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Nutritional status of Iowa State College women: VIII. Nitrogen, calcium and energy exchange during weight reduction

Edna Genevieve Brown
Iowa State College

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NUTRITIONAL STATUS OF IOWA STATE COLLEGE WOMEN VIII: NITROGEN, CALCIUM AND ENERGY EXCHANGE DURING WEIGHT REDUCTION

by

Edna Genevieve Brown

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Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

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I. INTRODUCTION

Excess body weight becomes a serious problem to many college girls. They are made acutely aware of the value of a slim, well-shaped figure both as a social asset while on the campus and as an economic asset in the professional life for which they are being trained. Awareness of excess weight in many cases appears to provide a motive for reduction and results in recourse to a variety of dietary routines which range all the way from a well-planned intake of all of the known essential nutrients to grossly unbalanced regimens whose only useful characteristic is a low content of calories.

The importance of a well fortified diet for girls of this age often is overlooked because of the assumption that growth has been completed. The study of 209 college women by Donelson and cooperators of the Regional Project of the North Central States (1943) is substantial evidence to the contrary. Measurements of the same subjects for four years demonstrated an annual increment in height which was statistically significant regardless of whether the student entered college at 17, 18, 19 or 20 years of age. Other investigators who also have taken measurements serially have noted annual growth increments (Barber and Stone, 1936; Gould, 1930).

On the other hand, measurements of weight, breadth and depth of chest, girth of arm and leg (Donelson *et al.*, 1943) failed to reveal significant annual increments in these dimensions. Apparently, the only trend in growth at this period is increase in height with attendant growth as shown in the retentions of the materials for such growth reported by McKay et al. (1942). Nine subjects who were pre-conditioned for 15 days to the diet of the experiment made average daily retentions during three balance periods of 0.741 gm. nitrogen, 0.098 gm. calcium, and 0.038 gm. phosphorus on intakes of 10.87, 1.120, and 1.240 grams of nitrogen, calcium, and phosphorus, respectively. These retentions indicate a probable growth of some non-fat soft tissues as well as the skeleton.

The importance of a good diet in building up body stores for child-bearing also should be considered at this age. Ebbs (1941), in a study of 400 Toronto women has confirmed and extended the work of Macie and co-workers on the influence of prenatal diet on the mother and child. In the chapter on this subject in the American Medical Association's "Handbook of Nutrition", Ebbs (1943) opens with the statement: "The ideal normal nutritional state for pregnancy would be one in which the maternal body was endowed with the proper nutritional elements before, during, and after the pregnancy . . . ."

Ebbs showed that among those women, who either by education or food supplementation received diets which could be evaluated as "Good" there were less complications affecting the mothers and infants than among the group whose diets throughout pregnancy were evaluated as "Poor".

The food requirements for pregnancy found by Ebbs, as well as those agreed upon by the Food and Nutrition Board of the National Research Council (1941), are considerably greater than non-pregnant requirements for the same individuals. When all of the practical difficulties encountered in the adjustment to pregnancy itself are considered it would seem foolish to forget the importance of a diet not only to provide for current needs but, as far as possible, for body stores, at that period of life which normally precedes child-bearing.

Further evidence of the failure to provide women of this age with sufficient nutriment may be found in the high incidence, among this group, of diseases associated with poor nutrition. This is exemplified in the number of deaths resulting from tuberculosis. In spite of drastic reduction of tuberculosis deaths for all ages and sexes in recent years, the rates for the two sexes in 1940 were about the same up to 14 years of age (Metropolitan Life Insurance Company, 1942). Between 14 and 25 years there is a rise in the rate for both sexes but the increase for young women is much greater than that for men. In the next 10 year period the rates for men again reach those for women. This difference in the sexes at the 14 to 25 year age period points to poorer nutrition of the female due perhaps to lack of provision for the physiological strain of menstruation and child-bearing.

The obvious method to bring about weight reduction and at the same time insure an intake of essential nutrients, other than calories, for the current and near-future needs of the college woman, would be education concerning nutritive needs and how they may be met in foods. However, more knowledge is needed concerning the components of a satisfactory reduction diet for post-adolescents. In weight reduction the energy requirements are of prime importance. An imbalance of energy intake and output has been assumed to be the cause of obesity (Newburgh, 1942). Can the caloric provisions which have been found suitable for weight reduction of adults be used for college women without interfering with the special metabolic requirements of subjects of this age? Are there any differences other than calorie in the food requirements during reduction of the obese college women as compared with the woman of normal weight?

The work of Bruch (1939a) on the growth pattern of obese children points to a difference in needs for growth of an individual depending upon previous growth rate. Bruch concluded that obese children are precocious in growth and sexual maturity as well as in weight gain. Consequently the slowing and eventual cessation of growth which takes place following the menarche may take place at a chronologically earlier age. Accordingly, a girl who has been obese since childhood may have less than the average nutritive needs for growth when she reaches college age. However, such a theory lacks objective proof.

The literature is fairly abundant in papers describing physiological differences in obese and non-obese individuals, but the evidence for the validity of the conclusions drawn frequently is unconvincing. Are the differences real or are they artifacts due to processes of experimentation? A confusing point in the literature is that much of the work on obese individuals has been done during periods of weight reduction. As a result, there is no way of knowing whether the abnormality found in the obese was due to the obese condition or to the condition of subsistence on a low caloric diet supplemented by utilization of body tissue. Furthermore, few control studies or normal individuals using the same experimental plan have accompanied reduction studies.

It has been the object of this study to investigate some phases of energy, nitrogen, and calcium metabolism of obese college women in such a way that requirements of these nutrients during weight reduction will be demonstrated. A pre- and a post-reduction period have been studied not only as control for the reduction period but to evaluate the maintenance requirements of an obese subject both before and after weight loss.

II. REVIEW OF LITERATURE

A. Adipose Tissue - Structure, Origin and Function

Obesity is defined by Newburgh (1943) as that condition in which the body contains an abnormally large amount of adipose tissue. Maximow and Bloom (1943) described adipose tissue as "loose connective tissue in which fat cells have displaced most of the other elements." The mature human fat cell is characterized in cross-section by its signet-ring appearance, a single large drop of neutral fat surrounded by a thin ring of cytoplasm in which the nucleus forms a thickened area at one point. In the narrow spaces between the fat cells, according to Maximow and Bloom, fibroblasts, lymphoid cells, and mast cells are scattered. "Collagenous fibers and elastic networks run in all directions . . . . The argyrophil fibers are well developed . . . and form a netlike basket around each fat cell . . . . The fat tissue always contains a richly developed network of blood capillaries." Rony (1940) mentioned also a rich network of vegetative nerve fibers in adipose tissue.

It is believed that the process of accumulation of fat in a fat-storing cell follows a consistent pattern. According to Maximow and Bloom, fat enters the cell in the form of its soluble components. In the cytoplasm a few droplets of fat appear first; these increase in size and fuse into a single drop which is surrounded by the cell protoplasm. When fat is withdrawn the process is reversed. There also is evidence that fat droplets may occur in the cell through the conversion of glycogen granules which have been deposited there (Maximow and Bloom, 1943).

The origin of the fat-storing cells, important to an understanding of their relation to body functions, was discussed by Wells (1940). He stated that the concept that adipose tissue is merely ordinary connective tissue in which fat had been deposited was unchallenged until about 1870. At that time the theory was advanced that the fatty tissue of mammals is a specific organ, entirely distinct from the connective tissues, and that it is derived from special primitive fat organs, characterized by the formation of highly vascular lobular structures in which a special type of cell exists, with the function of storing and giving up fat in accordance with the supply and demand.

About 1910 other workers contended that adipose tissue was derived from primitive connective tissue but that there were two kinds of fully developed fat cells, one arising from ordinary connective tissue cells laying on fat, and the other from the transformation of connective tissue cells to rounded or polygonal cells with abundant cytoplasm, which cells are collected in lobular groupings before beginning to take on fat. It was stated by another that perirenal fat came from a fat organ, while human subcutaneous fat was not derived from preformed lobes, but he believed that transitional forms between the two classes might exist.

According to Wells (1940) and Maximow and Bloom (1943) Wassermann's work (1926-1933) seems to have provided the most conclusive evidence of non-fibroblastic origin of adipose tissue. He and his associates had "shown more clearly the relation of the primitive fat organ to the small vessels and its origin from perivascular mesenchymal cells related to the reticulum" (Wells, 1940). Wells developed this idea, pointing out that according to Wassermann's theory fat organs are formed from the same embryonic elements as lymph nodes, namely, capillaries and reticulum cells of the vascular adventitia, which relationship is attested by the tendency for lymphoid tissues to sometimes replace fatty tissue, and conversely, especially as seen in the thymus. This also explains the close relationship of bone marrow and adipose tissue, and the extra-medullary hemopoiesis in the latter.

Maximow and Bloom (1943) have taken the rather conservative view that due to the close association of adipose and connective tissue elements no sharp limit can be drawn between the two tissues. However, they stated that though small droplets of neutral fat may occur in any connective tissue cell, there are special fat-storing cells, scattered singly or in groups, especially along blood vessels. New fat cells may develop any time in connective tissue of an adult, as seen in tissue cultures. However, the fibroblastic nature of the cells has not been proved conclusively; they may arise from undifferentiated mesenchymal cells, a fact which is substantiated by the evidence that new fat cells appear along the small blood vessels as one finds in the embryo. Also, in starvation the fat droplets become small, cytoplasm sends out tapering processes and the cells regain the appearance of fibroblasts, but as peculiar, sharply outlined, spherical or oval elements.

Wells criticised the theory of the connective tissue origin of fat on the basis that since connective tissue cells in some areas never take up fat regardless of the extent of weight gain, the taking up of fat cannot be a general property of connective tissue cells. He gives as examples the connective tissue of eyelids, cerebral membranes, and the backs of hands. He also quoted the demonstrations of Dogliotti and of Bremer that both brown and white fat have the property to store vital dyes, a property of reticulo-endothelial but not of ordinary connective tissue cells. This extensive study of Wells has built up a strong case for adipose tissue as a distinct organ closely related to the reticulo-endothelial system.

The activity of adipose tissues is also indicated by the work of Schoenheimer, who by the use of fat marked with heavy hydrogen, showed that food fat is deposited in adipose tissue before being oxidized.

The distribution of the adipose tissue of the human female may be considered from the point of view of the external fat or that lying just under the skin, and internal fat or that in the omentum and other internal organs.

The areas of internal fat of the normal individual, described by Wells (1940), are in the omentum and perirenal tissue. The periaortic fat pads appear to be specialized fatty tissue since they increase with age and are independent of the amount of body fat. According to Maximow and Bloom (1943), the fat of the bone marrow is also a specialized tissue and the transition from red bone marrow takes place with aging.

The distribution of external fat was described by McCloy (1936) who stated that the rather even distribution of external fat of the prepubescent female changes to more definitely defined fat pads in the postpubescent stage. He listed the location of fat pads as follows:

1. Above and behind the shoulders, just at and below the base of the neck.

2. On the back and upper part of the arm, including the large part of the posterior aspect of the deltoid muscle and the upper half or two-thirds of the triceps region.

3. Over and above the trochanters,

   a. from almost the height of the umbilicus and extending from the vertical level of the axillary line, downward and backward over the area of the gluteus maximus and the back part of the gluteus medius.

   b. just below the area described above from the anterior superior spine downward and diagonally backward to the part of the thigh just below the gluteal fold. This pad lies over the greater trochanter and sometimes extends quite a distance on the outside of the thigh.

4. Over the inside and outside of the thigh itself.

5. Over the abdomen, starting from just above the umbilicus and extending to the pubis, and outward almost to the vertical level of the anterior superior spines.

Even distribution of fat throughout all of the fat pads may take place, but McCloy stated that females seem to develop abdominal pads less and hip pads more than males. This tendency has been noted by Wells (1940), Reuer (1941) and many other clinicians.

The particular condition of fatty tissues extending the entire length of the leg was discussed by Allen and Hines (1940) as "Lipedema of the Legs". In this case the obesity is complicated by edema. They believed that the edema is due to lack of tone of the adipose tissue. When a person assumes erect posture there is a filtration of fluid from the vessels of the legs to the extravascular spaces. Normally, due to this filtration and to decreased circulation while in the upright position, the extravascular pressure becomes greater than that within the vessel within about 30 minutes, an equilibrium of fluid passage results and no edema of the tissue develops unless standing is prolonged. Allen and Hines have suggested that in lipedema, the increase in extravascular pressure does not take place due to low tone of the adipose tissue of the legs. Since equilibrium does not take place, an edema occurs which is not absorbed even during a long period spent in the horizontal position. These investigators have reported that weight reduction and the ordinary methods of combating edema were not beneficial in cases of lipedema of the legs. The question of factors other than fat, such as the nutritional one, might be raised to explain the production of low tissue tone.

If accumulation of fat represents merely storage of fat droplets in ordinary cells, the reversal of accumulation would seem to be simply an adjustment of energy balance, not involving other changes in metabolism. However, if adipose tissue is composed of specialized cells the process of weight reduction may be expected to be attended by other changes depending on the functions of these cells.

B. Factors of Energy Exchange Contributing to the Development of Obesity, Its Maintenance, and Its Reduction

There have been several excellent reviews in the recent literature concerning the energy exchange in obesity (Bruch, 1939a, 1939b, 1940a, 1940b; Newburgh, 1942; Wilder, 1932). The trend of current thought appears to be that (1) there is fairly general acceptance of the principle that obesity is the result of an intake of energy in the form of food greater than the energy output, (2) the basal metabolism of the obese is normal or greater than normal, and (3) by sufficient reduction of energy intake, weight reduction will take place. In the field of physiological regulation of obesity it appears that the endocrine factors have been overemphasized while the factor of tissue tone which is controlled by the sympathetic nervous system and its cranial nuclei, especially those in the hypothalamic region, is receiving increasing attention.

Newburgh (1942) has simplified his analysis of the subject into the doctrine that "obesity is invariably caused by an inflow of energy that exceeds the outflow and that this disproportion is brought about by abnormality of the appetite". This conclusion, in addition to the results of weight reduction reported from Newburgh's clinic, are likely to cause the prospective investigator to consider the subject of obesity a finished chapter except for a possible physiological explanation for the abnormal appetite. However, there are some findings in the literature which remain unexplained.

One factor which has led to contradictory reports in the literature is the failure, as mentioned above, to distinguish between the states of (1) weight gain, (2) maintenance of obesity, and (3) reduction of obesity. Bruch (1940a) pointed out that most obese adults, after reaching a certain weight, tend to keep that weight as constantly as normal persons. The basal energy requirements of these individuals appears to be somewhat higher than normal, the food intake is high, though not conspicuously so. During the period, however, when the condition is developing and the body accumulating progressive amounts of fat, the energy inflow must be above normal. This phenonemon of weight gain followed by maintenance of obesity rather than long continued weight gain also has been emphasized in the search for the causes of obesity which will be discussed later.

Intake and output of energy by college women will be reviewed.

Reports of both children and adults will be considered since studies of the college age, specifically, are extremely limited, and as has been pointed out in the preceding pages, while growth is slow during this period, the college age woman cannot be considered physically mature.

1. Energy intake.

Food intake and physical development of a large group of obese children, two to thirteen years of age, were studied by Bruch (1940a). The intake of these subjects, previous to dietary treatment, was estimated to be 2500 to 4000 calories per day. In 80 per cent of the children the intakes were regarded as large when compared to the amounts recommended by the pediatric clinic in which Bruch was practicing.

The most valuable information gained from Bruch's dietary study was the trend in composition of the diets. The chief overemphasis was on starchy food; the list of preferred foods being headed by bread, cake, ice cream, and candy. Macaroni and spaghetti were relished by the Italian children, and sour cream by obese Jewish children. High on the list of preferred foods were soups. Strange as this seems in a list of high caloric foods, it bears out Bruch's thesis that it is not a preference for carbohydrates or high caloric foods, specifically, so much as a carryover of an infantile liking for bland, easily eaten foods, which influences the selections of these children. No child in the group was thought to be eating a mixed, well-balanced diet. The dietary histories of obese children, reported by Mulier and Topper (1934), were similar in respect to quantity and quality to those of Bruch. Likewise in adults, the preponderance of carbohydrate in the diets of obese subjects has been noted; Dunlop and Lyon (1931) reported this as the outstanding characteristic of the dietary histories of about 500 obese subjects.

The especially interesting feature of the Bruch (1939a) work is the study of the advancement of other phases of development which usually are correlated with weight. The subjects were advanced in stature, and average or sometimes accelerated in skeletal maturity. Early sexual maturity was the rule for girls and was not uncommon for the boys.

Although Bruch did not study the mental development of these children, she suggested that mental development, as expressed by the intelligence quotient, frequently is advanced in obese children. It is apparent from these findings that obese children may differ quantitatively in their pattern of development although the weight increment is exaggerated.

It is paradoxical to the present writer that these children had made such advanced growth records not only in weight gain but in general physical and possibly mental development in the face of such poor food habits. Is there a factor in the high caloric diet of the obese child which investigators have failed to recognize? Has the current emphasis on early introduction of fruits and vegetables with consequent relegation of high energy foods to a distinctly second place of importance diminished the amount of growth promoting substances in the diet, or do these high caloric diets carry more growth-promoting factors than have been recognized? Obesity is obviously not desirable but stimulation of growth and development certainly has been considered a primary measure of good nutrition.

In the college age woman, little information of food intake as a factor in the development of obesity is found in the literature.

Increase of height in the college girl was noted by Donelson _et al._

(1943); between the first and second years of college the increase was 1.2 cm. while that of the following years was 0.4, 0.4, and 0.5 cm., respectively. Weight increased during the first year of study but was variable in subsequent years.

Height and weight increments reported by Barber and Stone (1936) and Gould (1930) are included with those of Donelson in Table 1.

Table 1. Height and Weight Increments of Women during Their First Year of College

Investigator	Weight increment	Height increment	Ratio of height increment to weight increment
	kg.	cm.	cm.: kg.
Donelson (1943)	0.48	1.20	1 : 0.4
Gould (1930)	0.67	0.42	1:: 1.6
Barber and Stone (1936)	1.15	0.40	1 : 2.9

Evaluation of these figures brings up the question of the normal weight increment which accompanies an increment of a unit of height at an age when excessive fat accumulation is found only in exceptional individuals. During some periods of active growth the ratio of height and weight increments is relatively constant (Boynton, 1937). For ages 10 to 13, Boynton reported weight increments in girls averaging 4.63 kg. and height increments, 6.10 cm. per year, an increase of 0.8 kg. in weight for each centimeter of growth in height. On this basis no fat accumulation would be expected in the group studied by Donelson but some would be expected in those studied by Gould and Barber and Stone. However the fat accumulation would be very small since even in the Barber and Stone study the average annual weight increment was only 0.85 kg. greater than that which would be expected to accompany the reported height increment.

Comparison of the caloric intakes of these same groups of students would have provided a valuable statistic of the energy necessary for fat accumulation in the college age woman. In the absence of this information, the caloric intakes of different groups of college women, unselected as to average weight for height, will be considered. Eight reliable studies from the literature and two from their own investigations were reported by Pittman <u>et al</u>. (1942). From these, it is found that the average total caloric intake per day for the groups studied ranged from 1805 to 2698 calories. For those studies in which the weights of the subjects were known, Pittman <u>et al</u>. calculated that the average daily caloric intake per kilogram of body weight ranged from 31.9 to 47.7.

If it can be assumed that intakes of 1805 and 2698 calories are characteristic of the college woman it will be evident that accumulations of fat at such a range of caloric intake will be minimal.

Exact studies of the caloric intakes of individual college age women are few and widely scattered through the literature. Some of the variations of experimentation which disqualify studies for this classification are:

1. Request that a subject select a diet equicaloric to her previous one but from a menu of different food constituents. The inability of subjects to select equicaloric diets from menus of widely different food constituents was demonstrated by Harrington (1930).

2. Expectation that an obese subject who already is calorie-conscious will select a test diet equicaloric to her usual food intake.

3. Failure to record weight changes during the observation period, or selection of an observation period which is too short to bring about weight changes.

Such exact records of caloric intake of young women of normal weight as were found in the literature are reported in Table 2.

Table 2. Caloric Intakes of Individual College Age Women of Normal Weight

Worker and subject	Days of diet analysis	Av. cal. per day	Av. cal. per day	Weight change during study
		total	per kg.	kg.
Pittman et al. (1942)				
Lu	56, consecutive	2045	35.6	-1.8
R	" "	2114	33.1	-1.5
M	" "	2093	40.0	0.4
O.M.	67, intermittent	2799	41.1	1.2
B.W.	" over 6 months	2292	40.4	-0.5
Coons & Schief-elbush (1931)				
19	42, consecutive	2565	44.0	0.0
20	" "	1953	34.0	0.0

With intakes of 35.6 and 33.1 calories per kilogram, respectively, subjects "Lu" and "R" lost weight. At 41.1 calories per kilogram, subject "O.M." gained. With the exception of subjects number 19 and 20, the findings reported here would indicate that the calories necessary for mere weight maintenance in a college age woman of normal proportions, were about 40 calories per kilogram of body weight, which is the midpoint of the range for groups of college women reported above. Undoubtedly, the caloric requirements for weight maintenance are greater or less for some individuals as the records of subjects number 19 and 20 illustrate.

