COMPARISON OF THREE METHODS OF DETERMINING THE ENERGY VALUE OF DIETS

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INTRODUCTION

Accurate estimation of the composition of the diet is a very important phase of a metabolic study. Two procedures can be used in determining the energy value and nutrient content of the diet. They are (a) laboratory analysis of individual foods or of food mixtures; and (b) calculation from tables of food composition. The second procedure can be achieved either by using a system of food exchanges or by using standard food composition tables.

During the spring of 1968, the Foods and Nutrition Department at Kansas State University conducted a metabolic study to determine the "Effect of Meal Frequency on Weight Loss in Obese Women." A comparison of three methods of determining the energy value of the diet represents but one of several phases of this research effort. The energy aspect of the study is reported herein.

A three-way comparison was made of the energy value of a metabolic test diet served to eight obese subjects participating in nitrogen balance studies while on a low calorie diet for weight reduction. A comparison was made of values obtained from food exchange lists, from food composition tables and of physiological fuel values, determined by bomb calorimetry with corrections made for incompleteness of digestion and urinary nitrogen loss.

REVIEW OF LITERATURE

Methods Used for Dietary Energy Determination

Metabolic studies require accurate determinations of the composition of the diet. Standard tables of food composition furnish only an approximation of the intake. In carefully conducted balance studies, repeated analysis of the diet is of utmost importance, since the nutrient content of food is influenced by many environmental conditions, such as season, soil and climate, and various methods of processing (1).

The energy value of foods depends upon their chemical composition, i.e., upon the relative amounts of the three energy nutrients--carbohydrate, fat, and protein--that they contain. It can be determined by three methods: (a) complete combustion of foods in a calorimeter corrected for physiological losses; (b) calculation from tables of food composition; or (c) calculation from a system of food exchanges.

Laboratory Analysis--Physiological Fuel Values. When organic material is oxidized, as occurs in animals by enzymes, or by fire in the case of physical burning, the major end products are water, carbon dioxide and energy. In theory, the amounts of end products from either pathway are identical. In physiological studies heat is measured in large calories, "kcal," the amount of heat needed to raise 1000 gm of water 1°C (2).

A bomb calorimeter (see Plates 1 and 2) is used to determine the caloric value of a given substance, a food for example. A weighed quantity of food placed in a metal vessel, a bomb, and is ignited in an atmosphere of oxygen by means of an electric spark. The bomb is surrounded by a measured volume of water of known temperature. The increase in temperature of the water multiplied by its volume gives the number of calories liberated by the combustion of the food (3). By such measurements it has been found that 1 gm of carbohydrate yields 4.1 kcal, 1 gm of fat yields 9.4 kcal, and 1 gm of protein yields 5.6 kcal. However, in the human body organic materials are not fully oxidized (2). This is due to incomplete digestion and absorption of food from the gastrointestinal tract. The degree to which a food is digested and absorbed depends upon the composition of that food, i.e., carbohydrates have an average coefficient of digestability of 98%; fat 95%; and protein 92%. In the case of protein, a further deduction is necessary. In human systems, urea, uric acid, creatinine, and other nitrogenous compounds derived from the deaminization of protein are excreted in the urine. These substances possess energy value. Determination of both the heat of combustion and nitrogen content of urine indicates that approximately 7.9 kcal per gm of urine nitrogen is equivalent to 1.25 kcal per gm of protein (2). This energy represents metabolic loss and must be subtracted from the digestable energy of protein. When the necessary corrections for these factors are made, the energy value of a food is designated as available energy or physiological fuel value. For each gram of carbohydrate, protein and fat, the physiological fuel value is 4.0, 4.0, and 9.0 kcal, respectively (2).

Tables of Food Composition--U.S.D.A. Handbook No. 8. The 1963 revision of Handbook No. 8 is the current link in a long chain of tables on the composition of food that have been issued by the U.S. Department of Agriculture over the past 70 years. In a detailed manner, Watt and Merrill (4) reported the historical background of this table and the development of food values in it. Compilation and evaluation of data on the composition and nutritive value of foods was initiated by W. O. Atwater toward the end of the 19th century. The first major publication in this field, "The Chemical Composition of American Food Material," prepared by Atwater and his co-workers, was published in 1896 (5), revised in 1899 (6) and again in 1906 (7).

Three other major publications in this series have been: "Proximate Composition of American Food Materials" (8); "Tables of Food Composition in

Terms of Eleven Nutrients" (9); and Handbook No. 8 "Composition of Foods--Raw, Processed, Prepared" (10). Values shown in Handbook No. 8 have been compiled chiefly from analyses of samples reported by chemists and scientists associated with colleges, universities, and agricultural experiment stations, government laboratories, and industry.

The terms "edible portion" and "as purchased" are used in these tables. The data for "edible portion" of foods are based on chemical analyses of the parts of foods ordinarily considered edible in this country. They are expressed in terms of 100 gm portions. The data for "1 pound as purchased" are the amounts of nutrients present in the edible part of one pound of food as obtained from the market, or from the home garden. These values represent the available energy after deductions have been made for losses in digestion and metabolism.

Food composition tables are useful work tools for nutritionists and dietitians. Values in these tables are used for comparing nutritive values of foods, for ascertaining the adequacy of an individual's dietary intake, for meal planning, and for determining amounts of food required for shipment in aid programs to the less developed countries (11).

Food Exchange System. The food exchange system was first introduced in 1950 for use by diabetics who require a controlled intake of carbohydrate, protein and fat. It is the result of the cooperative efforts of the American Dietetic Association, the American Diabetic Association, and the Diabetes Branch, U.S. Public Health Service (12). The exchange system divides all foods into six groups: namely, milk, meat, fruit, bread, vegetables (groups A and B) and fat. Specific quantities of each food in a group provide similar amounts of carbohydrate, protein and fat. These specified amounts of food are therefore approximately equal in energy value. For example, a meat exchange containing 7 gm of protein and 5 gm of fat provides 73 calories, a bread exchange containing 15 gm of carbohydrate and 2 gm of protein provides 68 calories, and a fruit exchange containing 10 gm of carbohydrates provides 40 calories. Values utilized in this procedure, like values in tables of food composition, take into consideration energy losses in digestion and metabolism.

Parente et al. (13) *reported* a study in which exchange lists were used in planning metabolic ward diets. The protein, fat, and calorie content of each of 10 menus were calculated. In addition, meals were analyzed in the laboratory. Nitrogen was determined by the Kjeldahl method, fat was extracted with anhydrous diethyl ether in the Goldfish apparatus, and calories were determined with an oxygen bomb calorimeter corrected for physiological losses by subtraction of 150 calories for fecal losses plus the energy equivalent of urinary nitrogen estimated as 92% of the protein multiplied by 1.25 calories. A comparison of analyzed values with those derived from the use of exchange lists showed that protein tended to be underestimated and fat and calories overestimated. The differences were due mainly to (a) lower butter fat content in the milk; and (b) leaner meats than those of the food exchange lists. The authors suggested a need for modifying exchange lists to correspond with values of local supplies of dairy products and meat.

Reliability of Nutrient Analysis and Food Tables

Laboratory analysis of food samples represent the most reliable procedure for determining the actual nutritive content of food eaten by an individual. Values obtained by this technique can then be used as a base line for comparison with other methods. This, however, is a costly and time consuming procedure.

When using food composition tables for dietary calculation, one should be mindful of the fact that data so obtained are only an estimate of the available nutrients (14). The reliability of calculated data depend upon the completeness of the description of the kind and amount of foods involved.

In the literature there are reports of differences in results of nutritive values obtained by laboratory analysis and by calculation from food tables. Whiting and Leverton (15) conducted a study of approximately 300 cases selected from the literature in which the same diet was analyzed in the laboratory as well as calculated from tables of food composition. They found that in more than 50% of the cases studied, values for calories and protein agree within 10%. For fat, however, results from the two methods agree within 10% for only 25% of the cases studied.

PROCEDURE

Metabolic Study Procedure

Test Subjects. Female test subjects were selected from students enrolled at Kansas State University in January 1968. Names of single women between the ages of 21 and 35 years were obtained from the Data Processing Center. A letter explaining the nature of a metabolic study, its objectives and requirements for participation was sent to these students. A body weight of at least 20% in excess of an individual's desired weight as judged by a table of desirable weight for women, ages 25 and over was used to screen potential test subjects.

Volunteers who met the weight requirement were then required to pass a medical examination administered by personnel of the Kansas State University Student Health Center. Further screening of subjects occurred through use of the Minnesota Multiphasic Personality Inventory Test (16) administered by the Kansas State University Counseling Center. Recommendations as to the emotional adequacy of subjects for test participation were then made by the Assistant Director of this center.

Test Protocol. Eight obese women, ages 21 or 22 years, served as subjects. They were randomly assigned to one of two groups. Four subjects (group A) consumed a low calorie diet divided among 6 meals per day, and four subjects (group B) consumed a diet of the same number of calories divided among 3 meals per day. These diet patterns were followed throughout the study.

Food portions were weighed to the nearest gram. All meals with the exception of the sixth meal were eaten in the metabolic suite, located in Justin Hall. The sixth meal was packaged, taken home after dinner and consumed in the mid-evening. Subjects in group B were provided with a fruit (one exchange) for their mid-evening snack. Subjects were required to eat all foods served to them. Black coffee, tea, and water were consumed ad libitum. No other food or drink was permitted.

