Weight Loss and Body Composition

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Abstract

BODY FAT ACCOUNTS for much of the excess weight in obese persons; but the amount of lean body tissue (muscle and other protein tissue) in the obese individual is similar to that found in the normal individual. In weight loss, primarily excess fat should be lost; not essential protein tissue.

Complete fasting has been proposed as a technique for losing weight, in lieu of partial caloric restriction. The present studies were carried out to evaluate these techniques for weight loss. Changes in body composition of obese rats were determined after the animals lost one third of their body weight on different regimens. Obese animals which were restricted to 37.5 and 60% of ad libitum caloric intakes required 53 and 93 days, respectively, to lose this weight, whereas those which were totally fasted required only 24 days. There were significant differences in body composition of these groups after weight loss.

Fasted animals lost more protein and less fat than did animals restricted in caloric intake; the fasted animals lost 18% of their total body protein, whereas the calorically restricted animals lost only 8–9%. Epididymal fat pads were twice as large in the fasted animals as in the calorically restricted animals. In fasted animals, liver weight loss was greater than in restricted animals, but liver fat levels were still high, as in the obese rats. Liver cholesterol levels were also elevated in fasted animals.

Neither the amount of fat nor the type of fat (unsaturation) in the diet had any significant effect on the rate of weight loss or on gross body composition. Type of fat affected fatty acid composition of plasma, but not of liver or depot fat.

The development of new methods for determining body composition in man has permitted reasonably accurate estimates of the amount of excess body fat in obese individuals. In obese subjects who lost weight on restricted caloric intakes of an otherwise nutritionally complete diet, most of the weight loss was as body fat, without significant loss of lean body tissue. The studies in man confirm the findings in animals.

The extra weight in obesity is mainly fat, with very little protein and some water; when weight is lost by restricted intake of a good diet, the composition of the tissue burned is quite similar to that comprising the extra weight. Fasting gives more rapid weight loss, but apparently less favorable changes in body composition.

TABLE I

Predicted Average Fat Levels for Men of Standard Weight, at Different Ages[a]

Age, yr	Fat, %
20	10.3
25	13.4
30	16.2
35	18.6
40	20.7
45	22.5
50	23.9
55	25.0

[a] From Brozek and Keys, Geriatrics, 8, 70 (1953).

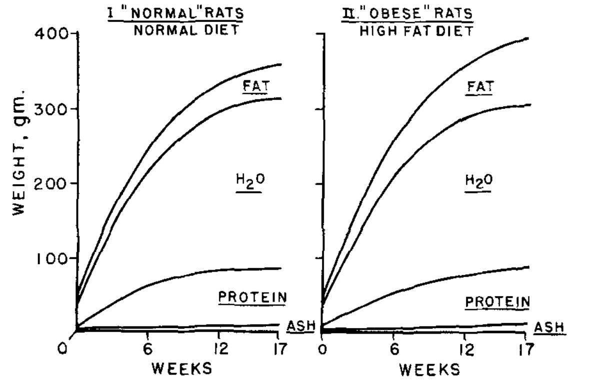

FIG. 1. Weight and body composition of rats on normal and high fat diets for 17 weeks.

Introduction

OBESITY IS CHARACTERIZED by an increase in both the percentage and total amount of fat in the body. When caloric intake is in excess of that needed for energy and growth requirements, the extra calories are converted to fat and stored as adipose tissue. Until recently, adequate data on the body composition of obese and normal individuals were not available. In the last two decades, rapid strides have been made in developing methods for the measurement of body composition and fat levels in man (1,2). These include determinations of specific gravity, skinfold thickness, density by underwater weighing, body volume by gas dilution, total body water, and K^{40} by scintillation counting.

The level of fat in man depends on age, sex and physical fitness. Well-fed infants have a high level of fat; this decreases to a very low level during rapid growth in adolescence and then increases again with age (3). Brozek and Keys (4) found an average of 10.7% fat in 148 young men with a mean age of 20.4 years, and 24.4% fat in 125 men averaging 52.2 years of age. From equations fitted to their data, they predicted the average fat content of men of standard weight as a function of their age (Table I).