The intake of 34 calories per kilogram, without loss of weight, of subject number 20 varied farthest from the responses of the other subjects. It may be significant that she was described as "ordinarily finds difficulty in preventing obesity". Since the subject was normal in weight when the study was being made, it might easily be inferred that she previously had been limiting her diet over a long period. It is interesting to compare the records of this subject to one reported by Harrington (1930) whose subject, after many weeks of weight reduction by low caloric diet, maintained her weight for four weeks on a diet of 28 calories per kilogram of body weight. Since the subject was still about 20 pounds above average weight, her intake per kilogram of average weight would be 32 calories. Since neither of these subjects had symptoms of hypothyroidism it might be inferred that prolonged restriction of calories was associated, at least temporarily, with a low subsistence level.

Caloric intakes of obese college age women are presented in Table 3.

Table 3. Individual Caloric Intakes of Obese College Age Women

Worker and subject	Deviation of wt. from ideal wt.	Av. cal./kg. of body wt.	Av. cal./kg. of ideal wt.
	per cent		
Pittman <u>et al.</u> (1942, 1944)			
LMR	26	29	36
Coons and Schiefelbusch (1931)			
1	32	27	36
2	22	30	36
Harrington (1930)			
Period 1	93	22	42
Period 2	93	25	49

The results for two periods of study of Harrington's subject previous to weight reduction are included. No weight change took place during the periods reported. Except for this case, weight changes during periods of observation of caloric intake were not reported.

In summarizing the very limited information concerning food intake of obese college age women, it may be said that during accumulation of fatty tissue food intake probably is relatively high; during maintenance of obesity it may or may not be conspicuously high; and that following weight reduction it would seem to be relatively low.

2. Energy output.

The relationship of energy output to obesity has been subjected to more investigation than that of energy intake in spite of the fact that the total output of energy, which would approximate the subject's normal output, is a much more difficult thing to measure than the intake.

Total energy output has been determined by (1) direct measurement of heat loss, (2) calculation from the quantity of oxygen used at a specific respiratory quotient, and (3) calculation of energy exchange from the loss of insensible weight. All of these techniques have been criticized but each has served a useful purpose.

Newburgh (1942), who used the method of insensible weight loss, found nothing unusual about the total metabolism of obese subjects except that the total energy expenditure of the more active individuals was large compared to that of normal subjects.

Basal metabolism, as a possible factor in total energy metabolism, has been studied extensively. The logic of this lies in the assumption that there is a constant minimal rate of energy output, an assumption which is not warranted (Du Bois, 1936, p. 184-188; Young, 1940). In college age women, Young found the total inter-individual variability was 2.41, as expressed by standard deviation in calories per square meter per hour; intra-individual variability was 1.41. In some subjects variation in the basal metabolism was almost negligible; in others it was highly significant. Selection of data, according to Young (1940), is responsible for the failure of some investigators to recognize the normal variation of basal metabolism.

Expression of the basal metabolic rate involves comparison of the metabolism of the subject to that of a standard derived from the measurements of the basal metabolism of a series of normal subjects. Calories per unit of surface area as a means of comparing individuals was suggested by the significant results of Rubner's application of Newton's law of cooling to the heat loss of warm-blooded animals. However, there has been little affirmative and considerable negative evidence for surface area as a determining factor in heat loss under basal conditions (Du Bois, 1936).

That heat loss is equal to heat production under basal conditions may be assumed since heat produced is being dissipated from the body in no other form than as heat. It is widely accepted that the oxidative activity of the protoplasmic mass is responsible for heat production. This factor, which has not been measured directly, may be highly correlated with surface area, and if so, would explain the apparent proportionality of surface area to basal metabolism. Weight and height, raised to certain powers, are also proportional to basal metabolism; formulas based on these measureable properties likewise have been made the basis for comparison of the basal metabolism of different individuals. In fact, since surface area is very difficult to measure, for practical purposes it is estimated from formulas derived from the height and weight of the few subjects in whom surface area has been measured.

Boothby and Sandiford (1922a) found that estimation of surface area by the Du Bois formula, corrected for age, was satisfactory for comparing the basal metabolism of 8614 subjects since small deviations from the average of the series were found. Talbot (1937) and Lewis (1937) demonstrated that for children of average body composition formulas based on weight and age gave the most satisfactory predictions of the basal metabolism.

In subjects of abnormal body build such as obesity, the validity of the Du Bois and other formulas as means of estimating surface area is not wholly acceptable. The number of the subjects who were actually measured for the preparation of surface area formulas and the varieties of body build represented were conspicuously limited. It may not be important, that the value determined by the Du Bois formula be a measure of surface area, however, it is important that it be a measure of the property of the body which is responsible for basal metabolism. Exactly what property is measured by the estimation of surface area by means of the height and weight measurements of obese women of college age is questionable.

Assuming that the linear formula of Du Bois is valid as a measure of the metabolic activity of the obese, the basal calories per 24 hours would increase with an increase in body weight and surface area, and would decrease during weight reduction. The latter was confirmed experimentally by Strang and Evans (1928), who found that the total calories produced per 24 hours by obese individuals were greater than those produced by individuals of the same height but of normal weight. During weight reduction the value again approached that of persons of average body composition. However, expressed as calories per square meter of surface area, basal metabolism of the obese would appear normal.

As an explanation for the elevated "total resting metabolism" in obesity, reported by Strang and Evans, the deductions of Short and Johnson (1936) are interesting:

> It is evident from the foregoing that in obesity there is an increase in the total metabolism. Since fat is comparatively inert, this increased heat production must be brought about by an increased activity of the muscle and gland tissues of the body. It is impossible to state the extent to which the fat tissue participates in this increased activity but it is probably only to a relatively small degree. . . .
>
> The question naturally arises as to the modus operandi of the increased metabolism in obesity. Since the thyroid gland is known to be one chief regulator of the metabolic rate, it would seem logical to assume that it might play a part in this connection. Certain indirect evidence of increased thyroid activity has been adduced in addition to the simple fact of increased metabolism. Increased pulse rates and blood pressures, frequent diminution of dextrose tolerance and a general upward tendency of the basal metabolisms with increasing weight are all suggestive.

Strang and Evans (1928) proposed that in the expression of the basal metabolism of obese individuals the standard of reference be an individual of the same height and age but of normal weight. For obese children, Bruch (1939b) found comparison to children of the same height and age preferable to those of the same weight and age because the general development of obese children seemed more closely correlated with height than with weight. Mulier and Topper (1934) used sitting height and age as the basis of comparison. Use of these proposed methods assumes that resting metabolism of the obese should be referred to the active protoplasmic mass of the non-fat tissues.

Opposed to the evidence of the inactivity of adipose tissue is that of Wells (1940) and others quoted above who emphasized the probability of greater than average metabolic functions of fat cells, indicated by the large amount of protoplasm within the cell and its peculiar relation to the vascular and nervous elements of the tissue.

Basal metabolism of obese subjects, expressed with reference to surface area calculated on the basis of absolute height and weight, has been shown to be within 10 to 15 per cent of normal in 76 of 94 cases (Boothby and Sandiford, 1922b). Strouse, Wang, and Dye (1924) and numerous other investigators have confirmed this finding. By expression on the basis of absolute height but normal weight, adult obese subjects have been shown to have "total resting metabolism " above normal in proportion to their deviation from normal weight (Strang and Evans, 1928; Short and Johnson, 1936).

Bruch (1939b) and Mulier and Topper (1934) found that on the basis of height and age the basal metabolism of obese children was greater than that of children of average body composition.

In a study of obese and normal college age women from the same geographical area, Coons (1931) found that the average basal metabolism of the obese, expressed as calories per square meter, was within three per cent of that for normal subjects; expressed as calories per centimeter, was 17 per cent higher; expressed as calories per kilogram, was 10 per cent lower. Remington and Culp (1931), using surface area as a basis of comparison, found a difference of two per cent between obese and normal student nurses.

Justification for either method, the conventional "calories per square meter" calculated from absolute height and weight, or the modified methods of Strang and Evans, or Bruch for the expression of the basal metabolism of obese college age women, remains open. The results of the former indicate normal basal metabolism, the latter, a metabolism elevated in proportion to the obesity. The evidence that an elevated "total resting metabolism" in the obese college age woman is an indication of excess thyroid production rests upon the choice of the standard of reference.

An increase in basal metabolism referred to surface area incident to increase in food intake, the "luxus consumption" theory of Grafe, has been discredited by Newburgh (1942) on the basis of Grafe's observation of increases in metabolism following weight gain were noted but it would appear that the increase was due to a previous decrease due to undernutrition. In an abnormally thin person, Newburgh reported that the only increase in metabolism incident to a 2000 calorie increase in diet was such an amount as would be expected with the observed increase in weight and surface area of the subject and increase in the specific dynamic action of food.

The effect of a low caloric diet in decreasing basal metabolism of subjects of normal body composition was demonstrated by Benedict (1919). An attempt to differentiate between the lowering of the basal calories per 24 hours in undernutrition and that observed in weight reduction of obese subjects was made by Strang and Evans (1928). They showed that the ratio of decrease in basal energy output to decrease in surface area was greater in the normal subjects than in the obese. However, even in the obese they found that the rate of decrease of basal calories was one and one-half times as great as the rate of decrease in surface area. The present author cannot agree with Strang and Evans' conclusion that, since during weight reduction the "total resting metabolism" of the obese was depressed at a lower rate than in the normals and never below the standard for height and age, it is a different metabolic process than that operating during the energy depression of undernutrition in normal subjects.

A decrease in the 24-hour oxygen consumption, during reduction of the obese, but only in proportion to the decrease in surface area, was noted by Master et al. (1942).

Energy expenditure to support activity usually is calculated as the difference between the total and the basal metabolism. Many technical difficulties are encountered in the measurement. In addition to the difficulties encountered in the use of the equipment, control of the subject, and consideration in the calculation of all of the factors involved, are difficulties in interpretation of the results.

The importance of the basal metabolism datum as the base line in the calculation of work energy frequently has been stressed. In experiments involving small amounts of additional energy exchange, an elevated base line on the day of the test may cause a large error in the calculation of the energy attributed to the factor being studied. However, denial of the validity of an elevated base line, because it is not within an empirically determined percentage of the usual basal metabolism of the subject, is not in accord with the findings reported on variation by Young, and Du Bois.

The validity of the total metabolism, determined by the method of oxygen consumption at a given respiratory quotient, may be impaired by failure to take into account oxygen debt due to anaerobic oxidations during exercise and the following recovery period. Dill et al. (1933) have pointed out that this phenomenon takes place when activity reaches a certain intensity and the extent and duration of both oxygen debt and compensation vary with the efficiency of the subject. Errors in the determination of the respiratory quotient may arise from several sources but the effect of the maximum error on the metabolic rate, calculated from the accepted caloric values of oxygen at different respiratory quotients (Du Bois, 1936, p. 34), reveals that the error cannot be more than six per cent and would seldom be nearly that great.

A review of experiments on controlled muscular activity revealed no greater conservation of energy by the obese than by normal subjects (Bruch, 1940b). In fact, the obese frequently were found to be less efficient than normal ones (Lauter, 1926; Kommerell, 1931; and Wilder, 1932). In studies of exercise following high fat diets which simulated the metabolic conditions of obesity during weight reduction, Krough and Lindhard (1920) found that efficiency of work was a straight line function of the respiratory quotient, in inverse relationship. It should be noted that Krough did not correct for anaerobic oxidation, which correction would probably further lessen the calculated efficiency at the lower respiratory quotients. This work suggests that the difference in the efficiency of obese subjects from normal ones may be dependent on the metabolic mixture oxidized. It is reasonable to assume that the effort of moving the excess weight of the body and the clumsiness resulting from so much weight would further decrease the efficiency of the obese in some activities.

Reports of energy expenditures in periods following exercise are controversial. Bernhardt (1930) found "negative phases", i. e., periods of decreased metabolic rate of one or more hours, which occurred most noticeably in times following light muscular work and after the intake of food. He stated that the sum of periods of decreased heat production during sleep and the "negative phases", could result in a total daily heat production near or even less than the value calculated from a basal test to be the 24-hour resting metabolism.

In an attempt to duplicate Bernhardt's work, Wilder et al. (1932) failed to find long "negative phases" since the rate of energy exchange returned to the base line within 15 minutes of the cessation of exercise. Small errors involved in determination of the base line or compensation for oxygen debt could account for the difference in the results of the two investigators.

The consept of a metabolic rate lower than basal, other than during sleep, conflicts with the whole theory of basal metabolism, however, such a state, one in which muscle mass is more relaxed than under the rather arbitrarily defined basal conditions, is not inconceivable to this writer. That any individual would be so inactive as to remain in such a state for a period of hours does not seem plausible.

Validity of Bernhardt's work had been suggested by the low rate of weight reduction of certain obese subjects when a diet equivalent to the subject's theoretical basal metabolism was employed. First, the accuracy of the food intake might be questioned. However, granting a reasonable accuracy in the execution of the dietary prescription, the difference between total and basal metabolism would still be small. Either the basal metabolism is a poor measure of the base line from which to calculate energy expenditure for activites or the energy expended for activities in these subjects is exceedingly small.

A decrease in the usual activities of some obese subjects has been pointed out as a cause of either gain in weight or failure to lose while ingesting low calorie diets. Greene (1939) found inactivity due to long illness, pregnancy and convalescence was associated with weight gain in 98 of the 154 cases studied. Bruch (1940b), from an investigation of the activity of 124 obese children, found that 92 of them could be considered as inactive.

Difference in efficiency of different individuals may also be a factor in total energy expenditure. Lauter (1926) has pointed out the possible saving of energy by the little movements which make up an activity.

Findings concerning the specific dynamic action of food as a factor in total energy output have not been conclusive, a fact which is not surprising since the amount of energy involved is small and the experimental period long and tiring to the subject. However, the reviews of Newburgh (1942) and Strang and McClugage (1931) indicate that no abnormality in the total energy output for specific dynamic action has been observed in the obese if the subjects are studied for a sufficient time after the intake of the food. One peculiarity in the specific dynamic action of the obese, noted by Strang and McClugage (1931), was that, in general, the increase of heat production during specific dynamic action was found to be delayed and therefore the rate of change decreased. The investigators suggested that the low rate of change in heat production in the obese, although not a direct factor in total metabolism, might be related to obesity by failure to produce the normal stimulation which results in satiety. However, it should be pointed out that Strang and McClugage's subjects were being treated with a 600 calorie diet at the time of the experiment and that the results of their experiment could just as logically be attributed to abnormally low glycogen reserves as to the state of obesity.

The saving of energy by the obese through protection from cold by the subcutaneous body fat and through relatively low body temperatures have been mentioned in the literature. Swift (1931) found that in subjects exposed to cold temperatures the metabolic rate was, in a general way, inversely proportional to the amount of subcutaneous fat. Lee _et al_. (1941) showed that the temperature at which metabolism rises in response to cold is influenced by the extent of wool covering and subcutaneous fat. The question of maintenance of average body temperature in the obese has not been well investigated. However, Howell (1940) has stated that temperature control may be interferred with by lesions in the hypothalamus; the midbrain, in some cases, has been shown to regulate the accumulation of fat.

In general, it might be concluded that in the accomplishment of specific amounts of work, obese subjects seem to use at least as much energy as normal ones, and that when, because of a high ratio of fat in the metabolic mixture, the respiratory quotient falls below that of normal individuals, the obese use more energy than normal. Energy output of the obese below average is not unusual but must be attributed to a decrease below average of activities or movements for activities, except as conservation of heat is provided in cold temperatures by subcutaneous adipose tissue.

3. Control of the imbalance between energy intake and output.

It would appear, although without much experimental evidence, that there is an imbalance between energy intake and output when weight gain takes place. Desire for food appears to be the obvious cause, but there would seem to be physiological and/or psychological bases for the desire which does not occur in all persons. Newburgh (1942) and Bruch (1940a) both comment on the appetites of obese subjects.

Appetite, according to Bruch, is related to previous sensations of taste and smell of food. A physiological response of appetite is the initial secretion of gastric juice, as shown by the work of Pavloff (1910), but at present no evidence is available indicating that any other specific bodily change underlies the appetite sensation.

Evidence that the stimulus is one of appetite rather than hunger has been shown by determinations of blood sugar concentration in the obese (Newburgh, 1942). Furthermore, Newburgh (1942) and Hubbard and Beck (1939) found that a mild degree of hyperglycemia, observed in many obese subjects, changed to normal when weight was reduced to normal. Hubbard and Beck (1939) confirmed the association of hyperglycemia with obesity by maintenance of normal concentrations of sugar in the blood during post-reduction periods in which 200 to 250 grams of carbohydrate were added to the reduction diets.

In the study of appetite, satiety, the adjunct to appetite, must be mentioned. Overeating in some of the subjects described by Bruch and Newburgh appears to be due to constant appetite and in others to lack of satiety at meal times.

Correlation of the nervous system with control of obesity has both a physiological and a psychological basis. The experimental evidence of the physiological basis follows two paths of investigations. First, the classic work of Smith (1930) differentiated the syndromes due to removal of the pituitary with and without injury to the hypothalamus. Smith found that obesity was produced only when the hypothalamus was injured. Using rats, Ransom et al., (1938 and 1939) were able to confirm Smith's results but when monkeys, cats or guinea pigs served as subjects, obesity failed to occur in cases of known lesions of the hypothalamus. The results of the work of Ransom et al. throw some doubt on the association of obesity and hypothalamic lesions in human subjects.

Newburgh (1942) and Bruch (1940a) reviewed the literature concerning the occurrence of obesity following encephalitis, a condition involving irritation of the midbrain. The findings were not uniform; obesity occurred in some cases but emaciation in others. Bruch (1940a) found only one subject in a group of 142 obese children who had suffered from encephalitis. In no other case did she succeed in establishing the diagnosis of an organic lesion at the base of the brain. However, she stated: "Many children. . . exhibited vegetative symptoms, such as slight disturbances in temperature regulation, in perspiration and in vasomotor control, all of which might be referred to some functional disorder in the autonomic centers. More impressive were changes in the behavior which sometimes closely resembled the behavior of children after encephalitis."

The second line of investigation is concerned with the neural regulation of fat deposits in connective tissue. Independently, Beznak and Hasch (1937), and Hausberger (1934) demonstrated that demobilization and storage of fat in rats, cats and rabbits both were decreased by unilateral sectioning of the sympathetic nerves to fat accumulations in the connective tissue. Since the demobilization was retarded more than the mobilization, large masses of fat accumulated on the operated side of the animals. This line of investigation is related to the first one since some impulses which are discharged through sympathetic nerves are initiated in the hypothalamus.

Wilder (1938) expressed the opinion that hereditary hyper-irritability of the subcutaneous region offered a plausible explanation for obesity. Much-quoted is the Danforth report of evidence of the role of heredity in the continuance of obesity in a strain of yellow mice.

Evidence for a hereditary factor in the occurrence of obesity in human subjects has been reported by Wilder (1938) and Gurney (1936). However, Wilder notes the warning by Joslin against too much confidence in heredity studies in which eating habits are involved lest environment rather than heredity be the real factor. Newburgh (1942) criticised the Danforth conclusions on the basis that the mice were victims of hereditary bulimia. Of the human studies, he comments: "Body build is inherited; obesity is not."

The psychological basis for the relation of the nervous system to obesity, according to Bruch, lies in the general recognition during the last decade of the fundamental role of the hypothalamic functions in transforming psychologic experiences into somatic manifestations. However, evidence for this hypothesis in regard to appetite takes the form of case histories rather than statistics due to the wide variation of conditions encountered. Bruch (1940a), Newburgh (1942), and Harrington (1930) have presented detailed case studies of periods of emotional stress associated with excessive eating. Bruch describes the case of a child sent to live with his aged grandfather who gave him no time for ordinary social contacts. Another child was badly frightened by his mother's attempt to break up a bad habit. Newburgh described the case of a young woman whose love affair was thwarted by her father, another whose husband continually made unreasonable demands upon her. Food or drink appears to give relief from the emotional strain to this class of subjects.

Of less spectacular nature is the emotional strain over food in the mother-child relationship. Bruch (1940a) has shown that at some time food has had exaggerated emotional significance for certain dependent obese children which has been satisfied by the consumption of large amounts of food. Failure to make the transition from infantile to normal adult food habits also may reflect earlier conflicts.