Before initiating the study, sufficient quantities of staple and frozen foods were purchased in single lots to minimize variations in food composition. Perishable foods were purchased on a weekly basis from the same vendor. For the most part, meats and combined meat and vegetable dishes were cooked in large quantities, portion controlled, and frozen.

Test Periods. A 64-day test period was initiated on February 1, 1968 and terminated on April 4, 1968. A four-day adjustment period preceded 10 periods of 6 days each. The purpose of the initial period was to introduce the subjects to their duties and responsibilities in the metabolic study and to accustom them to the experimental diet and the collection of excreta. The experimental phase of the study was divided into two parts. In part I, which consisted of the first 5 periods, subjects consumed 1500 calories per day (as ascertained by food exchanges); whereas in part II, during the remaining 5 periods, subjects consumed 1200 calories per day (again, as ascertained by food exchanges). Food aliquots were collected during days 1-6, 19-24, 37-42 and 49-54 for energy determinations. Excreta were collected during these same periods for nitrogen analysis.

Determination of Energy Value of Diets

Food Exchange System. The two metabolic diets used by group A (6 meals/day) and group B (3 meals/day) each contained the following number of food exchanges: 9 meat, 3 milk, 4 1/2 bread, 3 fat, 4 fruit, 2 vegetable of group A and 1 vegetable of group B. The meal distribution of food exchanges in the diets are recorded in Tables 1 and 2. Meals for each group were approximately isocaloric. The total amount of carbohydrate, protein and fat was calculated from values assigned to each food exchange. Both diets contained 150 gm carbohydrate, 98 gm protein, and 60 gm fat. The total energy value was then determined by multiplying the number of grams of each energy nutrient by its corresponding physiological fuel value. For carbohydrate and protein 4 kcal per gm were used and 9 kcal per gm for fat.

A six-day menu cycle with a wide variety of common foods was planned for each group. The diet of group A with its six meals per day contained a larger variety of foods but in smaller portions than did the diet for group B.

TABLE 1

Meal Distribution of Food Exchanges in Deits
1532 kcal

Time	Group A 6 meals/day Exchanges		CHO gm	Prot gm	Fat gm	Group B 3 meals/day Exchanges		CHO gm	Prot gm	Fat gm
7:30 A.M.	Meat	1	--	7	5	Meat	2	--	14	10
	Milk	1	12	8	--	Milk	1	12	8	--
	Bread	1	15	2	--	Bread	1	15	2	--
	Fat	1	--	--	5	Fat	1	--	--	5
						Fruit	1	10	--	--
10:00 A.M.	Fruit	1	10	--	--					
	Meat	2	--	14	10					
	Bread	1	15	2	--					
12:30 P.M.	Meat	2	--	14	10	Meat	3	--	21	15
	Veg A	1	--	--	--	Veg A	1	--	--	--
	Veg B	1	7	2	--	Veg B	1	7	2	--
	Bread	1/2	7	1	--	Bread	1 1/2	22	3	--
	Fruit	1	10	--	--	Fruit	1	10	--	--
						Milk	1	12	8	--
						Fat	1	--	--	5
3:00 P.M.	Meat	1	--	7	5					
	Bread	1	15	2	--					
	Fat	1	--	--	5					
	Milk	1	12	8	--					
5:30 P.M.	Meat	2	--	14	10	Meat	4	--	28	20
	Veg A	1	--	--	--	Veg A	1	--	--	--
	Bread	1	15	2	--	Bread	2	30	4	--
	Fruit	1	10	--	--	Fruit	1	10	--	--
						Milk	1	12	8	--
						Fat	1	--	--	5
8:00 P.M.	Meat	1	--	7	5	Fruit	1	10	--	--
	Fat	1	--	--	5					
	Milk	1	12	8	--					
	Fruit	1	10	--	--					
	Total		150	98	60	Total		150	98	60

TABLE 2

Meal Distribution of Food Exchanges in Diets
1206 kcal

Time	Group A 6 meals/day Exchanges		CHO gm	Prot gm	Fat gm	Group B 3 meals/day Exchanges		CHO gm	Prot gm	Fat gm
7:30 A.M.	Meat	1	--	7	5	Meat	2	--	14	10
	Milk	1/2	6	4	--	Milk	1	12	8	--
	Bread	1	15	2	--	Bread	1	15	2	--
						Fruit	1	10	--	--
10:00 A.M.	Meat	2	--	14	10					
	Bread	1	15	2	--					
	Fruit	1	10	--	--					
12:30 P.M.	Meat	2	--	14	10	Meat	3	--	21	15
	Veg A	1	--	--	--	Veg A	1	--	--	--
	Veg B	1	7	2	--	Veg B	1	7	2	--
	Fruit	1	10	--	--	Fruit	1	10	--	--
						Milk	1/2	6	4	--
						Bread	1	15	2	--
3:30 P.M.	Meat	1	--	7	5					
	Milk	1/2	6	4	--					
	Bread	1	15	2	--					
5:30 P.M.	Meat	2	--	14	10	Meat	3 1/2	--	24	17
	Veg A	1	--	--	--	Veg A	1	--	--	--
	Bread	1/2	7	1	--	Bread	1 1/2	22	3	--
	Fruit	1	10	--	--	Fruit	1	10	--	--
						Milk	1/2	6	4	--
8:00 P.M.	Milk	1	12	8	--	Fruit	1	10	--	--
	Fruit	1	10	--	--					
	Meat	1/2	--	3	2					
	Total		123	84	42	Total		123	84	42

This greater variety of foods was used to enhance acceptability. The total number of food exchanges per day, however, remained constant for both diets. In all meal plans, consideration was given to variety in color, texture, flavor and temperature as well as satiety value (Appendix, pp. 33-44).

In part II of the study, the energy value of each diet was reduced by 300 calories. This was accomplished by eliminating all fat exchanges, 1 milk exchange, and 1 bread exchange per day. This dietary change was implemented because of the subjects' dissatisfaction with their low weight loss.

Food Composition Table. The energy value of all menus in the 6-day cycle was calculated from Handbook No. 8 (4). Values for lean cuts of meat were used as all visible fat was trimmed away in the food preparation process. Where possible, values for "all varieties" of a food were used.

Physiological Fuel Value.

a. Collection and preservation of food sample.

Methods used for the collection and preservation of food were essentially those of Leichsenring et al. as described in "Methods Used for Human Metabolic Studies in the North Central Region" (17).

One-fourth of each day's food served to each group was collected daily during test days 1 through 6, 19 through 24 (Periods I and II), 37 through 42, and 49 through 54 (Periods III and IV) for energy determinations. Since tea and coffee were devoid of energy, these beverages were not included in test samples.

A day's food sample was mixed in a Waring blender with 100 gm of distilled water for 30 minutes at medium speed. The mixture was divided into 3 parts and stored in sterile plastic bags at 0°F.

Prior to analysis, frozen dietary samples were allowed to thaw at room temperature during a 2 to 3 hour period. After thawing, sample bags were inverted 50 times before the removal of the first sample and inverted an additional 25 times for each succeeding sample. Samples were weighed in a stainless steel capsule on an analytical balance to the 5th decimal. The weighed slurry was then dried in a vacuum oven at 100°F for approximately 20 hours and stored in a desiccator.

b. Bomb calorimetry

The energy value of each food composite was determined in duplicate by bomb calorimetry using the Parr plain oxygen bomb calorimeter. Procedures used for determinations are described in Parr Instrument Co. Manual No. 130 (10) (Appendix, pp. 45, 46).

c. Collection of urine.

Again, methods used for the collection and preservation of urine were those of Leichsenring et al. (17). Twenty-four urine samples were collected each day of each test period. On the first day of a collection period, a subject's rising sample was discarded as it was considered to be a part of the urine produced during the preceding day. The rising sample of all other days of the test period was included as a part of the 24 hour sample of the previous day.

The volume of urinary excreta for each 24 hour period was measured. Hydrochloric acid (35 to 38%) was added in quantities equal to 10% of the total urine volume. Each composite sample was then thoroughly mixed and duplicate aliquot portions (one-tenth by volume) were stored in glass bottles at room temperature.

d. Nitrogen determinations on urine.