The level of fat in women is much higher than in men. Young and co-workers (5) found body fat levels from 15.8–38.6%, with a mean of 28.7% in 94 young women, age 16 to 30, averaging 20.4 years.

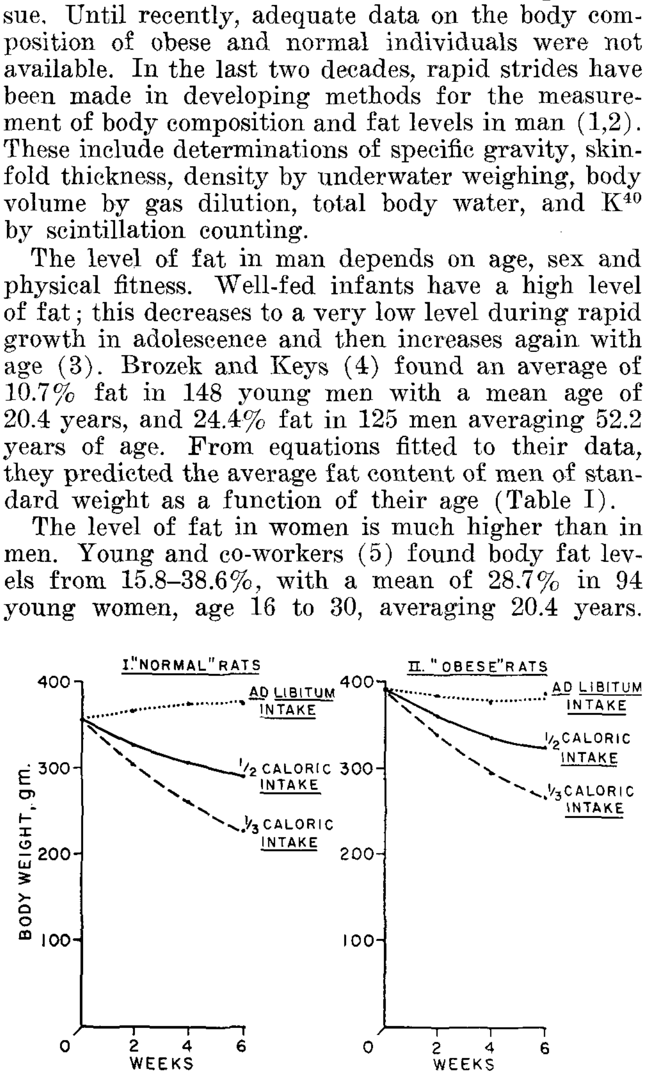

FIG. 2. Body weight changes of rats fed weight control diet.

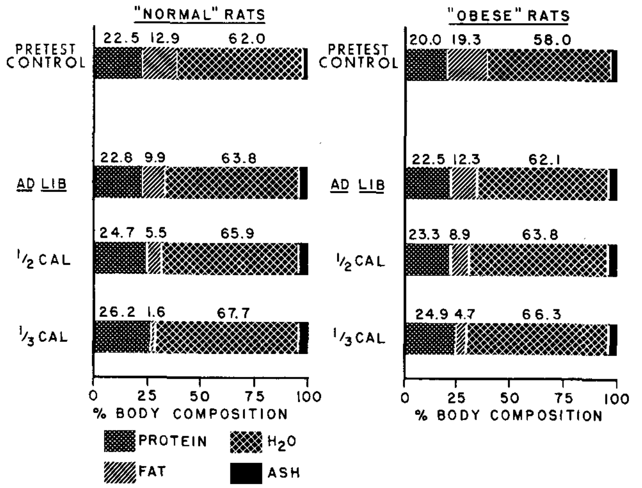

FIG. 3. Changes in body composition of rats on weight control diet.