Is this impulse to eat a result of hypothalamic stimulation evoked by certain emotional experiences which simultaneously stimulate the autonomic center, which in turn influences fat storage?

Other theories of abnormalities in appetite which indirectly may be related to the central nervous system also have been presented. As referred to above, Strang and McClugage (1931b) suggested that since the specific dynamic action of food occurs near the end of a meal, delay in the production of specific dynamic action observed in obese subjects might account for lack of satiety and desire to continue to eat more than appetite normally would have dictated.

Strang and an associate (1936) also found differences in skin temperatures of obese and normal subjects following a test meal. In the subjects of normal weight the elevation of skin temperature began shortly after the start of the meal and reached a maximum in about 60 minutes. The investigators believed that this also might be associated with the diminished satiety in the obese.it was diminished and delayed.

The literature concerning the effect of glandular disturbances on adipose tissue has recently been reviewed by Conn (1944). The evidence which he presented points to the fact that endocrine disturbances may affect the distribution but not the quantity of adipose tissue.

4. Respiratory quotient and ketosis.

The diet used to bring about weight reduction is low in calories in order to force oxidation of body fat. The respiratory quotient in obesity is of interest because it is an indication of the extent of oxidation of fat. Many investigators, finding low respiratory quotients, have interpreted them as an anomaly of the obese; they might better be interpreted as a characteristic of the high fat catabolism found during weight loss. In most cases of low respiratory quotients the previous diets have not been reported but Lyon et al. (1932) mentioned low caloric diets in all such cases studied by them. Furthermore, when two grades of caloric intake were employed for the same subjects, these investigators found a lower respiratory quotient during the period of lower food intake. With calories unchanged but the carbohydrate of the diet decreased, the respiratory quotient was reported to be still lower. Restricted food intakes and use of body fat may be suspected in other obese subjects in whom low respiratory quotients have been found. Hagedorn's report (1927) that following a high carbohydrate diet the respiratory quotients of the obese were lower than those of normal subjects may have been related to failure to prescribe the quantity as well as the quality of the diet.

In normal subjects under basal conditions, Krough and Lindhard (1920) found respiratory quotients between 0.88 and 1.00 folowwing several days of high carbohydrate diet, and between 0.71 and 0.80 following ingestion of a high fat diet. The respiratory quotient during work was found to decrease if the basal respiratory quotient had been high for that day, and increase if the basal quotient had been low. This relation of working to resting respiratory quotients was confirmed by Wrightinfton (1942). The respiratory quotient during work failed to rise above 0.74 in the one of Krough's subjects in whome weight losses were taking place.

A high rate of oxidation of body fat is desirable during reduction as long as it does not interfere with body functions, however, there appears to be a limit beyond which ketosis and ketonuria occur. The association of low respiratory quotients with ketonuria may be acceptable in a general way but Lyon <u>et al</u>. (1932) found only occasional ketonuria in obese subjects whose basal respiratory quotients ranged from 0.68 to 0.78 and the correlation was not high within this range. Evidence that the obese may tolerate highly ketogenic metabolic mixtures without ketosis was presented by Du Bois (1936, p. 259). However, in a study by McClellen <u>et al</u>. (1928) the ketogenic-antiketogenic properties of several diets were equal, but the obese subject in whom ketonuria was low had been receiving 25 grams of carbohydrate in his diet while the normal subjects with marked ketonuria had received only 5 to 10 grams. This would indicate that total carbohydrate rather than either proportion to fat or accomodation of the body was the important factor in ketonuria. Newburgh's report (1942) of acute acidosis occasioned by unusual activity in an obese subject who had been well adjusted to her diet demonstrated exercise as another factor in precipitating ketosis.

Quantitatively, ketonuria in obesity usually has been reported to be non-significant; Lyon <u>et al</u>. (1932) found no values above 0.5 mg. The extent to which such mild ketosis interferes with metabolism has not been studied.

C. Nitrogen Exchange

For women of college age a daily allowance of 75 grams of protein or 12 grams of nitrogen, has been recommended by the Food and Nutrition Board of the National Research Council (1941). This allowance is 36 per cent greater than the amount which provided nitrogen equilibrium in a group of college age women (McKay et al., 1942). These investigators found few individuals retaining nitrogen when the diet contained less than 8 grams per day and consistent increases in the retentions and increase in the number of subjects making retentions with intake greater than 8 grams; retentions of nitrogen were found in all subjects with intake greater than 12 grams.

Lanford and Sherman (1943) have suggested that poor quality of protein and low caloric content of the diet may bring about an increase in the protein requirement. McKay et al., found no evidence of this in the self-selected diets of the subjects which they studied. However, in reduction diets, the amount of calories would appear to require special consideration because of the possible use of protein as a source of calories in the absence of other materials. In particular, the amount of calories from carbohydrate would appear important due to the increase in the oxidation of body fat as a source of calories, referred to in the discussion of ketosis.

Keeton and Dixon (1933) produced satisfactory weight reductions in adults and at the same time nitrogen retentions of one to two grams per day in 12 of

15 subjects by providing 90 grams of protein, 1200 calories, and 60 to 150 grams of carbohydrate. In three subjects small negative nitrogen balances took place during periods of 28 to 70 days of diet. However, many clinicians prefer diets of lower caloric content. Strang et al. (1931) found nitrogen losses of 2 to 6 grams per week during the first few weeks of weight reduction of four subjects whose diets contained 60 grams of protein, 336 calories, and 10 grams of carbohydrate. The one subject for whom the calories and grams of carbohydrate were 444 and 30, respectively, also lost nitrogen from the body. After a time the losses diminished indicating that some physiological adjustment was being made. In all cases negligible losses or slight gains continued for 2 to 25 weeks but in the one subject who continued on the diet for 37 weeks, larger nitrogen losses again occurred after the 28th week. A decrease of nitrogen losses with time was not observed in a study of weight reduction of non-obese subjects (Benedict, 1919).

The importance of the carbohydrate content of the diet was demonstrated by the work of Jansen (1917). In six normal subjects a nitrogen loss of 0.3 to 2.7 grams occurred in a six day period of low caloric diet and weight reduction. The addition of 500 calories in the form of carbohydrate brought the subject practically into nitrogen equilibrium; when 900 carbohydrate calories were subtracted from the diet there was about two grams per day additional nitrogen loss.

From the evidence available the caloric and carbohydrate content of reduction diets which would prevent nitrogen losses are not clearly indicated. Several clinicians have pointed to the evidence of Strang et al. (1931) as proof of nitrogen equilibrium during indefinite periods of weight reduction by diets providing one gram per milligram of body weight of protein but low content of calories and carbohydrate, such as these investigators have used. Such an assumption does not seem justified from the evidence quoted.

For college age women the nitrogen allowance in the reduction diet should be sufficient to provide for a small amount of growth and occasional use of protein or energy, in addition to the requirements for maintenance. It would appear that the 12 gram allowance recommended by the National Research Council would not provide more than a safe amount of nitrogen during weight reduction although experimental support for this generalization is needed.

D. Calcium Exchange

For the college age woman the allowance of calcium recommended by the Food and Nutrition Board of the National Research Council (1941) is 1.0 grams per day. The margin between this allowance and the minimal requirement would not appear to be great from the work of McKay _et al_. (1942). They found that, in subjects with self-selected diets, losses were more frequent than retentions at calcium intakes of 0.8 grams, however, with intakes of more than 1.0 gram, losses were small in the few subjects in which they occurred. Mean daily retentions varied among individuals with similar intakes but a significant relation of intake to retention was shown by a coefficient of correlation of 0.50.

The influence of factors other than calcium intake upon its retention was also demonstrated by McKay _et al_. (1942). Subjects on a carefully selected basal diet supplemented by varying amounts of milk made greater retentions, especially at intakes below 0.8 grams, than the subjects on self-selected diets. Analysis of the cause of the difference in retentions in the two groups was not made but it was inferred to be related to a better balanced dietary.

One factor of the diet which might be expected to influence calcium retentions during weight reduction is the occurrence of ketosis. When this takes place, calcium may be excreted in the urine as the salt of the keto-acids. From the discussion above it would appear that if the production of ketone bodies takes place during weight reduction it ordinarily would be in small degree. Moreover, in a review of the literature, Knopp (1943), found the evidence contradictory for increased urinary calcium during ketosis.

The low fat allowance, which is a characteristic of reduction diets, suggests the possibility of good absorption of calcium from the gastro-intestinal track since free fatty acids would be present in minimal amounts to combine with the calcium. High fat in the diet often results in the formation of insoluble salts of calcium which are excreted in the stool (Marriott, 1941).

There is not much reason to question the adequacy of 1.0 gram of calcium per day in reduction diets unless the diet is obviously poor in other respects or the subject is one of those individuals in whom calcium intake must be high for retentions to take place. However, the inclusion of less than 0.8 gram of calcium in the reduction diets of a college age woman might not be expected to bring about the small retentions of calcium which appear to be desirable for a subject of this age.

E. Reduction Diets

Since it frequently has been emphasized that regardless of the regulators operating in individual cases, the chief qualification of a diet for weight reduction is that the calories eaten be less than the energy output, it would be expected that reduction diets would be quite individual in nature. However, in the diets commonly prescribed certain trends in caloric value and other constituents may be noted. Table 4 summarizes these trends.

The most outstanding characteristic of the diets for the adults is the extent of restriction of calories below the subject's probable energy expenditure. Calories accompany protein, minerals and vitamins in food, and so, when total calories are drastically restricted there is a limit to the intake of all of the various nutrients which will be included in the food. The result in many cases has been the inclusion of the bare minimal requirements rather than the allowances recommended by the National Research Council.

Although the psychological effect of rapid weight loss may be good in respect to gaining cooperation during reduction, diets of less than 1000 calories per day can be criticized further since they do not educate the subject in future eating habits.

Other practices of doubtful value in these diets are the complete omission of foods such as potatoes, an excellent source of potassium and other minerals, and of whole grain cereal, a valuable source of the B complex vitamins. Also, the use of vitamin concentrates in situations where it would appear that food could be employed to provide the same

Table 4. Recommendations for Daily Constituents of Reduction Diets As Reported in the Literature

Name of clinician	Calor- ies	Protein	Fat	CHO	Milk	Meat, etc.	Vegetable	Fruit	Bread	Special
		gm.	gm.	gm.	ml.	serving	serving	serving	slice	
						Adults				
Newburgh, (1942)	450	60	9	32	400	2	3, 1 raw, 3 & 6% only	2, pre- fer raw	none	Vitamin B complex
Strang & Evans, (1933)	450	55	low	40	none	2 & egg white or gelatin	"	3	"	Yeast, Vitamin D, Minerals
Bauer, (1941)	1100	135	20-30	85						
Spencer, (1931)	750	70	20-40	60-150						CLO if butter 30 gm.
Keeton & Dixon, (1931)	1200- 1500	90		10-60						
Mason, (1927)	200- 650	23-49	5-15							
						Children				
Bruch, (1940a)	1000- 1600	60-80			"Attention to adequate minerals and vitamins"					
Mulier & Topper, (1934)	Basal -	Per cent of calories 40	20	40	Young child only	Animal & Vegetable	3 & 6% only	3 & 6%	2-3 wh. gr.	

nutrients seems questionable to this investigator.

Emphasis on the improvement of poor food habits by attack on the psychological causes underlying them appears well chosen. Newburgh (1942) has advocated treatment of obese children by that method alone, on the assumption that with this correction growth will bring about reduction of the obesity. While one cannot depend upon growth to produce reduction of the adult, still, maintenance requirements of nitrogen, minerals and vitamins must not be neglected, and minimal allowances would not be more acceptable in reduction diets than in other ones. Furthermore, moderate reduction of calories allows the prescription of a diet to be both interesting in variety of foodstuffs and adequate in terms of accepted nutritional standards. If the obese individual has infantile food tastes as was inferred by Bruch (1940a), surely food education needs to be a part of a reduction routine.

Whether obese women of college age should be treated as children or as adults in the choice of diet for weight reduction remains a question; perhaps the extent of maturity should be the deciding factor, but without adequate laboratory study, maturity is hard to evaluate.

The rate of weight reduction produced by the diets prescribed by different clinicians also follows certain trends. These are noted in Table 5.

In the course of weight loss certain irregularities are met. The chief one has been related to temporary water retention. From the results of his own investigations, Newburgh (1942), has worked out an explanation of this phenomenon which he has presented in the form of a balance sheet. The factors included in the two sides of the balance sheet are:

Water available	Water excreted
In food	In urine
In drink	In stools
By oxidation	Insensible water
From previous hydration of body tissues oxidized	

The water of oxidation should not be overlooked since it is known that 1.07 gm. of water is obtained when one gram of fat is oxidized. The water

Table 5. Average Rate of Weight Reduction Reported in the Literature

Name of clinician	No. of subjects	Av. wt. loss, lbs. wk.	Prescribed caloric intake
Newburgh (1942)	Long series	3 - 5	450
Strang and Evans (1931c)	" "	3 - 5	450
Spencer (1928)	" "	1.5	750
Keeton and Dixon (1931)	9	2.2	1200 - 1520
Mason (1927)	5	3.5	200 - 600
Bruch (1940a)*		0.6	1000 - 1600
Mulier and Topper (1934)		0.7	Basal calories

*No weight loss desired except for very obese child.

of oxidation factors for protein and carbohydrate are 0.4 and 0.6, respectively. The water of hydration factors for protein and fat are approximately 3.0 and 0.1, respectively. The insensible loss of water as the means of removal of 25 per cent of the total heat loss also is not an insignificant proportion of the water balance.

Failure to lose or even gain in weight frequently has been reported during the use of diets of caloric content far below the estimated energy dissipation, but, according to Newburgh, "whatever the duration, it always gives way to a subsequent rapid loss of weight greatly in excess of the weight of the tissue destroyed". Irregularity in weight losses frequently have been noted by other workers when the subject seemed to be consuming a fairly constant diet.

F. Problems Suggested by the Literature

It has been suggested that fat cells differentiate when fat is taken up, become more active, and then revert to their former state when fat is lost. For this reason changes in quantity of body fat may involve metabolic changes related to the poorly understood functions of the fat cells. The cause of the accumulation of body fat is agreed to be an excess of energy intake over energy output but the drive which precipitates increased food intake has not been explained. The absolute maintenance energy requirements of obese women both before and following weight reduction need study. Investigations of dietary procedures designed to meet the rather specialized nutritive needs of weight reduction in the college age woman have not been made. It was to add to the available facts concerning the problems of obese young women that this study was undertaken.

III. PROCEDURE

A. General Plan of the Experiment

Obese college girls who desired to lose weight volunteered to serve as subjects of the experiment. Each subject's caloric requirement for weight maintenance was estimated by study of her self-selected diet before weight reduction was initiated. Then each subject was placed on a diet which would provide about 400 to 500 calories less than maintenance. When the subject was reduced to optimal weight for height and body build, food calculated to provide about 400 calories was added to her diet. The pre-reduction period has been designated Period I, the reduction, Period II, and the post-reduction, Period III.

Energy metabolism during the three periods was studied by basal metabolism tests and by a series of tests taken on the same day. Each series consisted of (1) a test under basal conditions, (2) a test two hours after a prescribed breakfast and just preceding exercise, and (3) a test immediately following exercise.

Nitrogen, calcium and phosphorus balances were carried out in Period I for subjects five to eight; in Period II for all subjects; and in Period III for the last six subjects. Herman reported the phosphorus balances (1944).

The study has been partly exploratory in nature. Since it was carried out for two subjects at a time, the results of the earlier studies suggested some changes in the procedure which were incorporated as the work developed. Both the master plan and the changes which were made will be presented.

B. Subjects

Eight girls, all carrying full college schedules and living in the college dormitories, were selected for study; weight, previous health record and estimated ability to cooperate determining the selection. The degree of obesity of the subjects was limited because it was desired to complete each experiment, or if possible two experiments, in a single school year. Furthermore, it was considered important to include some girls with obesity of limited degree because they seem to form a considerable number of the girls who carry out more or less unsupervised reduction regimens.

The health records of the subjects were free from serious illnesses and as far as possible free from suggestion of glandular abnormality. It was felt desirable to avoid the possibility of such complications in a preliminary paper. All of the subjects had been examined by the college physician since their entrance to college and were reported to be normal except for one who had never menstruated. The results of basal metabolism tests, made on all except one of the subjects before reduction were within the range previously determined to be normal for this locality (Pittman _et_ _al_., 1943). No determination was made for the one subject but there was nothing in her physical report to indicate any abnormality. The exact values are presented in Table 14 and will be discussed later.

Ability to cooperate was very important in these subjects since they were free to participate in normal social activities with their friends except at meal times.

The weight, height, age and extent of obesity before reduction is recorded in Table 6. The distribution of fat in the subjects previous to reduction may be found in Table 7. A brief protocol of the history of each subject is included in the appendix to this paper.

Table 6. Height, Age and Weight of Subjects Before Reduction

Subject	Age years	Height inches	Actual weight pounds	Estimated optimal weight pounds	Overweight per cent
1	22	65.3	174	132	32
2	19	63.8	138	123	11
3	18	62.3	156	130	20
4	19	63.3	164	130	26
5	20	65.0	165	130	27
6	19	66.0	170	140	21
7	20	67.0	179	150	19
8	19	61.6	137	120	14

It may be seen that the subjects varied in extent of obesity, body build, distribution of fat, and origin of obesity.

C. Diets

All of the subjects ate their meals at a supervised metabolism table at the college hospital. The diets were prepared under the direction of a dietitian. Trained attendants weighed the individual portions of food and supervised the diet table. Chattillon dietetic scales were used for weighings and complete records of the food eaten were kept at the time of the meal.

Table 7. Evaluation of Fat Distribution in the Subjects Studied

Subject no.	Upper back	Upper arm	Abdomen	Trochanter	Thigh	Comment
1	marked	marked	moderate	marked	marked and extends low	----
2	----	----	moderate	moderate	----	chubby, juvenile figure
3	----	slight	marked	marked	marked	marked lipedema below knee
4	----	marked	marked	marked	moderate	----
5	----	moderate	moderate	moderate	moderate	----
6	----	moderate	moderate	marked	marked	marked lipedema below knee
7	----	marked	moderate	moderate	moderate	----
8	----	moderate	marked	moderate	slight	chubby, juvenile figure

Caloric intakes during Period I were estimated in order to determine the amount of food to be allowed during Periods II and III. Calories were calculated by the use of food tables (Thompson and Ohlson, 1942; Waller, 1938).

All of the subjects were requested to try to eat the same quantity of food during Period I as they had been eating before the experiment, being especially careful not to decrease the amount. Subjects one and two were provided a diet of simple foods which could be accurately analyzed by use of food tables. However, this eliminated concentrated mixtures and so made a bulky, low caloric diet unless large amounts of bread and butter or simple sweets were ingested. Indulgence in food of this character apparently was too contrary to the psychology of the pre-reduction subject and accordingly, these two girls ate less calories than were estimated from records of their previous diets in the dormitory. Therefore, in spite of the probable inaccuracies in the calculation of the calories, the foods which were offered to the other subjects, were the ones served to the hospital staff, which included more concentrated mixtures such as pastries, dressings, etc. The caloric evaluation of this diet was checked in the last subject by serving in a late control period a diet of simple foods equicaloric to the average intake of the subject while eating the self-selected diet. Table 8 summarizes the calculated caloric value of the diets used in all periods.

The diets of subject one and two were reduced to 1000 calories because the investigator found that with less calories it was very difficult to provide a palatable diet, adequate in all known nutrients. Also, the basal diet of McKay _et al._ (1942) which had been extensively used for research with college women provided about that amount of calories if no ad libitum foods were included. Since in the other subjects the self-selected caloric intakes were greater, the diets for Periods II and III were greater also. Some uniformity in the diets was necessary to limit the amount of preparation.

Table 8. Caloric Intakes Used for Periods II and III and the Estimated Intakes of Period I

Subject	Diet pre-reduction	Weight changes in Period I per 30 days	Diet reduction	Diet post-reduction
1	1227	-1.0	1000	----
2	1238	0.0	1000	----
3	1736	0.0	1200	1570
4	1834	-1.2	1200	1570
5	1780	-4.0	1200	1570
6	2000	-1.5	a 1200 b 1276	1570
7	1900	0.0	1200	1570
8	1800	0.0	1200	a 1200 b 1150 c 1100 d 1025

The basal diet list of McKay *et al.* was used as the basis of the diets of Periods II and III. The food list consisted of specific amounts of certain readily available meats, cereals, fruits, and vegetables to be included in a five day period. The quantity of milk was the variable in the study of McKay *et al.* The quantities of milk used in the present study are included in the list of foods for Periods II and III, presented in Table 9. McKay's subjects added foods low in nitrogen, calcium, and phosphorus to provide sufficient calories for weight maintenance. Without these foods but with the inclusion of 500 milliliters of milk, the five day diet was estimated to contain 1000 calories per day. By further addition of 200 milliliters of milk and several servings of fruits and vegetables, an estimated 200 calories were added. The addition of calories chiefly in the form of protein in Period III was suggested by the rather flabby skin and muscle tone of subject four, the first subject for whom a post-reduction study was done. Although all of the other subjects seemed to have good muscle tone, the procedure used for subject four seemed advisable for the others since it was not possible to complete the nitrogen analyses for the reduction period and thereby have a specific indication of the nitrogen metabolism of the subjects before the post-reduction period began. Also, it was desirable to use uniform treatment of the subjects to simplify interpretation of the results, and to limit the amount of food preparation.