Nitrogen determinations of urine were made by the macro-Kjeldahl

EXPLANATION OF PLATE I

a. Motor

b. Calorimeter Jacket

c. Bomb Lid

d. Bomb

e. Bucket

f. Bomb Head

g. Thermometer

h. Observation Lens

i. Stirring Device

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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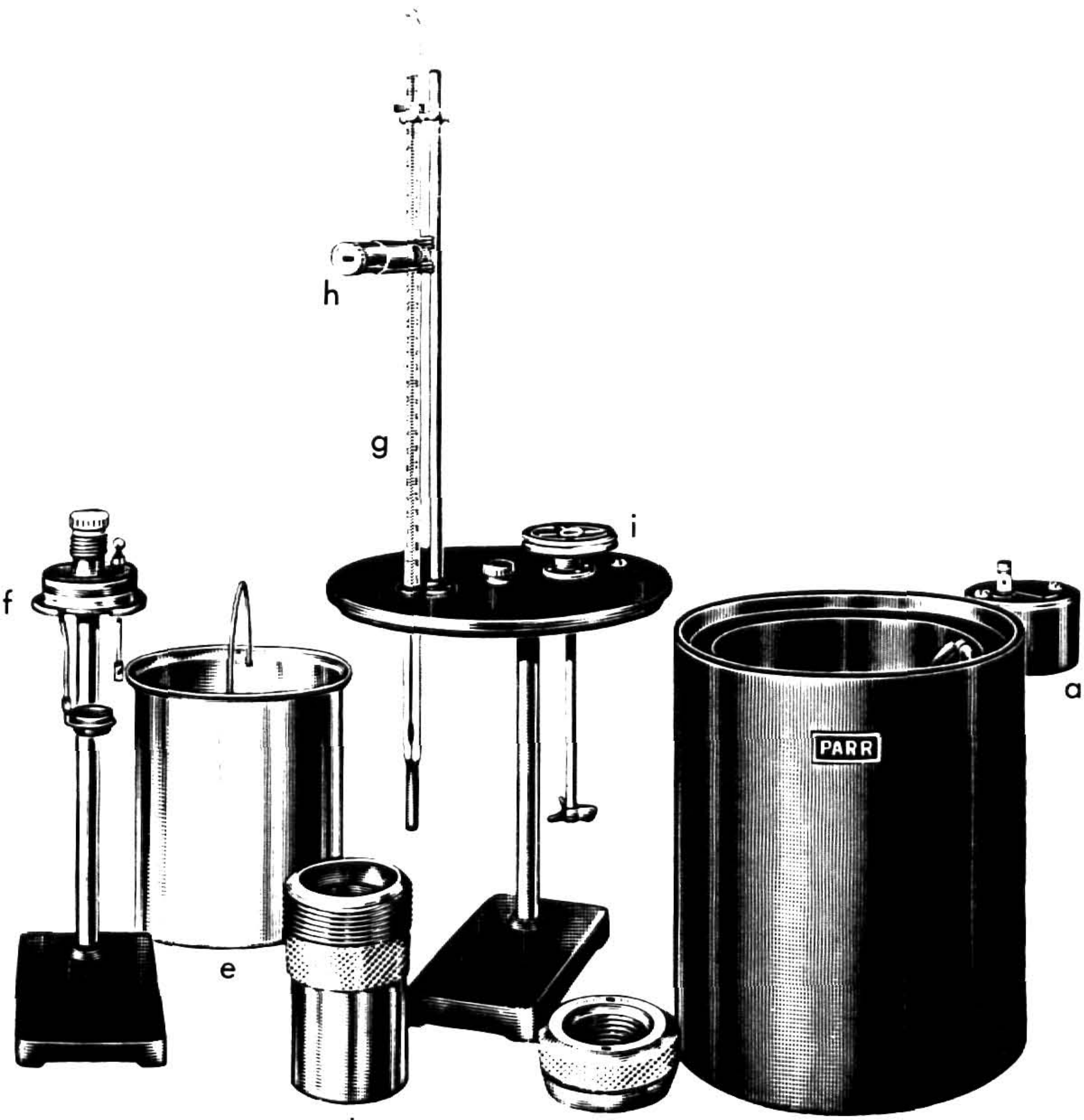
PLATE I

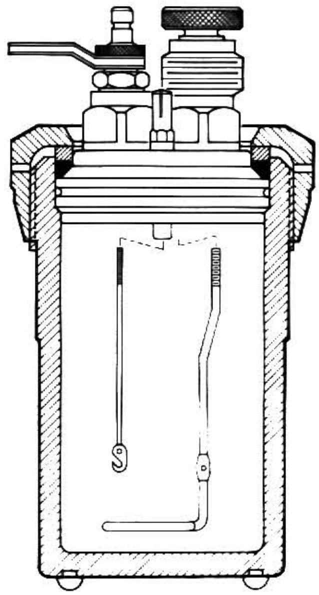


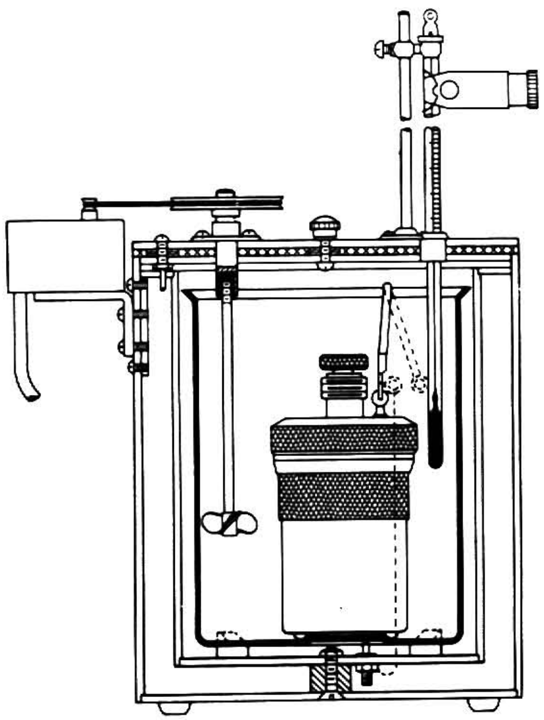
EXPLANATION OF PLATE II

Double Valve Bomb

Assembled Oxygen Bomb Calorimeter

PLATE II





procedure (17). Urine composites in sample bottles were inverted 50 times before removal of the first sample and inverted an additional 25 times for each succeeding sample. Ten ml of urine were used for each determination. Duplicate determinations were made for each composite sample (Appendix, p. 47).

e. Calculation of physiological fuel value.

The physiological fuel value of food consumed by each subject was calculated from the following formula:

$$\begin{matrix}\text{Physiological} \\ \text{Fuel Value}\end{matrix} = \begin{matrix}\text{Energy Value of} \\ \text{Food Consumed}\end{matrix} - \left\{\begin{matrix}\text{Energy Value} \\ \text{of Urine}\end{matrix} + \begin{matrix}\text{Energy Value} \\ \text{of Feces}\end{matrix}\right\} \quad (2)$$

Determinations of energy values of food consumed by subjects in groups A and B are described in preceding pages. The energy value of each subject's 24 hour urinary output was calculated from nitrogen data. For each gm of urinary nitrogen there is an energy loss of approximately 7.9 kcal (2). The energy value of the feces was based on the generally accepted coefficient of digestibility of 95% for the average mixed diet. Therefore, 5% of the energy value of a day's food intake was calculated as fecal energy loss (Appendix, p. 48).

Statistical Analyses

Analyses of variance were computed for the energy values of diets ascertained by three methods, food exchanges, food composition tables and physiological fuel values. T-test comparisons between energy values and confidence intervals were also calculated.

RESULTS AND DISCUSSION

Energy values of the diet obtained from the food exchange system, from food composition tables, and of physiological fuel values, determined by bomb calorimetry with corrections made for incompleteness of digestion and urinary nitrogen loss are recorded in Table 3.

Energy values in the diet calculated from food exchanges provide 1532 calories for the first two nitrogen balance test periods and 1206 calories for the third and fourth test periods. Because the same number of food exchanges were used for group A (6 meals per day) and group B (3 meals per day), the calorie content of the diets is identical for both groups during the same period.

Energy values of the diet calculated from food composition tables, however, provide different values each day for each group during the same period. The average energy values of each test period show that for group A (6 meals per day) the diet contained a larger number of calories than did the diet for group B (3 meals per day).

Physiological fuel values appearing in Table 3 are the average daily values for 4 subjects in that particular feeding pattern group. Again, the physiological fuel values for group A (6 meals per day) during all occasions are higher than that for group B (3 meals per day).

The higher calorie values for group A indicated in Table 3 were further studied by comparing the mean value, standard deviation of the mean, and central confidence intervals of both feeding patterns. The above measurements were calculated and are recorded in Table 4. Only the energy values obtained from food composition tables and of physiological fuel values were computed, since food exchange lists produced no differences between the two meal

TABLE 3

Calculated and Analyzed Energy Value of Diets
(kcal)

	Day	FES[a]	FCT[b]	Average PFV[c]		
Group A 6 meals per day						
Test Period		I,II	I,II	I	II	Ave
	1	1532	1512	1565	1561	1563
	2		1634	1765	1679	1722
	3		1613	1688	1657	1673
	4		1633	1660	1606	1633
	5		1508	1581	1553	1567
	6		1535	1541	1528	1534
	Ave		1572	1633	1597	1615
Test Period		III,IV	III,IV	III	IV	Ave
	1	1206	1241	1278	1367	1322
	2		1259	1388	1340	1364
	3		1227	1399	1317	1358
	4		1396	1535	1528	1532
	5		1119	1302	1260	1281
	6		1261	1182	1406	1294
	Ave		1250	1347	1369	1358
Group B 3 meals per day						
Test Period		I,II	I,II	I	II	Ave
	1	1532	1435	1574	1476	1525
	2		1520	1772	1608	1690
	3		1548	1498	1541	1520
	4		1612	1590	1544	1567
	5		1493	1597	1504	1550
	6		1473	1487	1528	1507
	Ave		1514	1586	1533	1560
Test Period		III,IV	III,IV	III	IV	Ave
	1	1206	1156	1306	1333	1320
	2		1161	1349	1364	1352
	3		1252	1238	1348	1293
	4		1367	1388	1409	1398
	5		1178	1281	1328	1304
	6		1200	1162	1303	1232
	Ave		1219	1287	1347	1317

[a]Food Exchange System
[b]Food Composition Table
[c]Physiological Fuel Value (n=4)

TABLE 4A

Energy Value Comparisons
Calculated vs Physiological Fuel Values
(Group A 6 meals per day)

Calorie Level		FCT[a] n=6	PFV[b] n=48
1500	Mean	1572	1615
	Standard deviation	25	10
	CI_{95}	$1515 \leq \mu \leq 1629$	$1594 \leq \mu \leq 1634$
1200	Mean	1250	1358
	Standard deviation	36	14
	CI_{95}	$1166 \leq \mu \leq 1334$	$1328 \leq \mu \leq 1388$

[a]Food Composition Table
[b]Physiological Fuel Values

TABLE 4B

Energy Value Comparisons
Calculated vs Physiological Fuel Values
(Group B 3 meals per day)

Calorie Level		FCT[a] n=6	PFV[b] n=48
1500	Mean	1514	1560
	Standard deviation	24	11
	CI_{95}	$1549 \leq \mu \leq 1659$	$1537 \leq \mu \leq 1583$
1200	Mean	1219	1317
	Standard deviation	33	10
	CI_{95}	$1143 \leq \mu \leq 1295$	$1293 \leq \mu \leq 1337$

[a]Food Composition Table
[b]Physiological Fuel Values

frequencies (6 meals vs 3 meals per day). In all instances, the mean and standard deviation for the 6 meals per day pattern (group A) are higher than for the 3 meals per day regimen (group B).