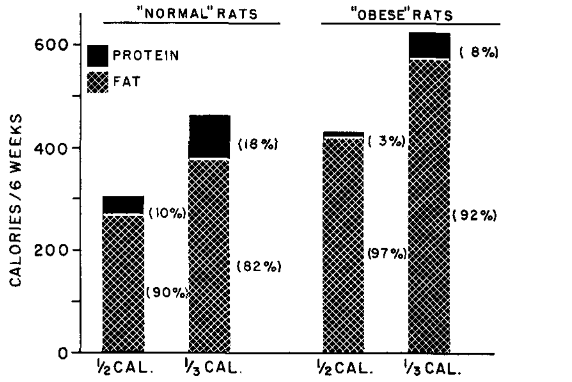

FIG. 5. Endogenous calories derived from body fat and protein during weight loss.

The characteristic fat depots in women may be useful as a reserve supply of calories in periods of physiological stress or caloric restriction. During periods of famine, women with their higher body fat levels, are generally able to withstand caloric deprivation better than do men.

Physical activity decreases the level of body fat. Schifferdecker et al. (6) showed that men of above average physical fitness had considerably less body fat than did otherwise comparable men of average fitness.

In obese subjects there is too high a level of fat, and the percentages of protein, minerals, and particularly water in the body are decreased. Ideally, in weight reduction in obese subjects, fat should be the main tissue lost, without markedly decreasing lean body mass and vital protein stores.

The present paper describes several studies on the effects of weight loss on body composition of rats, as measured by direct analysis, and reviews data from the literature on pertinent studies which have been conducted in man.

In the first study,[1] two large groups of male weanling rats were grown on a normal diet (20% protein, 10% fat) or on a high fat diet (29% protein, 63% fat). Groups of animals were sacrificed at intervals and analyzed for gross body composition. The rats on the high fat diet gained more weight and had more carcass fat than did those on the control diet (Fig. 1). After 17 weeks, the "obese" rats (not to be confused with the genetic strain commonly designated "obese") weighed an average of 392 g and the "normals," 355 g. Most of this difference was in body fat; the obese animals had 31 g more body fat than did the normals, although both groups had similar amounts of body protein, ash, and water.

At this time, the normal and obese rats were randomly subdivided into groups and fed a weighed control diet (Metrecal) which provided adequate protein, vitamins and minerals, even when allowed in restricted amounts. Animals received this diet either ad libitum or at ½ or ⅓ of the ad libitum intake. During the following six weeks, the animals receiving one half of ad libitum intake lost about 25% of their body weight, and those receiving one third of the ad libitum intake lost about 35% of their original weight (Fig. 2).

The changes in gross body composition are shown in Figure 3. The top bar shows the per cent of protein, fat, water and ash in the normal and obese controls before being fed the weight control diet. After losing one third of their body weight, the obese animals had 4.7% body fat, whereas the normal rats, which started with less fat, had only 1.6% body fat.

Figure 4 shows the gross composition of the weight which was lost by the normal and obese animals. Even though weight losses were approximately the same in both groups—67 and 69 g with one half of ad libitum calories—the obese animals lost mainly fat (47 g) and very little protein (2 g), whereas the normal animals lost 8 g of protein and only 30 g of fat. In the obese animals, only 3% of the body protein was lost, whereas in the normals, 12% of the body protein was lost. Comparable results were obtained in animals restricted to one third of ad libitum calorie intake.

The calories supplied by the body tissues during

[1] A preliminary report on this study was presented at the American Institute of Nutrition meeting, April, 1962, Fed. Proc. *21* (2), 398, 1962.

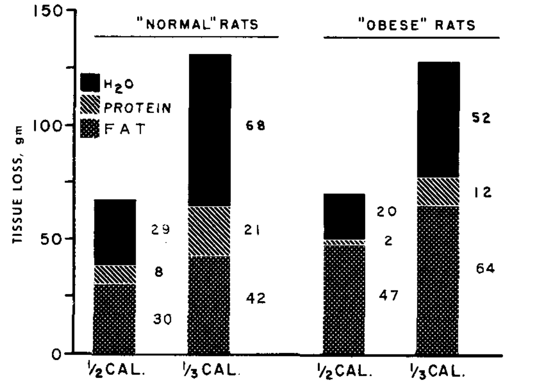

FIG. 4. Fat, protein and water lost during weight loss.