A diet in which the calories were the same but largely in the form of carbohydrate was used for subject five in a period following the high protein diet. For this purpose the foods added to the diet of Period II were as follows:

butter	20 grams
bread	60 "
graham cracker	10 "
10 per cent fruit or vegetable	100 "
sugar	15 "

This group of foods was estimated to contribute 62 grams of carbohydrate, 18 grams of fat and 7 grams of protein.

Table 9. Five-Day Food Routine

Reduction period: January 1942-June 1942	gm.	Reduction period: June 1943-April 1944	gm.	Post-reduction maintenance period gm.
Orange juice	200		300	300
Whole orange	100		100	100
Tomato juice	200		100	100
Tomato soup concentrate	70		30	30
Grapefruit	100		200	200
Peaches, canned	100		105	200
Pineapple, canned	80		110	110
Banana[1]	100		100	100
String beans, canned	70		70	170
Beets, canned	70		90	90
Cabbage	100		100	100
Carrots	100		100	100
Lettuce	100		100	100
Onions	10	Rutabaga, raw	20	20
Celery	50		110	110
Tomato	70		190	190
Peas, canned	70		160	360
Potatoes, white	600		600	600
Squash, winter[2]	100		100	100
Whole wheat bread	250		250	310
Whole wheat cereal, dry	100		100	100
Bacon	20		20	20
Lean meat	400		400	400

Table 9. Continued

	Reduction period				Post-reduction maintenance period	
	January 1942-June 1942		June 1943-April 1944			
	gm.		gm.		gm.
Salmon	90		90		90
Eggs, whole	150		150		650
Milk	2400		3140		3140
		Pear, canned	100		100
		Apple	230		230
		Dill pickle	20		20
				Graham cracker	5
Total calories	1000		1200		1600
Protein	68		68		100
Fat	37		37		54
Carbohydrate	125		150		175

[1]When available, 100 gm. orange juice were substituted.

[2]When available, 80 gm. carrots were substituted.

Calories, protein, fat, and carbohydrate were calculated from food intakes except in cases where the protein could be estimated from the determined nitrogen values. The usual conversion factor, 6.25, was employed for this calculation.

Menus were planned for five days dividing the prescribed foods as equally as possible and yet providing a maximum of variety in preparation. The same set of menus were used throughout an experiment. Limitations of the market sometimes required substitutions in the menu but the total caloric content was kept the same. The menus which were used for the 1200-calorie diet may be found in the appendix.

The subjects were required to eat all of their diet and nothing was permitted ad libitum except black coffee and plain tea. Small amounts of lemon juice, vinegar, and such seasonings which would not provide appreciable calories were permitted. Breakfast and supper for Sunday were weighed and packed by the attendants so that they could be eaten away from the hospital. The subjects were permitted to leave town during school vacations and not more than one other weekend during the experiment. Suggestions were made for the choice of food while away from the hospital but no food records were required; the weight records give evidence of the behavior during these periods. Absence from any other meal was reserved for special occasions and was requested rarely. Occasional guests were permitted at the diet table, especially in the case of visiting parents. By this policy it was hoped to gain a high degree of cooperation throughout the progress of the experiments.

The subjects were weighed weekly on the same day of the week at the same time of day. The weekly weights may be found in the protocols for each individual in the appendix.

D. Energy Metabolism

1. General procedure.

The energy metabolism series, consisting of a basal test, a pre-exercise base-line test, and an activity test were carried out during the reduction period only for subjects one and two. For all of the other subjects the series was performed during each dietary period. In all of the tests for the series the open circuit method was used. Periodic basal metabolism tests only, to determine fitness for participation in the study and to check on the progress of the subject, were made by the closed circuit method.

2. Techniques for basal metabolism.

The usual conditions for basal metabolism were observed (Du Bois, 1936, p. 124). Details of the procedure followed by the subjects of this study were as follows: a subject in the post-absorptive state who had had her usual amount of sleep came to the laboratory immediately after rising, walking a maximum distance of one mile. At the laboratory the subject lay comfortably covered on a bed in a room ventilated to the subject's taste. Conditions were controlled to avoid strong light or other forces which might disturb the subject. The test was made 30 to 45 minutes later, the time depending on the extent of exercise en route to the laboratory.

For the open circuit method a Tissot spirometer, connected to an outside air intake was used. The period for collection for the basal test was fifteen minutes. Samples of the expired air collected during the test periods were analyzed for oxygen and carbon dioxide in a Haldane apparatus. By quantitative comparison of the components of the inspired and expired gas mixtures the oxygen absorption and the respiratory quotient were determined and from these values the caloric exchange was calculated. Methods for these calculations have been described by Peters and Van Slyke (1932, p. 198-199, 205-207). In Table 10 analysis of outdoor air, a gas of standard proportions at the location of the experiment, are presented.

Table 10. Analyses of Outdoor Air for Oxygen and Carbon Dioxide

Sample	CO_2	O_2
	volumes	per cent
1	0.02	20.92
	0.02	20.92
2	0.03	20.91
	0.02	20.93
Theoretical value	0.03 ±1	20.93 ±2

A sample of the calculation sheet used will be found in the appendix.

A Benedict-Roth portable machine was used for the closed circuit determinations. Two eight minute tests were made with a brief rest period between them on each day of the test.

3. Techniques for the energy exchange in activity.

The 12 to 14 hour post-absorptive state was not deemed a normal one for the performance of exercise. Therefore, the frequently used procedure of determining the cost of activity immediately following a basal metabolism test was not followed. The plan decided upon was exploratory in nature. A basal test was made under the usual standard conditions. Then the prescribed breakfast of Period II, consisting of 100 grams of orange or grapefruit, 12 grams of toast, 20 grams of dry whole wheat cereal and 150 grams of milk was given, regardless of the dietary period. The subject was free to take part in light activities for an hour and a quarter. She then returned for rest in bed for three-fourths of an hour before the second test. It was believed that the second test would be a reliable base-line for the calculation of the increased energy expenditure of the exercise period on the assumption that forces which would influence the metabolism at the time of the base-line test would be likely to continue through the short exercise period to follow.

The exercise consisted of pumping a stationary bicycle in which some resistance had been placed for a period of eight to 12 minutes depending on the apparent fatigue of the subject, but in all cases the same amount of exercise for the same subject was used during each experimental period. The rate of bicycling was maintained by timing with a controlled source of march music.

Due to the limitations of the laboratory equipment, the collection of the expired gas while the exercise was in progress did not seem possible. However, it was believed that the stimulation of the exercise would increase the metabolism for some time following, and therefore the gas collection was made in the period following the exercise. The article of Dill et al. (1933) discussed in the review of literature unfortunately had not come to the attention of the experimenter before most of the work was completed, therefore adequate allowance for the complications of oxygen debt were not made in the plan of the experiment. During the work on the first four subjects there was no marked hyperventilation at the termination of the exercise. However, in the later subjects this was encountered and the collection period was delayed or split in an attempt to get a collection period free of hyperventilation.

E. Nitrogen and Calcium Determinations

Nitrogen and calcium intake, excretion and retention during the different dietary periods were studied by the balance technique. The frequency and timing of the balance periods is recorded on the weight charts and in the protocols which may be found in the appendix.

Seven-day sampling periods as recommended by Cox et al. (1942) were selected for each of the dietary periods. The foods and liquids were sampled by the customary procedure of securing an aliquot as the food was served. These aliquots were preserved and pooled for the 7-day period. Feces, marked by carmine, were pooled for the same period. Aliquots of urine for the 7 days were also preserved. All of the samples were digested with HCl, sieved, and made up to a convenient volume for analysis at a later date according to the method of Stearns (1929). Nitrogen was determined by the macro-Kjeldahl method. A wet ash was made for calcium determinations using the method of Stearns (1929). A modification of the McCrudden method as described by Stearns (1929) was used for calcium determination. Recoveries of known amounts of nitrogen are reported in Table 11, those of calcium in Table 12.

Table 11. Recovery of Nitrogen from Standard Solutions

Material	Date	Nitrogen in sample	Nitrogen recovered	Per cent of nitrogen recovered
		mg.	mg.	
$(NH_4)_2SO_4$	5/12/43	30.20	28.96	95.9
		30.20	29.50	97.7
		30.20	29.57	97.9
Average				97.1
$(NH_4)_2SO_4$	5/13/44	30.20	29.29	97.0
		30.20	29.06	96.2
		30.20	29.37	97.3
		30.20	30.18	99.9
		15.10	14.65	97.0
		15.10	14.46	95.8
		15.10	14.67	97.2
		15.10	14.50	96.0
Average				97.1
Creatinin	5/12/43	19.73	19.04	96.5
		19.73	18.92	95.8
		19.73	19.02	96.4
		19.73	19.38	98.2
Average				96.7

Table 12. Recovery of Calcium from Standard Calcium Acetate Solution and from an Unknown

Date	Calcium in aliquot of digest	Calcium added	Added calcium recovered	Added calcium recovered
	mg.	mg.	mg.	per cent
5/11/43	----	0.566	0.556	98.2
	----	0.566	0.560	98.9
	----	0.566	0.560	98.9
6/ 9/44	0.703	0.226	0.223	98.6
	0.703	0.226	0.228	100.6
	0.703	0.226	0.227	100.4
Average				99.3

F. Urinary Ketones

Urinary ketones were determined by Van Slyke's gravimetric method with Deniges' reagent (Peters and Van Slyke, 1932, p. 626-629). For the later subjects blank determinations were made on the urine sample after the ketones had been partially oxidized and volatilized, a procedure recommended for samples with small amounts of ketones (Van Slyke, 1917).

IV. RESULTS AND DISCUSSION

A. Weight Reduction

Graphs drawn from weekly weight records are presented for each of the eight subjects in Figures 1 to 8. The dotted portions in the curves indicate periods for which there were no weighed food records. The times at which various tests were made during the course of the experiments have been recorded on the charts to facilitate identification throughout the discussion. Detailed records of the weekly weighings may be found in the protocols in the appendix.

Period I, the period of self-selected diet, as may be seen, was characterized by weight maintenance or insignificant losses in all of the subjects except number five. At the point of each curve where the reduction diet began the curve drops sharply. During the course of reduction the slopes of the curves decrease in varying amounts, and in the case of subject eight, weight losses ceased after 12 weeks on the reduction routine. In all cases the regularity of the slopes of the curves are unusual for curves of weight reduction by dietary restriction. The regularity of weight loss is believed due to the constancy of the constituents of the five-day diet and thus the commonly encountered changes in water balance apparently were avoided. As a result the curves probably represent losses of body tissue more satisfactorily than those usually obtained. Weight losses are summarized in Table 13.

The individual losses were fairly uniform with the exception of

Figure 1. Weight Graph for Subject One

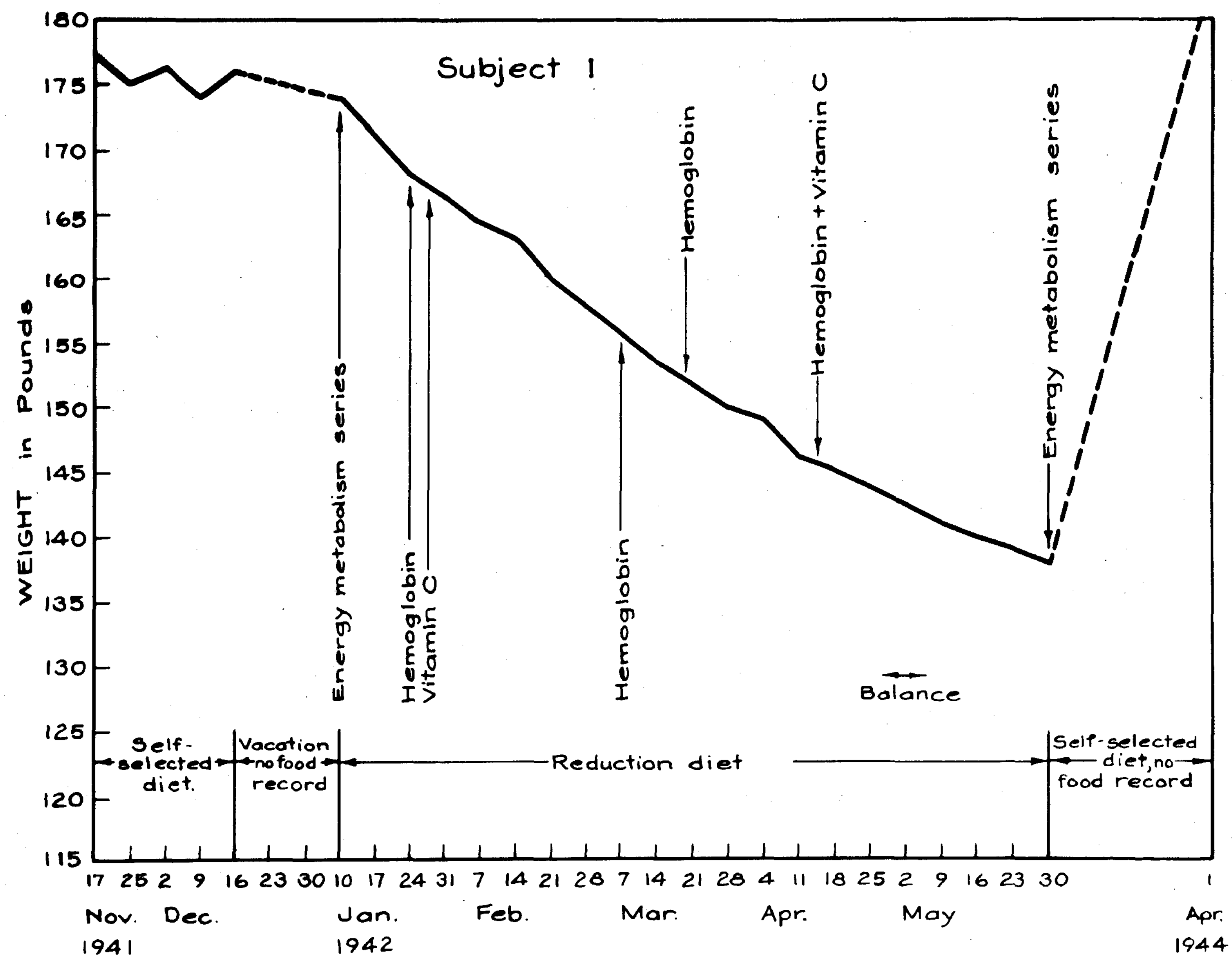

Subject 1
WEIGHT in Pounds
180
175
170
165
160
155
150
145
140
135
130
125
120
115
Energy metabolism series
Hemoglobin
Vitamin C
Hemoglobin
Hemoglobin
Hemoglobin + Vitamin C
Energy metabolism series
Balance
Self-selected diet.
Vacation no food record
Reduction diet
Self-selected diet, no food record
17 25 2 9 16 23 30 10 17 24 31 7 14 21 28 7 14 21 28 4 11 18 25 2 9 16 23 30 1
Nov. Dec. Jan. Feb. Mar. Apr. May Apr.
1941 1942 1944

Figure 2. Weight Graph for Subject Two

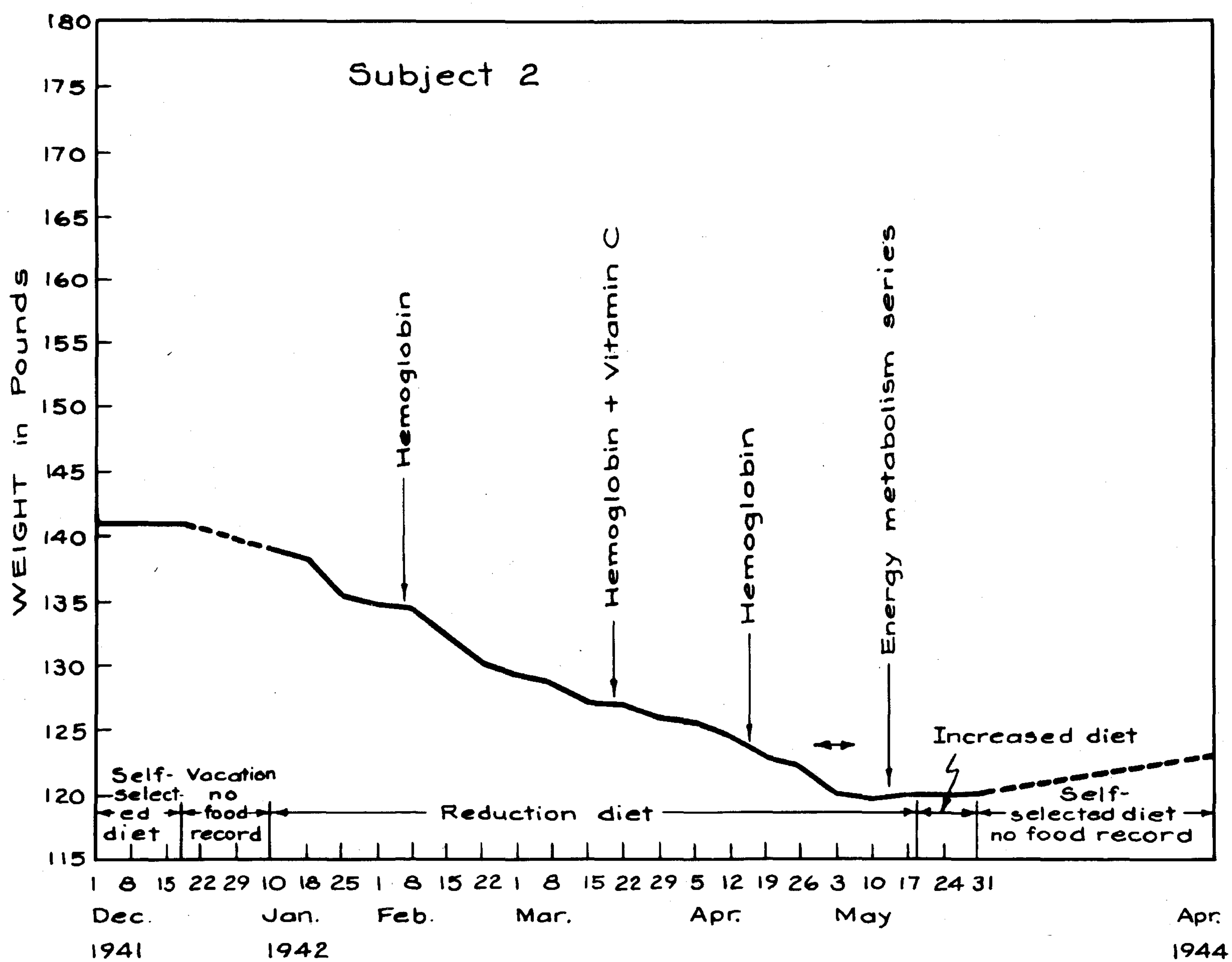
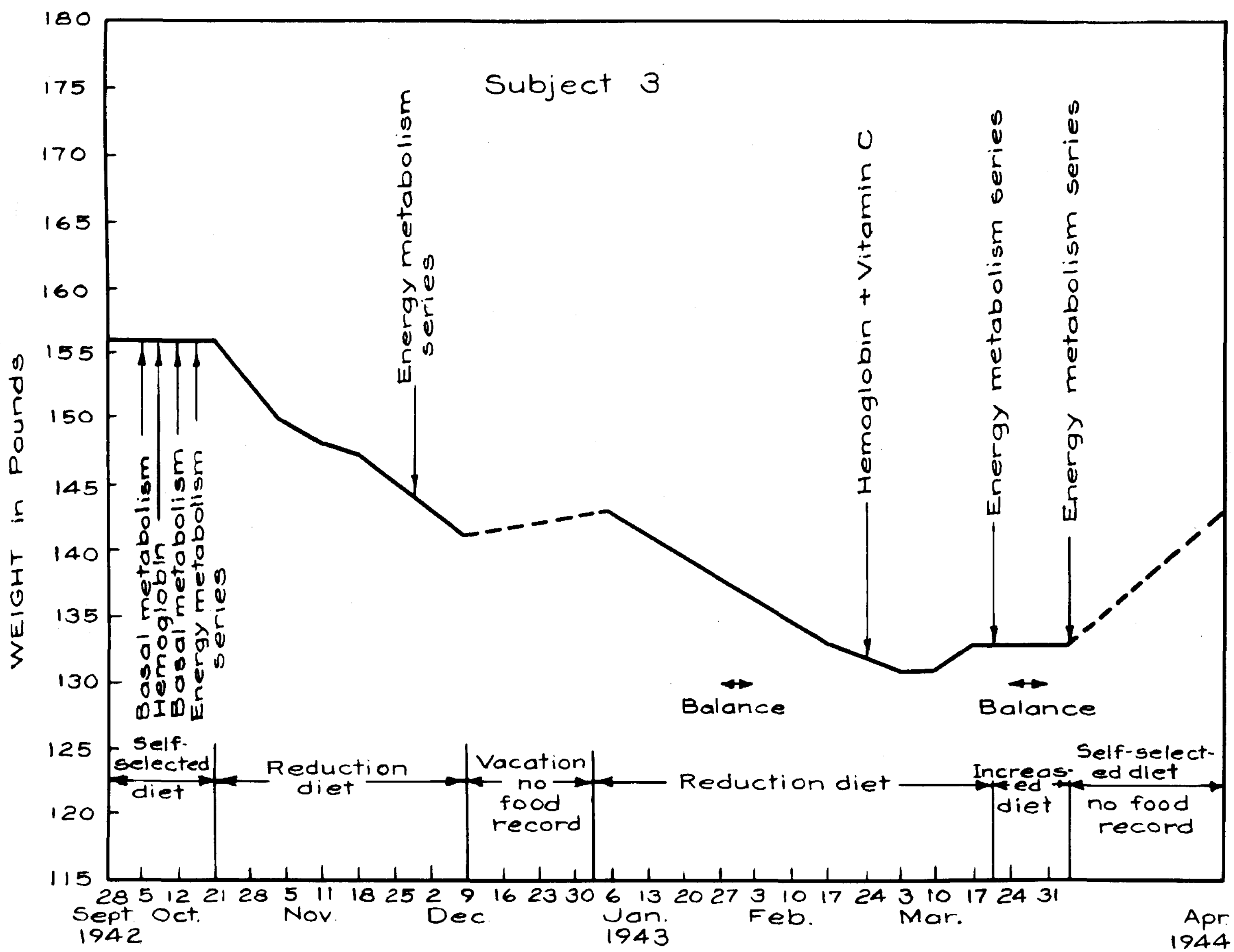