The central confidence interval (CI) is an interval estimate of the population mean. A CI_{95} indicates that the probability of failing to include the true mean in this interval has only a 5% chance. The length of this interval is important, as a shorter confidence interval represents more definite and useful statements. One factor affecting the length of the interval is the sample size. On an average, the larger the sample size, the shorter the confidence interval. Another factor involved in the interval length is the variance value, which is the square of the standard deviation of the mean. Usually, a smaller variance value is associated with a shorter confidence interval. This is true with the finding of CI_{95} as recorded in Table 4.

The statistical procedure, analysis of variance, was used to analyze the difference in calorie values calculated from food exchanges, from food composition tables, and of determined physiological fuel values. Three analyses of variance were performed. They compared values obtained by the use of (1) food exchange system (FES) versus food composition tables (FCT); (2) food exchange system versus physiological fuel values (PFV); and (3) food composition tables versus physiological fuel values. Values used in these comparisons represent the differences between energy values calculated or determined by two of the above three methods. When results of the analysis of variance indicated that differences exist between methods used in determining energy values of the diet, t-test and central confidence intervals were calculated. The purpose of using the t-test is to determine whether the true difference between these two methods is equal to zero. When the true mean difference equals zero, the t-test shows no difference in the energy value of diets calculated by the two methods used.

Table 5 records the results of the analysis of variance between values obtained from food exchange lists and food composition tables. Data indicate that there is a difference in calorie values between diets containing 6 meals per day and those containing 3 meals per day ($P < .10$). However, no difference exists between diets of different calorie levels, and no interaction between meal frequency and calorie level is noted. Since differences in the two methods of calculation occurred, a t-test was performed. The t-value ($t=1.32$ with 23 DF) was nonsignificant, and therefore indicates that the true mean difference between these two methods could be equal to zero. From a practical standpoint, it is concluded that food exchange lists and food composition tables can be used interchangeably to calculate the energy values of diets.

TABLE 5

Analysis of Variance for Differences Between Energy Values Determined by Food Exchange System (FES) and Food Composition Table (FCT) in the Order: FCT - FES

Sources of Variation	DF	MS	F	P
Frequency (F)	1	12285.37	2.20	<.10
Calories (C)	1	1890.37	0.34	n.s.
F x C	1	1134.38	0.20	n.s.
Error	20	5456.12		
Total	23			

Analysis of variance between values obtained from the food exchange system and physiological fuel values are recorded in Table 6. Results indicate that there are differences between diets containing 6 versus 3 meals per day, as well as between 1500 and 1200 calorie levels. There is no interaction between meal frequency and calorie level. Because of these differences, t-values and central confidence intervals were calculated and are recorded in Table 6A.

The differences in calorie values which occurred between these two methods are possibly caused by a greater variety of foods for group A (6 meals/day) and the use of group A vegetables for both group A and B. According to exchange lists, group A vegetables contain nominal amounts of calories and from a practical standpoint are neglected. Results in Table 6A indicate that diets of 6 meals per day (group A) have a higher t-value and a higher confidence interval when compared with the 3 meals per day diet (group B). The confidence interval for 3 meals per day is between 53 and 87 versus 99 and 137 for 6 meals per day. This smaller value indicates that the calorie content of the group B diet was closer to the calculated value than was that of the group A diet. This may be due to the fewer foods used in group B diets. Diets composed of 1500 calories also show a smaller t-value (6.76 versus 14.82) as well as a smaller confidence interval than diets containing 1200 calories (40 and 72 versus 114 and 150). Non-overlapping confidence intervals reenforce the differences between the two meal frequencies and the two calorie levels. This is unexpected but may be due to the higher proportion of calories supplied by fruits and vegetables in the 1200 kcal diet, as compared to calories supplied by fruits and vegetables in the 1500 kcal diet. Fruits and vegetables are foods whose composition tend to vary with variety,

TABLE 6

Analysis of Variance for Differences Between Energy Values Determined by Foods Exchange System (FES) and Physiological Fuel Values (PFV) in the Order: PFV - FES

Sources of Variation	DF	MS	F	P
Frequency (F)	1	111554.08	17.03	<.005
Calories (C)	1	279227.52	42.63	<.005
F x C	1	2408.33	0.36	n.s.
Error	188	6459.83		
Total	191			

TABLE 6A

The t-test Comparison Between Energy Values Determined by Food Exchange System and Physiological Fuel Values in the Order: PFV - FES

Sources of Variation		DF	t	CI_{95}
Frequency (F)	6 meals	95	12.28	$99 \leq \mu \leq 137$
	3 meals	95	8.14	$53 \leq \mu \leq 87$
Calories (C)	1500	95	6.76	$40 \leq \mu \leq 72$
	1200	95	14.82	$114 \leq \mu \leq 150$

growing conditions, and degree of maturity at harvest, storage and preparation. Whereas butter, bread, and milk are foods which tend to vary little in composition and are not affected by food preparation. These are the foods which were deleted during part II of the study to reduce the energy value of the diets by 300 calories.

Table 7 records the results of the analysis of variance between values obtained from food composition tables and physiological fuel values. Data show a significant difference between diets at differing calorie levels. No difference is found between the two meal frequencies, and no interaction occurred between meal frequency and calorie level. The differences in energy value again, probably resulted from day-to-day variation in nutrient composition of the foods. This source of error could only be limited by using a restricted and repetitive menu in the study, or using a formula diet made up of synthetic or purified natural products.

Since differences in the two calorie levels occurred, a t-test comparison was made. Results are recorded in Table 7A. Diets containing 1500 calories have a smaller t-value (6.33 versus 13.62) and smaller confidence interval (31 and 59 versus 88 and 118) than diets of 1200 calories. Again, these results may be due to the higher proportion of fruits and vegetables in the 1200 kcal diet.

In conclusion, four generalizations are evident:

(a) Determined physiological fuel values of the diets studied are higher than values obtained when calculations are made either from the system of food exchanges or tables of food composition. This occurred regardless of the total energy value of the diet (1500 versus 1200 calories) or meal frequency (6 meals versus 3 meals per day).

TABLE 7

Analysis of Variance for Differences Between Energy Value Determined by Food Composition Table (FCT) and Physiological Fuel Values (PFV) in the Order: PFV - FCT

Sources of Variation	DF	MS	F	P
Frequency (F)	1	417.13	0.08	n.s.
Calories (C)	1	164326.51	31.57	<.005
F x C	1	2140.00	0.41	n.s.
Error	188	5204.10		
Total	191			

TABLE 7A

The t-test Comparison Between Energy Values Determined by Food Composition Table and Physiological Fuel Values in the Order: PFV - FCT

Sources of Variation		DF	t	CI_{95}
Calories	1500	95	6.33	$33 \leq \mu \leq 59$
	1200	95	13.62	$88 \leq \mu \leq 118$

(b) The higher energy levels of diets obtained by laboratory determination of physiological fuel values may be due to: (i) differences in the composition of foods consumed by the subjects in this study and data used to determine average values found in tables of food composition; (ii) group A vegetables of the food exchange system are considered to contain nominal amounts of carbohydrate, but in reality contribute calories to the total energy value of the diet.

(c) The system of food exchanges can be used interchangeably with values found in tables of food composition. Statistical comparisons of the diets involved in this study indicate a nonsignificant difference in energy values when calculations are made from the system of food exchanges or values found in tables of food composition.

(d) The precision ordinarily desired in a metabolic research study requires that energy values of diets be determined by laboratory procedures.

SUMMARY

A comparison of the energy value of low calorie diets (1500 and 1200 calories) planned from a system of food exchanges was made with (a) values obtained from tables of food composition and (b) laboratory determined physiological fuel values. Physiological fuel values were based on data obtained from 8 subjects, 4 of whom consumed 6 meals per day and 4 of whom consumed 3 meals per day while participating in a weight reduction program.