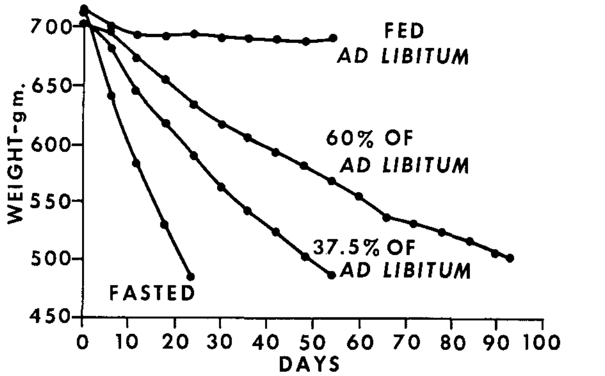

FIG. 6. Weight changes in obese rats with varying food intakes.

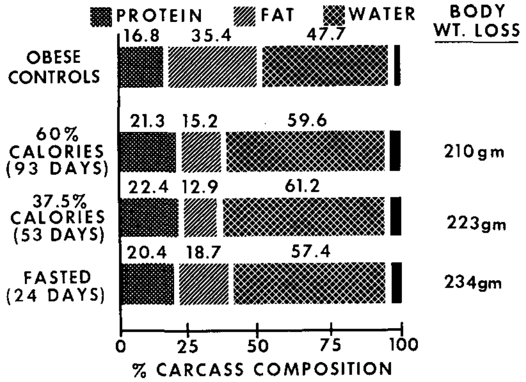

FIG. 7. Rat carcass composition after weight loss.

weight loss are shown in Figure 5. In the obese animals restricted to one third of the caloric intake, 92% of the endogenous calories were derived from body fat and only 8% from protein, whereas in the normal animals 82% of the calories were from fat and 18% from protein.

Another study was conducted to determine the effect of the rate of weight loss on changes in body composition when obese animals lost the same amounts of weight by different degrees of caloric restriction. Rats were kept on the high fat diet until they weighed over 700 g and had about 35% fat in the carcass. After sacrificing a representative group for initial control values, groups were fed a diet similar in composition to the weight control diet used in the first experiment. One group received the diet ad libitum, another at 60% of the ad libitum intake, another at 37.5%, and one group was fasted, receiving no food but allowed access to water. Figure 6 shows the rates of weight loss in these groups. After 24 days the group which was fasted lost 234 g; the group receiving 37.5% of the calories lost a similar amount of weight in 53 days, whereas the group receiving 60% of the calories required 93 days to achieve a similar weight loss. Each group was sacrificed for analysis at the time shown (Fig. 7). The terminal carcass composition of these rats is also shown in Figure 7. The obese controls contained 16.8% protein, 35.4% fat, and 47.7% water. Restriction of caloric intake to 60 or 37.5% of the calories reduced fat content of the carcass to about 15 and 13%, respectively, with concomitant increases in protein and water levels. However, the fasted group did not lose as much fat, and had 18.7% fat in the carcass.

Figure 8 shows the composition of the carcass tissue which was lost by each of these groups. This has been calculated from weight loss and changes in composition. It will be noted that in the animals on the

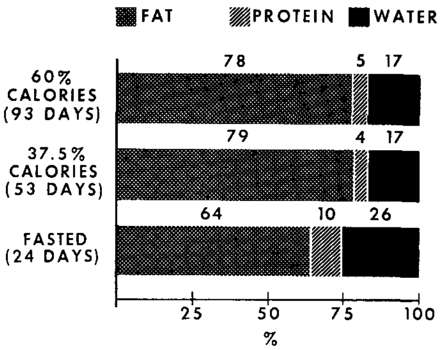

FIG. 8. Composition of carcass tissue lost during weight loss.