Subject 2
WEIGHT in Pounds
180
175
170
165
160
155
150
145
140
135
130
125
120
115
Hemoglobin
Hemoglobin + Vitamin C
Hemoglobin
Energy metabolism series
Increased diet
Self-select-ed diet
Vacation no food record
Reduction diet
Self-selected diet no food record
1 8 15 22 29 10 18 25 1 8 15 22 1 8 15 22 29 5 12 19 26 3 10 17 24 31
Dec. 1941
Jan. 1942
Feb.
Mar.
Apr.
May
Apr. 1944

Figure 3. Weight Graph for Subject Three



Subject 3
WEIGHT in Pounds
180
175
170
165
160
155
150
145
140
135
130
125
120
115
Basal metabolism
Hemoglobin
Basal metabolism
Energy metabolism series
Energy metabolism series
Hemoglobin + Vitamin C
Energy metabolism series
Energy metabolism series
Balance
Balance
Self-selected diet
Reduction diet
Vacation no food record
Reduction diet
Increased diet
Self-selected diet no food record
28 5 12 21 28 5 11 18 25 2 9 16 23 30 6 13 20 27 3 10 17 24 3 10 17 24 31
Sept. Oct. Nov. Dec. Jan. Feb. Mar. Apr.
1942
1943
1944

Figure 4. Weight Graph for Subject Four

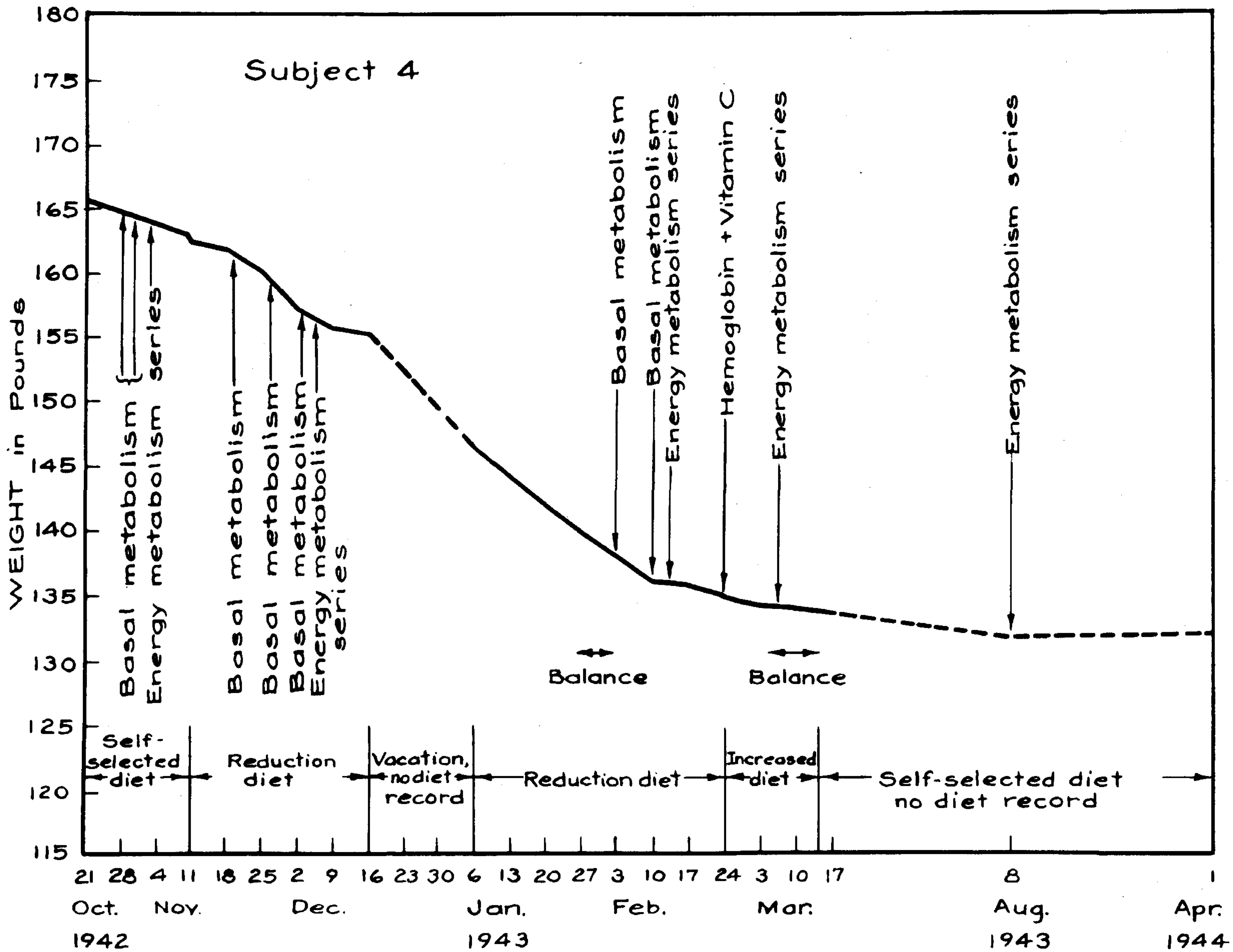

Subject 4
WEIGHT in Pounds
180
175
170
165
160
155
150
145
140
135
130
125
120
115
Basal metabolism
Energy metabolism series
Basal metabolism
Basal metabolism
Basal metabolism
Energy metabolism series
Basal metabolism
Basal metabolism
Energy metabolism series
Hemoglobin + Vitamin C
Energy metabolism series
Energy metabolism series
Balance
Balance
Self-selected diet
Reduction diet
Vacation, no diet record
Reduction diet
Increased diet
Self-selected diet no diet record
21 28 4 11 18 25 2 9 16 23 30 6 13 20 27 3 10 17 24 3 10 17 8 1
Oct. Nov. Dec. Jan. Feb. Mar. Aug. Apr.
1942 1943 1943 1944

Figure 5. Weight Graph for Subject Five

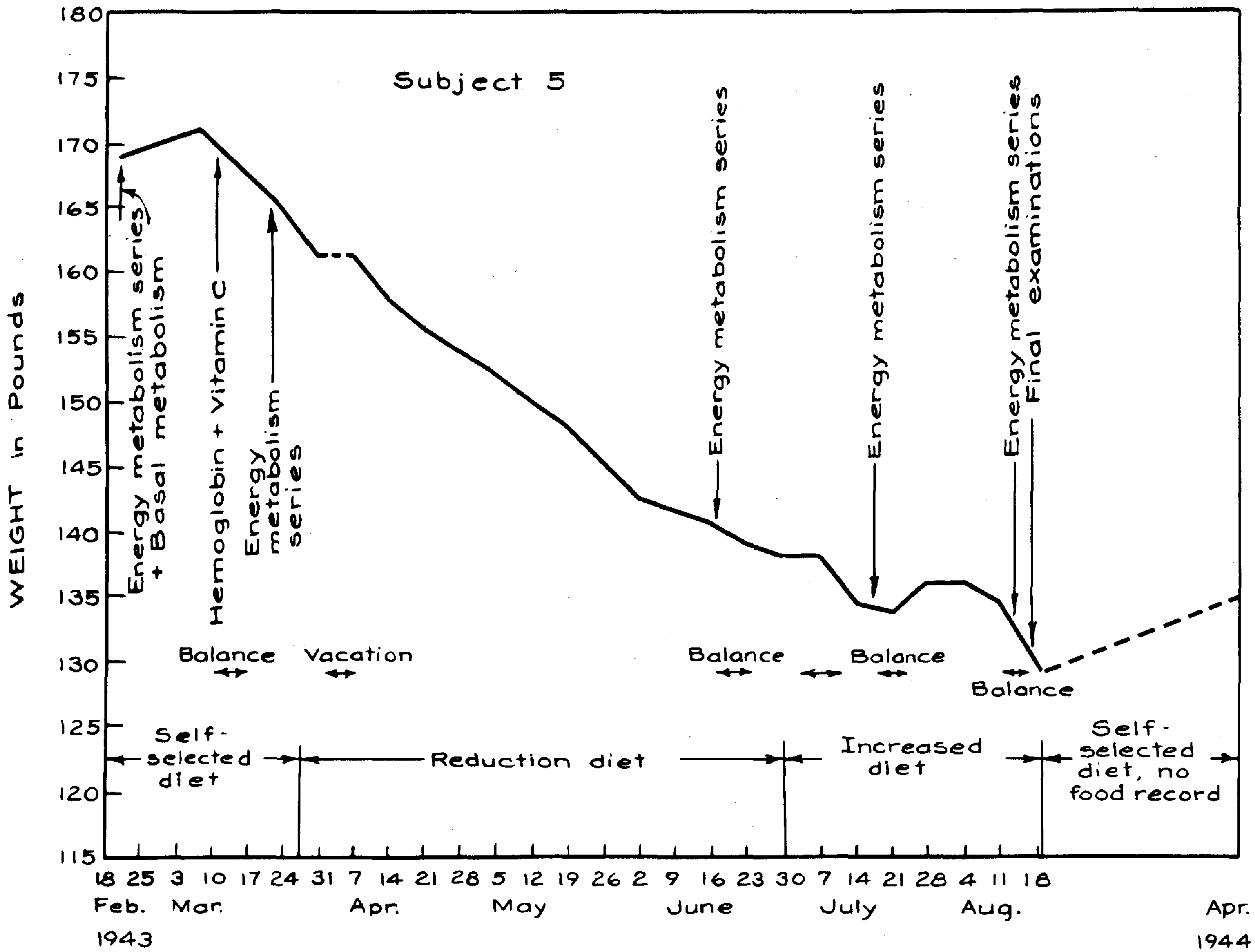

Subject 5
WEIGHT in Pounds
180
175
170
165
160
155
150
145
140
135
130
125
120
115
Energy metabolism series + Basal metabolism
Hemoglobin + Vitamin C
Energy metabolism series
Energy metabolism series
Energy metabolism series
Energy metabolism series
Final examinations
Balance
Vacation
Balance
Balance
Balance
Self-selected diet
Reduction diet
Increased diet
Self-selected diet, no food record
18 25 3 10 17 24 31 7 14 21 28 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18
Feb. Mar. Apr. May June July Aug. Apr.
1943
1944

Figure 6. Weight Graph for Subject Six

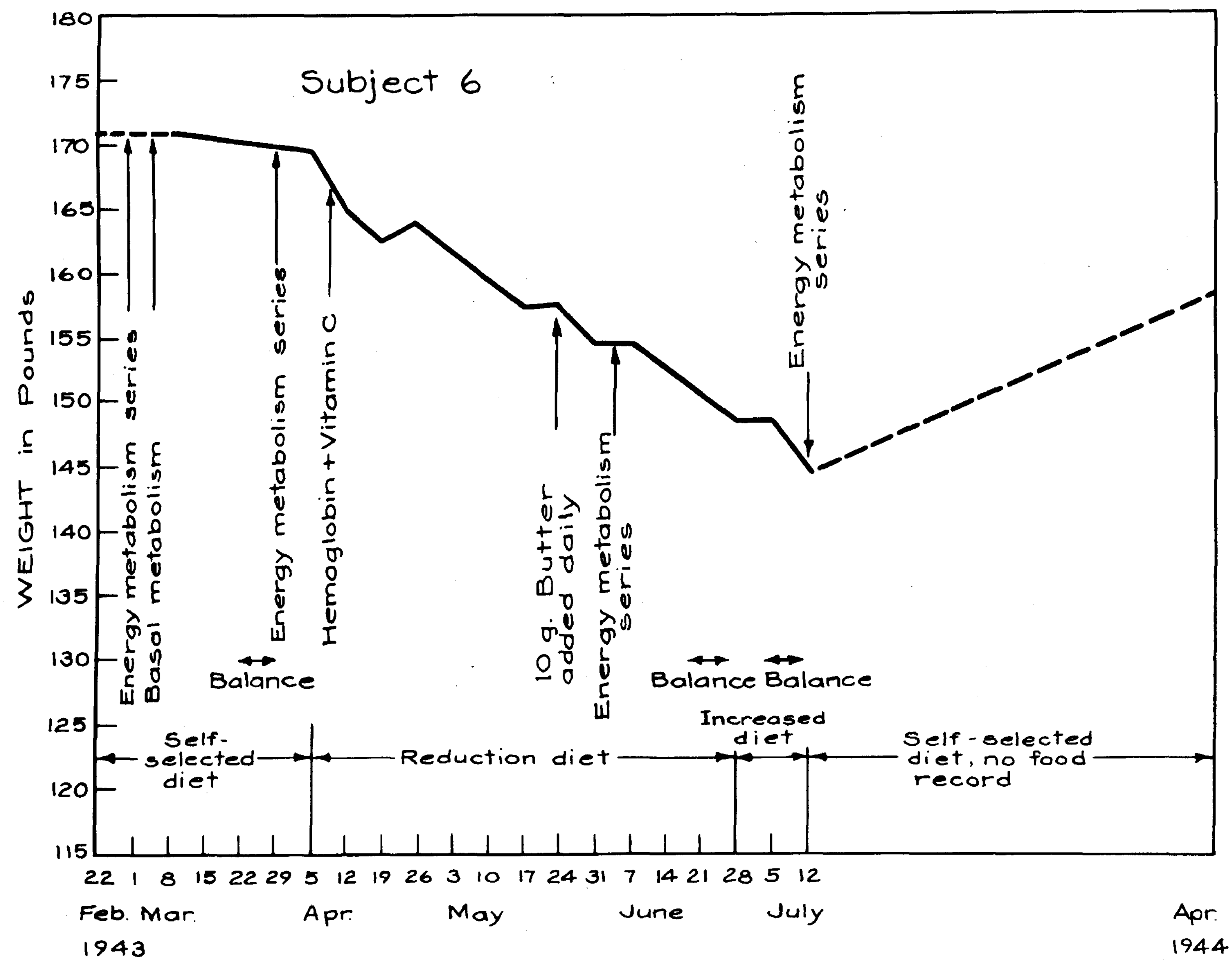
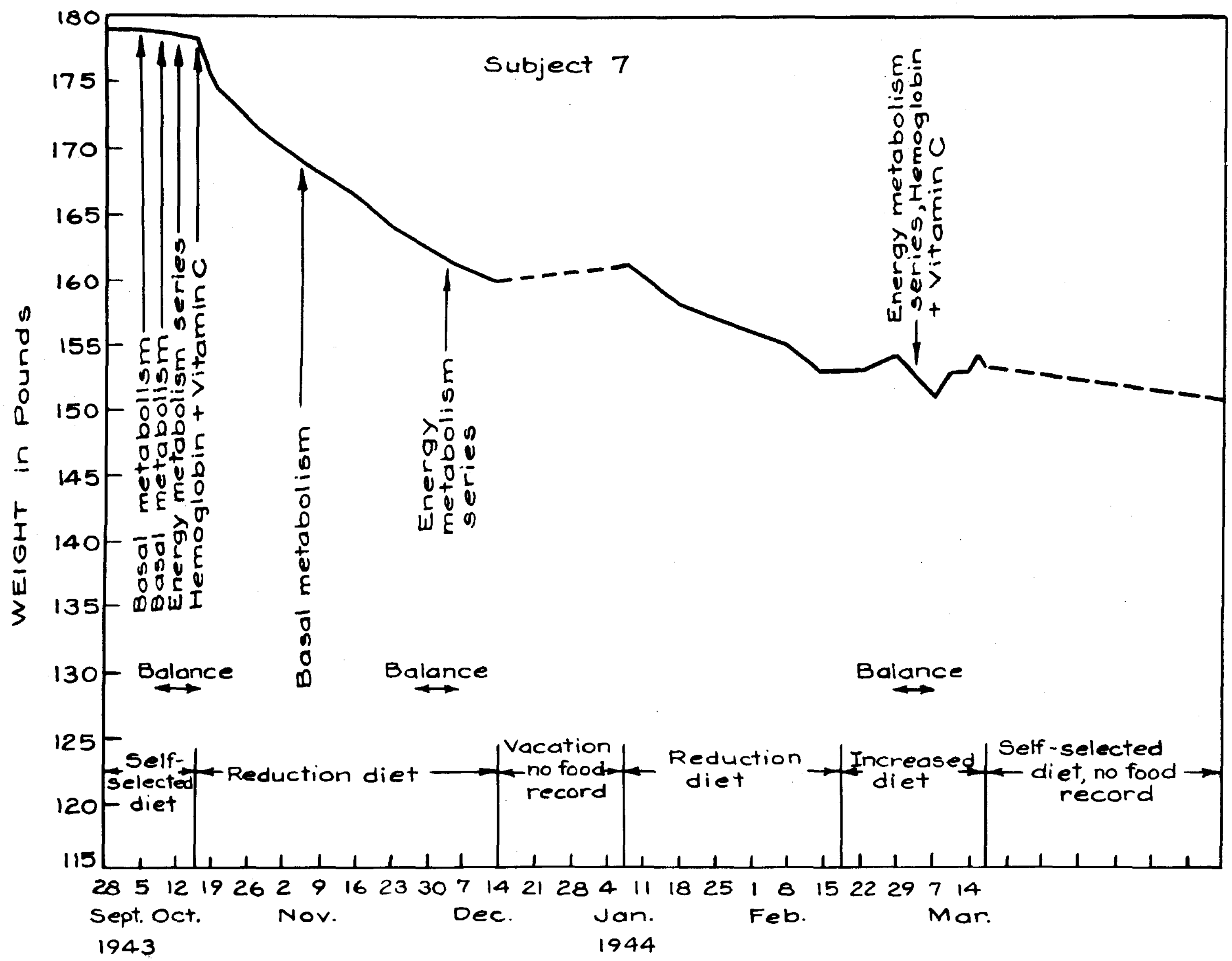
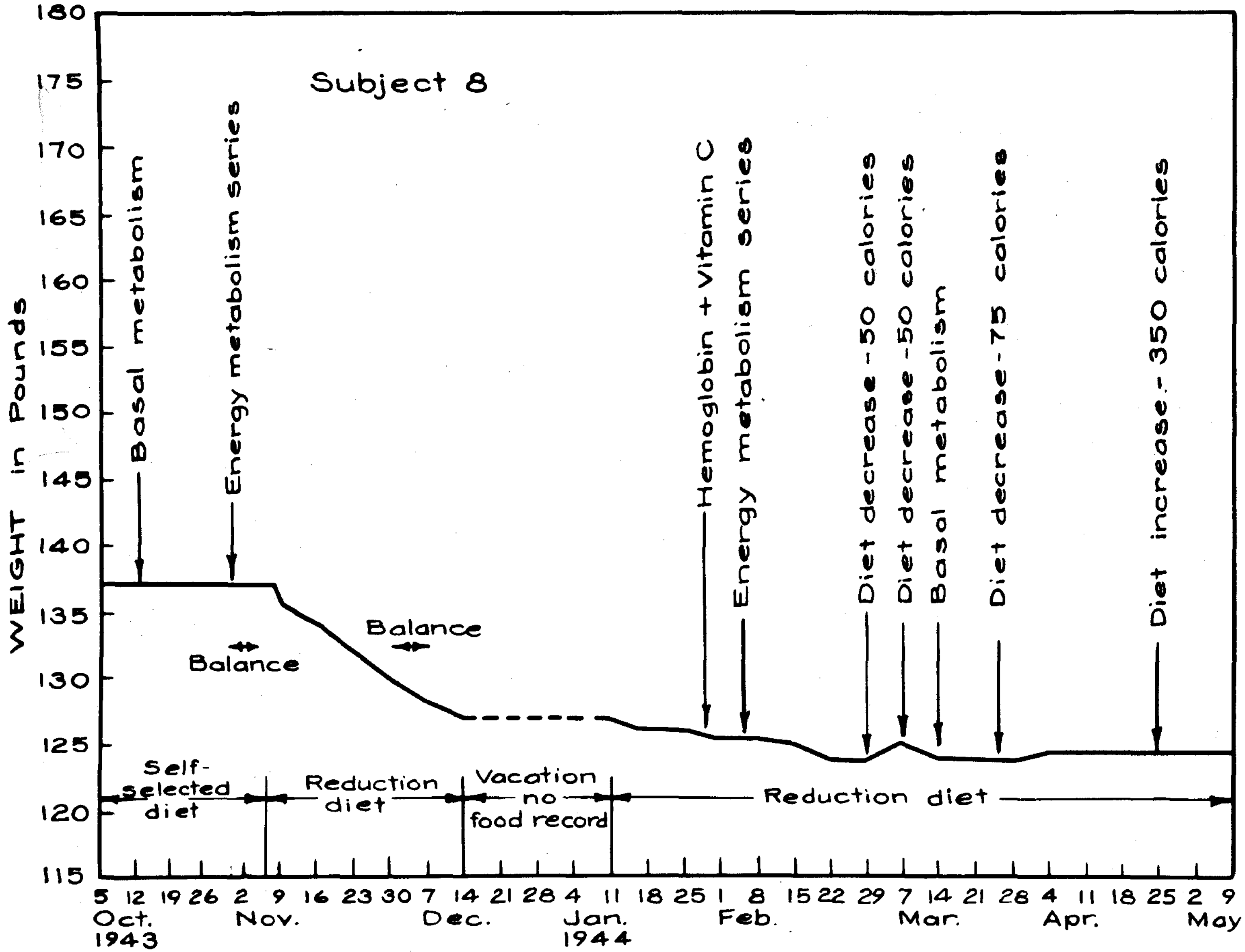