Statistical comparisons of the energy level of diets obtained as above were made by using analyses of variance, t-tests, and central confidence intervals. Analyses of variance included comparisons between energy values obtained from the system of food exchanges and tables of food composition; and between food exchanges and physiological fuel values. Analysis of variance were also made by comparing the energy values calculated from tables of food composition with those obtained from physiological fuel determinations.

Analysis of variance of the energy value of diets determined by the food exchange system and from food composition tables indicated that a difference existed between diets containing 6 meals and those containing 3 meals per day ($P < .10$). No difference, however, existed for the two calorie levels used (1500 vs 1200 kcal). Also no interaction occurred between meal frequency and calorie level. A further comparison, using the t-test showed no difference between sample mean value of diets containing either 6 or 3 meals per day.

Analysis of variance for energy values based on the food exchange system and physiological fuel value determinations indicated significant differences between meal frequency ($P < .005$) and calorie levels ($P < .005$). No interaction between meal frequency and calorie level, however, was detected. The t-test showed a higher value for diets containing 6 meals per day than for those containing 3 meals per day (t-value 12.8 versus 8.14). Similar results were obtained for the confidence interval, i.e., a value of 99 and 137 as compared to 53 and 87. The diets containing 1200 calories had a higher t-value than the 1500 diet (14.82 vs 6.76). Again, the same was true for the confidence interval (114 and 150 vs 40 and 72).

Analysis of variance between energy values based on food composition tables and physiological fuel value determinations indicated a significant difference between diets of differing calorie levels ($P < .005$). No difference was found between the two meal frequencies and no interaction existed between meal frequency and calorie level. Results of a t-test comparison between calorie levels were higher for the 1200 calorie diet than for the 1500 calorie diet (13.62 vs 6.33). The same held true for the confidence interval, i.e., a value of 88 and 188 vs 31 and 59.

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Appendix 1

Menus for 6 Meals and 3 Meals Per Day Feeding Patterns--1500 calories

Group A (6 meals/day)

7:30 a.m.	measure	gms
Egg, poached	1	50
Bread, white	1	23
Butter	1 t	5
Milk, skim	1 c	240
Coffee or tea	1/2 c	
10:00 a.m.		
Orange juice	1/2 c	120
Cottage cheese	1/2 c	112
Saltine crackers	5	20
Coffee or tea	1/2 c	
12:30 p.m.		
V-8 juice	1/2 c	120
Hamburger	2 oz	60
Roll, hamburger	1/2	15
Lettuce		50
Cauliflower		10
Zero salad dressing		15
Carrots	1/2 c	72
Pineapple slice	1 sl	100
Coffee or tea	1/2 c	
3:00 p.m.		
Swiss cheese	1 oz	30
Butter	1 t	5
Bread, whole wheat	1	23
Milk, skim	1 c	240
5:30 p.m.		
Baked chicken	2 oz	60
Broccoli	1/2 c	80
Potato, paprika	1 md	100
Lettuce		50
Zero salad dressing		15
Fruit cup	1/2 c	100
Coffee or tea	1/2 c	
8:00 p.m.		
Banana	1 sm	100
Milk, skim	1 c	240
S.M.P.		10
Walnuts		5

Group B (3 meals/day)

7:30 a.m.	measure	gms
Orange juice	1/2 c	120
Egg, poached	1	50
Bread, white	1	23
Butter	1 t	5
Cottage cheese	1/4 c	56
Milk, skim	1 c	240
Coffee or tea	1/2 c	
12:30 p.m.		
V-8 juice	1/2 c	120
Saltine crackers	2	8
Hamburger	3 oz	90
Roll, hamburger	1	30
Lettuce		50
Cauliflower		10
Zero salad dressing		15
Carrots	1/2 c	72
Butter	1 t	5
Pineapple slice	1 sl	100
Milk, skim	1 c	240
Coffee or tea	1/2 c	
5:30 p.m.		
Fruit cup	1/2 c	100
Baked chicken	4 oz	120
Broccoli	1/2 c	80
Potato, paprika	1 md	100
Bread, whole wheat	1	23
Butter	1 t	5
Lettuce		50
Zero salad dressing		15
Milk, skim	1 c	240
Coffee or tea	1/2 c	
8:00 p.m.		
Banana	1 sm	100

Appendix 1 (cont.)

Day II

Group A (6 meals/day)

7:30 a.m.	measure	gms
Ham, broiled	1 oz	30
Bread, white	1	23
Butter	1 t	5
Milk, skim	1 c	240
10:00 a.m.		
Grapefruit juice	1/2 c	120
Cheddar cheese	1 oz	30
Peanut butter	1 T	15
Graham crackers	2	14
Coffee or tea	1/2 c	
12:30 p.m.		
Salad plate		
Bologna	1 oz	30
Hard cooked egg	1	50
Asparagus	4 spr	60
Lettuce		50
Pickled beets		80
Zero salad dressing		15
Crackers, thin		5
Pear	1/2 c	100
Coffee or tea	1/2 c	
3:00 p.m.		
Butter	1 t	5
Dried beef	1 oz	30
Bread, rye	1	23
Milk, skim	1 c	240
5:30 p.m.		
Italian spaghetti		
Hamburger	2 oz	60
Sauce		100
Spaghetti	1/2 c	75
Cucumber		30
Radish		20
Apricots	2	75
Coffee or tea	1/2 c	
8:00 p.m.		
Mandarin oranges	1/2 c	100
Almonds		8
Milk, skim	1 c	240
S.M.P.		10

Group B (3 meals/day)

7:30 a.m.	measure	gms
Grapefruit juice	1/2 c	120
Ham, broiled	2 oz	60
Bread, white	1	23
Butter	1 t	5
Milk, skim	1 c	240
Coffee or tea	1/2 c	
12:30 p.m.		
Salad plate		
Bologna	2 oz	60
Hard cooked egg	1	50
Asparagus	4 spr	60
Lettuce		50
Pickled beets		80
Zero salad dressing		15
Crackers, thin	3	11
Bread, white	1	23
Butter	1 t	5
Pear	1/2 c	100
Milk, skim	1 c	240
Coffee or tea	1/2 c	
5:30 p.m.		
Italian spaghetti		
Hamburger	3 oz	105
Sauce		100
Spaghetti	1/2 c	75
Grated Swiss cheese	1/2 oz	15
Cucumber		30
Radish		20
Bread, rye	1	23
Butter	1 t	5
Apricots	2	75
Milk, skim	1 c	240
Coffee or tea	1/2 c	
8:00 p.m.		
Mandarin oranges	1/2 c	10[illegible]

Appendix 1 (cont.)

Day III

Group A (6 meals/day)

7:30 a.m.	measure		gms
Cheese toast			
Bread, white	1		23
Butter	1	t	5
Cheese, American	1	oz	30
Milk, skim	1	c	240
10:00 a.m.			
Grapefruit sections	1/2	c	100
Turkey	2	oz	60
Bread, rye	1		23
Coffee or tea	1/2	c	
12:30 p.m.			
Hot consommé	1/2	c	100
Baked halibut	2	oz	60
Succotash	1/2	c	90
Radish			20
Celery			30
Bread, whole wheat	1		23
Plums	2		100
Coffee or tea	1/2	c	
3:00 p.m.			
Peanut butter	1	T	15
Graham crackers	2		14
Milk, skim	1	c	240
Butter	1	t	5
5:30 p.m.			
Veal cubes	2	oz	60
Noodles	1/2	c	80
String beans	1/2	c	80
Cabbage salad			
Cabbage			50
Radish			10
Zero salad dressing			15
Cherries	1/3	c	75
Coffee or tea	1/2	c	
8:00 p.m.			
Apple	1	md	100
Edam cheese	1	oz	30
Pecans			7
Milk, skim	1	c	240

Group B (3 meals/day)

7:30 a.m.	measure		gms
Grapefruit sections	1/2	c	100
Cheese toast			
Bread, white	1		23
Butter	1	t	5
Cheese, American	1	oz	30
Turkey	1	oz	30
Milk, skim	1	c	240
Coffee or tea	1/2	c	
12:30 p.m.			
Hot consommé	1/2	c	100
Crackers	2		11
Baked halibut	3	oz	90
Succotash	1/2	c	90
Radish			20
Celery			30
Bread, whole wheat	1		23
Butter	1	t	5
Plums	2		100
Milk, skim	1	c	240
Coffee or tea	1/2	c	
5:30 p.m.			
Veal cubes	4	oz	90
Noodles	1/2	c	80
Butter	1	t	5
String beans	1/2	c	80
Cabbage salad			
Cabbage			50
Radish			10
Zero salad dressing			15
Cherries	1/3	c	75
Graham crackers	2		14
Peanut butter	1	T	15
Milk, skim	1	c	240
Coffee or tea	1/2	c	
8:00 p.m.			
Apple	1	md	100

Appendix 1 (cont.)