TABLE II
Calories Derived from Rat Carcass Fat and Protein During Weight Loss

	Wt loss	Fat calories		Protein calories	
	Gm	Cal	% of loss	Cal	% of loss
60% Calories	210	1197	97	36	3
37.5% Calories	223	1314	98	30	2
Fasted	234	1107	94	72	6

restricted diets, the tissue that was lost contained only 4 or 5% protein and about 79% fat, whereas in the fasted animals the tissue that was lost contained 10% protein and only 64% fat, showing a greater loss of lean body tissue in the fasted animals.

When calculated from another standpoint, these data show that the fasted animals lost 18% of their total carcass protein in 24 days, whereas the calorically restricted animals lost only 8 or 9% of their carcass protein in 53 or 93 days—while achieving the same weight loss. Table II shows the calories lost from fat and protein by these groups. Protein provided 6% of the endogenous calories in the fasted group, but only 2 or 3% in the animals receiving restricted diets.

There were also differences in weight loss in certain of the organs in the fasted animals, as shown in Table III. The livers of the obese animals weighed 15.4 g or 2.2% of the body weight and contained over 10% fat. After weight loss by caloric restriction, liver weights were 2.4% of the body weight but fat content was normal, about 3%. However, in the fasted rats, the livers were smallest, weighing only 8.4 g, or 1.8% of the body weight, but their fat content remained elevated, namely 10.7%. Epididymal fat pads, which contain about 90% fat, were significantly heavier (2.9% of body weight) in the fasted animals than in those which had lost weight more slowly by caloric restriction. In both liver and fat pads, less fat was lost during fasting than in caloric restriction.

Table IV shows findings on cholesterol levels. Plasma cholesterol levels were not significantly modified by reducing the caloric intake, but were decreased in the fasted rats, to 57 mg/100 ml; however, liver cholesterol levels were quite high in the fasted rats—even higher than those of the obese animals before fasting. This is interesting not only from the standpoint of weight loss in obesity, but also from the standpoint of other studies in lipid metabolism; many conclusions have been drawn from findings of changes in plasma cholesterol levels, without any knowledge of the concomitant changes in cholesterol levels in the liver and other tissues.

Figure 9 shows some of the results of another study on groups of obese rats during alternate fasting and feeding. (These rats represent additional groups run concurrently with the study shown in Fig. 6.) The unbroken line shows the rate of loss in these 700 g rats when receiving 37.5% of ad libitum intake; losing 219 g in 54 days. The other two groups were fasted for 3-day periods and fed for 3-day periods.

TABLE III
Organ Weights After Weight Loss by Rats

	Liver			Fat pads	
	Wt, g	% Body wt	Fat, %	Wt, g	% Body wt
Control	15.4	2.2	10.2	25.1	3.5
60% Calories	11.8	2.4	3.2	8.3	1.6
37.5% Calories	11.4	2.4	3.4	7.5	1.5
Fasted	8.4	1.8	10.7	13.9	2.9

TABLE IV

Cholesterol Levels After Weight Loss by Rats

	Plasma Cholesterol	Liver Cholesterol
	mg/100 ml	mg/gm
Control	82	3.5
60% Calories	88	2,7
37.5 Calories	91	2.8
Fasted	57	5.5

One group was restricted to 75% of ad libitum intake per day during the 3-day feeding periods—so that the total food intake was the same as those receiving 37.5% of ad libitum each day. The overall weight loss of this group was 227 g in 54 days. Rats in the third group were allowed to eat as much as they wanted to during the 3-day feeding periods. For a while this group responded similarly to the second group, but after a few weeks, the unrestricted group markedly increased food intake, and overall weight loss was only 138 g in 54 days. Body composition was nearly identical in the two groups with the same total food intake despite the differences in the feeding patterns. The losses of fat and protein were similar to those of the group restricted to 37.5% of its ad libitum food intake in the previous study. The group which was fasted and then fed ad libitum for these short periods also lost mostly body fat and water with very little loss of protein.