Subject 6
WEIGHT in Pounds
180
175
170
165
160
155
150
145
140
135
130
125
120
115
Energy metabolism series
Basal metabolism
Energy metabolism series
Hemoglobin + Vitamin C
10 g. Butter added daily
Energy metabolism series
Energy metabolism series
Balance
Balance
Balance
Self-selected diet
Reduction diet
Increased diet
Self-selected diet, no food record
22 1 8 15 22 29 5 12 19 26 3 10 17 24 31 7 14 21 28 5 12
Feb. Mar.
Apr.
May
June
July
Apr.
1943
1944

Figure 7. Weight Graph for Subject Seven



Subject 7
WEIGHT in Pounds
180
175
170
165
160
155
150
145
140
135
130
125
120
115
Basal metabolism
Basal metabolism
Energy metabolism series
Hemoglobin + Vitamin C
Basal metabolism
Energy metabolism series
Energy metabolism series, Hemoglobin + Vitamin C
Balance
Balance
Balance
Self-Selected diet
Reduction diet
Vacation no food record
Reduction diet
Increased diet
Self-selected diet, no food record
28 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 1 8 15 22 29 7 14
Sept. Oct. Nov. Dec. Jan. Feb. Mar.
1943
1944

Figure 8. Weight Graph for Subject Eight


Subject 8
WEIGHT in Pounds
180
175
170
165
160
155
150
145
140
135
130
125
120
115
Basal metabolism
Energy metabolism series
Hemoglobin + Vitamin C
Energy metabolism series
Diet decrease -50 calories
Diet decrease -50 calories
Basal metabolism
Diet decrease -75 calories
Diet increase - 350 calories
Balance
Balance
Self-selected diet
Reduction diet
Vacation no food record
Reduction diet
5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 1 8 15 22 29 7 14 21 28 4 11 18 25 2 9
Oct. 1943
Nov.
Dec.
Jan. 1944
Feb.
Mar.
Apr.
May

subjects two and eight. They were the smallest girls and also the ones whose juvenile figures suggested that growth still was taking place. The average weekly weight loss of subject three also appeared to be small but was complicated by a weight gain during the Christmas vacation and another

Table 13. Weight Losses during Reduction

Subject	Duration of reduction period	Total weight loss	Average weight loss per week
	weeks	pounds	pounds
1	20.0	36	1.8
2	18.0	19	1.1
3	18.0	23	1.2
4	12.0	29	2.0
5	12.5	25	2.0
6	12.0	21	1.7
7	14.5	27	1.9
8	11.0	13	1.1

near the end of Period II which was not explained although it was suspected that some additional food had been obtained. If these periods which were not characteristic of the reduction routine are omitted in calculation of the mean, the average weekly loss of subject three is 1.8 pounds, a value within the range for the other subjects.

During Period III weight was maintained in some of the subjects but not in all and a longer period would appear to have been desirable. Losses took place in subjects five and six coincident to mild diarrhea. These weight losses probably could be attributed to water rather than fat loss. The second weight loss in subject five occurred during a state of unusual mental strain at the time of final examinations. No explanation can be suggested for the weight irregularity of subject seven. It is evident that a longer time for Period III would have established whether or not these weight losses reflected the caloric intake used or were due to temporary changes in water balance. However, by the time the routine tests had been completed in Period III, some subjects were finding the five-day repetition of the diet monotonous and the motivation for weight loss was gone. Extension of Period III, although desirable, was not feasible in most cases.

B. Energy Exchange

The basal energy exchange of the subjects of the study was compared to a standard for Iowa State College women (Pittman et al., 1943) in order to establish the normalcy of the experimental group (Table 14). Both actual and ideal weight were used in estimating surface area (Strang and Evans, 1928). The values reported in Table 14 are the mean for all of the basal determinations made by both the open and closed circuit methods during any given period of study unless the test appeared to be invalid before calculation (Young, 1940).

The results show that before reduction the basal metabolic rate, calculated by either method of computing surface area, was within twelve per cent of normal for each subject of this study.

During Periods II and III values below the Iowa State College "norms" were found frequently in subjects three, six and seven.

When ideal weight was used in the calculation of surface area the basal metabolic rate appeared higher during obesity than when figured by the conventional method. However, the results of this study never were elevated more than 10 per cent above normal as was reported by Strang et al. (1928), but the lesser degree of obesity seen in this study may explain the difference.

It was believed that the relation of basal metabolism to weight reduction could be more accurately evaluated by comparison of the 24-hour

Table 14. Basal Metabolic Rate of Seven Subjects during Each Period of Study[1]

	Period I			Period II			Period III		
Subject	Actual weight	Ideal weight	No. of determinations	Actual weight	Ideal weight	No. of determinations	Actual weight	Ideal weight	No. of determinations
1	- 9	-4	1	- 9	- 7	1			
3	- 4	6	3	-13	- 9	2	-21	-19	1
4	- 9	4	2	1	3	7	6	2	2
5	- 3	4	2	- 9	- 7	1	- 7	- 6	2
6	- 5	4	4	-31	-28	1	-15	-13	1
7	-12	-4	3	-19	-13	2	-15	-12	1
8	- 6	-1	3	—	—	—	-10	- 9	4

[1]The basal metabolic rate was calculated as a percentage deviation from the Pittman standard (1943) with surface area estimated on the basis of (1) actual weight and (2) ideal weight. No basal metabolism tests were done on subject 2.

energy exchange of the same subject, during periods of reduction and weight maintenance, than by the comparison of the subject with a standard for normal subjects, involving an arbitrary estimation of surface area as reported in Table 14.

Therefore the mean basal metabolism during each dietary period, expressed as calories per 24 hours, is presented in Table 15. The means for the periods include only those subjects for whom there were tests for each period. During weight reduction, the mean 24 hour metabolism for the period decreased from the pre-reduction values. Except for sub-

Table 15. Mean Basal Calories, Pulse, Respiration and Oral Temperature before, during and after Weight Reduction

Period	Subject	Calories per 24 hrs.	Pulse	Respiration	Temperature
I	1	1471	74	12	98.4
	3	1379	60	15	97.1
	4	1358	62	13	97.7
	5	1481	64	8	97.8
	6	1498	68	19	97.3
	7	1387	60	12	97.5
	8	1270	68	14	97.6
	Average*	1421	64	13	
II	1	1262	65	12	97.6
	2	----	61	12	97.0
	3	1176	58	14	98.0
	4	1363	57	11	97.5
	5	1260	56	8	97.6
	6	996	60	17	97.2
	7	1234	52	9	----
	Average*	1175	56	14	
III	3	1039	59	13	----
	4	1289	55	10	97.2
	5	1274	54	12	97.3
	6	1217	52	17	97.0
	7	1262	53	11	----
	8	1178	60	17	97.3
	Average*	1216	54	13	

*Averages of values for subjects 3, 4, 5, 6, and 7.

ject four whose basal metabolism was unchanged, each subject had a lower basal metabolism after some weight losses had taken place and the depression continued into Period III.

It may be noted from the weight charts that the energy determinations during Period II were made many weeks after weight reduction had begun, a procedure employed in order to obtain the effect of a fairly prolonged reduction period. An even greater depression of basal energy expenditure at the beginning of weight reduction might have been expected from the results of Strang and Evans (1928) although the rate of weight losses recorded would not support such an hypothesis.

The mean basal metabolism for Period III and the mean for each individual subject during this period remained depressed except for subject six whose metabolism showed high variability from test to test. The failure of the basal metabolism to rise during Period III is surprising in view of the large increase in protein of the diet. Likewise, in the subject for whom determinations were made only in Periods I and III, the metabolism in Period III was lower than that in Period I. Evidence of decreased metabolism following periods of weight reduction was suggested by the report of Harrington (1930) whose subject maintained her weight on a relatively low caloric intake following prolonged weight reduction.

It is interesting to note (Table 15) that the basal pulse rate also was decreased during weight reduction, which seems to confirm the work of Short and Johnson (1936) although in their subjects the change was a reduction to normal from a previously elevated rate, while in this study the rate appears to be depressed from normal to below. The mean basal pulse rate for 114 Iowa State College women as calculated from the data of Young (1940) was 67, a value similar to that of Period I of this study and greater than Periods II and III.

The mean respiration rate for each of the three periods, 13-14 per minute, was only slightly less than 15, the mean for the 114 Iowa State College women, calculated from Young (1940).

The oral temperatures also reported in Table 15 appear to be essentially normal when compared to those of the larger study reported above in which the mean oral temperature was 97.7 degrees Fahrenheit with a standard deviation of 0.3.

In the estimation of the energy requirements for activity the importance of a base line has been discussed. The energy exchange under basal conditions and that found for the resting state two hours after the prescribed breakfast are presented for comparison in Table 16. In general, there was an increase in the metabolic rate, oxygen consumption and respiratory quotient in the metabolism determined two hours after breakfast.

The difference in the caloric expenditures, which appear to be fairly uniform for the three periods, may be summarized as follows:

1 test	was more than	10 per cent below basal				
13 tests	were within	" " "	of	"		
4 tests	were	11 to 20 per cent above basal				
3 tests	were	21 to 35	"	"	"	"
1 test	was more than	35	"	"	"	"

One can only speculate upon the cause of the increase or decrease of the base line determinations over the basal ones. Since the food ingested and the timing always was the same,a more uniform, specific dynamic effect would be expected although reports in the literature suggest considerable intra-individual variation. Activity during the two and one-half hours

Table 16. Basal vs. 2-hour Post-breakfast Energy Output for Use as a Base Line in Calculation of the Energy Cost of Activity

Period and subject		Date	Metabolism on Same Day as Exercise Test								Range of basal on other days cal./min.
			Basal			2 hr. after bkf.			Difference in calories, per cent of basal	Difference in RQ	
			Cal. per min.	O_2 per min.	RQ	Cal. per min.	O_2 per min.	RQ			
				liters			liters				
I	3	10/18	0.90	0.190	0.75	0.92	0.193	0.78	2	0.03	0.93-1.06
	5	3/21	0.96	0.197	0.85	1.15	0.232	0.93	20	0.08	0.97
	6	2/28	1.04	0.215	0.82	1.03	0.213	0.84	-1	0.02	1.11-1.30
	6	3/28	0.70	0.145	0.81	1.10	0.226	0.83	58	0.02	
	7	10/10	0.95	0.196	0.83	0.85	0.179	0.83	-10	0.00	0.95-1.00
	8	10/31	0.80	0.167	0.80	0.93	0.190	0.87	16	0.07	0.88-1.01
II	1	5/31	0.88	0.180	0.84	0.87	0.179	0.83	-1	-0.01	
	3	11/28	0.74	0.155	0.78	0.93	0.196	0.76	25	-0.02	
	3	3/20	0.89	0.181	0.91	0.83	0.169	0.87	-7	-0.04	
	4	12/ 6	0.96	0.202	0.76	1.02	0.209	0.87	6	0.11	0.90-1.03
	4	2/14	0.87	0.180	0.83	0.90	0.187	0.81	4	-0.02	
	5	6/20	0.88	0.182	0.80	0.94	0.196	0.79	7	-0.01	
	6	6/2	0.69	0.144	0.82	0.89	0.180	0.89	28	0.07	
	7	12/ 4	0.84	0.171	0.77	0.89	0.183	0.86	6	0.09	0.88-0.89
III	3	4/ 5	0.72	0.149	0.83	0.59	0.120	0.86	-18	0.03	
	4	3/ 7	0.90	0.188	0.79	0.92	0.192	0.79	2	0.00	
	4	8/ 8	0.89	0.187	0.77	1.17	0.238	0.89	32	0.12	
	5	7/18	0.86	0.179	0.83	0.93	0.192	0.85	8	0.02	
	5	8/15	0.90	0.187	0.83	1.01	0.207	0.87	12	0.04	
	6	7/11	0.85	0.177	0.78	0.86	0.176	0.85	1	0.07	
	7	3/ 4	0.88	0.168	0.81	1.03	0.211	0.87	17	0.06	
	8	2/ 5	0.72	0.151	0.76	0.70	0.146	0.83	-2	0.07	0.84 -0.89
Mean			0.855	0.177	0.807	0.930	0.192	0.844			

between tests consisted in going to church, reading, writing and a maximum walk of one-half mile, always followed by one-half hour of bed rest before testing. The increases noted could be attributed to stimulation from these factors or to increase or decrease of muscle tone or glandular activity.

Changes in the respiratory quotient appear to be more related to the dietary treatment since the respiratory quotient increases in every case during Periods I and III, while decreases were found in half of the determinations for Period II although they were minimal in amount.

Since the basal metabolic rate has been assumed by others to continue unchanged for short periods, the resting metabolism as determined here, preceding exercise, should be acceptable as a base line for evaluating the exercise which followed immediately and was so used.

Table 17 expresses the cost of activity in terms of the increases in the rate of oxygen consumption over that of the base line. Oxygen consumption rather than calories expended was chosen because it appeared to be less complicated by factors such as the carbon dioxide output. Even so, uncontrolled factors, other than the base line requirement, may contribute to the oxygen intake following exercise (Dill et al., 1933) and the post exercise stimulus to metabolism which it was desired to measure, probably was complicated by the presence of some oxygen debt. However, since the exercise was kept constant for the same subject, and since the experimental days were too far apart to provide training, both of which might have affected oxygen consumption, it was thought that the experimental situation was sufficiently uniform for each subject during the different dietary periods, that comparison of the periods on the basis

Table 17. Increase in Oxygen Consumption During the Recovery Period Following Exercise

Period and subject		Date	Oxygen consumption increase over base line	RQ following exercise	RQ basal	Time of air collection after exercise ceased
			cc./min.			min.
I	6	2/28	88	1.21	0.82	1- 8
	3	10/18	82	0.92	0.75	1-11
	6	3/28	78	0.94	0.81	1-11
	8	10/31	45	1.09	0.80	1- 6
	5	3/21	43	1.09	0.85	2-12
	4	11/ 1	11	0.85	——	1-13
	7	10/10	3	1.25	0.83	1-14
II	4	12/14	45	0.80	0.83	1-13
	7	12/ 4	43	0.84	0.77	6-17
	4	12/ 6	40	0.80	0.76	1-16
	3	11/28	40	0.86	0.78	1-13
	3	3/20	37	0.91	0.91	1-11
	6	6/ 2	34	0.99	0.82	1-11
	5	6/20	32	0.83	0.80	4-16
III	3	4/ 5	99	0.98	0.83	1-13
	8	2/ 5	68	1.11	0.76	1- 6
	5	7/18	52	1.06	0.83	3-15
	5	8/15	46	1.14	0.83	2-12
	6	7/11	39	0.97	0.78	1-13
	4	3/ 7	37	0.80	0.79	1-17
	7	3/ 4	5	0.95	0.81	1-12
		Subjects for whom results were obtained only during Period II				
II	1	5/31	61	0.94	0.84	1-13
	2	5/14	26	0.97	——	1-16

of oxygen consumption was valid. It will therefore be considered that the oxygen consumption during activity was the total result of the same stimulation in each period and the differences found with the changes in diet were due to physiological conditions. Evidence for the validity of the assumption may be seen in the uniformity of the oxygen increases of a single subject during the same dietary period on different days, as subject six in Period I, three and four in Period II, and five in Period III.

It was expected that at the termination of exercise the oxygen consumption would decrease sharply and then gradually approach the base line; the rate of decrease taking place more slowly with increases in intensity and duration of exercise and with decrease in efficiency of the subject. The respiratory quotient, at two to three minutes after the termination of exercise, was expected to rise to a peak as high as 2.0 followed by an irregular downward course most of which would lie within a range between 1.0 and the pre-exercise base line.

Since during the period studied both the oxygen consumption and the respiratory quotient may be expected to decrease with extension of time after the termination of exercise, lower values were expected in samples taken at longer times from the termination of the exercise.

Inspection of Table 17 shows that the changes in oxygen comsumption of the individuals from one dietary period to another were not uniform although it may be seen that the results in Periods I and III were similar for four of the six subjects. There were no marked changes in the results during the three dietary periods in subject five, and none in the two periods, I and III, for which there is data for subject eight.

When both oxygen consumption and the time of collection of the post-exercise sample are considered, increased oxygen consumption, inferring decreased efficiency, was found during Period II for subject seven while increased efficiency was found in subject three. Decreased efficiency during exercise was found in both Periods II and III in subject four, while for the same periods, increased efficiency was found for subject six. Thus, while the range of the figures for oxygen consumption were much narrower in Period II than in Periods I or III, there appeared to be no consistent effect on the efficiency of the individual in the performance of a standard exercise list.

The basal respiratory quotients appeared to be unchanged during the three dietary periods; the quotients of all of the exercise recovery periods were within the range of expected values following exercise.

An equally important factor of energy exchange and the one which has been controlled in this study is the energy intake. Decreased 24-hour basal metabolism was shown to take place during reduction. As soon as this takes place the energy requirements are less, the reduction diet becomes less effective and the rate of weight losses decreases. Also, the oxidation of fat produces large quantities of body water, which, if not immediately eliminated, would mask the losses of body fat which are taking place.

It was hoped that in Period I these complications would be avoided and that the self-selected diet would represent the obese subject's caloric requirements. The results of diet selection and concurrent weight changes are reported in Table 18. As may be seen, there were no weight gains, three small losses, and one significant loss. If the small losses can be disregarded the recorded intakes should be valid indications of the previous food consumption of these subjects, unless either or both of the factors mentioned above have complicated the experiment. There should be no possibility that oxidation of body fat was taking place but

Table 18. Caloric Intakes of Subjects during Period I

Subject	Mean calories	Days of Period I	Wt. change in Period I	Cal./kg. (actual wt.)	Cal./kg. (ideal wt.)
			pounds		
1	1227	30	-1.0	15.3	20.5
2	1238	18	0.0	19.3	21.8
3	1736	24	0.0	24.4	31.1
4	1834	19	-0.8	24.4	32.2
5	1780	30	-4.0	25.0	30.2
6	2000	29	-1.5	25.8	31.7
7	1900	17	0.0	23.4	27.9
8	1800	26	0.0	29.0	32.7

was not measured as weight loss because of water retention, since the periods of study in general were longer than 18 days (Newburgh, 1942). Examination of the weight curves of these subjects confirms this conclusion since the decreases in weight at the beginning of Period II, although greater than later in the treatment, are no greater than would be expected from the diet offered (Table 5, p. 24 and Table 7, p. 47). Subject seven is the only one whose weight losses during the first days of Period II suggest water retention in the pre-reduction period.