Day IV

Group A (6 meals/day)

7:30 a.m.	measure	gms
Egg, poached	1	50
Bread, white	1	23
Butter	1 t	5
Milk, skim	1 c	240
10:00 a.m.		
Applesauce	1/2 c	120
Spiced meat	2 oz	60
Bread, white	1	23
Coffee or tea	1/2 c	
12:30 p.m.		
Pineapple juice	1/2 c	120
Roast beef	2 oz	60
Peas	1/2 c	80
Lettuce		50
Cucumber		15
Zero salad dressing		15
Bread, rye	1	23
Coffee or tea	1/2 c	
3:00 p.m.		
Frankfurter	1	50
Bread, whole wheat	1	23
Butter	1 t	5
Milk, skim	1 c	240
5:30 p.m.		
Ham	2 oz	60
Rice	1/2 c	75
Spinach	1/2 c	100
Leaf lettuce		40
Celery		20
Zero salad dressing		15
Strawberries	1/2 c	100
Coffee or tea	1/2 c	
8:00 p.m.		
Apricots	1/2 c	75
Milk, skim	1 c	240
S.M.P.		10
Walnuts		5

Group B (3 meals/day)

7:30 a.m.	measure	gms
Applesauce	1/2 c	120
Egg, poached	1	50
Bread, white	1	23
Butter	1 t	5
Spiced meat	1 oz	30
Milk, skim	1 c	240
Coffee or tea	1/2 c	
12:30 p.m.		
Pineapple juice	1/2 c	120
Crackers, saltine	2	8
Roast beef	2 oz	60
Edam cheese	1 oz	30
Peas	1/2 c	80
Lettuce		50
Cucumber		15
Zero salad dressing		15
Bread, whole wheat	1	23
Butter	1 t	5
Milk, skim	1 c	240
Coffee or tea	1/2 c	
5:30 p.m.		
Ham	4 oz	120
Rice	1/2 c	75
Spinach	1/2 c	100
Leaf lettuce		40
Celery		20
Zero salad dressing		15
Bread, whole wheat	1	23
Butter	1 t	5
Strawberries	1/2 c	100
Milk, skim	1 c	240
Coffee or tea	1/2 c	
8:00 p.m.		
Apricots	1/2 c	75

Appendix 1 (cont.)

Day V

Group A (6 meals/day)

7:30 a.m.	measure	gms
Egg, poached	1	50
Bread, white	1	23
Butter	1 t	5
Milk, skim	1 c	240
10:00 a.m.		
Cottage cheese	1 c	112
Peach	1/2 c	100
Bread, whole wheat	1	23
Coffee or tea	1/2 c	
12:30 p.m.		
Chicken noodle casserole		
Chicken diced	2 oz	60
Celery		30
Chicken consommé	2 T	25
Water chestnut	8	25
Pimiento	1/2 md	80
Chinese noodles		18
String beans	1/2 c	80
Apple	1 md	100
Coffee or tea	1/2 c	
3:00 p.m.		
Tuna salad		
Tuna	1 oz	30
Celery		30
Bread, white	1	23
Butter	1 t	5
Milk, skim	1 c	240
5:30 p.m.		
Meat loaf	2 oz	60
Lima beans	1/2 c	50
Lettuce		50
Radish		10
Zero salad dressing		15
Fruit cup	1/2 c	100
Coffee or tea	1/2 c	
8:00 p.m.		
Banana	1 sm	100
Edam cheese	1 oz	30
Almonds		8
Milk, skim	1 c	240

Group B (3 meals/day)

7:30 a.m.	measure	gms
Peach	1/2 c	100
Egg, poached	1	50
Cottage cheese	1/2 c	56
Bread, white	1	23
Butter	1 t	5
Milk, skim	1 c	240
Coffee or tea	1/2 c	
12:30 p.m.		
Chicken noodle casserole		
Chicken diced	3 oz	90
Celery	1 oz	30
Chicken consommé	2 T	25
Water chestnut	8	25
Pimiento	1/2 md	10
Chinese noodles		18
String beans	1/2 c	80
Bread, whole wheat	1	23
Butter	1 t	5
Apple	1 md	100
Milk, skim	1 c	240
Coffee or tea	1/2 c	
5:30 p.m.		
Meat loaf	3 oz	90
Lima beans	1/2 c	50
Butter	1 t	5
Lettuce		50
Radish		10
Zero salad dressing		15
Edam cheese	1 oz	30
Bread, white	1	23
Fruit cup	1/2 c	100
Milk, skim	1 c	240
Coffee or tea	1/2 c	
8:00 p.m.		
Banana	1 sm	100

Appendix 1 (cont.)

Day VI

Group A (6 meals/day)

7:30 a.m.	measure	gms
Tomato juice	1/2 c	120
Peanut butter	1 T	15
Bread, white	1	23
Butter	1 t	5
Milk, skim	1 c	240
10:00 a.m.		
Orange juice	1/2 c	120
Corned beef	1 oz	30
Swiss cheese	1 oz	30
Bread, rye	1	23
Coffee or tea	1/2 c	
12:30 p.m.		
Lamb stew		
Lamb	2 oz	60
Celery		30
Onion	1 oz	30
Potato	1 oz	30
Carrots	1 oz	30
Lettuce		50
Zero salad dressing		15
Coffee or tea	1/2 c	
Pear	1 md	100
3:00 p.m.		
Egg, hard cooked	1	50
Bread, whole wheat	1	23
Butter	1 t	5
Milk, skim	1 c	240
5:30 p.m.		
Steak	2 oz	60
Mushrooms	1/4 c	20
Squash, hubbard	1/2 c	70
Potato, baked	1 md	100
Cucumber		30
Radish		20
Peach	1/2 c	100
Coffee or tea	1/2 c	
8:00 p.m.		
Grapefruit sections	1/2 c	100
Milk, skim	1 c	240
S.M.P.		10
Pecan halves		7

Group B (3 meals/day)

7:30 a.m.	measure	gms
Orange juice	1/2 c	120
Peanut butter	1 T	15
Bread, white	1	23
Egg, hard cooked	1	50
Butter	1 t	5
Milk, skim	1 c	240
Coffee or tea	1/2 c	
12:30 p.m.		
Tomato juice	1/2 c	120
Lamb stew		
Lamb	3 oz	90
Celery		30
Onion	1 oz	30
Potato	1 oz	30
Carrots	1 oz	30
Bread, rye	1	23
Lettuce		50
Butter	1 t	5
Pear	1 md	100
Milk, skim	1 c	240
Zero salad dressing		15
Coffee or tea	1/2 c	
5:30 p.m.		
Steak	4 oz	120
Mushrooms	1/4 c	20
Squash, hubbard	1/2 c	70
Potato, baked	1 md	100
Cucumber		30
Radish		20
Butter	1 t	5
Peach	1/2 c	120
Milk, skim	1 c	240
Coffee or tea	1/2 c	
8:00 p.m.		
Grapefruit sections	1/2 c	100

Appendix 2

Menus for 6 Meals and 3 Meals Per Day Feeding Patterns--1200 calories

Day I

Group A (6 meals/day)

7:30 a.m.	measure	gms
Egg, poached	1	50
Bread, white	1	23
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
10:00 a.m.		
Orange juice	1/2 c	120
Cottage cheese	1/2 c	112
Crackers, saltine	5	20
Coffee or tea	1/2 c	
12:30 p.m.		
V-8 juice	1/2 c	120
Hamburger	2 oz	60
Carrots	1/2 c	72
Lettuce		50
Cauliflower		10
Zero salad dressing		15
Pineapple slice	2 sl	100
Coffee or tea	1/2 c	
3:00 p.m.		
Swiss cheese	1 oz	30
Milk, skim	1/2 c	120
Bread, whole wheat	1	23
5:30 p.m.		
Baked chicken	2 oz	60
Broccoli	1/2 c	80
Potato, paprika	2 sm	50
Lettuce		50
Zero salad dressing		15
Fruit cup	1/2 c	100
Coffee or tea	1/2 c	
8:00 p.m.		
Banana	1 sm	100
Milk, skim	1 c	240
S.M.P.		10

Group B (3 meals/day)

7:30 a.m.	measure	gms
Orange juice	1/2 c	120
Egg, poached	1	50
Bread, white	1	23
Cottage cheese	1/4 c	56
Milk, skim	1 c	240
Coffee or tea	1/2 c	
12:30 p.m.		
V-8 juice	1/2 c	120
Hamburger	3 oz	90
Roll, hamburger	1/2	15
Carrots	1/2 c	72
Lettuce		50
Cauliflower		10
Zero salad dressing		15
Pineapple slice	2 sl	100
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
5:30 p.m.		
Baked chicken	4 oz	120
Broccoli	1/2 c	80
Potato, paprika	3 sm	100
Bread, whole wheat	1	23
Lettuce		50
Zero salad dressing		15
Fruit cup	1/2 c	100
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
8:00 p.m.		
Banana	1 sm	100

Appendix 2 (cont.)

Day II

Group A (6 meals/day)

7:30 a.m.	measure	gms
Ham, boiled	1 oz	30
Bread, white	1	23
Milk, skim	1/2 c	120
10:00 a.m.		
Grapefruit juice	1/2 c	120
Cheddar cheese	1 oz	30
Peanut butter	1 T	15
Graham crackers	2	14
Coffee or tea	1/2 c	
12:30 p.m.		
Salad plate		
Bologna	1 oz	30
Hard cooked egg	1	50
Asparagus	4 spr	60
Pickled beets		80
Zero salad dressing		15
Pear (half)	2	100
Coffee or tea	1/2 c	
3:00 p.m.		
Dried beef	1 oz	30
Bread, rye	1	23
Milk, skim	1/2 c	120
5:30 p.m.		
Italian spaghetti		
Hamburger	2 oz	60
Tomato sauce	1/2 c	100
Spaghetti	1/4 c	38
Cucumber		30
Radish		20
Apricots	2	75
Coffee or tea	1/2 c	
8:00 p.m.		
Mandarin oranges	1/2 c	100
Milk, skim	1 c	240
S.M.P.		10

Group B (3 meals/day)

7:30 a.m.	measure	gms
Grapefruit juice	1/2 c	120
Ham, boiled	2 oz	60
Bread, white	1	23
Milk, skim	1 c	240
Coffee or tea	1/2 c	
12:30 p.m.		
Salad plate		
Bologna	2 oz	60
Hard cooked egg	1	50
Asparagus	4 spr	60
Lettuce		50
Pickled beets		80
Zero salad dressing		15
Bread, white	1	23
Pear (half)	2	100
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
5:30 p.m.		
Italian spaghetti		
Hamburger	3 1/2 oz	105
Spaghetti	1/4 c	38
Tomato sauce	1/2 c	100
Grated Swiss cheese		15
Cucumber		30
Radish		20
Bread, rye	1	23
Apricots	2	75
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
8:00 p.m.		
Mandarin oranges	1/2 c	100

Appendix 2 (cont.)