Studies were also conducted to determine whether the level or type of fat in the diet would affect weight loss or body composition. In the first of these, shown in Table V, obese rats weighing approximately 400 g received a casein diet with 30% of the calories from protein but with 4, 20 or 66% of the calories from fat. Corn oil supplied most or all of the "unsaturated" fat and hydrogenated coconut oil alone was used to provide 66% of the calories as "saturated" fat. When these diets were fed at one third of the ad libitum intake for 31 days, weight losses were similar in all groups, although slightly higher on the saturated fat diet. None of the differences were significant. The losses of body fat, protein and water, calculated from analyses of body composition, also showed no real differences on all four diets, although a slightly smaller loss of fat was found on the 66% unsaturated fat diet, probably related to the smaller weight loss in this group.

Fatty acid composition in plasma, liver and depot fat was determined. Plasma fatty acids were affected by the type of fat, more than by level of fat in the diet, as shown by pertinent fatty acid levels in Table VI. The level of $C_{20:4}$ was increased in animals receiving higher levels of unsaturated fat, even though the animals were losing weight. Saturated fat mark-

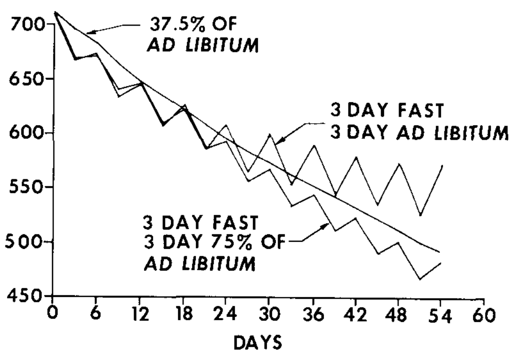

FIG. 9. Weight changes in obese rats during alternate fasting and feeding.

TABLE V

Effect of Dietary Fat on Weight Loss and Body Composition

Dietary fat — level		Body wt loss		Fat loss		Protein loss		Water loss	
	% cal	gm	%	gm	%	gm	%	gm	%
Unsaturated	4	118	29	54	66	15	18	48	21
Unsaturated	20	118	29	54	66	14	18	46	20
Unsaturated	66	108	27	45	56	15	19	47	21
Saturated	66	125	31	56	69	15	19	51	22

(401 g rats—31 day study)

edly decreased the levels of $C_{18:2}$ and $C_{20:4}$ in the plasma. Fatty acids in depot tissues and in the liver were similar in all four groups.

In another study on the effect of the level and type of fat in the diet (Table VII), the obese animals received either a saturated mixture of fats with a P/S ratio of 0.2 (70% lard, 20% butterfat and 10% coconut oil), or an unsaturated fat mixture with a P/S ratio of 3.0 (containing safflower oil plus small amounts of the above fats). The diets contained 20, 45 or 70% of the calories as fat, and the animals were restricted to one third of ad libitum calories. Body weight losses were similar on all six diets and the amounts of fat, protein and water lost from the body tissues were similar in all groups. The level of fat in the diet had no significant effect on weight loss or on body composition in this 28-day period.

It is pertinent to review some of the data in the literature on changes in body composition of obese men during loss of weight. Passmore et al. (7) calculated the composition of the tissue lost by seven obese subjects on a 400 to 500 cal/day reducing diet using data from nitrogen and energy balances. They found that the tissue lost contained approximately 73–83% fat (average 78%), 4–7% protein (average 6%), and 10–23% water (average 17%). These values agree closely with the findings in obese rats on a restricted diet (Fig. 8).

Berlin et al. (8) carried out comprehensive metabolic balance and body water-body density studies on three obese subjects receiving an 800 cal, 8 g nitrogen/day diet. The subjects lost weight rapidly for three to six days, due principally to water loss, following which weight loss was constant and primarily fat was lost. Absolute values of gross body composition were derived from measurements of body density, body water and total body electrolytes. Figure 10 shows a chart from their paper. During a 54-day period, subject WT lost approximately 60 lb. About 30 lb of this weight loss was due to loss of body fat, and there was also some loss of body water. However, lean tissue solids changed only slightly during the entire study.