That the caloric intakes of all of these subjects were low may be seen by comparison with normal girls of college age. From the review of the literature it was concluded that 40 calories per kilogram of body weight was average for weight maintenance for this age group. Comparison of the subjects of this study, even on the basis of ideal weight shows that they were eating far less than the average. The possibility that by long-continued restriction of calories insufficient in amount to cause marked weight loss, the energy requirements of these subjects had been depressed prior to the experiment, is suggested by the findings of Coons and Schiefelbusch (1931).

If the depression in metabolism reported above can be assumed to be progressive it would explain the gradual flattening seen in all of the weight curves. The decrease in rate of weight loss began between 9 and 14 weeks after the beginning of the reduction diet except for subject eight in which the weight loss began to decrease after 5 weeks. The diets chosen appeared to be satisfactory for the desired rate of weight loss except in the case of subject eight. In subjects two and eight, more rapid reduction might have been desirable from the subject's point of view, however, considering the indications of immaturity shown by their body contours, a conservative regimen of weight reduction appeared to be indicated. The diet of subject two had not been reduced far below her record for Period I but the diet of subject eight had been reduced by 600 calories, furthermore, the accuracy of the calculation of the diet of the latter for Period I had been checked by a period on a diet of similar caloric content but composed of simpler foodstuffs. This case has been difficult to explain on a basis of the laws of conservation of energy.

In view of the above, the case of subject eight might be reviewed briefly. For six weeks weight reduction took place at the same rate as that for the other subjects. At this time the subject left for the Christmas vacation. Small weight losses immediately after the subject's return were explained on the basis of readjustment to the five-day diet.

However, the weight losses could not be induced again in spite of decreases in the diet. The basal metabolism record was decreased from that of Period I and the test in February was 100 calories below the caloric intake while the results in April and May were 100 calories above the intake, and appeared to be normal in comparison to the Iowa standard. An increase of 400 calories was made in the diet without change in weight during two weeks.

Finally, with the permission of the college physician, 1 grain of thyroid was given daily. Weight losses of a pound a week took place until the experiment had to be terminated, two weeks later.

The effect of the increased diet in Period III is not very well demonstrated by the short period of study which was possible. There were no weight gains observed, a rather surprising fact in view of the small weight losses taking place in some subjects previous to the dietary additions and the failure of the basal metabolism to rise again to the pre-reduction values.

C. Nitrogen and Calcium Exchange

The effect of weight reduction on nitrogen and calcium metabolism may be seen in the intakes, excretions and retentions of these substances during the three experimental periods of this study.

The values for nitrogen exchange for the individual subjects are presented in Table 19. The means of the nitrogen intakes for Periods I, II and III were 12.71, 10.78 and 15.97 grams per day, respectively. Mean values were calculated from all of the determinations except 5b and 8 of Period III in which the diets were essentially different from the others of that

Table 19. Nitrogen Retentions

Period I. Self-selected Maintenance Diets Before Reduction

	Subjects			
	5	6	7	8
	gm./day	gm./day	gm./day	gm./day
Food	8.47	8.40	8.22	10.10
Liquids	2.96	5.92	3.55	3.23
Urine	8.06	7.94	10.17	9.40
Feces	0.90	1.10	0.90	1.09
Total intake	11.43	14.32	11.77	13.33
Total output	8.96	9.04	11.07	10.49
Retention	2.47	5.28	0.70	2.84

Period II. Low-caloric Diets During Weight Reduction

	Subjects								
	1	2a	2b	3	4	5	6	7	8
	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day
Food	8.36	8.36	8.38	7.98	7.89	7.87	7.87	7.66	7.66
Liquids	2.82	2.63	2.18	2.97	2.89	2.96	3.00	3.09	3.14
Urine	9.53	8.92	11.11	11.17	8.66	10.55	8.93	10.60	10.02
Feces	0.87	0.40	0.86	0.63	0.66	0.69	0.61	0.66	0.52
Menstrual discharge						0.05			
Total intake	11.18	10.99	10.56	10.95	10.78	10.83	10.87	10.75	10.80
Total output	10.40	9.32	11.97	11.80	9.32	11.29	9.54	11.26	10.54
Retention	0.78	1.67	-1.41	-0.85	1.46	-0.46	1.33	-0.51	0.26

Table 19. continued

Period III. Controlled Maintenance Diets Following Reduction

	Subjects							
	3	4	5a	5b	5c	6	7	8
	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day
Food	13.20	12.13	13.34	13.82	8.03	13.82	12.49	7.99
Liquids	2.70	2.84	3.05	3.03	2.91	3.03	3.03	2.38
Urine	14.57	15.29	14.34	13.45	10.63	14.64	15.91	8.26
Feces	1.27	0.62	1.07	1.07*	1.20	0.84	0.87	0.55
Menstrual discharge								0.09
Total intake	15.90	14.97	16.39	16.85	10.94	16.85	15.52	10.37
Total output	15.84	15.91	15.41	14.52	11.83	15.48	16.78	8.91
Retention	0.06	-0.94	0.98	2.33	-0.89	1.37	-1.26	1.37

*Estimated.

period. As may be seen, the intakes in Periods I and III were more than 12 grams, the allowance recommended by the Food and Nutrition Board of the National Research Council; the intake in Period II was somewhat lower. However, the latter was well above 8 grams, the amount found by McKay et al. (1942) to provide nitrogen equilibrium in a majority of the college age women studied by them.

The calcium intakes and outputs may be found in Table 20. The means of the intakes for Periods I, II and III were 1.397, 1.121 and 1.217 grams per day, respectively. The mean of Period I was skewed by subject six who drank an unusual quantity of milk. The mean intake for the other subjects during this period was 1.274 grams per day. The mean calcium intake for each of the periods was greater than the daily allowance of 1.0 grams, recommended by the National Research Council, and endorsed by the authors of the McKay study.

The figures of the most importance in the interpretation of the results of this study are the retentions of nitrogen and calcium. These might be evaluated by a comparison of the records of the individuals of of the group during the different dietary treatments. However, since the intakes of this study have not been the same for each dietary period, the results have been compared to those of McKay et al. (1942) in which diets of similar nitrogen and calcium intake were used (Table 21). The McKay study included 110 subjects eating self-selected diets and nine subjects consuming controlled diets at different levels of milk intake. The constituents of the controlled diets of the McKay study and this study were the same except for calories and total number of servings of fruits and vegetables.

Table 20. Calcium Retentions

Period I. Self-selected Maintenance Diets Before Reduction

	Subjects			
	5	6	7	8
	gm./day	gm./day	gm./day	gm./day
Food	0.394	0.347	0.462	0.422
Liquids	0.836	1.483	0.831	0.813
Urine	0.207	0.126	0.201	0.211
Feces	0.735	1.655	1.030	0.849
Total intake	1.230	1.830	1.293	1.235
Total output	0.942	1.781	1.231	1.060
Retention	0.288	0.049	0.062	0.175

Period II. Low-caloric Diets During Weight Reduction

	Subjects								
	1	2a	2b	3	4	5	6	7	8
	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day
Food	0.329	0.330	0.334	0.368	0.305	0.398	0.398	0.306	0.306
Liquids	0.594	0.634	0.623	0.873	0.782	0.825	0.778	0.775	0.771
Urine	0.119	0.135	0.100	0.145	0.200	0.176	0.229	0.202	0.181
Feces	0.747	0.464	0.670	0.935	0.869	0.894	1.034	0.887	0.832
Total intake	0.923	0.964	0.957	1.241	1.087	1.223	1.176	1.081	1.077
Total output	0.866	0.599	0.770	1.080	1.069	1.070	1.263	1.089	1.013
Retention	0.057	0.365	0.187	0.161	0.018	0.153	-0.087	-0.008	0.064

Table 20. continued

Period III. Controlled Maintenance Diets Following Reduction

	Subjects						
	3	4	5a	5c	6	7	8
	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day	gm./day
Food	0.470	0.324	0.471	0.330	0.429	0.426	0.256
Liquids	0.755	0.727	0.737	0.724	0.835	0.912	0.770
Urine	0.249	0.280	0.327	0.277	0.175	0.304	0.294
Feces	1.116	0.850	0.848	0.924	1.039	1.041	0.464
Total intake	1.225	1.051	1.208	1.054	1.264	1.339	1.026
Total output	1.365	1.131	1.175	1.201	1.214	1.345	0.758
Retention	-0.140	-0.080	0.033	-0.147	0.050	-0.006	0.268

Table 21. Nitrogen and Calcium Retentions with the Same Ranges of Intakes for the Three Periods of This Study and the McKay Study

Constituent of diet	McKay diet	Number of Subjects		Mean Intake		Mean Retention		Subjects Retaining	
		This study	McKay	This study	McKay	This study	McKay	This study	McKay
Period I									
Nitrogen gms.	self-selected	4	32	12.710	12.260	2.820	1.390	100	91
Calcium gms.	self-selected	4	4	1.397	1.385	0.144	0.136	100	100
								per cent	
Period II									
Nitrogen gms.	controlled	8	13	10.870	10.870	0.270	0.740	62	85
Calcium gms.	controlled	8	13	1.121	1.120	0.079	0.098	75	100
Period III									
Nitrogen gms.	self-selected	5	6	15.970	15.460	0.180	2.740	50	100
Calcium gms.	controlled	5	40	1.217	1.176	-0.029	0.104	40	100

During Period I the mean nitrogen retentions were greater in this study than in the McKay study. Although the mean nitrogen retention of this study was skewed upward by subject six who drank the large amounts of milk, when subject six was omitted from the average, the mean for the other three subjects still was greater than that of the McKay study. The mean calcium retentions were not influenced because subject six had the lowest calcium retention of the group, in spite of her large intake. Although the experimental data for this period are limited, they should establish these subjects as normal in respect to nitrogen and calcium retentions with the possible exception of calcium retention in subject six.

The retentions reported in this study must be viewed conservatively since only one balance was carried out for each period for each subject except in the case of subject two and subject five. In subject two there was nitrogen retention in one balance period and loss in the other, in subject five there were nitrogen retentions in both periods of observation. Keeton and Dixon reported that even with diets of 90 grams of protein per day, occasional negative balances occurred in some subjects. However, when the trend of the whole group of subjects was in the direction of decreased nitrogen retentions as occurred in Period II, the results would appear to be significant.

The calcium retentions in Period II of this study appear to be comparable with those reported by McKay <u>et al</u>. A comparatively lower calcium retention was anticipated because of possible loss of calcium if an acidosis had been produced due to high rate of fat oxidation during reduction. However, the carbohydrate intake, 125 to 150 grams per day, should have been high enough to have prevented this, and the absence of acidosis was confirmed by the determination of ketones in the urine which always was less than 100 milligrams per 24 hours, a figure well within the normal range (Shaffer, 1922).

Several possible explanations for the comparatively lower nitrogen retentions of Period II can be made. The most obvious is the competition for calories. It is possible that some protein in preference to body fat was used for energy because of greater ease of mobility. From the literature it was seen that nitrogen losses during reduction frequently were decreased to an insignificant level after a few weeks but in some cases persisted intermittently and in other cases regularly with nitrogen intakes of 14 gm. per day. The importance of the carbohydrate content of the diet, especially, was emphasized by Jansen (1917) but in this study, the aarbohydrate intake was relatively liberal.

An explanation which may be offered involves the results of the study of the phosphorus intake and output for the same subjects which were reported by Herman (1944). Marked increases of excretion of phosphorus in the feces were found during Periods II and III. Since phosphorus was not being absorbed it may be possible that nitrogen was not being retained for lack of phosphorus with which it frequently is associated in the body.

The retentions of Period III were most unexpected. Both in the amount retained and in the number of subjects retaining, the results of Period III were far less satisfactory with respect to both nitrogen and calcium than those of the McKay study at similar intakes of these nutrients. The major changes in the diet from Period II to Period III were the addition of meat and eggs, increasing the nitrogen per day from 11 to 16 grams , and the addition of one serving of fruit or vegetable. It is difficult to explain poorer retention of nitrogen since, in young women of normal weight, the balances of this nutrient were highly correlated with intake.

There also had been no real reason to expect a difference in the use of calcium in Period III. However, the mean retention of Period II changed to a loss in Period III and the number of subjects retaining decreased from 100 to 40 per cent.

In an effort to explain the findings of Period III, the form of excretion was studied. Table 22 presents the means of the determinations for nitrogen and calcium of the feces and urine during Periods II and III for subjects three, four, six and seven, for whom the intakes of nitrogen and calcium were comparable for both periods.

As may be seen, the increased nitrogen of the diet was excreted almost quantatively in the urine, the mean increase in intake being 5.13 grams and that in the urinary output, 4.88 grams.

The explanation concerning the phosphorus relationship, offered above, would appear to be the chief explanation for the even poorer nitrogen retentions of Period III which accompanied poorer retention of phosphorus, since the use of nitrogen for calories did not seem to be a factor here, as subjects five, six and seven were losing weight but three and four were not.

The increases in calcium excretion may be seen (Table 22) to be divided between the urine and feces. The increase in the feces was small and might be attributed to the bulk in the diet which Herman (1944) calculated and found to have increased from Period II to Period III. In four out of the five subjects whose intake to excretion relationships were studied (Table 22) the calcium in the urine increased from Period II to III. It is possible that the increase in calcium in the urine during this period might be attributed, as was the nitrogen, to failure of sufficient absorption of phosphorus for the formation of compounds which would be retained within the body.

Certain observations of the general physical status of the subjects were made at regular intervals during the experiment. Hemoglobin, cell

Table 22. Nitrogen and Calcium Excretions in Urine and Feces of Five Subjects of Comparable Nitrogen and Calcium Intakes during Periods II and III

		Nitrogen	Calcium
		gm.	gm.
Period II	Urine	9.98	0.190
	Feces	0.65	0.924
	Total output	10.63	1.114
	Total intake	10.84	1.162
Period III	Urine	14.86	0.267
	Feces	0.93	0.979
	Total output	15.79	1.246
	Total intake	15.97	1.217

volume, erythrocyte and leucocyte counts, and plasma vitamin C determinations have been reported by Herman (1944). Although all values were within normal ranges for this locality, decreases in the erythrocyte count took place during weight reduction in certain subjects.

From the point of view of the lay person the dietary regimen was highly satisfactory. The subjects lost the excessive fat pads with the exception of the fat of the legs which was described above as resembling lipedema. The failure to remove this condition suggests that it was not an uncomplicated fat accumulation.

The subjects were in excellent health throughout the experiments. Subject two had one severe upper respiratory infection, and subject four had a mild one. Other than that there were no illnesses during the five or seven months of treatment.

Menstruation was interrupted for a period of two months at the end of the experiment in subjects four, six and subject eight. No direct explanation for this can be given except that from both the energy and balance studies it would appear that the lowering of the basal metabolism might have been a factor, at least in subject eight.

The teeth of the subjects did not seem to be affected during the experiment except for the development of one cavity in subject eight. However, this subject had been in positive calcium balance at each time studied.

Skin eruptions cleared in the two subjects in which they had been present at the beginning of the experiment. The probable improvement in the nutritive value of the diet from the ones previously ingested was believed to be a factor in the improved condition of the skin.

The dietary habits of the subjects previous to the experiment had not been thoroughly investigated, however, comments on learning to like foods during the course of the experiment gave some indication of the past habits. Subject three had not drunk milk since childhood but it became one of her favorite foods. The number of foods included in the diet was not as extensive as it would have been if education of the subject's appetite had been the primary objective of the experiment. However, almost every subject encountered certain foods which were not favorites but nevertheless had to be eaten, and in almost all cases it was done pleasantly.

The long time results of treatment were investigated by a brief questionnaire sent to each subject from 9 to 24 months after the end of the experiment. The present weight, as reported, has been presented as the last point on the weight graphs. Three of the seven subjects had gained weight but only one to her earlier weight level. Of the three whose weight had not changed, two admitted having to omit desserts from their diets but the restriction was not annoying to them. The third was subject five who was the only subject to have marked weight loss during Periods I and III and it is possible that her energy requirements were higher than the others. Table 23 summarizes the information obtained from

Table 23. Caloric Intakes and Weight Changes since Leaving the Experiment

Subject	Calories	Weight change	Time since leaving experiment
		pounds	months
1	1900	+ 45	24
2	2400	0	24
3	1500	+ 9	15
4	1400	0	15
5	1500	0	10
6	2700	+ 13	9

the questionnaire.

Further details from the reports which the subjects have made subsequent to ending the experiment will be found in the protocols in the appendix.

V. SUMMARY

The effect of weight reduction upon the energy, nitrogen and calcium requirements of eight college age women has been studied. A period of self-selected diet preceded the weight reduction period, and a period of increased, controlled diet followed it. The diet for reduction was a liberal, controlled one, calculated to provide all of the nutritive requirements for this age group, except calories, in accepted amounts. Energy exchange was determined by a series of tests of oxygen consumption taken under basal conditions and before and after exercise. Nitrogen and calcium exchange were determined by the balance technique.

It was found that before reduction basal metabolism was within 12 per cent of the average determined for college age women of this locality; that it decreased during reduction in all cases except one; and that it remained depressed during the period of increased caloric intake which followed; while the basal respiratory quotient remained unchanged. The reduction routine, as such, appeared to have no consistent effect on the efficiency during prescribed exercise.

Nitrogen and calcium retentions during the self-selected dietary period were better than those reported by McKay (1942) for college age women, but during reduction the nitrogen retentions, decreased in the individual and in comparison with McKay's subjects at the same intake. In the third period, during which the diets of the two studies were the same except for fat and carbohydrate calories and bulk, both nitrogen and calcium retentions were less satisfactory than in those of the McKay

study. Two possible explanations for the decreased nitrogen retentions during weight reduction may be (1) competition for calories and (2) failure of absorption of sufficient phosphorus to combine with the nitrogen. The latter explanation is the only one which would account for the increased losses of nutrients in the third period when weight changes were minimal.

It also is possible to explain the increased urinary calcium during the period of increased diet following reduction as due to a lack of phosphorus for the formation of calcium-phosphorus compounds. The increased calcium of the feces might be attributed to decreased absorption resulting from the relatively high bulk which was estimated to be present in the diet. The increased losses of calcium in both the urine and the stool resulted in negative retentions in the post-reduction maintenance period.

From the clinical point of view, the results of reduction were satisfactory; excess fat pads were eliminated and the subjects were well both during and following the reduction routine.

Half of the subjects who have been followed for a year or more after reduction have maintained their weight at the reduced level; one subject regained her former weight and two subjects soon after leaving the dietary table, gained 9 and 13 pounds, respectively, but were maintaining the increased weight without further gains.

VI. CONCLUSIONS

1. Weight reduction of obese women of college age to average weight for height can be accomplished at the rate of 1.1 to 2.0 pounds per week by the use of controlled diets calculated to provide 1000 to 1200 calories and liberal amounts of all of the other known essential nutrients.
2. During reduction the general health of the subject may appear to be exceptionally good but the basal metabolism may be expected to be depressed below the average for women of this age.
3. The nitrogen retentions may not be expected to be as great as they are in non-reducing subjects eating essentially the same diet except for calories and the number of servings of fruits and vegetables.

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IX. APPENDIX

A. Protocols

For each subject a calendar of the individual experiment, a weekly record of weights, and a brief history of the subject is presented.

CALENDAR OF THE EXPERIMENT

Subject #1

Date	Notes
11/17/41 - 12/15/42	Self-selected diet
12/16/41 - 1/10/42	Vacation, no food record
1/11/42	Energy metabolism series
11/17/41 - 1/16/42	Thyroid medication by doctor's prescription
1/11/42 - 5/30/42	Reduction diet
1/23	Hemoglobin
1/27	Vitamin C
3/ 6	Hemoglobin
3/18	Hemoglobin
4/15	Hemoglobin & vitamin C
4/28 - 4/ 4	Nitrogen and calcium balance
5/31	Energy metabolism series
5/30/40 - - -	Self-selected diet, no food record

Weekly Weight Record

Date	Pounds	Date	Pounds
11/17/41	177	3/14/42	153 1/2
11/25	175	3/21	152
12/ 2	176	3/28	150
12/ 9	174	4/ 4	149
12/16	176	4/11	146
1/10/42	174	4/18	145
1/17	171	4/25	144
1/24	168	5/ 2	142 1/2
1/31	166 1/2	5/ 9	141
2/ 7	164 1/2	5/16	140
2/14	163	5/23	139
2/21	160	5/30	138
2/28	157 1/2		
3/ 7	155 3/4	4/ 1/44	185

Subject one, a senior in college, presented herself for weight reduction to make a more attractive appearance in her search for employment. The excess weight was accentuated by narrow shoulders, broad hips and a swaying gait. The face was slightly marred with acne but the teeth were in good condition with few fillings present. The subject had been obese since early childhood and had no idea of the cause of her original abnormality of weight. There were three sisters, living and well; the one brother had died of appendicitis. The age of the parents, father, 68, and mother, 59, might suggest a parent-child emotional strain over the food situation had been present. The subject had never menstruated but she stated that late onset of menstruation was characteristic of the women of her family, and, since the obesity dated from childhood it was believed not necessarily related to the amenorrhea. At the beginning of the experiment the subject was taking thyroid which had previously been prescribed by a physician. No thyroid was taken after January 17, 1942.