Day III

Group A (6 meals/day)

7:30 a.m.	measure	gms
Cheese toast		
Bread, white	1	23
Cheese, American	1 oz	30
Milk, skim	1/2 c	120
10:00 a.m.		
Grapefruit sections	1/2 c	120
Turkey	2 oz	60
Bread, rye	1	23
Coffee or tea	1/2 c	
12:30 p.m.		
Consommé	1/2 c	100
Baked halibut	2 oz	60
Succotash	1/2 c	90
Radish		20
Celery		30
Bread, whole wheat	1	23
Plums	2	100
Coffee or tea	1/2 c	
3:00 p.m.		
Peanut butter	1 T	15
Graham crackers	2	14
Milk, skim	1/2 c	120
5:00 p.m.		
Veal cubes	2 oz	60
Noodles	1/4 c	40
String beans	1/2 c	80
Cabbage salad		
Cabbage		50
Radish		10
Zero salad dressing		15
Cherries	1/3 c	75
Coffee or tea	1/2 c	
8:00 p.m.		
Apple	1 md	100
Edam cheese	1 oz	30
Milk, skim	1 c	240

Group B (3 meals/day)

7:30 a.m.	measure	gms
Grapefruit sections	1/2 c	100
Cheese toast		
Bread, white	1	23
Cheese, American	1 oz	30
Turkey	1 oz	30
Milk, skim	1 c	240
Coffee or tea	1/2 c	
12:30 p.m.		
Consommé	1/2 c	100
Baked halibut	3 oz	90
Succotash	1/2 c	90
Radish		20
Celery		30
Bread, whole wheat	1	23
Plums	2	100
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
5:30 p.m.		
Veal cubes	3 oz	90
Noodles	1/4 c	40
String beans	1/2 c	80
Cabbage salad		
Cabbage		50
Radish		10
Zero salad dressing		15
Cherries	1/3 c	75
Graham crackers	2	14
Peanut butter	1 T	15
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
8:00 p.m.		
Apple	1 md	100

Appendix 2 (cont.)

Day IV

Group A (6 meals/day)

7:30 a.m.	measure	gms
Egg, poached	1	50
Bread, white	1	23
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
10:00 a.m.		
Applesauce	1/2 c	120
Spiced meat	2 oz	60
Bread, white	1	23
Coffee or tea	1/2 c	
12:30 p.m.		
Pineapple juice	1/2 c	120
Roast beef	2 oz	60
Peas	1/2 c	80
Lettuce		50
Cucumber		15
Zero salad dressing		15
Coffee or tea	1/2 c	
3:00 p.m.		
Frankfurter	1	50
Bread, whole wheat	1	23
Milk, skim	1/2 c	120
5:30 p.m.		
Ham	2 oz	60
Rice	1/4 c	38
Spinach	1/2 c	100
Lettuce		40
Celery		20
Zero salad dressing		15
Strawberries	1/2 c	100
Coffee or tea	1/2 c	
8:00 p.m.		
Apricots	2	75
Milk, skim	1 c	240
S.M.P.		10

Group B (3 meals/day)

7:30 a.m.	measure	gms
Applesauce	1/2 c	120
Egg, poached	1	50
Bread, white	1	23
Spiced meat	1 oz	30
Milk, skim	1 c	240
Coffee or tea	1/2 c	
12:30 p.m.		
Pineapple juice	1/2 c	120
Roast beef	2 oz	60
Edam cheese	1 oz	30
Peas	1/2 c	80
Lettuce		50
Cucumber		15
Zero salad dressing		15
Bread, whole wheat	1	23
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
5:30 p.m.		
Ham	4 oz	120
Rice	1/4 c	38
Spinach	1/2 c	100
Lettuce		40
Celery		20
Zero salad dressing		15
Bread, white	1	23
Strawberries	1/2 c	100
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
8:00 p.m.		
Apricots	2	75

Appendix 2 (cont.)

Day V

Group A (6 meals/day)

7:30 a.m.	measure	gms
Egg, poached	1	50
Bread, white	1	23
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
10:00 a.m.		
Cottage cheese	1/2 c	112
Peaches	1/2 c	100
Bread, whole wheat	1	23
Coffee or tea	1/2 c	
12:30 p.m.		
Chicken noodle casserole		
Chicken diced	2 oz	60
Celery		30
Chicken consommé	2 T	25
Water chestnut	8	25
Pimiento	1/2 md	10
String beans	1/2 c	80
Apple	1 md	100
Coffee or tea	1/2 c	
3:00 p.m.		
Tuna salad		
Tuna fish	1 oz	30
Celery		30
Bread, white	1	23
Milk, skim	1/2 c	120
5:30 p.m.		
Meat loaf	2 oz	60
Lima beans	1/4 c	25
Lettuce		50
Radish		10
Zero salad dressing		15
Fruit cup	1/2 c	100
Coffee or tea	1/2 c	
8:00 p.m.		
Banana	1 sm	100
Edam cheese	1 oz	30
Milk, skim	1 c	240

Group B (3 meals/day)

7:30 a.m.	measure	gms
Peaches	1/2 c	100
Egg, poached	1	50
Cottage cheese	1/4 c	56
Bread, white	1	23
Milk, skim	1 c	240
Coffee or tea	1/2 c	
12:30 p.m.		
Chicken noodle casserole		
Chicken diced	3 oz	90
Celery		30
Chicken consommé	2 T	25
Water chestnut	8	25
Pimiento	1/2 md	10
String beans	1/2 c	80
Bread, whole wheat	1	23
Apple	1 md	100
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
5:30 p.m.		
Meat loaf	3 oz	90
Edam cheese	1 oz	30
Lima beans	1/4 c	25
Lettuce		50
Radish		10
Zero salad dressing		15
Fruit cup	1/2 c	100
Milk, skim	1/2 c	120
Bread, white	1	23
Coffee or tea	1/2 c	
8:00 p.m.		
Banana	1 sm	100

Appendix 2 (cont.)

Day VI

Group A (6 meals/day)

7:30 a.m.	measure	gms
Tomato juice	1/2 c	120
Peanut butter	1 T	15
Bread, white	1	23
Milk, skim	1/2 c	120
10:00 a.m.		
Orange juice	1/2 c	120
Corned beef	1 oz	30
Swiss cheese	1 oz	30
Bread, rye	1	23
Coffee or tea	1/2 c	
12:30 p.m.		
Lamb stew		
Lamb	2 oz	60
Celery	1 oz	30
Onion	1 oz	30
Carrot	1 oz	30
Lettuce		50
Zero salad dressing		15
Pear	2	100
Coffee or tea	1/2 c	
3:00 p.m.		
Egg, hard cooked	1	50
Bread, whole wheat	1	23
Milk, skim	1/2 c	120
5:30 p.m.		
Steak	2 oz	60
Squash, Hubbard	1/2 c	70
Potato, baked	1/2 sm	50
Cucumber		30
Radish		20
Zero salad dressing		15
Peaches	1/2 c	100
Coffee or tea	1/2 c	
8:00 p.m.		
Grapefruit sections	1/2 c	100
Milk, skim	1 c	240
S.M.P.		10

Group B (3 meals/day)

7:30 a.m.	measure	gms
Orange juice	1/2 c	120
Peanut butter	1 T	15
Bread, white	1	23
Egg, poached	1	50
Milk, skim	1 c	240
Coffee or tea	1/2 c	
12:30 p.m.		
Tomato juice	1/2 c	120
Lamb stew		
Lamb	3 oz	90
Celery	1 oz	30
Onion	1 oz	30
Carrot	1 oz	30
Lettuce		50
Zero salad dressing		15
Bread, rye	1	23
Pear	2	100
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
5:30 p.m.		
Steak	4 oz	120
Squash, Hubbard	1/2 c	70
Potato, baked	1/2 md	50
Cucumber		30
Radish		20
Zero salad dressing		15
Peaches	1/2 c	100
Milk, skim	1/2 c	120
Coffee or tea	1/2 c	
8:00 p.m.		
Grapefruit sections	1/2 c	100

Appendix 3

Data Sheet of Heat of Combustion of Food Samples

Date 4-1-69 Sample 2-7 group A
Sample No. 33 Room Temp. 81

Sample + Capsule 16.09000 gm.
Capsule . . . . 10.92880 gm.
Net sample . . . 5.16120 gm.