Christian and co-workers (9) studied the effect of weight loss on the fat and lean body mass in obese subjects, as measured by whole body liquid scintillation counting of K^{40}. Since all potassium, regardless of its source, contains a low, constant level of radioactive K^{40}, total body potassium can be deter-

TABLE VI

Plasma Fatty Acids After Weight Loss of Rats

Dietary fat — level		Plasma fatty acids % of total			
		C_{16}	C_{18}	$C_{18:2}$	$C_{20:4}$
	% cal				
Control		24	14	24	4
Unsaturated	4	17	10	22	16
Unsaturated	20	17	11	21	22
Unsaturated	66	14	8	23	31
Saturated[a]	66	25	26	9	5

[a] Hydrogenated.

TABLE VII

Effect of Dietary Fat on Weight Loss and Body Composition

Dietary fat — level		Body wt loss		Fat loss		Protein loss		Water loss	
	% cal	g	%	g	%	g	%	g	%
Saturated (P/S 0.2)	20	114	30	58	72	11	15	44	21
	45	109	29	57	71	9	13	41	19
	70	111	30	55	68	11	16	44	21
Unsaturated (P/S 3.0)	20	111	30	58	72	11	14	42	20
	45	107	28	52	64	11	14	42	20
	70	105	28	55	68	10	13	40	19

(375 g rats—28 day study)

mined quantitatively by counting the gamma ray emission. Chemical analyses of adult human cadavers have shown that the fat-free tissue or lean body mass contains on the average 68 mEq potassium per kilogram. This value is quite constant and can be used for estimation of lean body mass from potassium values.

These workers placed several groups of obese subjects on a Metrecal diet which supplied 900 cal/day for 8 weeks or longer. Body weight and total body potassium of each subject were determined prior to initiating the study and each week during the course of the experiment. As controls, three subjects whose weight remained essentially constant were measured weekly for potassium, lean body mass and fat content over a period of 8 to 10 months, both preceding and during the course of the experimental study, to establish reproducibility of lean body mass measurements.

Figure 11 shows the potassium, lean body mass and fat values in one of the control subjects whose body weight was essentially constant over a 300-day period. Lean body mass, calculated from body potassium, averaged 110 ± 3.5 lb with a standard deviation of 3.2% Body fat was approximately 53 lb, or 32% of the total body weight throughout the study.

The male subjects in one of the groups were 18 to 26 years of age and had an average initial body fat content of 28.2%; after 8 weeks, in which they lost an average of 25.3 lb, body fat was 19%. In a group of female subjects, ranging in age from 14 to 61 years, average fat content was 53% at the start of the study and 45% after 8 weeks; the subjects lost an average of 18 lb.

The lean body mass, as calculated from measurements of K^{40}, was determined in these subjects ten times during the course of the study and showed

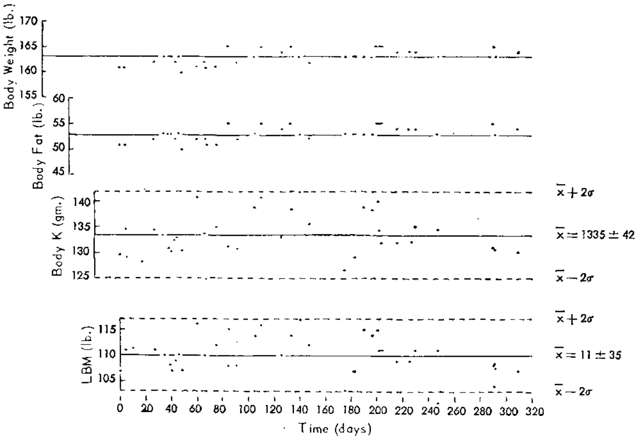

FIG. 11. Body fat and lean body mass in control subject. Christian et al., Am J. Clin. Nutr. *15,* 20 (1964).

no tendency to decline as weight was lost. The individual values for one of these subjects, a 28-year-old woman who lost 35 lb during the 8-week study, are shown in Figure 12. This subject weighed over 260 lb at the beginning of the study, of which approximately 150 lb was body fat. All of the lean body weight measurements fell within the limits of twice the standard deviation, just as did the values in the control subjects. In none of the subjects in this study, did lean body mass values show any tendency to decline during weight loss on this diet. The average lean body mass values for all of the 51 obese subjects prior to initiating the study was 126.8 lb, and at the end of the 8-week period it was 127.7 lb, an increase of 0.9 lb.