At the termination of the experiment the main objectives appeared to have been attained. The fat pads of the scapular region were gone, loss of fat from the legs permitted a normal gait, and the appearance of the subject was vastly improved.

During the next year in which she was happily adjusted to her employment the subject maintained her reduced weight, but during the second year, an unhappy one, excesses in eating were admitted and the weight increased to the pre-reduction level. The typical menu which was submitted included such items as "pie a la mode" and "chocolates between meals". The morale developed during reduction seemed completely broken.

CALENDAR OF THE EXPERIMENT

Subject #2

Date	Notes
12/ 1/41 - 12/18/42	Self-selected diet
12/19 - 1/10	Vacation, no food record
1/11/42 - 5/18/42	Reduction diet
2/17 - 2/23	Nitrogen and calcium balance
3/ 6	Hemoglobin
3/20	Hemoglobin & vitamin C
4/15	Hemoglobin
4/28 - 4/ 4	Nitrogen and calcium balance
5/14	Energy metabolism series
5/19/42 - 5/31/42	Increased diet
6/ 1/42 - - -	Self-selected diet, no food record

Weekly Weight Record

Date	Pounds	Date	Pounds
12/ 1/41	141	3/22/42	127
12/ 8	141	3/29	126
12/15	141	4/ 5	125 1/2
12/18	141	4/12	124 1/2
1/10/42	139 1/4	4/19	123
1/18	138	4/26	122
1/25	135 1/2	5/ 3	120
2/ 1	134 1/2	5/10	119 1/2
2/ 8	134 1/4	5/17	120
2/15	132 1/2	5/24	119 3/4
2/22	130	5/31	120
3/ 1	129		
3/ 8	128 1/2	4/ 1/44	123
3/15	127		

Subject two considered herself too chubby for her best social interests. She was well proportioned and only mildly overweight but was typical of many college girls who follow dietary regimens for weight reduction. The skin was clear but the teeth were in poor condition, contained many fillings and several teeth had been extracted. Menstruation was normal, had begun at 13 years of age. The only significant finding in the history was frequency of upper respiratory infections. The mother and father were in their forties, living and well; one brother was living and well. The subject had no idea of the cause of obesity which had been present since early childhood but poor nutritional habits might be suggested from the dental condition and respiratory infections.

Since leaving the experiment the weight remained the same and the subject was in good health except for minor colds and one case of influenza. From the menu submitted,the calculated caloric intake, while appearing relatively high for this subject, was explained by a 12-hour working day. The menu appeared well chosen and included few concentrated, high caloric foods.

CALENDAR OF THE EXPERIMENT

Subject #3

Date	Notes
9/28/42 - 10/21/42	Self-selected diet
10/ 1	Basal metabolism
10/ 9	Hemoglobin
10/ 9	Basal metabolism
10/18	Energy metabolism series
10/22/42 - 12/ 8/42	Reduction diet
11/28	Energy metabolism series
12/ 9 - 1/ 3/43	Vacation, no food record
1/26/43 - 2/ 1	Nitrogen and calcium balance
1/ 4 - 3/21	Reduction diet
2/23	Hemoglobin & vitamin C
3/20	Energy metabolism series
3/22/43 - 4/ 3/43	Increased diet
3/26 - 4/ 1	Nitrogen and calcium balance
4/ 4	Energy metabolism series
4/ 4/43	Self-selected diet, no food record

Weekly Weight Record

Date	Pounds	Date	Pounds
9/28/42	156	2/ 3/43	137
10/21	156	2/10	135
10/28	153	2/17	133
11/ 4	150	2/24	131 3/4
11/11	148	3/ 3	130 3/4
11/18	147	3/10	131
11/25	145	3/17	133
12/ 2	143	3/20	133
12/ 9	141	3/24	133
1/ 3/43	143	3/31	133
1/ 6	143	4/ 4	133
1/13	141 1/2		
1/20	140	4/ 4/44	143
1/27	138		

Subject <u>three</u> appeared very solidly built and showed good muscular development. Her moderate excess of weight, although rather evenly distributed, was accentuated by a concentration from knee to ankle. The skin was clear and teeth in excellent condition. Cod liver oil and high vitamin food had been included in the childhood diet. Menstruation began at ten and one-half years of age and continued normally. Mild hypothyroidism, reported in the mother, had been relieved by medication, but this subject stated that in her own case thyroid therapy had not changed her weight. An excellent student, the intellectual aptitude of the subject was markedly precocious. Obese since infancy, this subject's development appeared to follow the pattern described by Bruch (1939a).

Discouraged because weight reduction had not reduced the size of her legs in proportion to the other weight losses, subject three left the experiment in a rather defiant mood which resulted in regain of part of the weight lost. Since that time the diet has been restricted, especially between meals without change of weight. Health has been excellent since weight reduction.

CALENDAR OF THE EXPERIMENT

Subject #4

Date	Notes
10/21/42 - 11/ 8/42	Self-selected diet
10/28	Basal metabolism
10/30	Basal metabolism
11/ 1	Energy metabolism series
11/ 9/42 - 12/15/42	Reduction diet
11/19	Basal metabolism
11/27	Basal metabolism
12/ 3	Basal metabolism
12/ 6	Energy metabolism series
12/16 - 1/ 5/43	Vacation, no food record
1/ 6/43 - 2/23	Reduction diet
1/27 - 2/ 2	Nitrogen and calcium balance
2/ 3	Basal metabolism
2/10	Basal metabolism
2/14	Energy metabolism series
2/24/43 - 3/14/43	Increased diet
2/25	Hemoglobin & vitamin C
3/ 7	Energy metabolism series
3/ 8 - 3/14	Nitrogen and calcium balance
3/14 - - -	Self-selected diet, no food record
8/ 8/43	Energy metabolism series

Weekly Weight Record

Date	Pounds	Date	Pounds
10/21/42	165 1/2	2/ 3/43	138
11/ 9	164 2/3	2/10	136 1/4
11/11	164	2/17	136
11/18	162 1/2	2/24	135
11/25	160	3/ 3	134 1/4
12/ 2	157	3/10	134
12/ 9	155 1/4	3/14	133 3/4
12/16	155		
1/ 6/43	146 1/2	8/ 8/43	132
1/13	144		
1/20	142	4/ 1/44	132 1/2
1/27	139 1/2		

Subject four had a large bony framework which fairly well concealed the excess weight distributed in the hips, waist and large pendant breasts. Only fair muscular structure was indicated from tests of strength. The skin was clear, the current mouth condition good but there were many fillings present in the teeth. Menstruation was uneventful and regular, and began at the 13th year. The subject, daughter of a prosperous physician, reported ample early feeding including cod liver oil. Obese since early childhood, the subject had always been favored by the parents because of a congenital hip defect which although essentially corrected had required extensive hospitalization of the subject between one and three years of age and limited activities for some time after that. The condition of the hip was so improved by the weight loss during the experiment that a second operation, which had been planned for the near future, was pronounced unnecessary by the surgeon in charge.

Weight has been maintained at the reduced amount only by a policy of "no salad dressings, no butter except on toast, milk for a filler if the dormitory menu is high caloric, and black coffee, only, between meals." Excesses in eating, having brought about temporary weight gains, have been abandoned.

CALENDAR OF THE EXPERIMENT

Subject #5

Date		Notes
2/21/43 -	3/23/43	Self-selected diet
2/21		Energy metabolism series and basal metabolism
3/11		Hemoglobin and vitamin C
3/ 8 -	3/14	Nitrogen and calcium balance
3/21		Energy metabolism series
3/24/43 -	6/28/43	Reduction diet
4/ 1 -	4/ 4	Vacation
6/18 -	6/24	Nitrogen and calcium balance
6/20		Energy metabolism series
6/29/43 -	8/20/43	Increased diet
7/ 4 -	7/10	Nitrogen and calcium balance
7/18		Energy metabolism series
7/19 -	7/22	Nitrogen and calcium balance
7/13/43 -	7/16/43	Nitrogen and calcium balance
8/15		Energy metabolism series
8/13		Final examination
8/20/43		Self-selected diet, no food record

Weekly Weight Record

Date	Pounds	Date	Pounds
2/21/43	169	6/9/43	141 1/2
3/ 8	171	6/16	140 1/2
3/24	165	6/23	139
3/31	161	6/29	138
4/ 7	161	7/ 7	138
4/14	157 1/2	7/14	134 1/2
4/21	155 1/2	7/21	133 3/4
4/28	153 3/4	7/28	136
5/ 5	152	8/ 4	136
5/12	150	8/11	134 1/2
5/19	148	8/19	129
5/26	145 1/2		
6/ 2	142 1/2	4/ 1/44	135

Subject <u>five</u> presented the appearance of a female of greater maturity than her stated age. The skin was clear and beautiful but the teeth contained many fillings and several had been extracted. Musculature, both by appearance and strength test, seemed only moderately developed. The distribution of excess fat was uniform. Menstruation had begun at 12 years of age and had been regular and fairly profuse. The subject was the middle child of three, all living and well. Obesity had been present since infancy. The only suggestion which the history gave of the cause of obesity was the subject's background; she was reared on a highly successful midwestern farm where the parents took pride in the growth of their children as well as their stock.

Weight reduction brought about changes in body proportions of subject five resulting in a more youthful appearance. Since the termination of the experiment, the subject states that all of her desires for food have been satisfied without weight gain, however, inspection of the menu submitted indicates that the subject's desires for food, although including butter, ice cream, and coco colas, are conservative in quantity.

CALENDAR OF THE EXPERIMENT

Subject #6

Date		Notes
3/ 8/43 -	4/ 4/43	Self-selected diet
2/28		Energy metabolism series
3/ 3		Basal metabolism
3/22 -	3/28	Nitrogen and calcium balance
3/28		Energy metabolism series
4/ 5/43 -	6/29/43	Reduction diet
4/ 8		Hemoglobin & vitamin C
5/24		10 gm. butter added daily
6/ 2		Energy metabolism series
6/18 - -	6/24	Nitrogen and calcium balance
6/30/43 -	7/13/43	Increased diet
7/ 4 -	7/10	Nitrogen and calcium balance
7/11		Energy metabolism series
7/11/43 - - -		Self-selected diet, no food record

Weekly Weight Record

Date	Pounds	Date	Pounds
3/ 1/43	171	5/31/43	154 1/2
3/ 8	171	6/ 7	154 1/2
4/ 5	169 1/2	6/14	152 1/2
4/12	165	6/21	150 1/2
4/19	162 1/2	6/28	148 1/2
4/26	163 1/2	7/ 5	148 1/2
5/ 3	161 1/2	7/12	144 3/4
5/10	159 1/2		
5/17	157 1/2	4/ 1/44	158
5/24	157 1/2		

Subject six, although of approximately the same height and weight as Subject five, presented a markedly different appearance. In spite of broad shoulders, most of the excess weight was concentrated below the waist. Excellent development of musculature was evidenced by tests of strength. Evidence of a mild degree of acne was present and increasing at the time when the experiment was begun. The teeth contained many fillings, two were dead, and the occlusion was poor. Subject six was the youngest of four children, one other living and well, two of whom had been killed by accident. The mother and father, about 60 years of age, were living and well. Obesity in the subject began at age 16 following a prolonged upper respiratory infection which resulted in a loss of eight pounds. Attempts to stimulate the subject's appetite resulted in regain of the weight lost and additional gain. During the following winter the subject gained 32 pounds, part of which was lost during the summer on the farm. During the next winter 17 pounds had been gained up to the time when the experimental reduction was begun.

The results of weight reduction were somewhat disappointing. The losses were so largely confined to the upper part of the body that reduction was stopped before optimal weight was reached. Weight gain since the experiment was partly attributed to irregular between meal eating while working temporarily on a night shift. The general health of subject six has been excellent.

CALENDAR OF THE EXPERIMENT

Subject #7

Date	Notes
9/28/43 - 10/15/43	Self-selected diet
10/ 4	Basal metabolism
10/ 8	Basal metabolism
10/ 9 - 10/15	Nitrogen and calcium balance
10/10	Energy metabolism series
10/16	Hemoglobin & vitamin C
10/16/43 - 12/16/43	Reduction diet
11/ 5	Basal metabolism
11/29 - 12/ 5	Nitrogen and calcium balance
12/ 4	Energy metabolism series
12/17 - 1/ 5/44	Vacation, no food record
1/ 6/44 - 2/18	Reduction diet
2/19/44 - 3/14/44	Increased diet
2/29 - 3/ 6	Nitrogen and calcium balance
3/ 4	Energy metabolism series
3/ 2	Hemoglobin & vitamin C
3/14/44 - - -	Self-selected diet, no food record

Weekly Weight Record

Date	Pounds	Date	Pounds
9/28/43	179	2/ 8/44	155
10/ 5	179	2/15	153
10/12	178 1/2	2/22	153
10/16	178 1/4	2/29	154
10/19	175	3/ 7	151
10/26	172	3/ 9	152
11/ 2	170	3/10	153
11/ 9	168	3/11	153
11/16	166 1/2	3/12	153
11/23	164	3/13	153
12/ 7	161	3/14	153
12/14	160	3/15	154
1/ 7	162	3/16	153 1/2
1/18	158		
1/25	157	6/ 1/44	152
2/ 1	156		

Subject seven was a tall girl with well developed bone and muscle structure which was enhanced by perfect carriage. Heavy bone and muscle structure as well as excess fat was suggested. The skin was clear. The teeth were in excellent condition as there were only two fillings and those of recent date. The subject was the second of five children, all living and well. The parents, in their early fifties, were living and well. Reared on an Iowa farm, the subject had indulged in a great variety of outdoor exercises and had been supplied with an abundance of food. Always above average in height but never obviously obese, the subject was the frequent recipient of health prizes. Menstruation began at 12 years of age, was regular and moderate in duration and amount.

CALENDAR OF THE EXPERIMENT

Subject #8

Date	Notes
10/12/43	Controlled maintenance diet
10/14	Basal metabolism
10/31	Energy metabolism series
10/31 - 11/ 6/43	Nitrogen and calcium balance
11/ 7/43 - 12/14/43	Reduction diet
11/29 - 12/ 5	Nitrogen and calcium balance
12/14 - 1/11/44	Vacation, no food record
1/12/44 - 5/31	Reduction diet
1/28	Hemoglobin & vitamin C
2/ 5	Energy metabolism series
2/29	Decreased diet - 50 calories
3/ 8	Decreased diet - 50 calories
3/12 - 3/14	Basal metabolism
3/24	Decreased diet - 75 calories
5/16	Basal metabolism
5/17 - 5/24	1 gr. thyroid
5/24 - 5/31	1 1/2 gr. thyroid
6/ 1	1 gr. thyroid

Weekly Weight Record

Date	Pounds	Date	Pounds
10/12/43	137	2/15/44	125
10/19	137	2/22	124
10/26	137	2/29	124
11/ 2	137	3/ 7	125
11/ 6	137	3/14	124
11/ 9	135 1/2	3/21	124
11/16	134	3/28	124
11/23	132	4/ 4	124 1/2
11/30	130	4/11	124 1/4
12/ 7	128	4/18	124 1/4
12/14	127	4/25	124 1/4
1/11/44	127	4/30	124 1/4
1/18	126	5/17	124 1/4
1/25	126	5/24	123 1/4
2/ 1	125 1/2	6/ 1	122
2/ 8	125 1/2		

Subject eight had a small, chubby, juvenile figure. Musculature was moderately well developed, skin clear, and teeth excellent. The subject had always been slightly chubby but only recently become overweight to the present extent. The father, of Scandanavian descent, was a large man; the mother, of English extraction, had a small trim figure which, however, was maintained only by some restriction of diet. The one brother was of the father's build, two sisters and the subject were very like the mother. Report of early feeding specified the use of cod liver oil and an abundant and well chosen diet. Menstruation began at the age of 12 and was regular and moderate at all times except for two months during the previous summer when the subject was unusually active and losing weight. During the first year of college, although the subject continued to eat at home, she noted an increased appetite which she satisfied completely, believing energy expenditure had been equally increased as a result of additional walking. A gain of 17 pounds during the year prompted the subject to apply for weight reduction.

B. 5-Day Menus for Weight Reduction

Breakfasts

	Wt. in gms.
Fruit:	
Grapefruit juice or	100
Orange juice	100
Cereal:	
Oatmeal or	100
Whole wheat prepared cereal	20
Whole wheat bread (may be toasted)	12
Milk	180

Fruit juices are alternated when both are available.

B. 5-Day Menus for Weight Reduction

Lunch	Weight in grams	Dinner	Weight in grams
Bacon (cooked)	20	Meat	80
Tomato (raw)	40	Salad	
Whole wheat bread	60	Cabbage	50
Celery curls	30	Celery	30
Peaches	75	Mashed potato	100
Milk	200	Carrots (cooked)	80
		Custard	
		Milk	120
		Egg	1/2

Hamburger	50	Meat	70
Bun	40	Baked Potato	100
Lettuce	30	Green Beans	70
Dill Pickle	20	Raw carrots	10
Peas	70	Celery curls	10
Orange	100	Baked apple	100
Milk	200	Milk	200

Fish salad			
Fish	30	Tomato juice	100
Egg	1	Meat	80
Celery and lettuce	90	Potato	100
Pickled Beets	20	Baked squash	100
Tomatoes (raw)	80	Pineapple	70
Raw carrot	10	Milk	200
Whole wheat bread	30		
Apricots	75		
Milk	200		

Meat	50	Meat	70
Tomato concentrate	30	Potato	100
Peas	90	Beets	70
Lettuce	60	Raw rutabaga	20
Raw apple	100	Whole wheat bread	15
Whole wheat bread	30	Milk	200
Milk	200	Custard	
		Milk	120
		Egg	1/2

Scrambled egg	1	Fish	60
Potato	100	Potato	100
Lettuce	20	Stewed tomato	70
Pear	100	Cabbage (raw)	50
Milk	200	Mixed fruit	100
		Whole wheat bread	15
		Milk	200

B-383 C. Form for Recording the Metabolism Tests

Subject Date

Problem

Barometer ________ mm.		Casom factor	________
Temp. gasom. ________ °C.		Casom difference	________
		Total expired air at lab conditions	________
Casom Volume	(End ________ cm.	Correction factor	________
	(Start ________ cm.	Corrected volume expired air	________
	(Diff. ________ cm.	Vol. expired air/min.	________
Duration of test ________ min.		O_2 absorbed/min.	________
CO_2 expired ________ %		O_2 absorbed/hr.	________
CO_2 inspired ________ %		Cal. value O_2 at observed R/Q	________
CO_2 produced ________ %		Cal./hr. (total)	________
O_2, inspired, corr. ________ %		Surface area subject	________
O_2 expired ________ %		Cal./hr./sq. M. observed	________
O_2 absorbed ________ %		Cal./hr./sq. M. normal	________
CO_2 produced ________ %			
O_2 absorbed ________ %		Difference	
R/Q ________		Deviation from normal basal $\frac{\text{Diff.}}{\text{Normal}}$	________

Gas Analysis by ________

	Vol. meas.	Burette corr.	Final vol.
Total	____	____	____
After CO_2 absor.	____	____	____
Diff. CO_2	____	____	____
After O_2 absor.	____	____	____
Diff. O_2	____	____	____

$\frac{\text{Diff. } CO_2}{\text{Vol. sample}}$ ________ % CO_2 ________

$\frac{\text{Diff. } O_2}{\text{Vol. sample}}$ ________ % O_2 ________

Gas Analysis by ________

	Vol. meas.	Burette corr.	Final vol.
Total	____	____	____
After CO_2 absor.	____	____	____
Diff. CO_2	____	____	____
After O_2 absor.	____	____	____
Diff. O_2	____	____	____

$\frac{\text{Diff. } CO_2}{\text{Vol. sample}}$ ________ % CO_2 ________

$\frac{\text{Diff. } O_2}{\text{Vol. sample}}$ ________ % O_2 ________