OBSERVATIONS

TIME		TEMP.	
Min.	1/1000	F.	
0		78.050	
1		78.070	
2		78.080	
3		78.090	
4		78.095	
5		78.100	(a)
6	0	80.100	
		80.464	
6	25	80.600	
			(b)
6	50	80.950	
6	75	81.200	
7	0	81.400	
8		81.810	
9		81.950	
10		82.000	
11		82.025	
12		82.040	(c)
13		;	
14		;	
15		;	
16		;	
17		;	

Corrections:

Total calories		5300
Fuse wire, cal.	11	
Acid corr. cal.	11	
Total correction		22
NET CAL.		5278

"six tenth points"

0.6R = 0.6(82.040 (c) - 78.100 (a)) = 2.364 F.

Temp. at 0.6R = (78.100 + 2.364) = 80.464 F.

Time (b) = (6 Time pr. to 0.6R + .18 Time gain) = 6.18 min.

(b-a) = (6.18 - 5.00) = 1.18 min.

(c-b) = (12.00 - 6.18) = 5.82 min.

RADIATION RATES:

R_1 Ini. rate = 0.050 Prelim. temp. rise ÷ 5 Min. = 0.010 F/min.

R_2 End rate = 0 Final temp. fall ÷ 5 Min. = 0 F/min.

Temp. (c)	82.040
Scale Corr.	± 0.025
True temp. (c) . .	82.015
R_2 (c-b)	0.000
Corrected temp.	82.015
Temp. (a)	78.100
Scale corr.	± 0.023
True temp. (a) . .	78.677
R_1 (b-a)	0.012
Corrected temp.	78.089
Net temp. rise	3.926

1350 Water equiv. cal/F x 3.926 Net temp. rise = 5300 Total cal.

5278 Net kcal ÷ 5.16120 Net sample x 1666 Total wt./day = 1704 Cal/day

Appendix 4

Dietary Energy Value Determined by Oxygen Bomb Calorimetry

Test Period	Day	Energy Value (kcal)	
		Group A 6 meals/day	Group B 3 meals/day
I	1	1771	1787
	2	1982	1985
	3	1896	1710
	4	1869	1806
	5	1792	1805
	6	1741	1687
II	1	1772	1697
	2	1880	1827
	3	1880	1755
	4	1816	1759
	5	1743	1705
	6	1745	1730
III	1	1471	1506
	2	1577	1529
	3	1597	1425
	4	1730	1584
	5	1493	1465
	6	1373	1346
IV	1	1560	1530
	2	1511	1561
	3	1510	1545
	4	1727	1606
	5	1445	1526
	6	1600	1489

Appendix 5

Nitrogen Content of Urine (gms per day)

Period	Day	Group A 6 meals/day				Group B 3 meals/day			
		NL	PN	LP	JP	KA	GF	GO	LS
	1	14.45	16.04	14.92	14.48	9.99	17.73	16.83	17.74
	2	13.93	19.14	11.05	15.85	15.00	16.66	9.37	16.61
	3	10.81	16.48	16.28	14.36	15.55	15.76	17.66	17.52
I	4	15.33	14.00	14.06	15.12	15.09	16.81	15.51	16.20
	5	13.57	16.27	17.95	13.35	9.39	16.95	15.78	17.48
	6	14.85	14.32	15.26	12.88	14.77	16.95	13.89	12.93
	Ave	13.82	16.04	14.92	14.36	13.30	16.81	14.86	16.41
	1	15.48	16.69	13.42	15.89	16.55	16.92	18.72	16.70
	2	14.06	16.07	9.80	14.34	17.70	16.27	15.46	15.20
	3	11.38	23.57	15.05	15.27	16.05	15.55	16.28	15.65
II	4	15.60	15.16	14.17	15.37	16.44	15.51	15.53	16.98
	5	12.93	15.54	6.72	16.70	15.98	9.78	16.92	15.93
	6	13.04	17.24	14.32	14.70	13.95	14.94	13.21	16.68
	Ave	13.75	17.36	12.25	15.38	16.11	14.83	16.02	16.19
	1	15.80	14.06	14.42	15.93	15.90	14.88	15.62	16.07
	2	14.85	14.06	13.10	13.97	9.14	14.38	14.23	15.11
	3	15.91	13.88	14.57	15.41	14.37	14.33	12.50	17.33
III	4	14.88	12.48	13.47	14.22	16.82	13.04	14.36	15.14
	5	16.74	13.28	14.20	14.37	6.80	15.67	15.64	17.66
	6	17.28	18.99	14.45	11.02	16.28	12.04	14.05	15.97
	Ave	15.91	14.46	14.03	14.15	13.22	14.06	14.40	16.21
	1	14.98	15.82	14.91	12.41	14.56	14.33	15.04	17.08
	2	13.14	11.98	10.45	12.36	13.86	15.24	14.61	16.42
	3	15.82	15.91	13.86	13.86	14.31	15.90	14.40	16.05
IV	4	14.99	13.71	14.53	13.96	13.64	15.77	15.03	15.01
	5	15.25	15.18	15.37	11.55	13.78	15.40	16.11	16.52
	6	15.25	16.03	15.75	10.92	12.38	14.79	15.09	14.56
	Ave	14.90	14.44	14.14	12.52	13.76	15.24	15.05	15.94

Appendix 6

Daily Physiological Fuel Values of Subjects (kcal)

Period	Day	Group A 6 meals/day				Group B 3 meals/day			
		NL	PN	JP	LP	KA	GF	GO	LS
I	1	1569	1556	1565	1569	1619	1558	1565	1558
	2	1773	1732	1796	1578	1768	1754	1812	1755
	3	1716	1671	1672	1688	1501	1500	1494	1496
	4	1655	1665	1665	1657	1597	1583	1594	1588
	5	1595	1574	1560	1597	1641	1581	1590	1577
	6	1537	1541	1534	1552	1486	1469	1493	1501
II	1	1561	1551	1577	1557	1481	1478	1464	1480
	2	1675	1659	1709	1673	1596	1608	1614	1616
	3	1696	1600	1667	1665	1540	1544	1538	1543
	4	1602	1605	1613	1604	1541	1549	1548	1537
	5	1554	1533	1603	1524	1494	1543	1486	1494
	6	1505	1522	1545	1542	1534	1526	1540	1512
III	1	1272	1286	1283	1271	1305	1313	1303	1304
	2	1381	1387	1395	1388	1381	1339	1341	1334
	3	1391	1407	1402	1395	1240	1241	1255	1217
	4	1526	1546	1538	1532	1372	1402	1392	1385
	5	1286	1313	1306	1305	1338	1268	1268	1252
	6	1168	1154	1190	1217	1148	1182	1166	1151
IV	1	1364	1357	1364	1384	1339	1341	1334	1319
	2	1331	1340	1353	1337	1374	1363	1368	1353
	3	1309	1308	1325	1325	1355	1342	1354	1341
	4	1523	1533	1526	1531	1418	1402	1407	1408
	5	1253	1253	1352	1283	1341	1328	1323	1320
	6	1400	1393	1396	1434	1317	1298	1296	1300

COMPARISON OF THREE METHODS OF DETERMINING THE ENERGY VALUE OF DIETS

by

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B. S., National Taiwan University, 1966

AN ABSTRACT OF A MASTER'S THESIS

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A comparison of the energy value of low calorie diets (1500 and 1200 calories) planned from a system of food exchanges was made with (a) values obtained from tables of food composition and (b) laboratory determined physiological fuel values. Physiological fuel values were based on data obtained from 8 subjects, 4 of whom consumed 6 meals per day and 4 of whom consumed 3 meals per day while participating in a weight reduction program.

Statistical comparisons of the energy level of diets obtained as above were made by using analyses of variance, t-tests, and central confidence intervals. Analyses of variance included comparisons between energy values obtained from the system of food exchanges and tables of food composition; and between food exchanges and physiological fuel values. Analysis of variance were also made by comparing the energy values calculated from tables of food composition with those obtained from physiological fuel determinations.

Analysis of variance of the energy value of diets determined by the food exchange system and from food composition tables indicated that a difference existed between diets containing 6 meals and those containing 3 meals per day ($P < .10$). No difference, however, existed for the two calorie levels used (1500 vs 1200 kcal). Also no interaction occurred between meal frequency and calorie level. A further comparison, using the t-test showed no difference between sample mean values of diets containing either 6 or 3 meals per day.

Analysis of variance for energy values based on the food exchange system and physiological fuel value determinations indicated significant differences between meal frequency ($P < .005$) and calorie levels ($P < .005$). No interaction between meal frequency and calorie levels, however, was detected. The t-test showed a higher value for diets containing 6 meals per day than for those containing 3 meals per day (t-value 12.8 versus 8.14). Similar results were obtained for the confidence interval, i.e., a value of 99 and 137 as compared to 53 and 87. The diets containing 1200 calories had a higher t-value than the 1500 diet (14.82 vs 6.76). Again, the same was true for the confidence interval (114 and 150 vs 40 and 72).

Analysis of variance between energy values based on food composition tables and physiological fuel value determinations indicated a significant difference between diets of differing calorie levels ($P < .005$). No difference was found between the two meal frequencies and no interaction existed between meal frequency and calorie level. Results of a t-test comparison between calorie levels were higher for the 1200 calorie diet than for the 1500 calorie diet (13.62 vs 6.33). The same held true for the confidence interval, i.e., a value of 88 and 188 vs 31 and 59.