Allen et al. (10), studied the weight loss of a markedly obese woman on the 900-calorie Metrecal diet during the course of 81 weeks. During this time the patient lost 250 lb, of an initial weight of 470 lb. However, there are two striking aspects of this report. One is that the patient was in positive nitrogen balance or at least in nitrogen equilibrium, except for the first 4 of the 42 weeks, in which 167 lb were lost. Following this, the patient became pregnant, and while on the same diet lost 84 lb during pregnancy, but was in positive nitrogen balance or in nitrogen equilibrium during most of her pregnancy, although her dietary intake was only 900 cal/day.

Conclusions

From our increasing knowledge of body composition in man and the studies in animals, it is evident

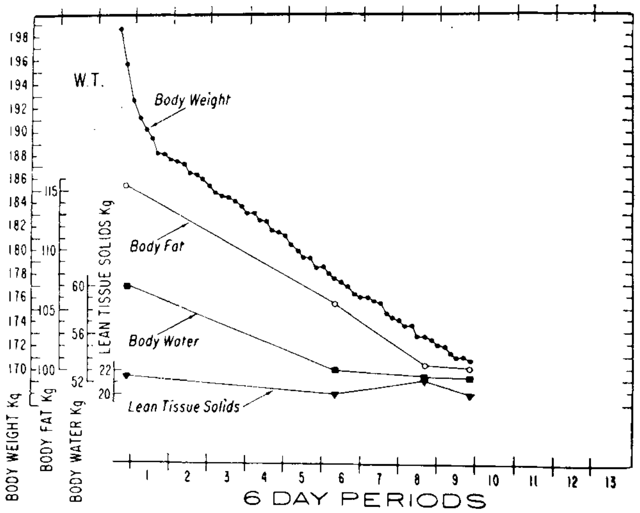

FIG. 10. Weight and body composition of an obese person during weight reduction with an 800 calorie diet. Berlin et al., Metabolism *11,* 302 (1962).

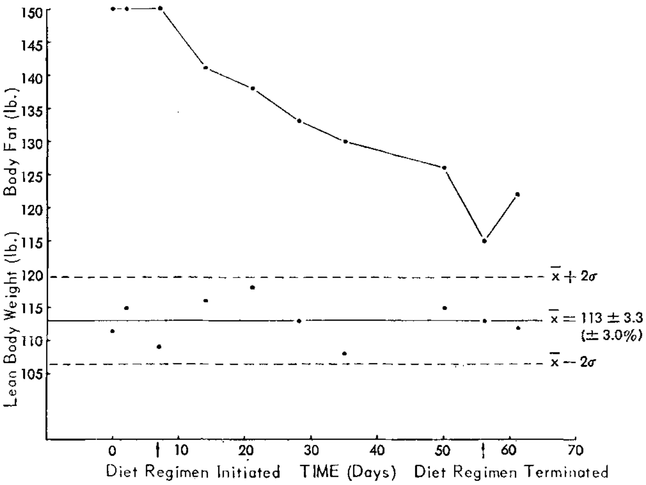

FIG. 12. Body fat and lean body mass during weight loss. Christian et al., Am J. Clin. Nutr. *15,* 20 (1964).

that the extra weight which we put on in obesity is mainly fat—with a little protein and some water—and that when we lose this extra weight by a diet restricted in calories—but otherwise adequate—the weight which is lost is mainly fat, with some water and a little protein, but with little or no loss of essential lean body tissue.

From studies in animals, it appears that complete restriction of calories or fasting results in loss of significant body protein—particularly liver protein. Cholesterol and total lipid levels in the liver are also elevated.

With the development of newer techniques for determining body composition in man, we should learn a great deal more about how subjects with different types of obesity respond to treatment.

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