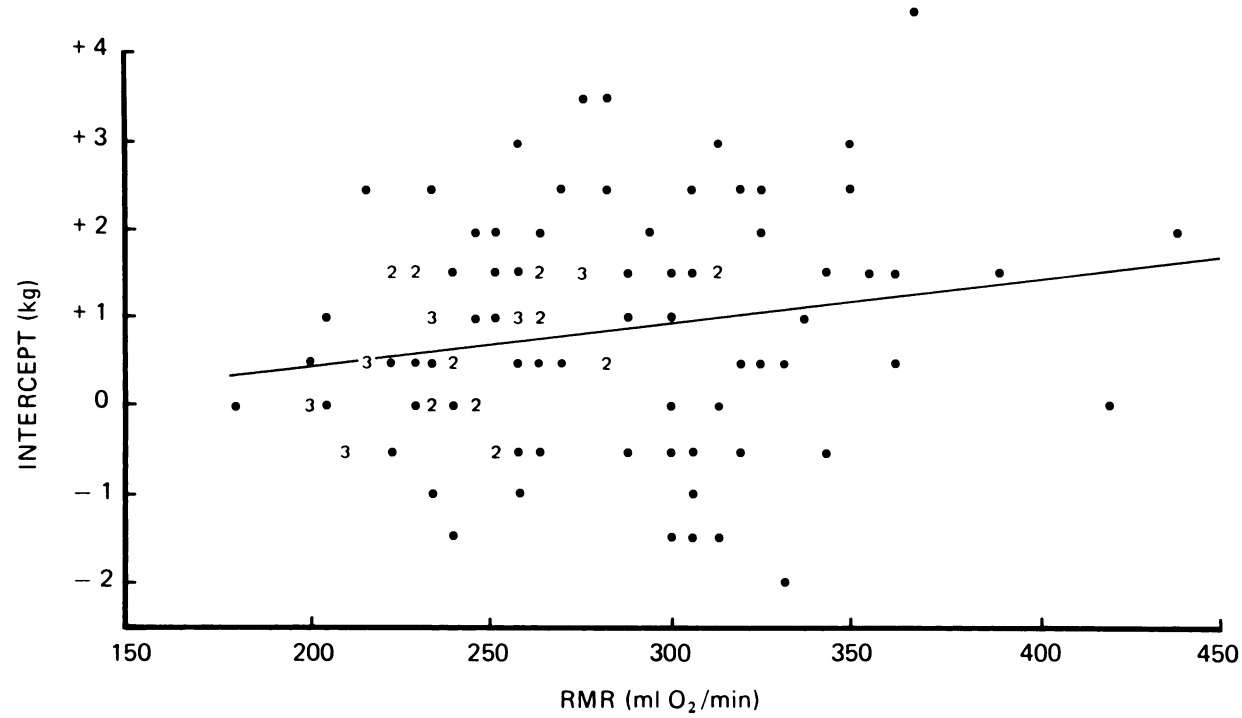

FIG 3. Scatter plot of the intercept at 0 time of the regression line for cumulative weight loss from days 7 to 21 against resting metabolic rate (RMR) on admission for the women shown in Figure 1. Regression line is $y = 4.93x - 524.8$; $r = 0.204$, $p < 0.05$.

kg on a diet supplying 800 kcal/d (3.4 MJ/d). This very large variety in overall weight loss might be taken to imply an equally large variety in energy requirement or alternatively that weight loss is not strictly proportional to energy deficit. Our analyses show that both these interpretations are untrue. The variation between individuals (5th to 95th centile) in overall weight loss (gradient) was only from 0.109 to 0.348 kg/d and this was well predicted ($p < 0.0001$) by RMR, which varied from 201 to 360 mL O_2/min. The main cause of the variation between individuals in overall weight loss was the early component (intercept), which on average accounted for only 16% of the total weight loss but which varied from −1.24 to 2.80 kg and was relatively weakly related to RMR ($p < 0.05$). Indirect evidence suggests that this early component of weight loss is probably water associated with glycogen. In terms of long-term energy balance, this small component of the energy stores of the body is relatively unimportant but because it accounts for a large part of weight change in the first few days of dieting it has a disproportionately large influence on the opinion of the dieter about the diet.

It should not be assumed that the results reported here for the rate and composition of weight loss among obese women on a diet supplying 800 kcal/d (3.4 MJ/d) for 21 d would necessarily apply to subjects with different amounts of body fat, or on different diets, or over different periods of time. We report our data because they apply to a range of obesity commonly seen in clinical practice and the diet was administered under very carefully controlled and uniform conditions. The review of Forbes (9) shows that, for a given low-energy diet the more obese the subject the smaller the proportion of FFM in the weight lost and for a given degree of obesity the lower the energy content of the diet the higher the proportion of FFM in the weight lost. During total starvation, N conservation gradually improves with time (10) and a similar effect is observed on a diet supplying 800 kcal/d (11).

Our data are relevant to the controversy about the use of very-low-calorie diets. One of the reasons advanced for using these diets is that there are some obese people with a very efficient metabolism; therefore, a traditional reducing diet of ~1000 kcal/d may lead to an increase in weight in this unfortunate group of people (12). If this were true then a very-low energy intake would be necessary to produce weight loss. However, if a woman needed < 1000 kcal/d (4.2 MJ/d) to maintain weight, her RMR would need to be < 143 mL/min and we have never observed such a low metabolic rate in any obese person. However, in the short term, weight may be gained even on a diet supplying 800 kcal/d (3.4 MJ/d). Of the 108 patients reported here there were several in whom a negative intercept resulted in an overall weight gain in the first few days and it was not until day 13 of the diet that every individual was below (and thereafter remained below) admission weight. It is easy to understand why such people may come to believe that it is impossible to lose weight on a conventional reducing diet and therefore they give up trying before the true rate of weight loss becomes evident. ∎

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